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REVIEW

Association between eating rate and obesity: a systematic review and meta-analysis

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BACKGROUND: The association between eating rate and obesity has recently been reported. However, the findings remain inconclusive.
OBJECTIVES: We undertook a systematic review with a meta-analysis of published epidemiological studies to provide a reliable close estimate of the association between eating rate and obesity.
METHODS: A comprehensive search of MEDLINE, EMBASE and CINAHL was conducted to identify studies that reported quantitative estimates for indices of obesity based on the category of eating rate. Interventional studies or studies conducted using children as subjects were excluded. Two independent researchers extracted the data. A summary estimate was calculated using a random-effects model, and subgroup analyses were conducted to identify sources of heterogeneity.
RESULTS: Data from 23 published studies were eligible for inclusion. The mean difference in body mass indices (BMIs) between individuals who ate quickly and those who ate slowly was 1.78 kg m^{-2} (95% confidence interval (CI), 1.53–2.04 kg m^{-2}). The pooled odds ratio of eating quickly on the presence of obesity was 2.15 (95% CI, 1.84–2.51). There was evidence of significant quantitative heterogeneity in the magnitudes of the association across studies (I^2 = 78.4%, P-value for heterogeneity <0.001 for BMI, I^2 = 71.9%, P-value for heterogeneity <0.001 for obesity), which may be partially explained by differences in the type of study population (a weaker association was observed for BMI in diabetic patients).
CONCLUSIONS: Eating quickly is positively associated with excess body weight. Further studies are warranted to determine whether interventions to slow the speed of eating are effective for weight control.

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INTRODUCTION

Overweight and obesity in humans have increased globally in both developed and developing countries. Worldwide, the percentage of men with a body mass index (BMI) $\geqslant$25 kg m^{-2} increased from 28.8% in 1980 to 36.9% in 2013, whereas that of women increased from 29.8 to 38.0% during the same period.[1] Similarly, the number of overweight and obese people increased from 857 million in 1980 to 2.1 billion in 2013.[1] Given its adverse consequences,[2–4] the obesity epidemic has become a major public health concern. Therefore, a practical and effective strategy for the prevention and treatment of obesity is crucial.

Diet therapy has an important role in the treatment of overweight and obesity. Recommendations on energy balance and macronutrient intake have been established,[5] but appropriate eating behaviors for the prevention of obesity remains uncertain. Among eating behaviors, reducing eating rate is frequently advocated as a simple and effective method for control of food intake and thus body weight.[6] Several epidemiological studies suggested that eating quickly was associated with an increased prevalence of obesity,[7–10] but their findings remained inconclusive.[11,12] Considering the epidemic and deleterious impact of obesity, a better understanding of the precise nature of the association between eating rate and obesity would be beneficial from both clinical and public healthcare perspectives. Herein, we report the results of a systematic review with a meta-analysis of published epidemiological studies undertaken to obtain a reliable and precise measure for the association between eating rate and obesity.

MATERIALS AND METHODS

Data sources and searches

The Meta-analysis of Observational Studies in Epidemiology guidelines for the conduct of meta-analyses of observational cohort studies were followed.[13] Relevant published studies were identified with computerized searches of MEDLINE via Ovid (from 1946 through September 2014), EMBASE (from 1966 through September 2014), and CINAHL (from 1987 through September 2014) databases using relevant text words and medical subject headings, including all spellings of 'eating rate,' 'eating speed,' 'eating time,' 'slow eating,' 'quick eating,' 'fast eating' and 'rapid eating' and these words combined with all spellings of 'body mass index,' 'body weight' and 'obesity' (See Supplementary Appendix). The search was limited to cross-sectional studies, case-control studies and cohort studies without language restrictions. The reference lists from identified articles were manually scanned to identify other relevant studies.

Study selection and data extraction

Studies were included if they reported quantitative estimates and standard errors (SEs; or 95% confidence intervals (CIs)) of indices

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of obesity according to a category of some measure of eating rate, namely, the mean value of or the change in body weight or BMI, the frequency of obesity, the odds ratio (OR) for the presence of obesity or the relative risk for the development of obesity. The definition of eating rate was based on that presented in each study. Obesity was defined as BMI $\geqslant 25\,kg\,m^{-2}$ in all included studies. Studies were excluded if they met the following criteria: (1) an interventional study; (2) a study population that included children; and (3) a study reporting the estimate of an effect without the ability to derive the SE. Two authors (TO and TN) independently conducted the literature search and data extraction using a standardized approach. Any discrepancies regarding eligibility or quality of a study were resolved by consensus after a third author (YH) reviewed the paper.

Statistical analysis

The difference in the mean values of BMI (or body weight) and the ORs for the presence of obesity in the categories for the fastest versus slowest eating rates were calculated for each study. Summary estimates of the mean difference or the OR, and their 95% CIs, were obtained using a random-effects model. Multiple estimates of subgroups (for example, sex or diabetes status) from one study[8,10,14–18] were combined using a fixed-effects model to create a single pairwise comparison.[19] Heterogeneity across the included studies was analyzed using Cochran's Q test and the I^2 statistic, which approximates the proportion of total variation in the estimates caused by between-study heterogeneity. The possible sources of heterogeneity were investigated by comparing the summary results obtained from subsets of studies grouped by the characteristics of the included studies. Tests of heterogeneity between subgroups were estimated using a meta-regression analysis. Graphic representations of the potential publication bias were generated using a funnel plot of the mean differences or natural logarithms of the ORs versus their SEs and were assessed visually as well as using Egger's test and Begg's test, which performed a linear regression and a rank correlation between the observed effect estimates and observed standard errors for the statistical evaluation of funnel plot asymmetry, respectively. A two-sided P-value of < 0.05 was considered statistically significant for all analyses. All analyses were performed using Stata software (release 13; StataCorp, College Station, TX, USA).

RESULTS

Literature search and characteristics of included studies

A flow chart detailing the process of study identification and selection is shown in Figure 1, and characteristics of the included studies are listed in Table 1. The literature search yielded 3925 articles, of which 61 were reviewed in full. Finally, 23 published studies[7–12,14–18,20–31] were eligible for inclusion in the analysis, of which 20 were cross-sectional studies,[7–11,14–18,21–30] two were longitudinal studies[20,31] and one provided results from both study designs.[26] The eating rate was evaluated using self-reporting in 22 studies [7–11,14–18,20–31] and using an eating monitor in one study.[12] In one study, the data from only male subjects were included in the analysis, because no data from female subjects were reported.[22] Seventeen studies[7,8,10,14–17,20,22–27,29–31] provided an estimate of the association between eating rate and indices of excess body weight that was adjusted for confounding factors, whereas six studies[9,11,12,18,21,28] reported the unadjusted analysis.

Association of eating rate with BMI: cross-sectional study

Fifteen cross-sectional studies[7,9–12,14,17,18,22,25–30] investigated the association between eating rate and the mean value of BMI, 12 of which were included in the meta-analysis. Subjects eating quickly had a significantly higher mean value of BMI than those eating slowly: the pooled estimate of the mean differences in BMIs between those eating quickly and slowly was $1.78\,kg\,m^{-2}$ (95% CI, $1.53–2.04\,kg\,m^{-2}$; Figure 2a). There was evidence of significant heterogeneity in the magnitudes of the associations across the included studies ($I^2 = 78.4\%$, P-value for heterogeneity < 0.001), although all point estimates were located on the right side of the forest plot. The sensitivity analysis excluding two studies that used medium eating rate as a reference group[14,27] had little effect on the finding, although the heterogeneity in the association across the studies was attenuated: a pooled mean difference in BMI of $1.92\,kg\,m^{-2}$ (95% CI, $1.71–2.13\,kg\,m^{-2}$; $I^2 = 58.0\%$, P-value for heterogeneity $= 0.01$).

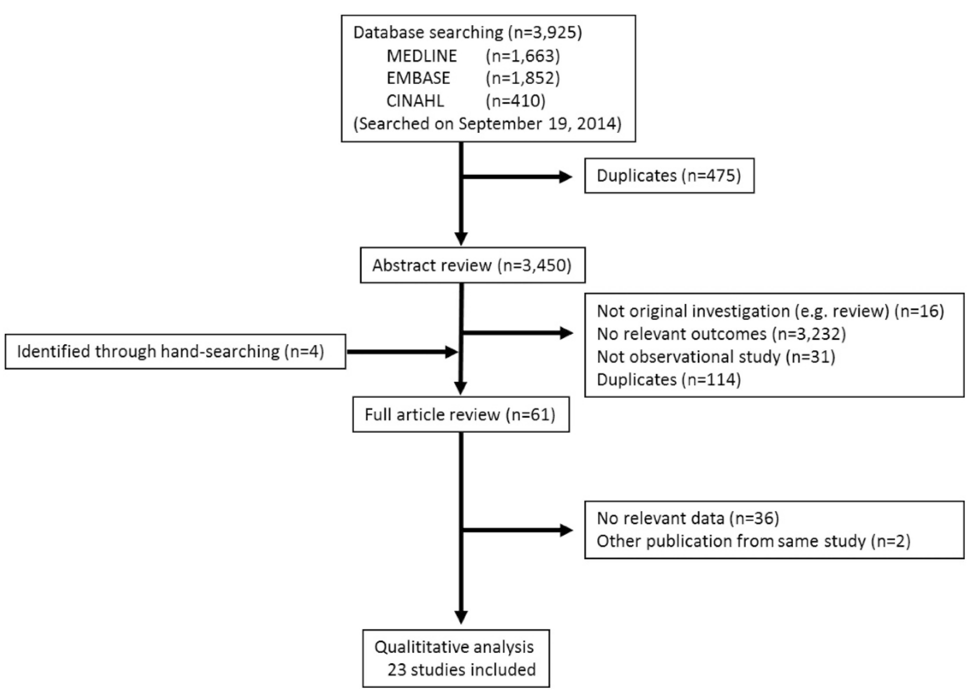

Figure 1. Identification process for eligible studies.

Table 1. Characteristics of the studies reporting on the association between eating rate and indices of obesity

Authors	Country	N of subject (% men)	Mean age (years)	Mean BMI (kg m^{-2})	Study population	Evaluation of eating rate	Category of eating rate: Quickly	Category of eating rate: Reference	Outcome	Level of adjustment
Cross-sectional study										
Shigeta *et al.*[21]	Japan	453 (70)	53	23.4	Medical checkup	Self-report	Eating rapidly	Normally	%Obesity	None
Takayama *et al.*[22]	Japan	372 (100)[a]	NR	NR	Diabetes or hyperlipidemia	Self-report	Quickly	Slowly	Mean BMI	Age
Sasaki *et al.*[7]	Japan	1695 (0)	18	20.8	Students	Self-report	Very fast	Very slow	Mean BMI	Physical activity category, experience of dieting, nutrient intake(protein, fat, dietary fiber)
Otsuka *et al.*[14]	Japan	4742 (79)	47.8	23.0	Civil servants	Self-report	Very fast	Medium	Mean BMI	Age, smoking status, physical activity, and alcohol drinking habit, energy intake
Maruyama *et al.*[8]	Japan	3287 (34)	53.4	23.2	Medical checkup	Self-report	Eating quickly	Not eating quickly	%Obesity	Age, smoking status, regular physical activity, occupation, intake of total energy, total dietary fiber, alcohol, survey area
Nishitani *et al.*[23]	Japan	595 (100)	41.8	23.5	Manufacturing plant workers	Self-report	Eat fast	Not eat fast	%Obesity	Age
Hsieh *et al.*[15]	Japan	8466 (74)	52.5	NR	Health examination (participants not eating until feeling full)	Self-report	Eating rapidly	Not eating rapidly	%Obesity	Age
Kimura *et al.*[24]	Japan	290 (100)	43.6	23.5	Municipal employees	Self-report	Tend to eat quickly	Not tend to eat quickly	%Obesity	Age, work place, marital status, occupational physical activity, leisure-time physical activity, current smoking, current alcohol drinking, job stress score, energy intake
Leong *et al.*[25]	New Zealand	1515 (0)	45.5	25.8	General	Self-report	Very fast, relatively fast, medium, relatively slow	Very slow	Mean BMI	Age, smoking status, menopause status, thyroid condition, prioritized ethnicity, socioeconomic status, physical activity
Tanihara *et al.*[26 b]	Japan	529 (100)	38.4	23.8	Office workers	Self-report	Fast	Slow, Medium and slow[c]	Mean BMI, % Obesity	None (BMI), age, drinking, smoking, regular exercise (obesity)
Kral *et al.*[12]	USA	46 (35)	36.7	48.7	Severely obese person	Eating monitor			Mean BMI, Body weight	None
Mochizuki *et al.*[11]	Japan	170 (100)	51.4	23.4	Health checkup	Self-report			Mean BMI	None
Saito *et al.*[27]	Japan	426 (50)	59.4	24.9	Diabetes	Self-report	Quickly	Medium	Mean BMI	Age, sex, current smoking, alcohol consumption, usual physical activity
Sakurai *et al.*[9]	Japan	2050 (100)	45.9	23.4	Health checkup	Self-report	Fast	Slow	Mean BMI, % Obesity	None
Mochizuki *et al.*[28]	Japan	3929 (100)	49.2	23.5	Students	Self-report	Very fast	Very slow/slow	Mean BMI	None
Ekuni *et al.*[16]	Japan	1918 (59)	18-19	20.7	Students	Self-report	Quickly	Normal. slow	%Obesity	Men: frequently eating a fatty diet. Women: taking part in regular physical activity.
Lee *et al.*[17]	Korea	8775 (55)	47.9	23.9	Health checkup	Self-report	<5 min per meal	$\geqslant 15$ min per meal	Mean BMI, % Obesity	Age, alcohol, smoking, exercise and total energy intake (BMI)
Ohkuma *et al.*[10]	Japan	7275 (51)	64.9	NR	NFG, IFG, diabetes	Self-report	Very fast	Slow	Mean BMI, % Obesity	Age, sex (BMI), age, sex, total energy, dietary fiber, current smoking, current drinking, regular exercise (Obesity)
Mochizuki *et al.*[30]	Japan	320 (100)	47.2	24.2	Health checkup	Self-report	Very fast	Very slow/slow	Mean BMI	Age, alcohol intake, energy intake, smoking, physical activity
Mochizuki *et al.*[29]	Japan	900 (0)	53.1	22.2	Health checkup	Self-report	Very fast/relatively fast	Very slow/ relatively slow	Mean BMI	Age, alcohol intake, energy intake, smoking, physical activity
Nagahama *et al.*[18]	Japan	56865 (74)	46.4	23.3	Health checkup	Self-report	Fast	Slow	Mean BMI	None
Longitudinal study										
Gerace *et al.*[20]	USA	437 (100)	35.4	25.8	Firefighters	Self-report	Faster at the station	Not different by location	Mean BW (pound)	Race, smoking, age, %IW, marital status, worried over financial security
Tanihara *et al.*[26 b]	Japan	529 (100)	38.4	23.8	Office workers	Self-report	Fast	Medium and slow	Mean BMI	Age, BMI, drinking, smoking, regular exercise
Yamane *et al.*[31]	Japan	1314 (51)	18.4	20.2	Students	Self-report	Quickly	Slow	%Obesity	Gender, frequently consuming fatty foods

Abbreviations: BMI, body mass index; NFG, normal fasting glucose; IFG, impaired fasting glucose. Obesity or overweight were defined as BMI $\geqslant 25$ kg m^{-2} in all studies listed above. [a]Data from only male patients were included in the meta-analysis because data from female patients were not reported. [b]This study reported results from both a cross-sectional survey and a longitudinal survey. [c]Reference was defined as slow for mean BMI, and medium and slow for % obesity.

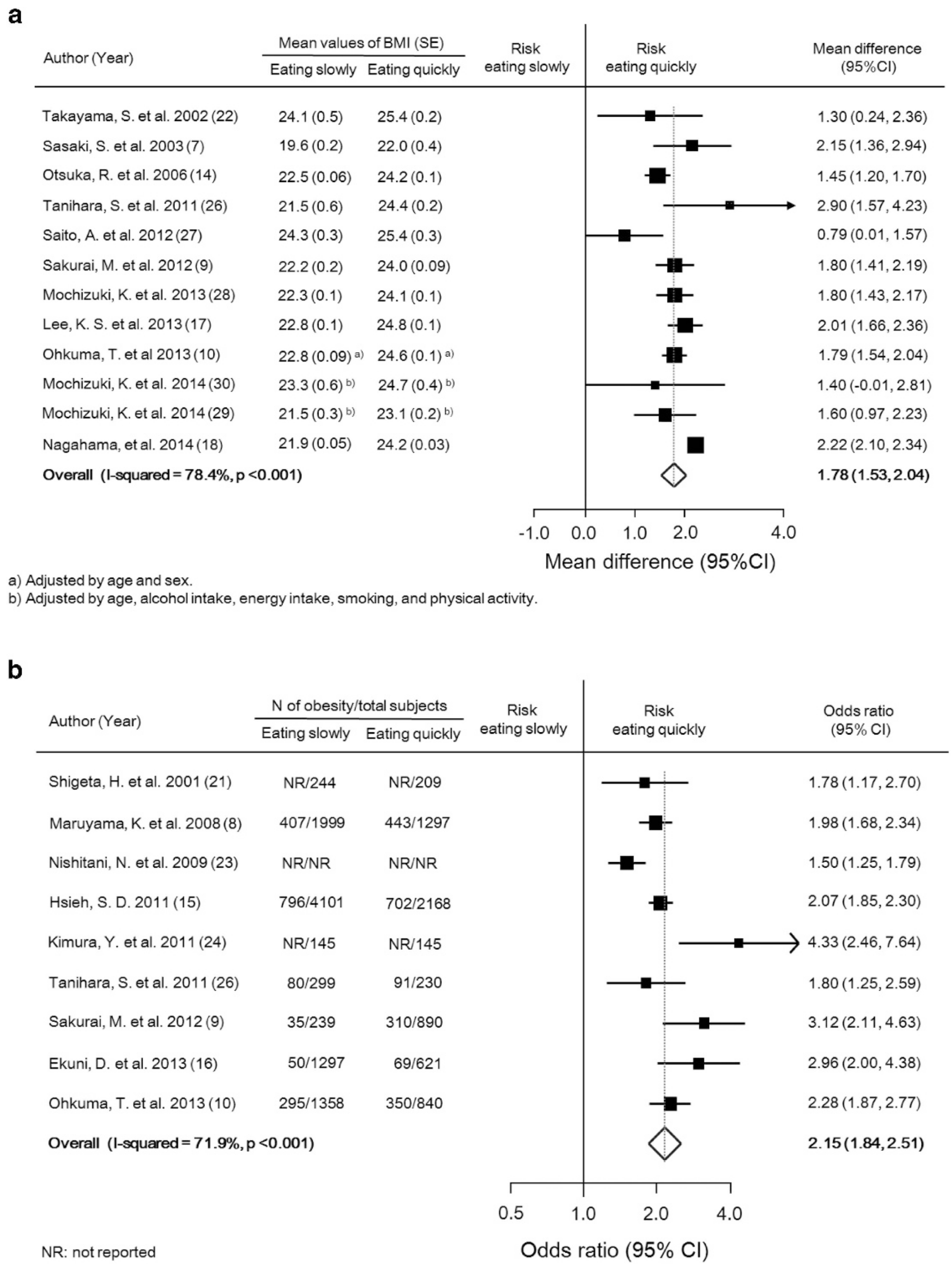

Figure 2. Forest plot of the mean differences in BMIs (**a**) and the odds ratios for obesity (**b**) in association with eating rate. CI, confidence interval.

Three studies[11,12,25] were excluded from the meta-analysis because they had no available data: two studies[11,12] provided correlation coefficients between eating rate and BMI or body weight that were not significant, and one study[25] revealed a positive association between eating rate and BMI (Table 2A).

Association of eating rate with obesity: cross-sectional study

Ten studies[8–10,15–17,21,23,24,26] reported on the association of eating rate with the presence of obesity. After excluding one study that did not report the value of the OR and its 95% CI,[17] the remaining nine studies were included in the meta-analysis. All of the included studies demonstrated that eating quickly was significantly associated with a greater likelihood of obesity, but the magnitude of the association was heterogeneous across the studies ($I^2 = 71.9\%$, P value for heterogeneity < 0.001; Figure 2b). The pooled OR for eating quickly with the presence of obesity was 2.15 (95% CI, 1.84–2.51).

Subgroup analysis

The subgroup analysis indicated that the type of study population was one of the sources for between-study heterogeneity in the association between a faster eating rate and a higher mean BMI (Figure 3a); the mean difference in BMI from the 3 studies having participants with diabetes was lower than that in the 11 studies having participants without diabetes (mean difference 1.32 kg m^{-2} (95% CI, 0.90–1.74 kg m^{-2}) versus mean difference 1.89 kg m^{-2} (95% CI, 1.64–2.15 kg m^{-2}), respectively; P value for heterogeneity = 0.038). In the subgroup analysis for the presence of obesity,

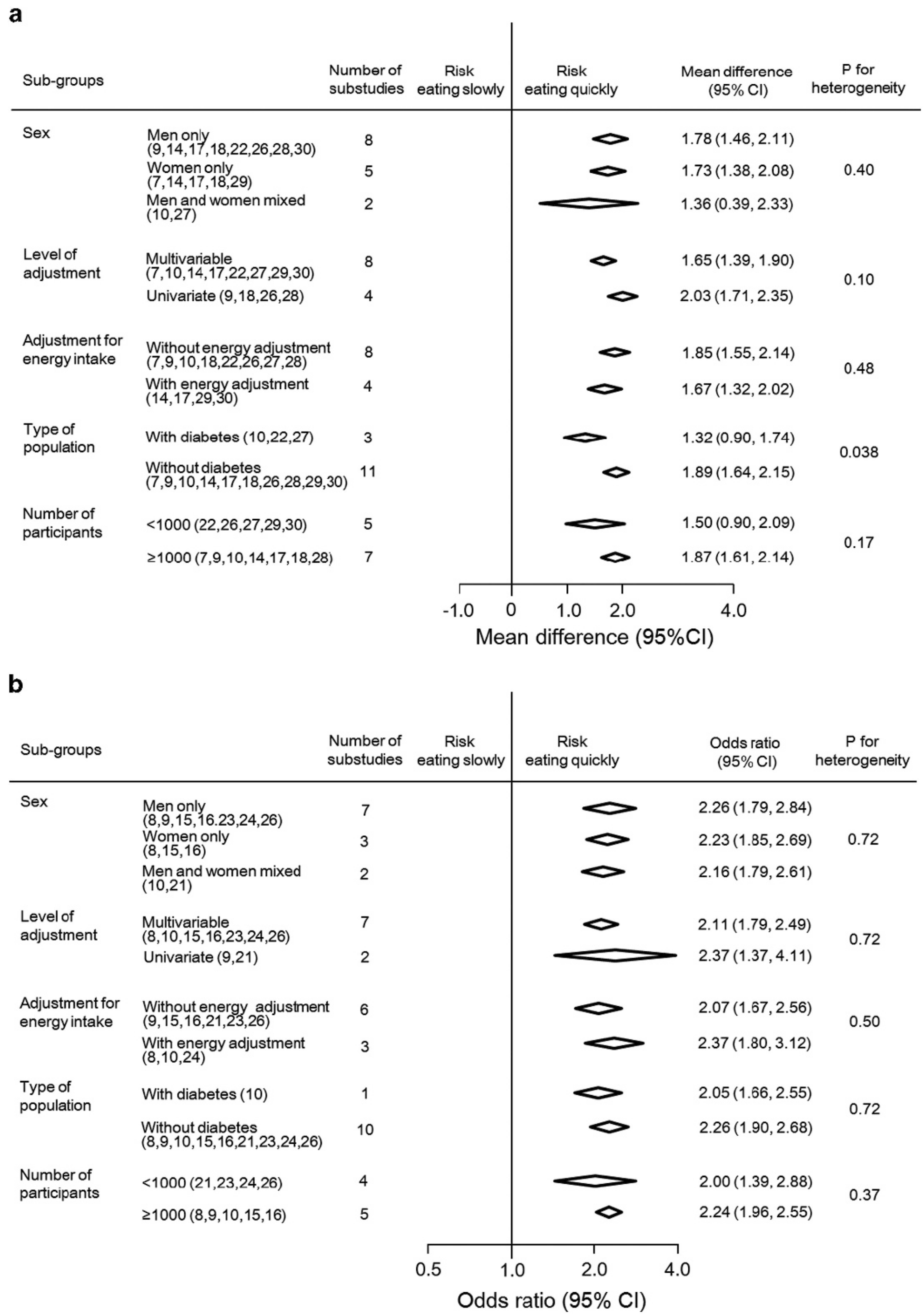

Figure 3. Subgroup analysis for the association of eating rate with BMI (**a**) and the odds ratio for obesity (**b**) based on study characteristics. CI, confidence interval.

however, no significant heterogeneity in the association between types of study population was detected (Figure 3b). There was no evidence for a significant difference in the association between subgroups of sex, level of adjustment, adjustment for energy intake or number of participants (Figures 3a and b).

Publication bias

A funnel plot showed a symmetric pattern (Figures 4a and b), without significant evidence of the presence of publication bias in statistical tests for funnel plot asymmetry (for BMI: Egger's test $P = 0.08$, Begg's test $P = 0.68$; for obesity: Egger's test $P = 0.22$, Begg's test $P = 0.17$).

Association of eating rate with obesity: longitudinal study

Three studies longitudinally examined the association of eating rate with the increase in body weight[20,26] and the risk of developing obesity.[31] Gerace *et al.*[20] found that firefighters who ate faster at the station than elsewhere gained 9.9 pounds over 7 years, whereas firefighters with a constant eating speed gained 6.8 pounds ($P < 0.006$). This relationship persisted after adjustment for race/ethnicity, smoking status, age, percentage of ideal weight, marital status and worry over financial security. Tanihira *et al.*[26] reported that after adjusting for confounders, participants eating quickly gained 1.10 kg (95% CI, 0.23–1.97 kg) more over 8 years than those eating moderately and slowly. Yamane *et al.*[31] showed

Table 2. Summary of the results of the studies excluded from the meta-analysis (A) and the longitudinal studies (B)

(A)

Authors	*Evaluation of eating rate*	*Definition of categories of eating rate*	*Result*
Leong *et al.*[25]	Self-report	Very fast, relatively fast, medium, relatively slow and very slow	BMI increased by 2.8% (95% confidence interval: 1.5 to 4.1%) for every one-category increase in eating rate
Kral *et al.*[12]	Eating monitor		No statistically significant correlations between eating rate and BMI or body weight (data not shown)
Mochizuki *et al.*[11]	Self-report	Moderately fast, fast, intermediate, slow and moderately slow	No statistically significant correlations between eating rate and BMI (correlation coefficient: 0.099, $P = 0.201$)

(B)

Authors	*Evaluation of eating rate*	*Comparisons*	*Result*
Gerace *et al.*[20]	Self-report	'Eating faster at the fire station t han elsewhere' vs 'Others'	Firefighters who reported eating faster at the station than elsewhere gained more than all others over 7 years (9.9 vs 6.8 pounds, $P < 0.006$).
Tanihara *et al.*[26]	Self-report	'Fast' vs 'Medium and slow'	Fast eaters had a higher average weight gain than the medium and slow eaters over 8 years (1.9 vs 0.7 kg, $P = 0.008$).
Yamane *et al.*[31]	Self-report	'Eating quickly' vs 'Eating slow'	Subjects eating quickly had an increased risk of developing obesity compared with those eating slow after 3 years (odds ratio 4.40, 95% confidence interval 2.28-8.75).

that fast eating was significantly associated with an increased risk of developing obesity in a 3-year follow-up study conducted in Japanese university students (OR, 4.40; 95% CI, 2.22–8.75; Table 2B).

DISCUSSION

In the present meta-analysis, we showed a significant positive association between eating quickly and excess body weight. People who ate quickly were shown to have a significantly higher BMI and to be obese. This relationship was consistent for several subgroups, including sex, level of adjustment, adjustment for energy intake and number of participants, whereas the magnitude of the association between eating speed and BMI was weaker in individuals with diabetes than in those without the disease. These findings highlight that the speed of eating is an important factor for weight control.

There are several plausible pathophysiologic mechanisms to explain the association between eating quickly and excess body weight. Several epidemiologic studies[7,14,17,28,30] and a recent meta-analysis[32] showed that people who ate quickly tended to have more energy intake than those who ate slowly. This may be because fast eaters ingest more energy before the brain recognizes the satiety signal, which is triggered by nutrient ingestion, gastric distension and the release of gut factors, including cholecystokinin.[33] Lower postprandial levels of the anorexigenic gut hormones peptide YY and glucagon-like peptide-1 after a meal short in duration[34] may also contribute to the association. However, the results of our subgroup analysis with an adjustment for energy intake did not indicate significant heterogeneity (Figures 3a and b), which suggests the presence of a mechanism other than energy intake. Another plausible explanation for the association between eating quickly and excess body weight may be a decrease in mastication in the fast eaters and subsequent inactivation of neuronal histamine. In rats, activation of histamine neurons suppressed food intake physiologically through H1-receptors in the satiety centers.[35] In addition, histamine neuronal activation accelerated lipolysis, particularly in visceral adipose tissue, and upregulated gene expression for the uncoupling protein family through sympathetic efferent nerves.[35]

In the present study, there was evidence of heterogeneity in the magnitude of the association between eating rate and BMI and the OR for obesity across the included studies. One potential source for this heterogeneity may be the differences in the definition of the categories of eating rates among the included studies. For example, the sensitivity analysis excluding two studies that used medium eating rate as a reference group reduced the heterogeneity in the association among the studies. In the subgroup analysis, we found significant heterogeneity in the association of eating rate with the mean differences in BMIs between groups of diabetes status. Studies conducted with diabetic patients showed a weaker association than those conducted with nondiabetic individuals. However, this is likely owing to chance because no difference was observed in the OR for the presence of obesity between diabetes statuses, although impaired insulin secretion in diabetic patients[36] may also account for the association. The obesogenic effect of eating quickly may be weakened in diabetic patients because of the decreased anabolic action of insulin. Thus, we could not clarify the source of the heterogeneity in this study. Nevertheless, this heterogeneity does not alter our conclusion because heterogeneity was related only to the strength of the positive association and not with the direction of this association.

The strengths of the present review are its inclusion of a large number of participants, immediate applicability to a clinical question, and clear results. The findings have direct implications for the clinical management of weight control, highlighting the importance of how to eat in addition to the traditional dietary instructions for what and how much to eat. Some limitations of our study should be noted. First, eating rate was evaluated using a self-reported questionnaire in most of the included studies. However, a high level of concordance between self-reported eating rate and friend-reported eating rate as a standard has been demonstrated.[7] Other validation studies also indicated a correlation of self-reported eating rate with measured eating rate in the laboratory[37] and recalled duration of eating.[38] Second, most studies included in this review were conducted with a Japanese

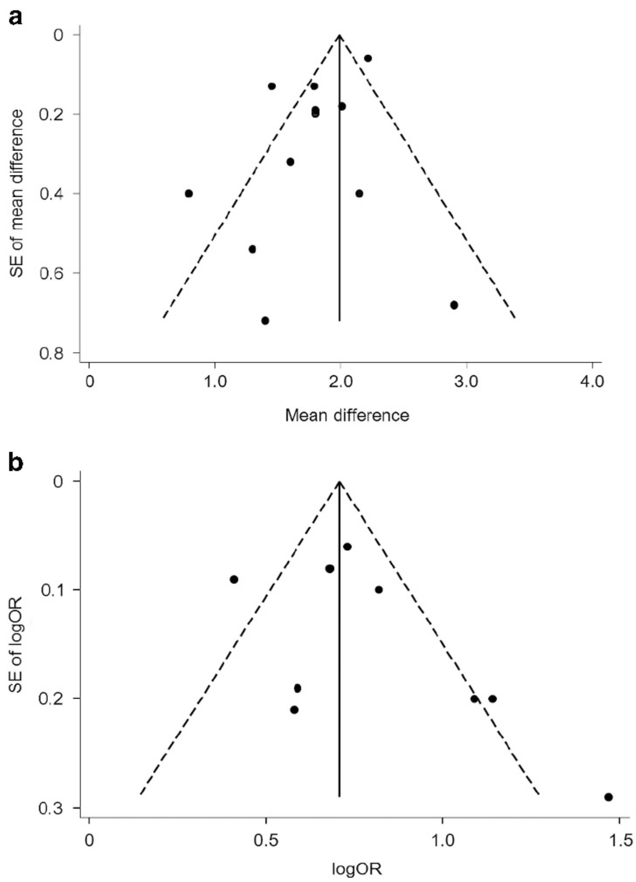

Figure 4. Funnel plot of the mean differences in BMIs versus the standard errors (**a**) and the natural logarithms of the odds ratios for obesity versus the standard error (**b**) OR, odds ratio; SE, standard error.

population. Considering the difference in dietary habits across racial or regional backgrounds, the generalizability of the current findings may be limited. In addition, the present studies focused on the influence of eating speed on obesity in adults, but recent cross-sectional and longitudinal studies conducted in children have also shown a positive association between eating fast and childhood obesity.[39,40] Further studies to ascertain the association in other races and children may be needed. Third, all the studies included in the meta-analysis were from cross-sectional studies, which do not allow the deduction of causal relationships. However, three longitudinal studies showed that a faster eating rate was associated with increased BMI and a higher risk of obesity over time. In addition, a prior randomized controlled trial retraining eating behavior to slow the speed of eating and reduce portion size was beneficial for weight reduction.[41] Further longitudinal observational studies or randomized controlled trials will be required to test the causal relationship. Fourth, the definitions of the categories for the eating rate differed across the studies included in this analysis, which may be a source of heterogeneity in the association. Fifth, we could not include two studies reporting no significant correlation between eating rate and BMI in the analysis.[11,12] Excluding these studies may tend toward biasing an overestimation of the association. However, these two limitations are unlikely to change our conclusion, because almost all included studies showed a positive association between eating rate and BMI, and the two excluded studies had much smaller sample sizes than those in the included studies. Finally, there may be other unmeasured confounding factors in addition to those evaluated in the present meta-analysis.

In conclusion, the findings of the present meta-analysis clearly showed that eating quickly was associated with increased BMI and obesity. This study provides a critical contribution to weight-management practices because the importance of how to eat was clearly demonstrated, adding to prior evidence regarding what and how much to eat. Instructions to eat slowly may be widely efficacious because of the simple nature of this weight-management practice both in public health and clinical settings. Although further interventional studies are needed to conclude a causal relationship between eating rate and obesity, more emphasis may be placed in clinical practice on slowing the speed of eating.

AUTHOR CONTRIBUTIONS

TO and TN designed and conducted the research, analyzed the data and wrote the paper. YH, UN, YK and TK helped with the data interpretation, contributed to the discussion and revised the paper. TN had primary responsibility for the final content of the manuscript. All authors participated in critically revising and approving the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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