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Public Health

journal homepage: www.elsevier.com/puhe

Review Paper

Is there a relationship between body mass index and academic achievement? A meta-analysis

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ARTICLE INFO

Article history:
Received 1 May 2018
Received in revised form
20 September 2018
Accepted 5 November 2018
Available online 15 January 2019

ABSTRACT

Objective: To date, although there have been several systematic reviews about the relationship between overweight/obesity and academic performance, none of the reviews were conducted quantitatively, thus the extent overweight/obesity is related to academic performance still remains unclear. Thus, the aim of this study was to quantitatively review the scientific evidence on the association between body mass index (BMI) and academic performance.

Study design: A systematic review of articles examining such relationship was undertaken using four databases, namely, PubMed, Web of Science, EBSCOhost and ProQuest Dissertations & Theses Global. The search period covered the research literature up to July 2017.

Methods: Data from 60 selected studies (involving 164,049 participants) were extracted and analysed following procedures for meta-analysis.

Results: Sixty studies met all inclusion criteria and were included. Using a random-effects meta-analysis model, a weak negative correlation between BMI and academic achievement ($r = -.111$; 95% confidence interval [CI]: −.155 to −.067; $P < .01$) was revealed. After conducting a series of moderator analyses, such a relationship was found to be significantly moderated by regions and students' study grades.

Conclusions: BMI is weakly and negatively associated with academic achievement. For a better understanding of such a relationship, future studies are needed to explore whether there is a causal relationship and also explore whether there are other factors that potentially moderate such a relationship.

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https://doi.org/10.1016/j.puhe.2018.11.002

Introduction

Globally, the prevalence of obesity has increased dramatically over the past few decades for children, adolescents and adults in both developed and developing countries.[1] Given that it has become clear that obesity is closely linked to various physical and psychological health risks[2–5] and lower health-related quality of life,[6,7] obesity has become a major global health challenge.

In addition to the well-known associations between obesity and the health-related outcomes, obesity has also been shown to be associated with students' academic performance.[8–10] To the best of our knowledge, the exploration of such an association started from Canning and Mayer (1966) who found that obese college applicants were more likely to be rejected than non-obese applicants,[11] and since then, numerous studies in this area have been conducted, and relevant empirical findings about this issue have accumulated.[8–10,12,13]

Body mass index (BMI) has been widely used in research and project evaluations for weight status, and previous studies that aimed at exploring the relationship between obesity and academic achievement typically used BMI in their studies.[10] Although there have been numerous empirical studies about the relationship between obesity and academic achievement, the findings are inconsistent, with the findings ranging from a negative correlation of .56[14] to a positive correlation of .28.[15] Such inconsistency makes it difficult to have a clear understanding about the nature (i.e., positive or negative) and the magnitude (i.e., strength) of the relationship between weight status and academic achievement.

In previous studies, several factors (e.g. grade level, gender, geographic region, subjects and the assessment of academic achievement) have been suggested to be culprits for the observed inconsistency between obesity and academic achievement. For instance, Mo-suwan et al.[16] found that grade might be an important factor because their study showed that such association only existed among adolescents from seventh to ninth grade, but not among children from third to sixth grade; Black et al.[17] reported that the negative relationship between obesity and academic achievement only existed among boys but not for girls; Kobayashi[18] compared such association between Japan and America and found that the negative association between obesity and academic achievement only existed in American college students, but not in Japanese college students; Coe et al.[19] found that the correlations varied by subjects (i.e., math, English and social studies); and finally, Maccann and Roberts[20] reported that obese students obtain lower school grades, but they showed equivalent intelligent test scores as non-obese students.

To the best of our knowledge, five related systematic reviews[8–10,12,13] have been conducted, but conclusions were inconsistent among these reviews. Specifically, Taras and Potts-Datema,[8] Burkhalter and Hillman[9] and Caird et al.[10] concluded that obesity could be associated with poor academic performance, while Martin et al.[12] and Santana et al.[13] suggested that there was no strong evidence for the existence of such association. Moreover, all these systematic reviews were conducted in children and adolescents, and college students were not included. However, there have been many related studies available for college students,[18,20–24] and in order to have a more comprehensive understanding of the research literature about such relationship and to make possible comparisons on such relationship across different developmental stages, we included studies involving college student samples in this meta-analysis. It is important to point out that, all the previous five systematic reviews were conducted qualitatively, and no quantitative syntheses have been conducted up to now. As a result, the extent to which BMI is correlated with academic achievement and the factors that could have moderated this association remain unclear.

The present study used the meta-analytic approach to examine two issues: (1) what the overall relationship was between BMI and academic achievement; and (2) to what extent some salient study features (e.g., gender groups, age) might have contributed to the inconsistency of the findings as shown in previous studies.

Methods

The present meta-analysis was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement.[25]

Search strategy and selection criteria

Four databases, namely, PubMed, Web of Science, EBSCOhost (all databases used, e.g., ERIC, PsycINFO and MEDLINE) and ProQuest Dissertations & Theses Global were searched up to July 2017. The following two sets of terms were searched simultaneously using the AND Boolean operator: (1) 'weight' OR 'overweight' OR 'obesity' OR 'obese' OR 'adiposity' OR 'body mass index'; and (2) 'academic performance' OR 'academic achievement' OR 'school grades' OR 'GPA' OR 'school achievement' OR 'school performance' OR 'school marks' OR 'educational outcome' OR 'class grades' OR 'standardized test' OR 'course grade.' In a follow-up search, Google Scholar was searched to find additional related articles and dissertations, which were not contained in the databases that we used. In addition, the reference list of included articles or dissertations were also scanned to find additional relevant studies that might meet our selection criteria.

Selection and exclusion criteria

Studies were selected if they met all of the four following criteria: (1) written in English; (2) peer-reviewed journal articles or dissertations; (3) data on non-overweight participants (e.g., BMI percentile < 85th for children and BMI < 25 kg/m^2 for adults) were included; (4) both BMI and academic achievement were treated as continuous variables, and the correlation coefficient between them was calculated; or BMI was categorical variable (i.e., based on BMI, participants were classified into groups with different weight status, while academic achievement was continuous variable, and academic achievement was compared by weight categories) or both BMI and academic achievement were treated as categorical variables, and contingency table of weight category × academic achievement category was presented.

Excluded studies were (1) those that not written in English, (2) conference abstracts, (3) reviews, (4) only overweight/obese participants were included, (5) zero-order correlation not available (e.g., only partial correlation between BMI and academic achievement after controlling for other variables, such as gender) and (6) comparisons of academic achievement were made after controlling for other variables.

Data extraction

For each study included in the current meta-analysis, the following information was extracted: (1) name of the first author; (2) type of publication (journal article or dissertation); (3) publication year; (4) sample size; (5) percentage of females; (6) age of participants (range and mean); (7) grade; (8) assessment of BMI (based on self-reported or measured data of weight and height); (9) academic subjects (language and arts, math, science, social studies or mixed); and (10) assessment of academic performance (standardised, unstandardised or mixed). In the process of data extraction, two authors (XC and FH) of this meta-analysis coded the selected articles independently first. A limited number of coding discrepancies between the two coders were later resolved by discussion among the research team. It should be noted that, as a quantitative synthesis of previously published studies, this meta-analysis did not have any data related to BMI calculation. Instead, we systematically collected the measures of association between BMI and academic achievement as reported from all original studies included. In addition, based on the information reported in the original articles, the nature of BMI data or weight status information from all the included studies were coded for further analyses in this meta-analytical study.

Quality assessment

Study quality was assessed by two authors (J.H. and X.C.) of this work using an adapted quality appraisal tool (Appendix A), which is specially designed for assessing the quality of cross-sectional studies.[26–30] This tool focuses on assessing the methodological quality of a study and includes six questions about sampling, study response rate, instrument reliability and validity, origin of data source and associations between the two variables interested.[26] Each of the six questions is rated as either ‘yes’ or ‘no’ corresponding to the score of ‘1’ and ‘0’, respectively. The methodological appraisal score is obtained by the total being divided by the total number of items (i.e., six) and multiplied by 100. Then, methodological appraisal scores of 0–33%, 34–66% and 67–100% indicate bad, satisfactory and good methodological quality, respectively.[26,29,30]

Statistics

Because the Pearson product–moment correlation coefficient r is standardised and itself can serve as an effect size,[31,32] and it is also the most common effect size measure used in studies of academic performance,[33] the effect size r was used to represent the direction and strength of associations between BMI and academic achievement. Thus, the correlation coefficient between BMI and academic achievement was the primary effect size in the present meta-analysis, and other forms of effect sizes were transformed into r based on the converting formulas between two different forms of effect sizes.[34] Because the variance depends strongly on the value of correlation coefficient if synthesis of effect size is based on the correlation coefficient itself, the correlation coefficients were converted to the Fisher's z scale using the equation: QUOTE $z = 0.5 \times \ln\left(\frac{1+r}{1-r}\right)$, with r denoting the correlation coefficient, and ln denoting the natural logarithm.[32] Then, all analyses were performed using the transformed values, and once the analyses were finished, the results were back-transformed to correlation coefficients using the equation: $r = \frac{e^{2z}-1}{e^{2z}+1}$.

Because meaningful variation in effect sizes between studies was anticipated in the present study, a random-effects model was most appropriate for the overall analysis, and mixed-effects models were most appropriate for moderator analyses.[35] Thus, the overall combined effect size was calculated by a random-effects model, and mixed-effects models were used for moderator analyses. Moreover, in order to ensure independence of the effect sizes for each of the studies included in this meta-analysis, each study should contribute only one effect size to the meta-analysis.[36] Thus, when a study reported multiple overall effect sizes,[19,23,37–45] the effect sizes were combined into one effect size that was included in the overall analysis. When a study reported both overall effect size and subgroup effect sizes, such as gender,[46] the overall effect size was used in the overall analysis, while the subgroup effect sizes by gender were only used for moderator analyses.

The heterogeneity of the effect sizes was quantified using the Cochrane Q statistic, and the I^2 index was used to represent the percentage of variation across studies that is due to heterogeneity rather than chance.[47] According to Higgins and Thompson,[47] I^2 values of 25%, 50% and 75% indicate low, moderate and high heterogeneity, respectively. Publication bias was assessed using the funnel plot approach and checking the significance of Egger's test that quantifies the estimated bias as reflected in the funnel plot, with a non-significant P value indicating insufficient evidence for publication bias.[48,49]

All the analyses for the effect sizes described previously were carried out using the Comprehensive Meta-analysis (Version 2.0; Biostat, Englewood, NJ), a statistical analysis software especially designed for conducting meta-analysis.

Results

Study selection

The process of selecting the usable studies for this meta-analysis is graphically shown in Fig. 1. Specifically, 5751 records were identified from the four databases and 59 records were identified from Google Scholar, which, taken together, resulted in a total of 5810 records. After removing duplicates, 4021 were remained in the pool. Two hundred and sixty-three

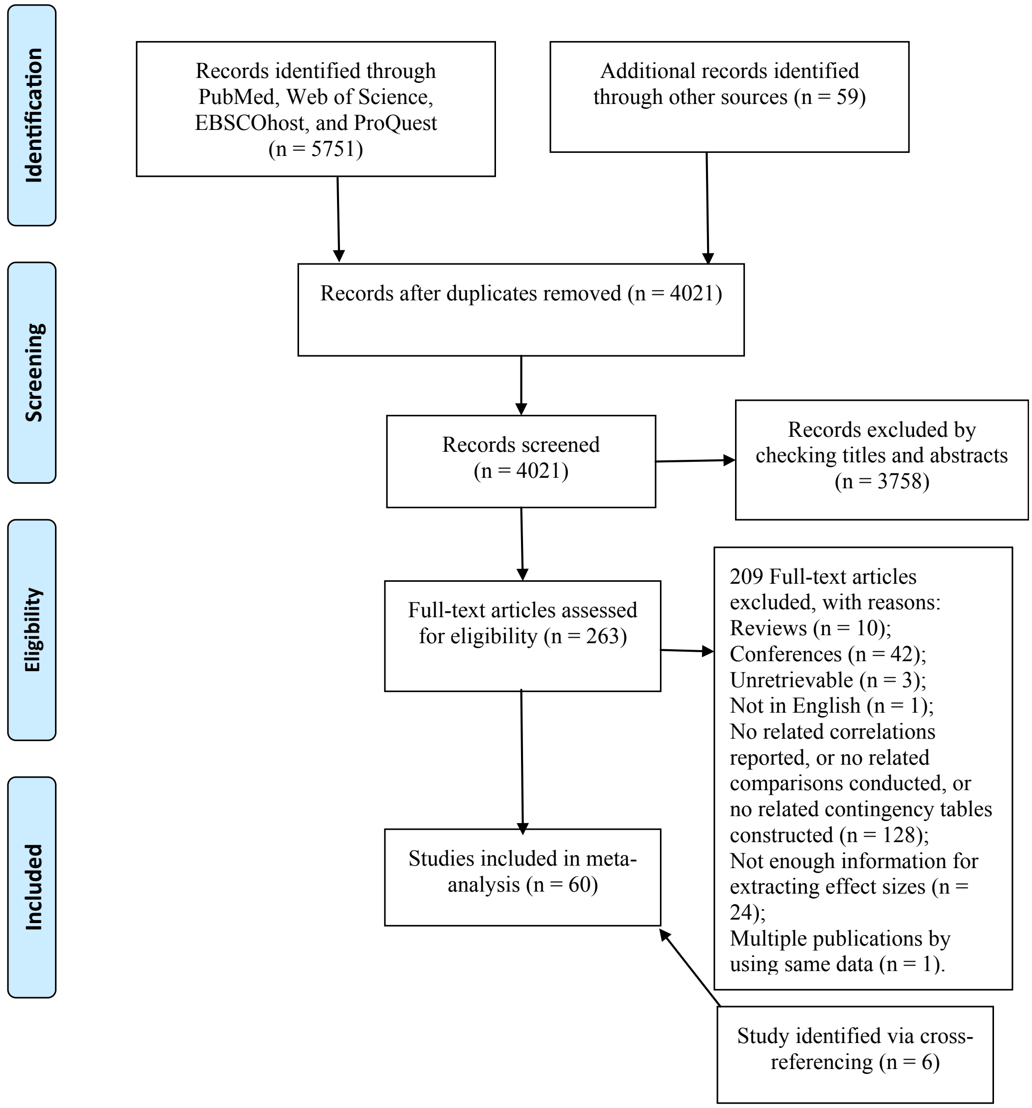

Fig. 1 – Flow diagram of search strategy and study selection

were included in the full-text review after exclusion by titles and abstracts. Based on the 263 full texts, 59 were identified as having met the selection criteria. Furthermore, one additional study was identified and included by checking the reference lists of the 59 included articles. In total, 60 studies were included in the present meta-analysis. Among these included studies, 38 studies reported correlations between BMI and academic achievement,[14,15,17–21,23,38,39,41–43,45,46,50–72] 14 studies reported mean differences of academic achievement by weight category[16,24,37,40,73–81] and eight studies reported contingency tables of weight category × academic achievement category.[22,82–88]

Descriptive characteristics of the studies included

The 60 selected studies involved a total of 164,049 participants with age ranging from 4 to 34 years old[18,84] and contained 67 independent samples because five studies[18–20,42,72] used more than one independent samples in their studies (e.g., Kobayashi[18] reported the correlations between BMI and academic achievement for Japanese and American college students separately). The dates of publications ranged from 1999 to 2017. Among the 60 selected studies, 49 were peer-reviewed journal articles, and 11 studies were dissertations. Fourteen studies were conducted in Asia, seven studies in Europe, 41 studies in North America and five studies in other regions (e.g., Australia, South Africa, etc.). As for the quality of the 60 included studies (Appendix A), 49 had good quality scores (67–100%), 11 had satisfactory quality scores (34–66%) and no study had a low score (0–33%). Thus, all 60 studies were included in the final review. The details of the 60 studies included in this meta-analysis are presented in Table 1.

Overall analysis

Among the 60 studies included in this meta-analysis, the correlation between BMI and academic achievement among children and adolescents with overweight and obesity ranged from −.560[14] to .280[15]. A statistically significant pooled overall negative correlation, $r = -.111$ (95% confidence interval [CI]:

Table 1 – Characteristics of the 60 studies included.

First author and publication year	Country	Participants characteristics	BMI assessment	Academic achievement assessment and subjects	Overall effect size
Adaili, 2016[82]	Saudi Arabia	260 students/100% female/age range; not reported; mean age: 16 y/grade: 10th	Measured	Mid-term marks (subjects: not reported)	−.025
Aimé, 2017[21]	Canada	298 students/100% female/age range: 18–29 y; mean age: 23.01 y/grade: college	Measured	GPA (subjects: psychoeducation, psychology, educational sciences, administrative sciences, social work and nursing)	−.179
Al-Drees, 2016[22]	Saudi Arabia	409 students/50% female/age range: 18–25 y; mean age: 21.33 y/grade: college	Measured	GPA (subjects: not reported)	−.142
Alswat, 2017[37]	Saudi Arabia	424 students/25% female/age range: 12–18 y; mean age: 15.44 y/grade: not reported	Measured	GPA (subjects: biology, chemistry, physic and math)	−.071
Agarwal, 2013[23]	India	60 students/48% female/age range: 18–21 y; mean age: 18.81 y/grade: college	Measured	Marks obtained in all the tutorials, completion tests and first terminal examination (subjects: anatomy, physiology and biochemistry)	−.058
Bahe, 2016[50]	The United States	2835 students/49% female/age range: not reported; mean age: not reported/grade: elementary to high schools	Measured	The Academic Accountability School Rating (AASR; subjects: not reported)	−.026
Barrigas, 2012[73]	Portugal	792 students/50% female/age range: 6–12 y; mean age: not reported/grade: first to sixth	Measured	For first to fourth grades: a questionnaire filled in by their teachers and assessment test in the same subjects. For fifth to sixth grades: the school tests at the end of the second term (subjects: Portuguese, mathematics and sciences)	.025
Black, 2015[17]	Australia	6796 students/48% female/age range: 8–13 y; mean age: 18.81 y/grade: third, fifth and seventh	Measured	The National Assessment Program-Literacy and Numeracy (NAPLAN; subjects: math and literacy)	−.111
Booth, 2014[51]	The United Kingdom	5966 students/54% female/age range: not reported; mean age: 11 y/grade: key stage 2	Measured	Compulsory national achievement tests (subject: English)	−.105
Capawana, 2016[45]	The United States	5573 students/49% female/age range: not reported; mean age: not reported/grade: fifth	Not reported	Academic report card grades and Massachusetts Comprehensive Assessment System (MCAS; subjects: math, reading and writing)	−.061
Castelli, 2007[38]	The United States	259 students/49% female/age range: not reported; mean age: 9.5 y/grade: third to fifth	Measured	The Illinois Standards Achievement Test (ISAT; subjects: mathematics and reading)	−.280
Chen, 2012[74]	Taiwan	409 students/48% female/age range: not reported; mean age: not reported/grade: first	Measured	School records at the end of each grade (subjects: language, mathematics, science and social studies)	.041
Clark, 2009[39]	The United States	9471 students/48% female/age range: not reported; mean age: not reported/grade: first to fifth	Measured	School grades in five subjects (subjects: math, reading, language, science and social studies) and Texas Assessment of Knowledge & skills (TAKS; subjects: reading, math, writing and science)	−.085
Coe (a), 2013[19]	The United States	291 students/53% female/age range: not reported; mean age: not reported/grade: third	Measured	The Michigan Education Assessment Program (MEAP; subjects: mathematics, English/language arts [ELA])	−.114
Coe (b), 2013[19]	The United States	706 students/45% female/age range: not reported; mean age: not reported/grade: sixth	Measured	The MEAP (subjects: mathematics, ELA and social studies)	−.070
Coe (c), 2013[19]	The United States	704 students/46% female/age range: not reported; mean age: not reported/grade: ninth	Measured	The MEAP (subjects: mathematics, ELA and social studies)	−.055
Cottrell, 2007[40]	The United States	968 students/49% female/age range: 9–13 y; mean age: 10.6 y/grade: fifth	Measured	The West Virginia Educational Standards Test (subjects: mathematics, reading/language arts, science and social studies)	−.069

(continued on next page)

Table 1 – (*continued*)

First author and publication year	Country	Participants characteristics	BMI assessment	Academic achievement assessment and subjects	Overall effect size
Crosnoe, 2004[75]	The United States	10,254 students/50% female/age range: not reported; mean age: 15.83 y/grade: 7 - 12th	Self-reported	Self-reported their grades in the past year (subjects: math, science, English and social studies)	−.115
Desai, 2015[41]	India	273 students/50% female/age range: 7–10.5 y; mean age: not reported/grade: second to fifth	Not reported	School-wide exam scores (subjects: mathematics and Kannada language)	−.020
Du Toit, 2011[66]	Republic of South Africa	212 students/56% female/age range: 9–12 y; mean age: not reported/grade: fourth to sixth	Measured	Average of percentages achieved by the learner in each of the eight learning areas (subjects: languages, mathematics, natural sciences, technology, social sciences, art and culture, life orientation and economic and management sciences)	−.070
Esmaeilzadeh, 2013[52]	Iran	538 students/0% female/age range: 15–17 y; mean age: 15.7 y/grade: high school	Measured	CGPA from the last semester (subjects: not reported)	−.204
Eveland-Sayers, 2009[46]	The United States	134 students/46% female/age range: not reported; mean age: 9.7 y/grade: third to fifth	Measured	The 2005 TerraNova standardised academic achievement test (subjects: mathematics and reading/ language arts)	−.090
Florin, 2011[53]	The United States	11,012 students/51% female/age range: 14–17 y; mean age: not reported/grade: 9th to 12th	Measured and self-reported	Self-reported grades (subjects: not reported)	−.110
García-Hermoso, 2017[54]	Chile	395 students/50% female/age range: not reported; mean age: 12.2 y/grade: seventh	Measured	Students' grades from the schools' official records at four time points in the first semester (subjects: mathematics and language)	−.190
Golam H., 2014[88]	Bangladesh	198 students/51% female/age range: 10–14 y; mean age: 11.72 y/grade: sixth	Measured	GPA (subjects: not reported)	.219
Guindon Sr (a), 2014[42]	The United States	72 students/49% female/age range: not reported; mean age: not reported/grade: sixth	Measured	The New Jersey Assessment of Skills and Knowledge (NJASK; subjects: language arts, math, science and social studies)	.015
Guindon Sr (b), 2014[42]	The United States	77 students/52% female/age range: not reported; mean age: not reported/grade: seventh	Measured	NJASK (subjects: language arts, math, science and social studies)	−.020
Guindon Sr (c), 2014[42]	The United States	74 students/57% female/age range: not reported; mean age: not reported/grade: eighth	Measured	NJASK (subjects: language arts, math, science and social studies)	.095
Han, 2012[55]	The United States	2631 students/47% female/age range: not reported; mean age: 11.07 y/grade: fifth and eighth	Measured	Item Response Theory (IRT)-scale test scores (subjects: reading and math)	−.136
Hill–Jones, 2008[43]	The United States	35 students/63% female/age range: 15–19 y; mean age: not reported/grade: 10th to 12th	Measured	Subject Area Testing Program (subjects: algebra I, biology I, English II and US history)	−.092
Huang, 2006[76]	The United States	666 students/100% female/age range: 11–14 y; mean age: not reported/grade: seventh	Measured	Self-report grades in the last year and GPA (subjects: not reported)	−.528
Izidoro, 2014[83]	Brazil	59 students/42% female/age range: 9–11 y; mean age: 9.4 y/grade: fourth	Measured	Teste de Desempenho Escolar (subjects: reading, spelling and arithmetic test)	−.114
Judge, 2007[77]	The United States	13,680 students/49% female/age range: not reported; mean age: 9.24 y/grade: third	Measured	Direct assessment using IRT scale scores (subjects: reading and math)	−.052
Kahil, 2013[56]	The United States	517 students/42% female/age range: 12–13 y; mean age: not reported/grade: eighth	Measured	The TAKS (subject: math)	−.173
Kalantari, 2016[57]	Iran	580 students/50% female/age range: 7–9 y; mean age: 18.81 y/grade: high school	Measured	CGPA (subjects: not reported)	−.200

Kamijo, 2012[78]	The United States	126 students/50% female/age range: 7–9 y; mean age: not reported/grade: elementary school	Measured	The Wide Range Achievement Test third edition (subjects: reading, spelling, arithmetic)	−.166
Kobayashi (a), 2009[18]	Japan	72 students/46% female/age range: 18–26 y; mean age: not reported/grade: college	Measured	GPA (subjects: not reported)	−.024
Kobayashi (b), 2009[18]	The United States	57 students/54% female/age range: 18–34 y; mean age: not reported/grade: college	Measured	GPA (subjects: not reported)	−.261
Kristjánsson, 2010[58]	Iceland	6346 students/51% female/age range: 14–151 y; mean age: not reported/grade: 9th to 10th	Self-reported	Self-report average grades (subjects: Icelandic, mathematics, English and Danish or, alternatively, Swedish or Norwegian)	−.120
Krukowski, 2009[84]	The United States	1071 students/46% female/age range: 4–13 y; mean age: 9.5 y/grade: elementary and middle schools	Measured	Parent-reported school performance (subjects: not reported)	−.081
Kukulu, 2010[85]	Turkey	737 students/46% female/age range: 10–15 y; mean age: not reported/grade: sixth to eighth	Measured	School records (subjects: not reported)	−.036
LeBlanc, 2012[59]	The United States	1963 students/60% female/age range: not reported; mean age: 10.5 y/grade: fourth to sixth	Measured	Criterion-referenced tests annually (subjects: ELA, mathematics, science and social studies)	−.015
Lu, 2014[79]	Taiwan	8690 students/51% female/age range: not reported; mean age: not reported/grade: seventh	Measured	Comprehensive cognitive ability scores	−.057
Maccann (a), 2013[20]	United States	383 students/49% female/age range: 12–15 y; mean age: not reported/grade: eighth	Measured	Self-report and parent report of grades from the previous semester (subjects: English, mathematics, science and social studies)	−.153
Maccann (b), 2013[20]	The United States	1036 students/64% female/age range: 18–25 y; mean age: not reported/grade: college	Measured	Self-report and parent report of grades from the previous semester (subjects: English, mathematics, science and social studies)	−.165
Marsan, 2014[60]	The United States	227 students/56% female/age range: not reported; mean age: not reported/grade: sixth to eighth	Measured	The Connecticut Mastery Test (subjects: reading, writing, math)	−.092
Martinez, 2014[61]	The United States	66 students/42% female/age range: 5–8 y; mean age: 6.2 y/grade: second	Measured	The District performance assessment (subjects: English/language arts and mathematics)	−.070
Morita, 2016[62]	Japan	315 students/48% female/age range: 12–13 y; mean age: not reported/grade: seventh	Measured	The total grade point (GP) of school subjects evaluated by school teachers (subjects: GP5: Japanese, mathematics, social studies, sciences and English; GP8: Japanese, mathematics, social studies, sciences, English, music, arts and home economics/vocational technology)	−.114
Mo-suwan, 1999[16]	Thailand	571 students/57% female/age range: not reported; mean age: 13.8 y/grade: seventh to ninth	Measured	GPA, grades from final exams (subjects: math, Thai language)	−.087
Odlaug, 2015[24]	The United States	1765 students/58% female/age range: 18–58 y; mean age: 22.6 y/grade: college	Measured	Self-reported scholastic achievement (subjects: not reported)	−.121
Pellicer-Chenoll, 2015[14]	Spain	444 students/51% female/age range: not reported; mean age: not reported/grade: high school	Measured	GPA (subjects: not reported)	−.560
Rajagopal, 2017[63]	The United States	579 students/51% female/age range: not reported; mean age: not reported/grade: sixth to eighth	Measured	GPA (subjects: not reported)	−.446
Ramaswamy, 2010[15]	The United States	45 students/53% female/age range: 7–12 y; mean age: 9.33 y/grade: third to fifth	Measured	Standard academic achievement scores provided by teachers (subjects: English, reading, mathematics, social studies and science)	.280
Rauner, 2013[64]	The United States	11,742 students/50% female/age range: not reported; mean age: not reported/grade: fourth to eighth	Measured	The Nebraska State Accountability (subjects: math and reading)	−.085

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Table 1 – (*continued*)

First author and publication year	Country	Participants characteristics	BMI assessment	Academic achievement assessment and subjects	Overall effect size
Sardinha, 2014[87]	Portugal	1531 students/49% female/age range: 12–14 y; mean age: 12.3 y/grade: seventh	Measured	Marks at the end of the academic year (subjects: mathematics, Portuguese, English and sciences)	−.147
Shore, 2008[80]	The United States	566 students/46% female/age range: not reported; mean age: not reported/grade: sixth to seventh	Measured	GPA from year-end student report cards (subjects: not reported)	−.168
Srikanth, 2015[65]	The United States	1211 students/54% female/age range: not reported; mean age: 12.45 y/grade: sixth to eighth	Measured	The TAKS (subjects: reading and math)	−.080
Stroebele, 2013[86]	The United States	1095 students/47% female/age range: 10–17 y; mean age: not reported/grade: fifth	Self-reported	Self-reported grades (subjects: not reported)	−.083
Thompson, 2013[44]	The United States	680 students/50% female/age range: 8–12 y; mean age: not reported/grade: fourth to sixth	Measured	District benchmark test results and report card grades (subjects: language arts/reading, math and science)	−.114
Tonetti, 2015[67]	Italy	37 students/35% female/age range: not reported; mean age: 18.16 y/grade: high school	Self-reported	Actual grade obtained at the final school-leaving exam (subjects: not reported)	−.420
Tremblay, 2000[68]	Canada	5146 students/percentage of female: not reported/age range: not reported; mean age: 12 y/grade: sixth	Self-reported	Grade 6 assessment (subjects: reading and mathematics)	−.036
Vassiloudis, 2014[69]	Greece	528 students/52% female/age range: 10–12 y; mean age: not reported/grade: elementary school	Measured	Teachers evaluated students' academic performance (subjects: language, mathematics, physics, history, geography, spelling, reading comprehension, writing composition, oral expression, numerical ability and the ability to solve mathematical problems)	−.220
Viera, 2005[81]	The United States	142 students/77% female/age range: 14–17 y; mean age: 15.49 y/grade: high school	Measured	Self-reported GPA (subjects: social studies, science, math, English literature and writing)	−.067
Welk, 2013[70]	The United States	38,992 students/47% female/age range: not reported; mean age: not reported/grade: 3rd to 12th	Measured	The TAKS (subjects: not reported)	.240
Wellman, 2012[71]	The United States	126 students/100% female/age range: not reported; mean age: 18.14 y/grade: college	Measured	GPA and Scholastic Aptitude Test	−.113
Wingfield (a), 2011[72]	The United States	66 students/48% female/age range: not reported; mean age: not reported/grade: fourth	Measured	The Florida Comprehensive Assessment Test (FCAT; subjects: reading and math)	−.010
Wingfield (b), 2011[72]	The United States	66 students/50% female/age range: not reported; mean age: not reported years/grade: fifth	Measured	The FCAT (subjects: reading and math)	−.370

BMI: body mass index; CGPA: Cumulative Grade Point Average.

−.155 to −.067; $P < .01$), was obtained, indicating that generally, BMI had a weak association with academic achievement. Based on the statistically significant result of Begg's and Egger's test ($P < .001$), publication bias was indicated in the current meta-analysis. Using Duval and Tweedie's trim and fill analyses,[48] 18 missing studies were imputed for rendering the publication bias test statistically non-significant at the .05 level. This correction of publication bias resulted in a slightly larger overall pooled effect size, $r = -.164$ (95% CI: −.221 to −.105; $P < .01$).

Furthermore, the results also showed substantial and statistically significant heterogeneity ($Q_{(66)} = 3889.033$, $P < .001$; $I^2 = 98.38$) of the reported correlations across the included studies. More specifically, it was estimated that 98.38% of the total observed variability across the studies could be attributed to the between-study differences, rather than to random chance. In a meta-analysis, a statistically significant and substantial heterogeneity points to the need of conducting moderator analyses.[89] Therefore, to understand what study features may have contributed to the inconsistencies of the findings across the studies, moderator analyses were conducted, and the findings were reported below.

Moderator analyses

Table 2 presents the results of weighted mixed-effects analysis of variance analysis findings for the selected moderator variables. The moderator variable ‘region’ was found to be statistically significant ($Q = 8.178$, $P < .05$). Specifically, Europe showed the largest pooled effect size ($r = -.204$; 95% CI: −.290 to −.114; $P < .01$), followed by North America ($r = -.106$; 95% CI: −.164 to −.047; $P < .01$) and Asia ($r = -.066$; 95%CI: −.111 to −.020; $P < .01$).

For the moderator variable of gender, although females showed a larger pooled effect size ($r = -.152$; 95% CI: −.209 to −.094; $P < .01$) than that of males ($r = -.085$; 95% CI: −.122 to −.048; $P < .01$), the statistical test for this moderator variable was not statistically significant ($Q = 3.749$, $P > .05$).

A significant moderator effect test was found for grades ($Q = 15.608$, $P < .01$). More specifically, elementary school students showed the smallest pooled effect size ($r = -.075$; 95% CI: −.102 to −.047; $P < .01$), followed by a larger pooled effect size for middle school students ($r = -.128$; 95% CI: −.177 to −.079; $P < .01$) and by the largest pooled effect size for high school students ($r = -.184$; 95% CI: −.225 to −.111; $P < .01$). For studies involving college students, the pooled effect size ($r = -.139$; 95% CI: −.170 to −.108; $P < .01$) was smaller than that of high school students.

As for the moderator effect of school subjects, a non-significant effect was found ($Q = 4.401$, $P > .05$). Descriptively, the differences among the effect sizes across different school subjects were small, with language/arts having a pooled effect size of $r = -.080$ (95% CI: −.096 to −.063; $P < .01$), math of $r = -.080$ (95% CI: −.099 to −.060; $P < .01$), science of $r = -.105$ (95% CI: −.151 to −.059; $P < .01$) and social studies of $r = -.072$ (95% CI: −.090 to −.054; $P < .01$).

With regard to the moderator effect of the assessment of BMI (i.e., BMI based on self-reported data or measured data of weight and height), a non-significant effect was found

Table 2 – Results of the weighted ANOVAs of categorical moderator variables.

Variable	k	r	95% CI Lower limit	95% CI Upper limit	Contrast Q
Region					8.178*
Asia	14	−.066	−.111	−.020	
Europe	7	−.204	−.290	−.114	
North America	41	−.106	−.164	−.047	
Other	5	−.115	−.129	−.100	
Gender					3.749
Female	17	−.152	−.209	−.094	
Male	15	−.085	−.122	−.048	
Mixed	48	−.095	−.149	−.041	
Grades					15.608**
College	8	−.139	−.170	−.108	
High school	10	−.184	−.225	−.111	
Middle school	22	−.128	−.177	−.079	
Elementary school	16	−.075	−.102	−.047	
Mixed	11	−.038	−.158	−.084	
Subjects					4.401
Language/arts	27	−.080	−.096	−.063	
Math	27	−.080	−.099	−.060	
Science	6	−.105	−.151	−.059	
Social studies	5	−.072	−.090	−.054	
Mixed	39	−.137	−.205	−.067	
BMI assessment					.080
Measured	60	−.109	−.157	−.060	
Self-report	4	−.099	−.149	−.048	
Standardised or not					2.756
Standardised	31	−.076	−.139	−.013	
Unstandardised	40	−.136	−.168	−.104	

ANOVA: analysis of variance; BMI: body mass index; CI: confidence interval.
*$P < .05$, **$P < .01$.

($Q = .080$, $P > .05$). Descriptively, the correlations from the studies using the two approaches were close to each other: $r = -.109$ (95% CI: −.157 to −.060; $P < .01$) for studies that used measured data for calculating BMI, and $r = -.090$ (95% CI: −.149 to −.048; $P < .01$) for studies that used self-reported data for calculating BMI.

For the moderator variable of academic achievement assessment (standardised vs. non-standardised measures), although the studies using standardised academic achievement measures had smaller pooled effect size ($r = -.076$; 95% CI: −.139 to −.013, $P < .01$) than that from the studies using unstandardised academic achievement measures ($r = -.136$; 95% CI: −.168 to −.104, $P < .01$), the difference was not statistically significant ($Q = 2.756$, $P > .05$).

Discussion

By quantitatively synthesising previous literature about the association between BMI and academic achievement, the current meta-analysis was the first study that quantitatively reviewed such association with a meta-analytic approach. Our results suggested an overall weak and negative relationship between BMI and academic achievement, and the association was significantly moderated by study features such as region and grade.

Our findings suggested that this relationship between BMI and achievement was larger in American and European samples than in Asian samples. It is intriguing to note that among the studies that used Asian samples, the estimate of pooled effect size was the smallest and minimal (close to 0), indicating that almost no relationship between BMI and academic achievement was reported from the studies involving Asian samples. This is in line with the study[18] that directly compared the associations of BMI and academic achievement between two countries (the United States vs. Japan), which reported that BMI had a significant negative correlation with grade point average for American college students, while a non-significant and small correlation for Japanese college students. Thus, our finding further highlights possible cultural differences in the relationship between BMI and academic achievement. Because of this potential culture difference, future research may need to explore why the academic performance of students in Western countries is more closely related to their weight status.

With respect to gender, the findings from previous studies were inconsistent, with some studies[51,62,72] reporting that the correlation for females was higher than that for males, while some other studies reporting either the opposite[17] or no gender difference[66] at all. Using a meta-analytic approach, our study revealed that, although the estimate of such correlation in females was higher than that in males, the difference was not statistically significant, indicating that there might be no gender difference for such association or the gender effect might be further moderated by other confounding variables (e.g., grade[72] and sociodemographic factors[17]). For example, one study[72] reported that there was no gender difference in the correlation between BMI and academic achievement for the fourth-grade students, but significant gender difference in this regard for the fifth-grade students. Thus, future studies may further explore what factors may further moderate this gender effect.

For the effect of grade, interestingly, our findings revealed that the associations between BMI and academic performance varied by grades, with the pooled effect size in elementary school samples lower than those in middle school, high school and college. Our finding is consistent with the study conducted by Mo-suwan et al.[16] who found that such association only existed among adolescents in seventh to ninth grade, but not among children in third to sixth grade. Thus, compared with students in middle school and higher grade levels, students in elementary school are still in their childhood period and are less concerned about their weight.[16] Therefore, the potential influence of body weight on academic achievement might change with the physical and psychological development of students.

For the effect of the assessment of BMI (i.e., BMI derived from self-reported height and weight vs. BMI derived from measured height and weight), to the best of our knowledge, no previous studies have explored this issue. However, considering that weight status screened from self-reported BMI may be different from that based on measured BMI,[90] the methods of BMI assessment could be a potential moderator factor. In the current meta-analysis, we found a non-significant effect of BMI assessment, indicating that there might be no effect from the assessment of BMI on such relationship. One potential reason for this might be that, although there are some absolute differences between self-reported BMI and measured BMI, a large number of studies have reported that self-reported BMI is highly correlated with measured BMI (generally >.90).[91–93] Thus, statistically, there might be little difference between the correlation (between BMI and academic achievement) based on self-reported BMI and the correlation based on measured BMI. However, as no empirical studies have explored this effect, the confirmation of this finding is highly recommended in future studies.

Moreover, with respect to school subjects (i.e., math, reading, etc.), our results showed that, descriptively, the estimated correlation for science was the largest, followed by language/arts, math and social studies. However, it should be noted that there were no statistically significant differences among them. This finding is in line with most previous research that reported similar correlations between BMI and academic achievement by different subjects,[17,39,41,45,59,64,94] but different with some other studies that reported different correlations for different school subjects.[19,65,68] However, according to the study conducted by Guindon Sr,[42] the correlations between BMI and language scores and math scores were similar in sixth grade sample (.15 vs. .15 for language and math, respectively), but different in seventh grade sample (.03 vs. −.07 for language and math, respectively) and eighth grade sample (.17 vs. .02 for language and math, respectively). Thus, our finding of no school subject effect might be a result of other confounding factors (e.g., grade). For better understanding of this issue, future research is needed to explore more potential moderators.

For the assessment of academic achievement (standardised tests vs. unstandardised tests), according to previous literature,[20] due to the potential negative attitude and social discrimination against students with overweight and obesity, the academic achievement for students with overweight and obesity by unstandardised tests (e.g., marks evaluated by teachers) might be lower than that based on standardised tests. Thus, the assessment of academic achievement might moderate the association between BMI and academic achievement. Thus, we grouped the 60 studies included in the current meta-analysis by standardised tests and unstandardised tests. The related results showed no significant difference between the two groups of studies. This finding is consistent with another study,[14] which reported that the assessment of academic achievement accounted for limited variance of students' academic achievement, and teachers' potential bias was very unlikely to lead to poor performance of the overweight students.

Limitations

It should be noted that the present study has some limitations that should be considered. First, although four databases (e.g., PubMed, Web of Science, EBSCOhost and ProQuest Dissertations & Theses Global) and Google Scholar were used to find potential studies, it is possible that some studies were missed because of 'not included in these databases'. Second, only peer-reviewed journal articles in English and dissertations in English were included in our study, and other forms (e.g., conference papers) were not. These inclusion criteria might be a source for the publication bias found in our study. Third, although the effects from several potential moderators (e.g., region, grade and gender) have been explored, it is possible that there are some other confounders (e.g., socioeconomic status,[10] how height and weight were measured or reported [e.g., with or without shoes] and the time interval between BMI measured/reported and academic scores obtained) that has not been included into our analysis due to lack of such information. Finally, all studies included in the current meta-analysis were observational studies, so it is prudent not to draw any conclusions about causal relationship between BMI and academic achievement.

Conclusion

In conclusion, the results of the current meta-analysis indicated that generally, BMI had a weak negative correlation with academic achievement, suggesting that overweight status is inversely related to academic achievement. Also, moderators such as region and grade significantly contributed to the observed heterogeneity of the associations between BMI and academic achievement across the 60 included studies. For better understanding of this and related issues, it is recommended that future studies may explore whether there are other factors that potentially moderate such association and also to explore potential interactions among the related factors.

Author statements

Ethical approval

Not applicable for this research.

Funding

No funding was received.

Competing interests

The authors have nothing to disclose.

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Appendix A. Quality assessment of the 60 included studies.

First author, y	Q1	Q2	Q3	Q4	Q5	Q6	Total	Quality (%)
Adaili, 2016	1	1	1	0	1	1	5	83.3
Aimé, 2017	1	1	1	0	1	1	5	83.3
Al-Drees, 2016	0	0	1	0	1	1	3	50.0
Alswat, 2017	1	0	1	0	1	1	4	66.7
Agarwal, 2013	1	0	1	0	1	1	4	66.7
Bahe, 2016	1	0	1	0	0	1	3	50.0
Barrigas, 2012	1	0	1	0	1	1	4	66.7
Black, 2015	1	0	1	1	1	1	5	83.3
Booth, 2014	1	0	1	1	1	1	5	83.3
Capawana, 2016	1	0	1	1	0	1	4	66.7

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First author, y	Q1	Q2	Q3	Q4	Q5	Q6	Total	Quality (%)
Castelli, 2007	1	0	0	1	0	1	3	50.0
Chen, 2012	1	0	1	0	1	1	4	66.7
Clark, 2009	1	0	1	1	1	1	5	83.3
Coe, 2013	1	1	1	1	0	1	5	83.3
Cottrell, 2007	1	0	1	1	1	1	5	83.3
Crosnoe, 2004	1	1	1	0	0	1	4	66.7
Desai, 2015	1	0	1	0	1	1	4	66.7
Du Toit, 2011	1	0	1	0	1	1	4	66.7
Esmaeilzadeh, 2013	1	0	1	0	1	1	4	66.7
Eveland-Sayers, 2009	1	0	1	1	1	1	5	83.3
Florin, 2011	0	1	1	0	1	1	4	66.7
García-Hermoso, 2017	0	1	1	0	1	1	4	66.7
Golam H., 2014	1	0	1	0	1	1	4	66.7
Guindon Sr, 2014	1	0	1	1	1	1	5	83.3
Han, 2012	1	0	1	1	0	1	4	66.7
Hill-Jones, 2008	1	0	1	1	1	1	5	83.3
Huang, 2006	0	0	1	0	1	1	3	50.0
Izidoro, 2014	0	0	1	1	1	1	4	66.7
Judge, 2007	1	0	1	1	0	1	4	66.7
Kahil, 2013	1	0	1	1	0	1	4	66.7
Kalantari, 2016	1	1	1	0	1	1	5	83.3
Kamijo, 2012	1	0	1	1	1	1	5	83.3
Kobayashi, 2009	0	0	1	0	1	1	3	50.0
Kristjánsson, 2010	1	1	0	0	1	1	4	66.7
Krukowski, 2009	1	0	1	0	1	1	4	66.7
Kukulu, 2010	1	0	1	0	1	1	4	66.7
LeBlanc, 2012	1	0	1	1	1	1	5	83.3
Lu, 2014	1	0	1	1	0	1	4	66.7
Maccann, 2013	1	0	1	0	1	1	4	66.7
Marsan, 2014	0	0	1	1	1	1	4	66.7
Martinez, 2014	1	0	1	1	1	1	5	83.3
Morita, 2016	1	0	1	0	1	1	4	66.7
Mo-suwan, 1999	0	0	1	0	1	1	3	50.0
Odlaug, 2015	1	0	1	0	1	1	4	66.7
Pellicer-Chenoll, 2015	1	1	1	0	1	1	5	83.3
Rajagopal, 2017	1	0	1	0	1	1	4	66.7
Ramaswamy, 2010	0	0	1	0	1	1	3	50.0
Rauner, 2013	1	0	1	1	1	1	5	83.3
Sardinha, 2014	1	0	1	0	1	1	4	66.7
Shore, 2008	1	0	1	0	1	1	4	66.7
Srikanth, 2015	1	0	1	1	1	1	5	83.3
Stroebele, 2013	1	0	0	0	1	1	3	50.0
Thompson, 2013	1	0	1	1	1	1	5	83.3
Tonetti, 2015	1	0	0	0	1	1	3	50.0
Tremblay, 2000	1	0	0	1	1	1	4	66.7
Vassiloudis, 2014	0	0	1	0	1	1	3	50.0
Viera, 2005	0	0	1	0	1	1	3	50.0
Welk, 2013	1	1	1	1	1	1	6	100.0
Wellman, 2012	0	0	1	1	1	1	4	66.7
Wingfield, 2011	1	0	1	1	1	1	5	83.3

Q1. Sampling method: was it representative of the population intended in the study?
Q2. Was a response rate mentioned within the study? (Respond no if response rate is below 60)?
Q3. Was BMI obtained using measured height and weight?
Q4. Was academic performance assessed by valid and reliable instruments?
Q5. Was it a primary or secondary data source?
Q6. Was the relationship between BMI and academic performance explored?