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Longitudinal associations between weight status and academic achievement in primary school children

Amanda Watson[1,2] | Ninoshka J. D'Souza[1] | Anna Timperio[1] | Dylan P. Cliff[3,4] | Anthony D. Okely[3,4] | Kylie D. Hesketh[1]

[1]Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Science, Deakin University, Geelong, Victoria, Australia

[2]Alliance for Research in Exercise, Nutrition and Activity (ARENA), School of Health Sciences, University of South Australia, Adelaide, South Australia, Australia

[3]Early Start, Faculty of Arts, Social Sciences and Humanities, University of Wollongong, Wollongong, New South Wales, Australia

[4]Illawarra Health and Medical Research Institute, Wollongong, New South Wales, Australia

Correspondence
Amanda Watson, University of South Australia, CEA-14, GPO Box 2471, Adelaide, SA 5001, Australia.
Email: amanda.watson@unisa.edu.au

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Summary

Background: Evidence for longitudinal associations between childhood weight status and academic achievement remains unclear due to considerable heterogeneity in study design, measures of academic achievement and appropriate categorization of weight status.

Objective: To examine longitudinal associations between childhood weight status (underweight, healthy weight, overweight/obese) and academic achievement in the transition from preschool to primary (elementary) school among Australian school children.

Methods: Data were from the Healthy Active Preschool and Primary Years study. Height and weight, for calculating BMI were measured at baseline (preschool age 3–5 years; 2008/9) and follow-up (primary school age 6–8 years; 2011/12). Academic achievement was measured at age 9 years.

Results: No associations between BMI *z*-score or weight category in the preschool years and later NAPLAN scores were found for boys. For girls, having a higher BMI *z*-score ($B = -13.68$, 95%CI: -26.61, -0.76) and being affected by overweight ($B = -33.57$, 95%CI: -61.50, -5.24) in preschool was associated with lower language scores. Remaining affected by overweight from preschool to primary school was associated with lower numeracy ($B = -25.03$, 95%CI: -49.74, -0.33), spelling ($B = -33.5$, 95%CI: -63.43, -3.58), language ($B = -37.89$, 95%CI: -72.75, -3.03) and total achievement scores ($B = -24.24$, 95%CI: -44.85, -3.63) among girls. For boys, becoming affected by overweight was associated with lower spelling ($B = -38.76$, 95%CI: -73.59, -3.93) and total achievement scores ($B = -27.70$, 95%CI: -54.81, -0.58).

Conclusions: Associations between being affected by overweight/obesity and poorer academic achievement were more pronounced in girls than boys, indicating potentially inequitable impacts of excess weight and highlighting the greater need for intervention among girls. However, stronger study designs are needed to confirm our findings.

KEYWORDS
academic achievement, children, longitudinal cohort studies, obesity

1 | INTRODUCTION

One in six children in OECD countries is affected by overweight or obesity.[1] Children with overweight and obesity are at increased risk of poor physical and psychosocial health.[2] In addition, overweight and obesity have been linked with poor academic achievement in childhood.[3,4] There are several pathways through which overweight may influence academic achievement. Psychosocial pathways suggest that rejection and hurtful comments from peers (e.g. weight-related teasing, jokes and derogatory names) may influence self-esteem and intellectual self-efficacy[5] and subsequently academic achievement. In addition to peers, teachers may also display negative attitudes/biases towards children affected by overweight and obesity,[6] which may promote low self-esteem and influence academic achievement. Another pathway involves absenteeism as children with overweight report more school absenteeism than their non-overweight counterparts,[7] which may impact academic achievement.[8] Physiological pathways suggest that obesity-related illnesses, such as the metabolic syndrome, sleep disturbance and sleep deprivation[9,10] may be also linked to poorer academic achievement.[11]

It may be important to investigate associations between overweight and obesity and academic achievement in the transition from preschool to primary school. Overweight and obesity tracks from childhood into adolescence and adulthood, and is associated with multiple adverse health, socio-emotional and scholastic outcomes. Thus, the implications of early onset obesity are profound for human capital and prevention has the potential for life-long economic and health-related benefits.[12]

In a systematic review[3] of 31 longitudinal studies of the association between overweight and obesity and academic achievement among children and adolescents aged 3–18 years, only eight studies included preschool-aged children and investigated associations over the transition from the preschool to the primary school years. Results from these eight studies were largely inconsistent. Three of the eight studies (conducted in the US[12,13] and Netherlands[14]) reported that children for whom overweight or obesity persisted from preschool/kindergarten into primary school had worse academic achievement (math, reading and teacher-rated school performance) in primary school, compared with those who never experienced overweight or obesity. Four studies (from the US and Canada) reported no association.[15–18] The final study of the eight showed sex differences,[8] which have also been demonstrated in a further study published since the systematic review.[19] Developing overweight between kindergarten and primary school was associated with lower scores in math and reading tests for US girls, but not boys.[8] Children in kindergarten with overweight or obesity had poorer reading and math achievement in primary school among US children, particularly girls.[19]

Combined, findings from these nine studies published to date indicate that the association between weight status and academic achievement in the transition from preschool/kindergarten to primary school remains unclear and warrants further investigation. There are several possible reasons for these inconsistencies, including the children were not tracked through primary school, geographical and age differences in the study populations, choice of covariates, follow-up duration (1–8 years) and differences in measures of academic achievement, and classification of weight categories, where some studies combined overweight and obese weight categories,[14,15,18] while others separated categories.[19] Some compared children experiencing obesity (BMI > 95 percentile) with children not experiencing obesity (BMI < 95 percentile), effectively placing healthy weight and overweight children in the same category.[8,12,13,16,17] Given potential differences in academic achievement based on weight experience, it may be inappropriate to combine overweight and healthy weight. It is also important to distinguish between underweight and other weight categories. To our knowledge, only one study has distinguished underweight from healthy weight. That study indicated that being at risk of underweight in early childhood was associated with poorer teacher-rated academic achievement.[15]

Additionally, while weight categories have clinical significance, this approach cannot detect change in BMI within weight categories. It may be important to investigate how BMI change, both within and between different weight categories, can influence academic achievement; however, to our knowledge, no study has done this. Lastly, most studies have been conducted in the Northern Hemisphere (US, Canada and the Netherlands); none have been conducted in Australia. In Australia, there are public (government) and private (Catholic and Independent) schools. All school sectors operate under the same National curriculum, and there is no evidence of differential outcomes by school sector.[20] In contrast, research examining school sector effects on academic achievement shows considerable variation between countries.[21–23] Thus, exploring associations in the Australian school context seems warranted.

This study builds on the current literature by: (1) including underweight, healthy weight and overweight/obese weight categories; (2) using both categorical and continuous BMI measures and (3) examining associations in the Australian school context. Thus, this study aimed to examine longitudinal associations between overweight and obesity and academic achievement in the transition from preschool to primary (elementary) school among Australian school children. Sex differences in associations were also explored.

2 | METHODS

2.1 | Subjects

Data were from the Healthy Active Preschool and Primary Years (HAPPY) study. HAPPY is a longitudinal cohort study of children from 65 preschools (52.4% response) and 71 childcare centres (54.1% response) located within different socioeconomic areas across metropolitan Melbourne, Australia. From these centres, a total of 1002 (10.5% response) parents of children aged 3–5 years agreed to participate. Baseline data collection occurred in two waves, August to December 2008 and June to November 2009, and the sample was followed up approximately 3 years later (age 6–8 years) from August 2011 to March 2012 and June 2012 to April 2013 (77% retention).

Complete data for these analyses was available for 476 children at baseline, 443 at follow-up, and 418–422 at both time points and 392–396 (depending on outcome) for analyses by weight change category after removal of underweight children. Of the 418–422 participants with complete data at both time points, 26 were removed from the analyses by weight change category due to being affected by underweight at either timepoint, resulting in a final analytic sample of 392–396 (depending on outcome).

Ethical approval for HAPPY was obtained from the Deakin University Human Research Ethics Committee (EC 291–2007), Department of Education and Early Childhood Development (2011_001008) and the Catholic Education Office (1714). Written informed consent was obtained from parents at each time point. The Australian Curriculum Assessment and Reporting Authority provided approval to access academic achievement data for those children with parent consent.

2.2 | Outcome measure

Academic achievement was determined by results on the National Assessment Program – Literacy and Numeracy (NAPLAN) tests for Year 3 students (age approx. 9 years).[24] NAPLAN is a standardized annual assessment undertaken by students in Years 3, 5, 7 and 9 attending Australian schools.[24] Standardized scores are produced for five academic domains: language (grammar and punctuation), reading, writing, spelling and numeracy[24] and then converted to a scale score. Scale scores range from 0 to 1000, with a mean of 500 and a standard deviation of 100. Total achievement comprised the arithmetic mean of all academic domains. With consent from parents, NAPLAN results were procured from the Australian Curriculum Assessment and Reporting Authority (ACARA) and matched to participants' HAPPY data using standard data linkage procedures.

2.3 | Exposure measure

Height and weight were measured at each data collection point by trained researchers following standardized measurement procedures. Height was measured using a Wedderburn Seca portable rigid stadiometer, and weight using Wedderburn Tanita portable digital scales. Both measures were taken twice. A third measure was taken if there was more than 0.5 cm or 0.5 kg difference between the first and second measurements, with the mean of the two closest results used in analyses. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres (kg/m^2) and converted to BMI *z*-scores using the World Health Organization child growth standards.[25] A BMI z score change variable was created by subtracting baseline BMI *z*-scores from follow-up values.

The International Obesity Taskforce Criteria were used to categorize BMI as underweight, healthy weight, overweight or obese.[26] A weight change variable was created to capture the change in weight category between baseline (aged 3–5 years) and follow-up (aged 6–8 years). As few children were classified as obese (<2%), the overweight and obese categories were combined, herein referred to as 'overweight'. As few children were underweight, these children were excluded from analysis by weight change category. Thus, weight change categories were: 'always healthy weight' (healthy weight at baseline and follow-up), 'always affected by overweight' (overweight at baseline and follow-up), 'developed healthy weight' (overweight at baseline and healthy weight at follow-up) and 'became affected by overweight' (healthy weight at baseline and overweight at follow-up).

2.4 | Covariates

Parent proxy-reports of potentially confounding factors that may be correlated with both overweight and academic achievement were controlled for in analyses. There is some evidence that having a mother who experiences overweight, lower socioeconomic position, living in a single parent household, and having no siblings is associated with experiencing overweight for children[27] as well as poorer cognitive function[16] and academic achievement.[28,29] These variables, along with child age, were included in the regression models. Maternal education (proxy for socioeconomic position) was categorized as (1) below university education and (2) university education. Maternal BMI, (derived from height and weight), number of siblings (none, 1, 2, or 3+) and household composition (single or dual parent household) were reported by parents.

3 | ANALYSES

All analyses were conducted using Stata version 13.0. Four separate models were conducted. Linear regression was used to investigate associations between (1) BMI *z*-score at age 3–5 years and at age 6–8 years with later NAPLAN scores; (2) weight category ('overweight', 'underweight' and 'healthy weight') at age 3–5 years and at age 6–8 years and later NAPLAN scores (referent category was 'healthy weight'); (3) change in BMI *z*-score between age 3–5 years and age 6–8 years and later NAPLAN scores and (4) change in weight category between age 3–5 years and 6–8 years ('always healthy weight', 'always affected by overweight', 'developed healthy weight' and 'became affected by overweight') and later NAPLAN scores (referent category: 'always healthy weight'). Analyses controlled for child age, maternal education (as a proxy for SEP), maternal BMI, number of siblings and household composition, and were adjusted for clustering by the childcare centre through which they were recruited. All analyses were stratified by sex due to sex differences in academic achievement[30] and BMI.[31] It was not considered necessary to adjust for clustering by the school children transitioned to, nor consider a multilevel framework given children in the study dispersed to 181 different schools, and for 122 of those schools, clusters comprised only 1–2 children. There was no evidence of clustering by school for the outcome total academic achievement (ICC = 0.086).[32]

TABLE 1 Descriptive characteristics of participants

Characteristics	Age 3–5 years (T1)		Age 6–8 years (T2)	
	Boys	Girls	Boys	Girls
n (%)	256 (54)	220 (46)	249 (56)	194 (44)
Age; years mean (SD)	4.62 (0.68)	4.47 (0.68)	7.62 (0.69)	7.50 (0.68)
Maternal education; *n* (%)				
<University	90 (35)	86 (39)	75 (31)	65 (35)
≥University	164 (65)	133 (61)	166 (69)	121 (65)
BMI z-score mean (SD)	0.69 (0.94)	0.48 (0.81)	0.42 (0.95)	0.36 (0.88)
Weight category; *n* (%)				
Healthy weight (ref)	204 (80)	177 (80)	211 (85)	154 (79)
Underweight	10 (4)	10 (5)	9 (4)	9 (5)
Overweight/obesity	42 (16)	33 (15)	29 (12)	31 (16)
Weight change				
Always healthy weight (ref)	-	-	182 (78)	137 (77)
Always affected by overweight	-	-	16 (7)	20 (11)
Developed healthy weight	-	-	23 (10)	10 (6)
Became affected by overweight	-	-	13 (6)	10 (6)
Parents in household; *n* (%)				
Two-parent household	236 (92)	210 (95)	216 (90)	174 (93)
Single-parent household	20 (8)	10 (5)	24 (10)	13 (7)
Number of siblings				
0	35 (14)	40 (18)	27 (11)	22 (12)
1	142 (55)	110 (50)	110 (45)	93 (49)
2	54 (21)	61 (28)	79 (33)	69 (36)
3+	25 (10)	8 (4)	27 (11)	6 (3)
	Boys		Girls	
Mean (SD) and range NAPLAN score				
Language	469.08 (88.38) 193.0–771.5		483.97 (91.42) 262.3–771.5	
Reading	472.53 (84.78) 230.2–651.1		472.53 (78.31) 280.7–770.3	
Spelling	431.68 (78.83) 239.5–603.7		444.76 (71.14) 239.5–638.8	
Writing	431.99 (61.79) 94.5–582.5		456.44 (48.64) 285.4–617.6	
Numeracy	452.03 (77.31) 246.1–740.6		434.22 (71.41) 232.1–739.0	
Total achievement	450.81 (65.34) 278.56–608.2		458.38 (59.83) 322.5–641.3	

4 | RESULTS

Characteristics of participants are described in Table 1. Approximately, one in six (16% of boys and 15% of girls) children experienced overweight or obesity at age 3–5 years, and a similar proportion at age 6–8 years (12% of boys and 16% of girls). There were no significant sex differences for maternal education, language, reading or spelling scores at either time point, and no significant sex differences in BMI *z*-scores at age 6–8 years. At baseline, boys scored significantly higher on numeracy tests ($p = 0.01$) and lower on writing tests ($p < 0.001$), which were slightly older ($p = 0.02$) and had significantly higher BMI z-scores ($p = 0.01$) compared with girls. Skewness and Kurtosis for the outcome variables were: Grammar (skewness = 0.38; kurtosis = 3.95), numeracy (skewness = 0.38; kurtosis = 3.55), writing (skewness = −0.86; kurtosis = 5.78), spelling (skewness = −0.02; kurtosis = 2.88) and reading (skewness = −0.00; kurtosis = 3.38). Compared on baseline characteristics, including age ($p = 0.97$), BMI *z*-score ($p = 0.06$) and weight category ($p = 0.24$), those included in the analyses were not significantly different from those excluded from analyses. Relative to children in the analytic sample, the proportion of children with a tertiary educated mother was lower in the excluded sample ($p < 0.001$).

Table 2 describes the associations between BMI *z*-score at each time point (T1: age 3–5 years and T2 age 6–8 years) and later NAPLAN scale scores, as well as the association between change in BMI *z*-score between T1 and T2, and later NAPLAN scores. For girls, compared with BMI *z*-score at age 3–5 years, BMI *z*-score at age 6–8 years was more strongly associated with lower scores in most NAPLAN domains at age 9 years. Specifically, a one-unit higher BMI *z*-score at age 6–8 years was associated with scores up to 21 points lower in numeracy, spelling and language at age 9 years. For boys, there was no significant association between BMI *z*-score at either time point and later NAPLAN scores. Change in BMI *z*-score (relative increase) between T1 and T2 was associated with lower NAPLAN scores at age 9 years for both boys and girls.

Table 3 describes the association between weight category at age 3–5 years (T1), and 6–8 years (T2) with later NAPLAN scores. For boys, experiencing underweight at age 6–8 years was associated with writing scores 68 points lower at age 9 years, relative to having healthy weight. For girls, experiencing underweight at age 6–8 years was associated with reading scores 45 points lower at age 9 years, relative to those experiencing healthy weight. In addition, for girls, experiencing overweight at age 3–5 years was associated with scores 33 units lower for language at age 9 years, compared with those experiencing healthy weight.

Table 4 describes the association between change in weight category between age 3–5 years and age 6–8 years with later NAPLAN scores. For boys, becoming affected by overweight was associated with scores 39 units lower for spelling, and scores 28 units lower for overall achievement at age 9 years, compared with boys who remained a healthy weight across both time points. For girls, remaining affected by overweight across both timepoints was associated with scores 24 units lower for overall achievement, 25 units lower for numeracy, 34 units lower for spelling and 38 units lower for language at age 9 years, compared with girls who were always a healthy weight. In addition, becoming a healthy weight was associated with 39 units lower reading scores for girls at age 9 years, compared with girls who were always a healthy weight.

5 | DISCUSSION

This study examined associations between BMI z-score and weight category in the preschool (aged 3–5 years) and early primary school years (aged 6–8 years) and subsequent academic achievement at Year 3 (aged approximately 9 years). This study also examined whether change in BMI *z*-score and weight category between the preschool and primary school years was associated with later academic achievement. There were five main findings. First, BMI z score and weight category (underweight and overweight) in the primary school years were more strongly associated with poorer NAPLAN scores, compared with BMI z score and weight category in the preschool years. Second, change in BMI z score (relative increase) and change in weight

TABLE 2 Associations between BMI *z*-score at ages 3–5 years (T1) and ages 6–8 years (T2), and change in BMI *z*-score with Year 3 NAPLAN scores (age approx. 9 years)[a]

	NAPLAN score in Year 3					
	Numeracy *B* (95% CI)	Reading *B* (95% CI)	Writing *B* (95% CI)	Spelling *B* (95% CI)	Language *B* (95% CI)	Total achievement *B* (95% CI)
Boys						
T1 BMI z-score	3.29 (−5.98, 12.55)	−3.74 (−14.27, 6.80)	7.27 (−2.44, 16.98)	−6.04 (−16.30, 4.22)	0.27 (−10.32, 10.86)	0.07 (−8.10, 8.25)
T2 BMI z-score	−5.19 (−15.23, 4.86)	−9.82 (−20.48, 0.83)	5.86 (−4.22, 15.94)	−7.79 (−19.24, 3.67)	−4.35 (−15.63, 6.94)	−4.23 (−12.81, 4.35)
Δ in BMI z-score	**−17.20 (−29.20, −5.20)**	−11.54 (−25.71, 2.63)	−6.42 (−17.82, 4.98)	−11.07 (−27.05, 4.91)	**−15.58 (−29.72, −1.44)**	**−12.17 (−23.27, −1.06)**
Girls						
T1 BMI z-score	−10.10 (−22.93, 2.73)	4.37 (−8.33, 17.07)	1.41 (−6.09, 8.92)	−4.12 (−16.12, 7.87)	**−13.68 (−26.61, −0.76)**	−4.44 (−13.80, 4.91)
T2 BMI z-score	**−17.32 (−28.81, −5.83)**	−7.02 (−21.54, 7.49)	−2.60 (−10.19, 4.98)	**−15.11 (−29.72, −0.50)**	**−21.16 (−36.06, −6.27)**	**−12.68 (−23.08, −2.27)**
Δ in BMI z-score	**−22.40 (−40.21, −4.58)**	**−18.10 (−36.16, −0.04)**	−10.50 (−22.53, 1.53)	**−21.91 (−40.73, −3.08)**	−14.62 (−37.58, 8.34)	**−17.62 (−32.03, −3.20)**

Abbreviation: CI, confidence interval.

[a]Figures in the table represent the association between BMI z-score at age 3–5 years, and at age 6–8 years, as well as change in BMI z-score over time and later NAPLAN scores at age approx. 9 years. Models controlled for child age, maternal BMI, SEP, household composition and number of siblings, adjusted for centre of recruitment.

Note: Bold values indicate statistically significant associations ($p < 0.05$).

TABLE 3 Associations between weight category at age 3–5 years (T1), and age 6–8 years (T2) and later NAPLAN scores[a]

	NAPLAN score in Year 3					
	Numeracy *B* (95% CI)	Reading *B* (95% CI)	Writing *B* (95% CI)	Spelling *B* (95% CI)	Language *B* (95% CI)	Total achievement *B* (95% CI)
Boys[b]						
T1 underweight	−37.08 (−77.60, 3.43)	−19.54 (−76.51, 37.43)	−40.98 (−116.25, 34.30)	9.13 (−36.53, 54.78)	−5.53 (−43.48, 32.43)	−19.10 (−62.02, 23.82)
T1 overweight	−9.05 (−33.90, 15.79)	−12.72 (−42.11, 16.68)	4.26 (−16.57, 25.09)	−15.40 (−39.54, 8.74)	−6.44 (−39.12, 26.24)	−7.96 (−29.68, 13.76)
T2 underweight	−22.75 (−64.31, 18.81)	2.80 (−35.36, 40.97)	**−68.32 (−113.36, −23.29)**	−51.95 (−115.85, 11.95)	−21.57 (−61.41, 18.27)	−32.51 (−69.86, 4.85)
T2 overweight	−9.92 (−38.24, 18.39)	−18.05 (−51.59, 15.50)	11.47 (−16.03, 38.97)	−22.67 (−51.33, 6.00)	−5.73 (−40.25, 28.79)	−9.06 (−34.63, 16.50)
Girls[b]						
T1 underweight	1.94 (−72.42, 76.31)	−56.49 (−119.39, 6.41)	−30.86 (−63.33, 1.61)	−45.43 (−104.97, 14.10)	−43.44 (−90.53, 3.65)	−34.83 (−82.56, 12.90)
T1 overweight	−19.07 (−41.82, 3.68)	−17.01 (−39.97, 5.95)	−8.72 (−24.85, 7.40)	−17.65 (−42.39, 7.09)	**−33.37 (−61.50, −5.24)**	**−19.14 (−36.57, −1.72)**
T2 underweight	−3.45 (−41.17, 34.27)	**−45.47 (−90.63, −0.32)**	−5.05 (−35.22, 25.13)	−0.75 (−57.51, 56.01)	17.61 (−38.34, 73.56)	−7.42 (−45.13, 30.30)
T2 overweight	−21.18 (−46.49, 4.13)	−1.16 (−40.45, 38.13)	−8.64 (−27.66, 10.38)	−27.16 (−61.71, 7.39)	−17.57 (−50.00, 14.86)	−15.41 (−39.22, 8.40)

Abbreviation: CI, confidence interval.
Model controlled for child age, maternal BMI, SEP, household composition and number of siblings, adjusted for centre of recruitment.
[a]Figures in the table represent the relationship between weight category at age 3–5 years, and at age 6–8 years and later academic achievement at approx. age 9 years.
[b]Referent category is 'healthy weight'.
Note: Bold values indicate statistically significant associations ($p < 0.05$).

category ('always affected by overweight' and 'became healthy weight') between the preschool and primary years were associated with poorer subsequent academic achievement. Third, associations were stronger for girls, compared with boys. Fourth, experiencing underweight for age in the primary school years was associated with poorer academic achievement. Fifth, becoming a healthy weight in the transition from preschool to primary school was associated with lower academic achievement.

We found that the association between BMI and weight category in the primary school years, compared with the preschool/kindergarten years, was more strongly associated with subsequent poorer academic achievement, particularly for girls. The difference in NAPLAN scores for children with a higher BMI was the equivalent of almost 6 months of schooling.[33] Several mechanisms may explain the differences in findings between preschool and primary school years. Negative attitudes to overweight may consolidate in the primary school years,[34] and thus the stigma of overweight and associated weight-related teasing (and effects on academic achievement) may not be prevalent in the preschool years. For example, a study of weight-related bias demonstrated attitudes to obesity were less favourable as children got older.[34] Thus, weight-related teasing and subsequent effects on academic achievement may not be present until the primary school years. It is also possible that cognitive consequences of overweight occur later in child development.[35] Lastly, the stronger associations observed at age 6–8 years, compared with 3–5 years, may be because this age is more proximal to when Year 3 NAPLAN tests are taken. Nonetheless, our findings contrast Yu and colleagues[19] who reported obesity status during kindergarten was associated with lower reading and math scores at Grade 2 via teacher evaluation of non-cognitive skills (e.g. social skills, behavioural problems and approaches to learning). A further study reported overweight status in kindergarten was not associated with reading or math achievement in Grade 1.[17] However, those studies were conducted in the US where Kindergarten is the equivalent of the first year of primary school in Australia, perhaps contributing to divergent results. Additionally, Yu and colleagues[19] investigated the mediating effect of teacher evaluations of children's non-cognitive skills in the association between overweight status and academic achievement, providing a further possible explanation for divergent results.

Change in weight status between the preschool and primary school years was also associated with poorer academic achievement, with associations different for boys and girls. Becoming affected by overweight (boys) and remaining affected by overweight (girls) in the transition from preschool/kindergarten to primary school was associated with lower academic achievement at age 9 years (Grade 3), compared with those who remained a healthy weight across both timepoints. The difference in scores for those who remained overweight, compared with those who remained a healthy weight across both timepoints, is the equivalent of approximately six months of schooling.[33] Findings from previous studies are mixed; some report no association,[15–18] while others report remaining affected by obesity throughout kindergarten and primary school was associated with poorer academic achievement in early and middle primary school,

TABLE 4 Associations between change in weight category between age 3–5 years and age 6–8 years and later NAPLAN scores[a]

	NAPLAN score in Year 3					
	Numeracy B (95% CI) Boys: $n = 224$ Girls: $n = 170$	Reading B (95% CI) Boys: $n = 223$ Girls: $n = 170$	Writing B (95% CI) Boys: $n = 225$ Girls: $n = 170$	Spelling B (95% CI) Boys: $n = 225$ Girls: $n = 171$	Language B (95% CI) Boys: $n = 225$ Girls: $n = 171$	Total achievement B (95% CI) Boys: $n = 223$ Girls: $n = 169$
Boys[b,c]						
Always affected by overweight $n = 15$	−19.95 (−58.79, 18.89)	−19.13 (−80.64, 42.38)	9.14 (−33.55, 51.83)	−36.35 (−82.22, 9.53)	−11.81 (−70.09, 46.47)	−15.74 (−59.57, 28.09)
Became affected by overweight $n = 12$	−19.08 (−57.26, 19.10)	−37.56 (−78.74, 3.61)	−10.43 (−31.38, 10.53)	**−38.76 (−73.59, −3.93)**	−31.25 (−68.56, 6.06)	**−27.70 (−54.81, −0.58)**
Became healthy weight $n = 20$	−5.13 (−50.09, 39.83)	−14.94 (−52.23, 22.36)	−1.05 (−23.83, 21.72)	−5.14 (−36.88, 26.59)	−5.18 (−43.06, 32.70)	−6.36 (−35.22, 22.50)
Girls[b,c]						
Always affected by overweight $n = 18$	**−25.03 (−49.74, −0.33)**	−8.02 (−39.64, 23.60)	−16.94 (−39.74, 5.86)	**−33.50 (−63.43, −3.58)**	**−37.89 (−72.75, −3.03)**	**−24.24 (−44.85, −3.63)**
Became affected by overweight $n = 10$	−29.04 (−73.84, 15.75)	−4.47 (−65.83, 56.89)	−11.25 (−38.36, 15.87)	−24.15 (−72.75, 24.45)	−23.88 (−82.90, 35.13)	−19.83 (−64.02, 24.35)
Became healthy weight $n = 9$	−3.70 (−39.02, 31.61)	**−39.25 (−69.52, −8.99)**	7.17 (−15.93, 5.86)	8.21 (−40.81, 56.63)	−34.96 (−99.48, 29.56)	−12.46 (−48.53, 23.61)

Model controlled for child age, maternal BMI, SEP, household composition and number of siblings, adjusted for centre of recruitment.

[a]Figures in the table represent the relationship between change in weight category between age 3–5 years, and age 6–8 years and later academic achievement at approx. age 9 years.

[b]Referent category is 'always healthy weight' (boys: $n = 178$; girls: $n = 134$).

[c]Underweight children excluded from analyses ($n = 26$).

Note: Bold values indicate statistically significant associations ($p < 0.05$).

compared with those who never experienced obesity.[12–14] However, associations tapered off as children got older (although remaining significant)[12] suggesting that the academic-related impacts of overweight/obesity may be strongest during early primary school, and that other unmeasured factors (e.g. family income and cognitive skills) may be associated with poorer academic achievement in the later primary school years.

We also found that weight status was more strongly associated with future academic achievement for girls, compared with boys. Similarly, Yu and colleagues indicated those who were affected by overweight and obesity in kindergarten had poorer reading and math achievement in primary school among US children, particularly for girls.[19] Datar and Sturm[8] also found that girls (but not boys) who became affected by overweight between kindergarten entry and end of Year 3 had lower Year 3 math and reading scores, compared with those who remained healthy weight. Weight-related teasing and effects on academic achievement may be more prevalent among girls, compared with boys.[5] Thus, the stronger association found for girls may be expected, and anti-bullying programs targeting weight-related bias might be important alongside obesity prevention programs in schools to negate any adverse effect on academic achievement.

We found that experiencing underweight for age in the primary school years was associated with lower NAPLAN scores for both girls and boys, while experiencing underweight for age in the preschool years was not. Bisset and colleagues[15] reported being at risk of underweight was associated with poorer academic achievement. With conflicting results, and few studies investigating this link, it is not possible to conclude definitively the academic effects of underweight. Nonetheless, the link between underweight and poorer academic achievement is plausible given the link between underweight[36] and nutritional deficiency[37] and poorer cognitive development.

A somewhat surprising finding was becoming a healthy weight was associated with lower reading scores for girls, compared with girls who were always a healthy weight, suggesting the impact of having experienced overweight in preschool may continue, even after the weight issue has resolved. This contrasts findings from Carter and colleagues[18] who reported that children who grew out of obesity between age 2–5 and 8–11 years had better math achievement than their peers who were always a healthy weight. With few studies and divergent findings, further research is warranted.

A previous study found adolescents affected by obesity who participated in any amount of physical activity had a higher likelihood of flourishing and academic engagement compared with those who did not participate in any physical activity.[38] Thus, interventions targeting academic achievement among children affected by overweight and obesity may consider encouraging physical activity.

6 | LIMITATIONS

There was little variation in NAPLAN scores when categorized by achievement levels established by ACARA, with few participants in the sample classified as 'below national minimum standard' (<3%) or 'at national minimum standard' (<5%). NAPLAN tests are designed for group-level comparisons and monitoring progress within individuals over time, and are intended for use in combination with other school-based assessments not available for inclusion in this study.[39] In our study, there were relatively few children in each weight change category; most were in the 'always healthy weight' category. Additionally, the prevalence of overweight and obesity in the sample (12% to 16%) was lower than the national average (25%).[40] Thus, findings must be interpreted with caution. A further limitation relates to the low response rates of approximately 50% of preschools/childcare and approximately 10% of invited families. Although we had complete data for approximately 70% of the sample, the included sample was highly educated with 63% of mothers having completed a university degree. Therefore, findings may not be generalizable to families with less educated mothers. The findings may not be generalizable to families of different composition, such as single father and grandparent families given the vast majority of families in this study were dual parent. Nonetheless, 68% of families in Australia with children aged 10–16 years are dual parent, and 25% are single parent.[41] Thus, our findings are likely to be generalizable to the majority of children. Lastly, the current study was observational, and despite the longitudinal design, causality cannot be established. Randomized-controlled trials or robust quasi-experimental designs are needed to determine if preventing overweight between preschool and primary school leads to improvements in academic achievement. BMI-based classification for overweight and obesity has some limitations, including being unable to distinguish between lean muscle and fat mass and identify the distribution of fat.

7 | CONCLUSIONS

This study provides evidence of associations between weight status and academic achievement in the primary school years. This highlights the importance of overweight/obesity prevention to ensure children not only experience healthy weight but are more likely to achieve to their academic potential. Negative impacts were more pronounced in girls than boys, indicating potentially inequitable impacts of excess weight and highlighting the greater need for intervention among girls. Randomized-controlled trials or robust quasi-experimental designs are needed to determine if preventing overweight in the transition from preschool to primary school improves academic achievement. For maximum effectiveness, childhood obesity prevention interventions may target the early to middle primary school years (age 5–10 years) and include a combination of diet and physical activity intervention components.[42]

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CONFLICT OF INTEREST

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ORCID

Amanda Watson https://orcid.org/0000-0002-9058-3435
Ninoshka J. D'Souza https://orcid.org/0000-0003-2630-4662

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