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RESEARCH ARTICLE

The Health Care Cost Implications of Overweight and Obesity during Childhood

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Objective. To investigate whether childhood overweight at age 4–5 increases publicly funded health care costs during childhood, and to explore the role of timing and duration of overweight on health costs.

Data Sources. The Longitudinal Study of Australian Children (2004–2008) and linked records from Medicare, Australia's public health insurance provider (2004–2009).

Study Design. The influence of overweight status on non-hospital Medicare costs incurred by children over a 5-year period was estimated using two-part models and one-part generalized linear models (GLM). All models controlled for demographic, socioeconomic, and parental characteristics.

Principal Findings. Being overweight at age 4–5 is associated with significantly higher pharmaceutical and medical care costs. The results imply that for all children aged 4 and 5 in 2004–2005, those who were overweight had a combined 5-year Medicare bill that was AUD$9.8 million higher than that of normal weight children. Results from dynamic analyses show that costs of childhood overweight occur contemporaneously, and the duration of overweight is positively associated with medical costs for children who became overweight after age 5.

Conclusions. This study reveals that the financial burden to the public health system of childhood overweight and obesity occurs even during the first 5 years of primary school.

Key Words. Childhood, overweight, obesity, medical costs, health care

The World Health Organization describes childhood obesity as "one of the most serious public health challenges of the 21st century" (WHO 2011). One quarter of Australian children aged 5–17 years are now overweight or obese (Australian Bureau of Statistics 2009) and even higher prevalence rates are found among children in the United Kingdom and the United States (Sassi 2010). One of the greatest concerns of childhood overweight and obesity is the high risk of persistence into adulthood (Must 1996). Adult obesity, associated with increased risk of developing chronic diseases including type 2 diabetes and cardiovascular disease, is now one of the leading causes of morbidity and mortality (Mokdad et al. 2004; Haslam and James 2005). Emerging evidence suggests that overweight and obesity in childhood can also increase the risk of childhood health problems including asthma, sleep apnea, hypertension, abnormal glucose intolerance, and even type 2 diabetes, which until recently was thought only applicable to adults (Anderson 2003; Must and Daniels 2006). In addition, overweight and obese children can experience discrimination from their peers, lowered self-esteem, depression, and other psychosocial problems (Dietz 1998).

With overweight and obesity being largely preventable, the detrimental health consequences alone call for a high prioritization of effective interventions to reverse the trend. Adding further grounds for action are the economic implications of overweight and obesity, not only for the individuals involved but also for government and society. In a health system with universal public insurance, such as in Australia, higher medical utilization raises the health care costs for all taxpayers. Even under a private health insurance system, higher medical costs raise premiums for all fund members, including those of healthy weight.

It is recognized that obesity in adults is associated with substantially higher medical utilization and costs (Finkelstein, Fiebelkorn, and Wang 2003; Wee et al. 2005; Yang and Hall 2008). Some studies (Johnson, McInnes, and Shinogle 2006; Finkelstein and Trogdon 2008; and Skinner et al. 2008; Monheit, Vistnes, and Rogowski 2009; Trasande and Chatterjee 2009) have examined the association between overweight and medical expenditure in children in the United States using data from the Medical Expenditure Panel Survey. However, previous studies have only analyzed costs over a short time frame (typically 1 year) and have not explored the dynamics behind overweight status and its associated costs. Past studies have also relied on parental reports of height and weight to classify children as overweight, and they have generally omitted important control variables (such as parental characteristics).

This article contributes to the literature by investigating the association between childhood overweight and non-hospital health care costs over a longer time frame than previous studies. It examines costs incurred over a 5-year period to capture health conditions that may take some years to

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develop. It also explores whether health care costs increase with the duration of the child being overweight, and whether being overweight increases medical costs contemporaneously or some years later. This study utilizes records from Australia's universal health insurance system, Medicare, which have been uniquely linked to survey data from the Longitudinal Study of Australian Children (LSAC). The analyses use measured height and weight, and include an extensive set of child and parental characteristics. By assessing the implications of childhood overweight on government-funded health costs, insight is given into the costs of childhood overweight that are borne by society. Given the increasing prevalence rates of childhood obesity, this has important policy implications.

DATA

The Longitudinal Study of Australian Children

The LSAC is a representative panel survey of Australian children. It began in 2004 when the children were aged 4–5. A clustered survey design was used to collect information on each child. The study design for data collection is described in detail by Soloff, Lawrence, and Johnstone (2005). Essentially, postcodes were stratified by state/territory and by metropolitan and non-metropolitan area. A set of postcodes from each strata were randomly selected, and then children (in the desired age cohort) were randomly selected from the Medicare enrollment database within each selected postcode. Only one child per family was included in the sample selection process. Data were collected biennially by face-to-face interviews with the child's primary parent at their home. Additional information from the parents was collected using self-complete questionnaires. The study utilizes data from the first three waves of the 4–5 year old cohort, collected in 2004, 2006 and 2008, which were linked to each child's Medicare records, covering a 5-year period from April 2004 to March 2009. The response rates for the second and third surveys were 89.6 percent and 86.9 percent of eligible respondents, respectively.

Study Sample

A total of 4,534 children in the first survey were linked to Medicare records and therefore eligible for inclusion in this study.[1] After excluding children with missing values for any variables included in the model, the total sample size for the primary analysis (A) was 4,335. Children who were present for all three surveys (N = 3,899) were eligible for inclusion in the dynamic analysis (B), and after excluding children with missing values, 3,670 children were included in Analysis B.

Medical Costs

Medicare in Australia provides free or subsidized health care to all permanent residents. It is financed largely from general taxation revenue. Medicare records include complete data on non-hospital medical care and pharmaceutical payments made by the government under the Medicare Benefits Scheme (MBS) and the Pharmaceutical Benefits Scheme (PBS).

Pharmaceuticals. Under the PBS, the government subsidizes eligible prescription medicines, funding the difference between the fixed patient copayment and the listed drug price.[2] The PBS covers prescription medicines for most medical conditions, but it does not include over-the-counter medicines or medicines provided to patients in hospitals.[3]

Medical Care. The MBS covers the cost of medical treatment by physicians including general practitioners and specialists up to a pre-determined benefit amount (which applies nationwide). In the majority of cases (80 percent), doctors charge exactly the benefit amount (known as bulk-billing) and thus patients receive free care at the point of delivery (Department of Health and Ageing 2011). For services where doctors choose to charge a higher fee, patients face some out-of-pocket expenses. However, the government-funded component of costs for these services is the same as for bulk-billed services. The MBS costs included in this study provide complete information on non-hospital medical care funded by the government. Public hospital services are not included in MBS records and therefore could not be analyzed. Although hospital care makes up a large component of health costs for the whole population, inpatient stays are not common for this age group. Only about 5 percent of the LSAC children reportedly stayed in a hospital over a 12-month period.

To provide some information on how childhood overweight may influence hospital utilization and costs, additional analyses on the relationship between overweight status at age 4–5 and the likelihood of having a hospital stay were conducted. Parental reports on whether the child stayed in a hospital in the past year (taken from the second and third surveys) were used as the dependent variable. The results of the hospital analysis are shown in Table 1.

Analysis A: For the primary analysis (Analysis A), PBS and MBS costs were analyzed separately. MBS costs were adjusted to 2008 prices (in AUD). For each child, costs were aggregated from April 2004 to March 2009. This allowed estimation of the impact of the child's overweight status (measured at age 4–5) on government-funded non-hospital medical care and pharmaceutical costs incurred from when the child was aged 4–5 until aged 8–9. A duration of 5 years for costs was chosen instead of a shorter period as many health consequences attributable to being overweight take time to develop (e.g., type 2 diabetes), whereas other ailments may occur immediately (e.g., sleep apnea or gastroenterological disorders) (Silles 2009). The mean (standard error) unadjusted PBS and MBS costs for the total 5-year period across all children were \$75 (4) and \$871 (15), respectively.

Analysis B: For Analysis B, the relationship between the timing and duration of overweight status (over a 5–year period) and costs incurred in 2008–2009 (when the child was aged 8–9) was investigated. Here, only MBS costs (the main component of Medicare costs for children) incurred in the latest available year (2008–2009) were used. The mean (standard error) unadjusted MBS cost in 2008–2009 across all children was \$190 (5). PBS costs were not analyzed here because in 2008–2009 <20 percent of children incurred any PBS costs and average costs were small (<\$28).

Table 1: Marginal Effects from Logit Models for the Probability of Staying in a Hospital

	Stayed in Hospital in Year Prior to Survey 2 (when aged 5–6)		*Stayed in Hospital in Year Prior to Survey 3 (when aged 7–8)*	
	M.E.	*S.E.*	*M.E.*	*S.E.*
Overweight	0.013	0.010	0.006	0.009
Underweight	0.000	0.016	0.001	0.016

Notes. Marginal effects are the discrete change from the reference, interpreted as a unit change in the probability of having a hospital stay (using parental reports).
Overweight status was measured in Survey 1 (when aged 4–5).
All other control variables (including health conditions) were included in the model, but estimates are not shown.

Variables

Overweight and Obese. Body mass index (BMI) (kg/m^2) was calculated using each child's weight and height, as measured by the interviewer. Children were classified as either underweight, normal, or overweight (including obese) according to age- and gender-specific international BMI cut-off points (Cole et al. 2000, 2007). For Analysis A, overweight status is measured at age 4–5.

For Analysis B, to assess the role of timing of overweight status, indicators for whether the child was overweight at each survey or not were included. A significant association between medical costs in 2008–2009 and being overweight in the third survey (S3) would indicate contemporaneous overweight status is important for medical costs, whereas a significant association with being overweight in the first (S1) or second survey (S2) would indicate that past overweight status is important.

In analyzing the duration of overweight status, children who were overweight at S3 were categorized according to how long they had been overweight: only at S3; only at S2 and S3; or all three surveys. The reference category was "not overweight for all surveys."[4] An additional indicator for all other weight combinations was included.

Control Variables. To isolate the influence of overweight status on Medicare costs, a range of demographic, socioeconomic, and maternal characteristics were included in the model. These characteristics were either time-invariant (e.g., gender) or taken from the first survey, so that the control measures precede the incurrence of Medicare costs. For consistency, the same control variables were used for both analyses (A and B). These include indicators for the child's gender; whether they were aged 5; the presence of siblings; and the type of school attended (day care, preschool, or school). Indicators for language spoken at home (English, non-English European, Asian, or other) were included to control for ethnic and cultural background. A non-English primary language may also influence access to health promotion information or reflect socioeconomic status, which may impact on the child's health (Nickens 1995; Flores, Olson, and Tomany-Korman 2005).

It is recognized that low birth-weight babies are at increased risk of serious health problems (Almond, Chay, and Lee 2005), and infants who are breast-fed experience fewer health problems (Cunningham, Jelliffe, and Jelliffe 1991). To account for these important underlying determinants of health, indicators for low birth weight (<2,500 g) and whether the child was breast-fed at 6 months of age (the global health recommendation by the World Health Organization) were included in the model. Dummies representing the state of residence (to account for exogenous variation in state policies), and indicators for whether the child resides in an inner-regional, rural, or remote area (to account for accessibility to medical services) were also included.

Characteristics of the child's mother were entered in the model because the mother's characteristics can influence not only the child's health status but also the decision to seek medical treatment for the child. The following indicators relating to the child's mother were included in the model: highest educational attainment (university, technical college, high school, or no high school); single-parent; works full time (35+ hours per week); smoking status; and possession of a health care card (which allows low-income families access to cheaper prescription medicines).

Health Conditions. Health conditions or general health measures were not included in the base model because the aim was to estimate the direct association between overweight status and health care costs. This may occur through various health conditions (e.g., asthma or hypertension). An advantage of this approach is that it makes no a priori decisions as to which health conditions are due to obesity but allows for the possibility that obesity may lead to high health costs in conjunction with any health condition (see Johnson, McInnes, and Shinogle 2006; Monheit, Vistnes, and Rogowski 2009).

However, omitted health conditions may confound the relationship between overweight and health costs if they are not attributable to having an elevated BMI. The indicators for low birth weight and breast-feeding were included to control for the increased risk of some health conditions that occur independently of overweight. To further minimize the potential for confounding, several common child health conditions (which may increase health costs but are not likely to be attributable to overweight) were included in a supplementary model. This model included additional indicators for whether, at age 4–5, the child reportedly had a mental health illness; attention deficit hyperactivity disorder (ADHD); hearing problems; vision problems; eczema; or ear infections. Estimates for both the base model and supplementary model are presented. Descriptive statistics of the explanatory variables are presented in Table 2.

Table 2: Descriptive Statistics of Explanatory Variables

Variable	*All* *N = 4,335*	*Overweight* *N = 890*	*Not Overweight* *N = 3,445*
Child's Characteristics			
Normal—*ref*	74.29		
Overweight	20.68		
Underweight	5.03		
Male	51.75	47.68	52.81*
Age 5	18.76	21.81	17.97*
Low birth weight	6.59	4.97	7.01*
Breast fed at 6 months	55.07	48.52	56.78**
Speaks English—*ref*	86.52	83.18	87.39*
European language	3.46	5.13	3.03*
Asian language	5.43	3.92	5.82*
Other language	4.58	7.77	3.75**
Has at least one sibling	88.91	86.90	89.44†
Pre-school—*ref*	53.52	53.49	53.52
School	17.71	19.47	17.26
Day care	24.10	21.96	24.66
Not at school	4.67	5.08	4.56
Lives in city—*ref*	55.70	54.41	56.03
Lives in inner-regional area	24.44	26.82	23.82
Lives in rural area	16.29	15.89	16.39
Lives in remote area	3.57	2.88	3.75
Mental health	0.08	0.13	0.06
ADHD	1.20	1.85	1.03
Hearing problems	3.21	3.80	3.06
Vision problems	2.78	2.76	2.79
Eczema	12.51	13.00	12.38
Ear infections	7.98	9.73	7.52†
Mother's Characteristics			
Has university degree—*ref*	24.82	22.63	25.39†
Has diploma	36.87	37.10	36.81
High school graduate	12.64	11.73	12.88
Did not finish high school	25.67	28.54	24.92†
Non-smoker—*ref*	65.23	59.99	66.59**
Smoker	20.86	24.61	19.89**

continued

Table 2. *Continued*

Variable	*All* *N* = *4,335*	*Overweight* *N* = *890*	*Not Overweight* *N* = *3,445*
Smoking status missing	13.91	15.40	13.52
Works full time	19.56	21.42	19.08
Single	13.87	15.45	13.46
Health Care Card holder	23.40	25.60	22.83

Notes. Shows proportion of sample with characteristics.
†, *, ** indicate significant difference between the proportion for overweight and non-overweight children at $p < .10$, $p < .05$, and $p < .01$, respectively.
Ref—denotes variable was the reference group in all models.
Indicators for each of the eight state and territories of Australia were included in all models, but descriptive statistics are not shown. All characteristics measured at first survey (age 4–5).
ADHD, attention deficit hyperactivity disorder.

ANALYTIC STRATEGY

Analysis A: Overweight at Age 4–5 and Five-Year Pharmaceutical and Medical Care Costs

As is typical with medical cost data, the data are right-skewed, which is accounted for in the modeling.

Pharmaceutical. The PBS data have a very high proportion of zeros (55 percent), which represent those who did not purchase prescription medicines subsidized by the government over the 5-year period. For the PBS data, a two-part model was employed (Duan et al. 1983), which first models the probability of costs being >0, followed by a model of the distribution of costs, given costs were >0. This approach is commonly employed to model health care costs (see Mullahy 1998 and Manning 1998). The two parts are assumed to be independent and estimated separately.

The first part was estimated using a logit model, and the second part using ordinary least squares (OLS) regression on log PBS costs. The predictions from the first and second part were multiplied to generate total predicted PBS costs. The model for the second part was selected by comparing the performance of the OLS log-linear model against GLMs with gamma, Guassian, and inverse Guassian distributions combined with log, power (0.5), and power (−1) links. Following Manning and Mullahy (2001) and Jones (2010), the choice of link function and distribution was guided by the Pregibon link test and Park test. The performance of the GLM models was tested using the Copas test for accuracy of the predicted dependent variable values, the root mean squared error (RMSE), and mean average predicted error (MAPE). Goodness of fit was also examined using the Akaike Information Criteria (AIC). The OLS log-linear model performed better than all GLM models.

The residuals from the log-linear model are practically normally distributed (skewness 0.32, kurtosis 3.01),[5] and a Breusch–Pagan heteroscedasticity test shows the residuals have constant variance, implying that the retransformed estimates (into AUD$) from the log-linear model are unbiased without application of the Duan (1983) smearing factor.[6]

Medical Care. For the MBS data, two-part models were not warranted because 99 percent of children sought non-hospital medical care over the 5-year study period. One-part GLMs were estimated with combinations of log, power (-1), and power (0.5) links and gamma and Gaussian distributions. Using the accuracy tests (described above), the model that best fitted the data was the gamma distribution with log-link.

Costs Differences for Overweight Children. Predictions from the PBS and MBS models were used to determine differences in health care costs incurred by children who were overweight compared with those of normal weight. This was calculated by taking the difference in predicted costs if overweight children were overweight (given all child and maternal characteristics), and the predicted costs if overweight children were in the normal weight range (setting the overweight indicator to zero). The percentage difference in health costs (cost difference divided by costs if overweight children were normal weight) is also presented. Costs were predicted for each child then averaged over the population of children. Standard errors were calculated using the bootstrap method (500 replications), which accounts for the original sampling design.

Analysis B: Timing and Duration of Overweight Status on Medical Care Costs at Age 8–9

A one-part GLM model (gamma distribution with log-link) was also used for the *timing* and *duration of overweight* models of Analysis B.

All estimations were performed using *Stata* (StataCorp 2009) and account for stratification and clustering. Sample weights were employed to take both the probability of selecting each child in the study and an adjustment for non-response in the first wave into account. Longitudinal sample weights were employed in Analysis B (which use data from all three surveys) to adjust the sample for attrition.

RESULTS

Analysis A

Descriptive Statistics. As shown in Table 2, at age 4–5, 21 percent of the sample were overweight, 52 percent were men, and most (87 percent) spoke English at home. About a quarter of mothers held a university degree and an additional 37 percent held a diploma or certificate. Twenty-one percent of mothers smoked, and almost many (20 percent) worked full time. Less than one percent of children had a mental illness, while 8 percent suffered from ear infections and 13 percent had eczema. The sample proportions for overweight and non-overweight children show that overweight children were more likely to be female, aged 5, speak a language other than English at home, and have a mother who smoked or was less educated. Children who had a low birth weight or were breast fed at 6 months were less likely to be overweight. Estimates of PBS and MBS costs from the base and supplementary models are presented in Table 3.

Pharmaceuticals. Result from the base model (1) show that compared with children of normal weight, those who were overweight at age 4–5 had a significantly higher probability of incurring PBS costs (by about 7.1 percentage points [$p < .01$]) over the following 5 years of life. The results from the log-linear model show that for those who incurred PBS costs, being overweight significantly increased PBS costs by about 31 percent ($p < .01$). Being underweight also increased the probability of incurring PBS costs ($p < .10$) but had no significant impact on costs incurred in the log-linear model. The associations between overweight and PBS costs attenuated with the inclusion of health conditions (Model 2) but remained significant ($p < .01$).

In both models (1 and 2), the probability of incurring PBS costs and the amount of costs incurred were higher for males and children who spoke an Asian or other (non-English and non-European) language at home. Those who were breast-fed at 6 months had a lower probability of incurring PBS costs, and

Table 3: Analysis A Estimates: PBS and MBS Costs from 2004 to 2009

	(1) PBS Costs				(1) MBS Costs		(2) PBS Costs				(2) MBS Costs	
	Part 1: Logit		Part 2: OLS‡		GLM§		Part 1: Logit		Part 2: OLS		GLM	
N = 4,335	M.E.[a]	S.E.	M.E.[b]	S.E.	M.E.[c]	S.E.	M.E.[a]	S.E.	M.E.[b]	S.E.	M.E.[c]	S.E.
Child's Characteristics												
Overweight	0.071**	0.018	31.29**	10.72	86.57**	32.98	0.064**	0.017	25.44**	10.00	63.86*	29.35
Underweight	0.058†	0.033	−10.15	15.66	56.95	61.41	0.061†	0.033	−6.55	15.41	79.00	63.43
Male	0.027*	0.013	37.04**	9.84	90.74**	26.28	0.025†	0.013	31.50**	9.16	81.86*	26.03
Age 5	−0.016	0.019	7.68	11.07	−32.47	34.38	−0.016	0.019	6.27	10.45	−30.57	33.16
Low birth weight	0.022	0.029	30.82*	17.79	148.22**	56.30	0.016	0.030	29.23*	16.77	127.98*	52.74
Breast fed	−0.042**	0.015	−5.40	6.77	−48.68†	25.96	−0.036*	0.015	−0.54	6.92	−31.65	25.35
Europe	0.034	0.044	9.44	22.21	334.53**	95.39	0.043	0.045	16.05	23.57	363.89**	97.75
Asian	0.171**	0.033	60.73**	21.96	216.15**	59.50	0.172**	0.032	65.72**	22.99	238.40**	59.21
Other lang.	0.145**	0.039	48.19**	21.30	170.99*	71.28	0.153**	0.039	58.41**	22.97	209.77**	69.60
Sibling	−0.011	0.022	−18.47*	8.01	−182.48**	49.03	−0.011	0.022	−20.76*	7.76	−190.42**	48.52
Mother's Characteristics												
Diploma	0.086**	0.017	16.74	12.72	60.51†	32.56	0.085**	0.017	17.51	12.44	57.49†	31.91
High school	0.079**	0.024	23.66†	15.33	88.31*	42.33	0.076**	0.023	21.14	14.42	83.81*	42.07
No high school	0.164**	0.023	16.63	13.76	62.47	43.10	0.165**	0.023	18.59	13.41	49.91	41.31
Smoker	0.030	0.020	−7.74	7.91	−102.96**	32.96	0.025	0.020	−10.72	7.34	−116.14**	30.05
Works full time	−0.073**	0.018	−8.66	9.34	−67.88*	32.07	−0.071**	0.018	−7.99	9.35	−61.76*	31.17
Single	0.197**	0.027	−1.38	7.94	−4.45	44.24	0.196**	0.027	−1.72	7.57	−36.44	38.87
HC Card	0.395**	0.021	14.98†	8.54	17.09	34.38	0.394**	0.020	18.33*	8.49	26.09	32.25
Child health conditions												
Mental health							0.203	0.204	523.49**	248.37	527.75	848.53
ADHD							0.366**	0.067	430.56**	119.34	912.49**	192.91

continued

Table 3. *Continued*

	(1) PBS Costs				*(1) MBS Costs*		*(2) PBS Costs*				*(2) MBS Costs*	
	Part 1: Logit		*Part 2: OLS*[‡]		*GLM*[§]		*Part 1: Logit*		*Part 2: OLS*		*GLM*	
N = *4,335*	*M.E.*[a]	*S.E.*	*M.E.*[b]	*S.E.*	*M.E.*[c]	*S.E.*	*M.E.*[a]	*S.E.*	*M.E.*[b]	*S.E.*	*M.E.*[c]	*S.E.*
Hearing problems							0.039	0.039	−5.80	14.92	162.82*	71.22
Vision problems							0.092*	0.041	21.11	19.12	279.71**	69.18
Eczema							0.101**	0.022	58.90**	16.96	232.65**	42.24
Ear infections							0.063*	0.027	62.78**	21.53	385.54**	51.20

Notes. (1) Base model, (2) with health conditions included.

†, *, **statistical significance at $p < .10$, $p < .05$, and $p < .01$, respectively.

Also included in the models: indicators for school type; region of residence; state/territory of residence; mother's smoking data missing.

Marginal effects are the discrete change of dummy variables from 0 to 1, interpreted as:

[a]change in $p(y > 0)$;

[b]% change in y;

[c]change in y ($AUD).

GLM, generalized linear models; MBS, Medicare Benefits Scheme; OLS, ordinary least squares; PBS, Pharmaceutical Benefits Scheme.

among those who incurred costs, a low birth weight was associated with greater costs. Children of mothers who were single or had a lower level of education were more likely to incur PBS costs, whereas children of mothers who worked full time were less likely to incur PBS costs. Health conditions were generally associated with substantially higher probabilities of incurring PBS costs.

Medical Care. The base model estimates (see Table 3) demonstrate that overweight children had significantly higher MBS costs (by approximately $87 [$p$<.01]) compared with children who were normal weight. Being underweight was not significantly related to MBS costs. When health conditions were included (Model 2), medical costs for overweight children remained significantly higher than for normal weight children (by about $64 [$p$<.05]), but the cost difference was lower than in the base model.

In both MBS cost models, boys incurred greater costs. Having a low birth weight or speaking a language other than English at home significantly increased MBS costs. Lower levels of maternal education was associated with higher MBS costs, while children with mothers who smoked or worked full time had significantly lower medical costs. In Model 2, most health conditions were associated with significantly higher medical costs. Few children had a mental illness and the cost variance was large, which explains the insignificant result for having a mental illness.

Pharmaceutical and Medical Care Cost Differences by Overweight Status. Table 4 shows that being overweight at age 4–5, holding all child and maternal characteristics constant, was associated with pharmaceutical costs that were on

Table 4: Analysis A Estimates: Average Predicted Cost Differences for Overweight Children (Compared with Normal Weight)

	PBS	*MBS*	*TOTAL (MBS + PBS)*
(1) Base Model			
Cost difference ($)	34.78 (8.81)	86.57 (31.27)	121.35 (32.41)
Percentage cost difference (%)	58.84 (15.47)	10.00 (3.69)	12.92 (3.59)
(2) Includes Health Conditions			
Cost difference ($)	29.36 (8.60)	63.86 (29.83)	93.22 (35.4)
Percentage cost difference (%)	49.72 (14.39)	7.33 (3.48)	9.71 (3.81)

Notes. Bootstrapped standard errors are in parentheses.
MBS, Medicare Benefits Scheme; PBS, Pharmaceutical Benefits Scheme.

average \$35 (59 percent) higher and medical costs that were on average \$87 (10 percent) higher over the 5-year period, than if the children were not overweight. After adjusting for health conditions, the average cost increases for overweight children were slightly lower, at \$29 (50 percent) for pharmaceutical expenses and \$64 (7 percent) for MBS costs.

Analysis B

In the first survey, about 20 percent of the sample was overweight. By the third survey, this increased to 24 percent. About 59 percent of children remained not overweight for all three surveys, whereas 12 percent were overweight for all three surveys. About 7 percent of the sample did not become overweight until the third survey.

The results from the timing and duration of overweight status models are shown in Table 5. For brevity, only estimates for the child's overweight status are shown. The timing model demonstrates that being overweight in S3 was associated with significantly higher MBS costs in 2008–2009 (by about \$34 in the base model and \$30 in the model adjusted for health conditions), but being overweight in either S1 or S2 had no significant impact on costs. These results suggest that contemporaneous overweight status is important in

Table 5: Analysis B Estimates: Impact of Timing and Duration of Overweight Status on MBS Costs in 2008–2009

	(1) Base Model		*(2) Includes Health Conditions*	
N = *3,670*	*M.E.*[a]	*S.E.*	*M.E.*[a]	*S.E.*
(1) Timing of Overweight				
OW in S3	33.98*	16.40	30.12*	15.58
OW in S2	−4.04	16.62	0.55	16.38
OW in S1	−12.23	13.58	−17.09	13.31
(2) Duration of Overweight				
OW in S3 only	36.68	22.47	30.95	21.28
OW in S2 and S3 only	87.24**	32.43	84.30*	33.54
OW in all surveys	4.87	13.05	2.79	13.21
Other weight	15.04	15.56	6.19	14.85

Notes. *, ** indicate statistical significance at $p < .05$ and $p < .01$, respectively.
All other control variables were included in the model, but estimates are not shown.
[a]Marginal effects are the discrete change of dummy variables from 0 to 1, interpreted as a unit change in MBS costs (in AUD\$).
MBS, Medicare Benefits Scheme.

determining MBS costs, and that past overweight status alone does not appear to play an important role.

The results from the duration model show a positive but insignificant association between costs and becoming overweight at S3. Children who became overweight one survey earlier (at S2) incurred significantly more medical costs (about $87 more in the base model and $84 more in the model adjusted for health conditions) than those of stable non-overweight children, suggesting that a longer duration of overweight is associated with higher medical costs. However, the association between duration of overweight and medical costs does not appear to extend to children who were overweight for all three surveys. MBS costs for these children were not significantly different from those of stable non-overweight children. This finding is considered further below.

Hospital Use Analysis

Estimates from the logit models of the probability of children staying in a hospital are shown in Table 1. Children who were overweight (or underweight) at age 4–5 did not have a significantly different probability of staying in a hospital at age 5–6 or at age 6–7 than children of normal weight. This indicates that overweight status may not have a substantial influence on hospital costs incurred during childhood.

DISCUSSION

This study primarily investigates government-funded health care costs during childhood that are associated with being overweight at age 4–5. Over the 5-year period, during which children were aged 4–5 to 8–9 years, overweight children incurred significantly higher PBS (pharmaceutical) and MBS (medical care) costs. This is in accordance with the clinical literature, which finds childhood overweight to be associated with more health problems during childhood (Dietz 1998; Must and Anderson 2003) and supports previous studies that find a positive relationship between childhood overweight and costs (Hampl et al. 2007; Finkelstein and Trogdon 2008; Trasande and Chatterjee 2009).

This study reveals that the financial burden of overweight and obesity occurs even during the first 5 years of primary school and demonstrates that prevention of overweight in children as young as 4–5 years could have significant economic (in addition to health) implications.

The results show that after controlling for child and maternal characteristics, children who were overweight at age 4–5 on average incurred an additional $93 (10 percent) in non-hospital Medicare costs (PBS plus MBS) over 5 years. Extrapolated to the population level, these results imply that for all children aged 4 and 5 in 2004–2005, those who were overweight had a combined 5-year Medicare bill, approximately AUD$9.8 million higher than that of children who were normal weight.[7]

The results from the dynamic models show that higher medical costs at age 8–9 are associated with being overweight at age 8–9, but not with overweight status at earlier ages. This implies that being overweight is associated with significantly higher contemporaneous medical costs, and that past overweight status alone does not significantly increase costs. The insignificant result for past overweight status suggests that if childhood overweight is treated, the medical care costs in future years are likely to return to levels similar to normal weight children. This highlights potential cost savings from policies aimed at treating (not just preventing) childhood overweight.

The duration model shows there is a positive association between the duration of overweight and medical costs incurred among children who became overweight at some stage during the first few years of school. Children who became overweight by age 6–7 (and remained overweight at age 8–9) incurred considerably more MBS costs than children who were not overweight until age 8–9. This finding provides economic support for policies aimed at preventing and treating childhood overweight as early as possible.

The result of an insignificant association for children who were overweight for all three surveys is unsupportive of the hypothesis that medical costs increase with duration of overweight. According to parental reports in LSAC, children who were overweight for all three surveys had significantly worse levels of general health, and parents of these children were significantly more concerned about the weight of their child than parents of normal weight children (results shown in Appendix A). This suggests that children who were long-term overweight were in need of medical care, and parents appeared to be aware of this need. It is possible that these children experienced severe health complications that required direct hospital care (and therefore bypassed treatment by general practitioners). However, parental reports of hospital visits reveal that long-term overweight children were not more likely to have stayed in a hospital in the year prior to S3 (see Appendix A). It remains unclear why children who were overweight for all three surveys did not incur more health care costs than stable non-overweight children at age 8–9. Further investigation into the longer-term medical care consequences of these children as they enter adolescence may be informative.

The models also provide information on the influence of other demographic and socioeconomic characteristics on Medicare costs. The significant gender difference in Medicare costs supports evidence that boys tend to have more injuries and chronic illnesses (Australian Institute of Health and Welfare 2009). Children who spoke a language other than English incurred higher Medicare costs than children who spoke English at home. These findings are supportive of the established literature on the ethnic disparities in child health, which can be explained to some extent by socioeconomic status (Nickens 1995; Flores, Olson, and Tomany-Korman 2005). Maternal characteristics played an important role in determining Medicare costs. The finding that children of more highly educated mothers incurred fewer costs supports the literature of a positive effect of mother's education on child health (Currie and Moretti 2003; Chen and Li 2009).

A key strength of this study is that longitudinal, linked data on children were used to gain information on measured body weight and health care costs over 5 years. This enabled an investigation of health care costs associated with overweight that may develop over a longer period of time, and an exploration of the dynamics of childhood overweight in relation to health care costs. These analyses have not been possible in previous studies that used a cross-sectional data.

The analysis does not include hospital cost data, which is difficult to access, particularly individual-level data. However, it is not clear that hospital data would provide substantially more information because inpatient stays for this age group are not common. Furthermore, based on parental reports on whether children stayed in a hospital in the past year, childhood overweight at age 4–5 is found to be insignificantly associated with the likelihood of a hospital visit at age 5–6 or age 7–8.

The extrapolation of the additional costs incurred by overweight children to the population level should be interpreted with caution, as it is based on the accuracy of the predicted average Medicare cost of overweight children and assumes the weighted prevalence of overweight in the LSAC corresponds to the actual population prevalence of overweight for children aged 4–5 years. The LSAC study is still in its infancy with only three waves available. Therefore, it was only possible to investigate children from ages 4–5 years through to 8–9 years. As the survey progresses, further information about the relationship between overweight and medical costs in older children and adolescents can be investigated.

CONCLUSION

This study provides unique evidence that childhood overweight at age 4–5 is associated with significantly higher publicly funded medical and pharmaceutical costs for children during their first 5 years of school. It also demonstrates that the costs of childhood overweight occur contemporaneously and that duration of overweight is positively associated with medical costs for children who become overweight after age 5. From a health and well-being perspective, there is undoubtedly a need for a high prioritization of solutions for childhood overweight. From an economic perspective, these findings suggest that cost-effective strategies for both the prevention and early treatment of childhood overweight could pay sizable dividends to the government and society at large, both currently and into the future.

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NOTES

1. Ninety-three percent of children in the LSAC were successfully linked to Medicare data. Results were not adjusted for linkage to Medicare. However, a logit analysis showed that the probability of linkage to Medicare was not significantly associated with child's weight, which suggests little to no selection bias on the main analyses.

2. In 2008, the copayment was $32.90 or $5.99 for concession card (including health care card) holders. The copayment is indexed annually. Copayments and prices are applicable nationwide.
3. Medicines dispensed in hospitals are provided free to patients, but they are funded under separate health care arrangements with states.
4. Underweight children were included here because they do not have significantly different medical care costs to normal weight children (see Results of Analysis A).
5. Perfectly normal has skewness = 0 and kurtosis = 3.
6. Duan's smearing estimator (1983) provides a consistent estimate of expected costs if the errors are not log-normal. It provides less precise estimates if the error is truly normal. Mean predictions of costs using the Duan smearing estimator were about 5 percent further from actual mean costs than predictions without the smearing estimator, implying unadjusted estimates provide a closer fit to the data.
7. Calculated using the total average cost differences (PBS and MBS) in the model that adjusts for health conditions ($93.22), a total population of children aged 4 and 5 of 509,937 (Australian Bureau of Statistics 2006) and an average prevalence of overweight of 20.5 percent using the LSAC population weighted average of the children at age 4–5. Using the base model estimates, the total additional cost for overweight children is $12.1 million.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Table S1. Marginal Effects from Models of Reported Health Status of Child, Concern about Child's Weight and Hospital Stays.

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