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ORIGINAL RESEARCH

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Impact and recovery of the COVID-19 pandemic on weight status of children and adolescents

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Summary

Recent evidence suggests the immediate effects of the COVID-19 lockdowns and restrictions have resulted in increased weight in children and adolescents. However, the longer-term effects have not been assessed. The aim of this study was to examine the impact and longer-term effects of the COVID-19 pandemic on BMI and weight status of children and adolescents. This study used routinely collected clinical data from the Sydney Children's Hospitals Network, comprising two socio-demographically diverse children's hospitals in New South Wales, Australia from 2018 to 2021. Of 245 836 individuals ≤18-years assessed, mean BMI percentile increased from 58.7 (SD 31.6) pre-COVID-19 to 59.8 (SD 31.7) ($p < .05$) post-restrictions and overweight/obesity increased by 5.5% (obesity alone 6.3%), predominantly in children <12-years and from lower socioeconomic backgrounds. The trend in BMI percentile was steady pre-COVID-19 ($\beta = -0.03$ [95% CI -0.07, 0.01]), peaked immediately following COVID-19 restrictions ($\beta = 1.28$ [95% CI 0.24, 2.32]) and returned to pre-pandemic levels over ensuing 21 months ($\beta = -0.04$ [95% CI −0.13, 0.04]). Routine anthropometric measurement facilitates ongoing monitoring and evaluation of the weight status of children and adolescents, helping to identify those at-risk. Despite initial BMI and weight increases among children and adolescents, longer-term follow-up highlighted a return to pre-pandemic rates, possibly attributed to state-wide policies aimed at reducing childhood obesity.

KEYWORDS

adolescent, child, COVID-19, obesity, overweight

What is already known about this subject?

- Overweight and obesity in young people has shown increasing prevalence, with widening socioeconomic disparities.
- Lockdowns/restrictions associated with the COVID-19 pandemic have resulted in weight gain among children and adolescents.

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What this study adds?

- Population rates of BMI and weight status of Australian children and adolescents increased following COVID-19 restrictions, mostly among those from most disadvantaged areas.
- Weight status of children and adolescents returned to pre-COVID-19 pandemic levels after the longest follow-up period of 18-months.
- State-wide health policies may have moderated the effect of COVID-19 pandemic on child/ adolescent overweight and obesity.

1 | INTRODUCTION

Obesity is a complex global public health challenge, placing significant health and direct and indirect economic costs on individuals and healthcare systems.[1,2] The prevalence of overweight and obesity among children and adolescents has increased globally from 4% in 1975 to over 18% in 2016.[3] Recent estimates show increasing prevalence, with widening socioeconomic disparities in obesity.[4–7] Obesity in young people is concerning not only because of the elevated risk of serious health conditions such as asthma, sleep apnoea, bone and joint problems, hypertension, dyslipidemia, insulin resistance/type 2 diabetes and psychological problems,[8,9] but also because childhood obesity is associated with higher weight in adulthood, leading to increased risk of developing chronic disease.[10]

In 2020, the coronavirus (COVID-19) pandemic caused major disruptions to healthcare systems, economies and education. One of the main impacts of COVID-19 was the introduction of public health restrictions and social policies in late-March 2020 with significant closure of major facilities and services, including schools and workplaces and restrictions to movement and gatherings. From a health perspective, the closure of schools affected the ability of young people to undertake regular exercise and incidental activity.[11] In addition, recreational areas including playgrounds, beaches and gyms were closed and regular out of school sport and recreational activities were suspended. Studies show that when children are out of school (e.g. on weekends and during summer holidays) and with a loss of routine, they are physically less active, have much longer screen time, irregular sleep patterns and less favourable diets, all resulting in weight gain and a loss of cardiorespiratory fitness.[12,13] Such negative effects on health are likely to be worse when children are confined to their homes, with little to no outdoor activities, while experiencing family and individual stress, as during the COVID-19 restrictions.

Recent publications have reported an increase in the weight and/or body mass index (BMI) of children and adolescents post-pandemic compared to pre-pandemic levels. However, many of these studies were small, examined various forms of weight status, differed in the ages, age groups or health status of the cohort studied, or did not measure socioeconomic status.[14–20] Further, most studies only examined short-term effects with follow-up from 2 to 4 months and longer-term impact not assessed past 11 months. These studies tended to show an increase in BMI/weight status, but it is unclear whether these changes were sustained. The aim of this study was to examine the impact and longer-term effects of the COVID-19 pandemic on BMI and weight status of children and adolescents.

2 | METHODS

2.1 | Study population and data sources

This was a retrospective study using deidentified clinical data from the Sydney Children's Hospitals Network (SCHN) in New South Wales (NSW), Australia from January 2018 to December 2021. The SCHN is the largest paediatric health entity in Australia comprising two large children's hospitals in two diverse ethnographic regions of metropolitan NSW, the Sydney Children's Hospital (SCH) and The Children's Hospital at Westmead (CHW). The study population included all children from birth to 18 years who presented to hospital outpatient clinics and emergency departments (ED) or were admitted to hospital. Deidentified data were collected from the Children's Weight, Height and Weight Status Extract, data routinely collected from each hospital which includes admission date, date of birth, sex, postcode, height/ weight/BMI, facility (SCH or CHW) and clinical setting (outpatient, emergency or admitted).

2.2 | Study outcomes

The study outcomes were defined by age-sex adjusted BMI and weight percentiles. BMI was determined if height and weight were recorded by dividing the weight in kilograms by height in metres squared (kg/m^2). Date of birth and date of presentation to hospital were used to calculate age-sex adjusted weight (if height was not available) and BMI percentiles using growth charts from the US Centers for Disease Control and Prevention (CDC) for children aged 2–18 years,[21] and age-sex adjusted weight percentiles from the World Health Organization (WHO) for children aged 0–24 months.[22] BMI group using calculated BMI percentile was categorized as: 1. Underweight (<5th percentile), 2. Normal (5th to <85th percentile), 3. Overweight (≥85th to <95th percentile) and 4. Obese (≥95th percentile).[21]

2.3 | Study factor and covariates

The main study factor of interest was the impact of the COVID-19 pandemic restrictions on weight status. In NSW, public health measures were introduced on 16 March 2020 with increasing restrictions including school closures implemented across the state by the end of March.[23] For our analyses, 1 April 2020 was used as the pre/post COVID-19 restriction reference point, with 'pre-COVID-19' defined as the period from January 2018 to March 2020 and 'post-COVID-19' defined as the start of the restriction period from April 2020 to December 2021.

Sociodemographic characteristics assessed included age, sex, socioeconomic status and geographical area. The postcode of residence of each individual was used to assign a socioeconomic disadvantage score corresponding to the Australian Bureau of Statistics Socio-Economic Index for Areas.[24] These scores were categorized into quintiles, with quintile 1 representing the most disadvantaged and quintile 5 the least disadvantaged areas. Similarly, postcodes were also used to assign area of residence (major cities, regional and remote) based on the Accessibility and Remoteness Index of Australia.[25] Clinical details comprising the facility (CHW/SCH) and clinical setting (outpatient, ED and admitted) were also characterized.

2.4 | Statistical analysis

Descriptive statistics of the socio-demographic and clinical characteristics of children and adolescents were determined, firstly comparing those with BMI and/or weight data to those who did not using Chi-squared analysis for categorical variables and *t*-test for continuous variables. BMI and weight percentiles were compared pre/post COVID-19 restrictions by calculating overall mean difference, as well by sociodemographic characteristics. BMI percentiles were used for all analyses with weight percentiles only shown for overall comparison pre/post-COVID-19 restrictions.[26] A secondary analysis was conducted using data for only those children with weight and/or BMI data measured pre/post COVID-19 restrictions using repeated measures and pairwise comparisons.

Interrupted time series (ITS) analysis incorporating all BMI measurements was conducted using autoregressive integrated moving average (ARIMA) models[27] to examine the temporal change in the BMI percentiles pre/post COVID-19 restrictions. We used the R forecast package to select the best fit model with minimal Akaike's Information Criterion and maximum likelihood estimation. Models evaluated the regression coefficients before, immediately after (step) and the trend following the COVID-19 restrictions. We also included a counterfactual forecast predicting the BMI centile curve from the start of the COVID-19 restriction period using the same ARIMA models. Poisson regression models were used to assess the temporal trend and multivariable models to adjust for potential confounding by sociodemographic and clinical characteristics.

We used generalized estimating equations models with a multinomial response to assess the effect of the lockdown on the BMI group of children accounting for the correlation of repeated measures and adjusting for demographic and clinical factors. Rate ratios (RR) and 95% confidence intervals (CI) were calculated and used to compare the BMI percentile changes. Data were analysed using SPSS v28 and SAS v9.4 and statistical significance indicated by *p*-value <.05. Ethics approval was provided by the NSW Population and Health Services Research Ethics Committee (2020/ETH03238) and Sydney Children's Hospitals Network Ethics Committee (2021/STE04446).

TABLE 1 Socio-demographic and clinical characteristics comparing measurements of children with BMI/weight data pre- and post-COVID-19 restrictions

Sociodemographic and clinical characteristics	Pre-COVID-19; $N = 145\ 116$ n (%)	Post-COVID-19; $N = 100\ 720$ n (%)
Age (years): Mean (SD)	7.9 (5.25)	8.3 (5.31)
Age groups (years)		
0–1	25 579 (17.6)	16 179 (16.1)
2–4	26 618 (18.3)	17 384 (17.3)
5–11	52 638 (36.3)	35 803 (35.5)
12–15	30 676 (21.1)	23 658 (23.5)
>16	9605 (6.6)	7696 (7.6)
Sex		
Male	80 956 (55.8)	55 603 (55.2)
Female	64 160 (44.2)	45 117 (44.8)
Born in Australia		
Yes	134 681 (93.6)	93 442 (93.7)
No	9268 (6.4)	6269 (6.3)
Socioeconomic status		
1 Most disadvantaged	26 770 (19.0)	18 787 (19.2)
2	14 599 (10.4)	9769 (10.0)
3	22 530 (16.0)	15 347 (15.7)
4	38 899 (27.6)	27 412 (28.0)
5 Least disadvantaged	38 175 (27.1)	26 737 (27.3)
Geographical location		
Major city	130 404 (91.0)	90 919 (91.2)
Inner regional	10 510 (7.3)	7116 (7.1)
Remote	2460 (1.7)	1660 (1.7)
Facility		
CHW	90 566 (62.4)	63 175 (62.7)
SCH	54 544 (37.6)	37 533 (37.3)
Clinical setting		
Emergency	977 (0.7)	569 (0.6)
Inpatient	38 594 (26.7)	33 252 (33.3)
Outpatient	104 995 (72.6)	66 093 (66.1)

Abbreviation: SD, standard deviation.

3 | RESULTS

A total of 1 316 639 records were extracted for analyses. Of these, 245 836 (18.7%) had weight measurements, including 203 955 (15.5%) BMI measurements for 86 794 children. Socio-demographic characteristics were mostly comparable between children with and without weight/BMI data, however fewer children presenting to emergency (1% vs. 28%) and more children admitted to hospital (29% vs. 10%) had recorded measurements (Table S1). For children with recorded data, the average age was 8.1 years, over half were male (55.5%) and two-thirds attended CHW. Sociodemographic and clinical

TABLE 2 Comparison of BMI and weight pre- and post-COVID-19 restrictions

BMI percentile (age 2–18 years)	Pre-COVID-19; *N* = 119 462 Mean (SD)	Post-COVID-19; *N* = 84 493 Mean (SD)	Mean difference (95% CI[a])
Overall	58.7 (31.6)	59.8 (31.7)	1.08 (0.80, 1.36)
Pairwise comparison (1 pre and 1 post measurement) (*N* = 17 602)	57.7 (31.8)	60.1(31.6)	2.38 (2.04, 2.73)
	***n* (%)**	***n* (%)**	
BMI group[b]			$p < .001$
Underweight	7582 (6.3)	5271 (6.2)	
Normal	77 277 (64.7)	53 375 (63.2)	
Overweight	17 456 (14.6)	12 907 (15.3)	
Obesity	17 147 (14.4)	12 940 (15.3)	
Weight percentile (0–18 years)	***N* = 145 116**	***N* = 100 720**	
Overall	54.2 (32.6)	55.8 (32.8)	1.56 (1.30, 1.83)
Pairwise comparison (*N* = 17 601)	52.7 (33.0)	56.9 (32.4)	4.20 (3.89, 4.52)

Abbreviations: CI, confidence interval; SD, standard deviation.
[a]*p*-value <.05 is indicative where CI does not include 0.
[b]Chi-squared = 64.3.

TABLE 3 Socio-demographic and clinical characteristics comparing mean BMI percentiles pre- and post-COVID-19 restrictions

Sociodemographic and clinical characteristics	Pre-COVID-19; *N* = 119 462 Mean (SD)	Post-COVID-19; *N* = 84 493 Mean (SD)	Mean difference (95% CI[a])
Sex			
Male	57.8 (32.4)	58.8 (32.6)	1.00 (0.63, 1.39)
Female	59.8 (30.5)	61.0 (30.5)	1.13 (0.72, 1.53)
Age groups (years)			
2–4	57.7 (31.6)	59.4 (31.0)	1.70 (1.10, 2.30)
5–11	59.3 (31.3)	61.1 (31.5)	1.78 [1.36, 2.20]
12–15	59.1 (31.7)	59.3 (32.0)	0.19 [−0.36, 0.73]
>16	56.8 (32.6)	56.0 (32.5)	−0.80 [−1.78, −0.18]
Facility			
CHW	58.6 (32.0)	60.5 (32.0)	1.87 (1.51, 2.22)
SCH	58.9 (30.8)	58.7 (31.2)	−0.27 (−0.72, 0.18)
Socioeconomic status			
1 Most disadvantaged	62.2 (32.2)	63.6 (32.0)	1.43 (0.77, 2.08)
2	59.6 (32.3)	63.2 (31.9)	3.61 (2.72, 4.51)
3	60.3 (31.7)	61.0 (32.2)	0.63 (−0.09, 1.36)
4	58.8 (31.4)	59.7 (31.6)	0.89 (0.36, 1.42)
5 Least disadvantaged	54.9 (30.8)	55.8 (30.8)	0.88 (0.35, 1.40)
Geographical location			
Major city	58.6 (31.6)	59.7 (31.7)	1.10 (0.80, 1.39)
Inner regional	59.0 (31.6)	60.7 (31.5)	1.63 (0.60, 2.67)
Remote	60.1 (32.1)	62.5 (30.9)	2.42 (0.27, 4.56)
Clinical setting			
Emergency	64.1 (34.7)	63.0 (33.6)	−1.13 (−3.03, 5.28)
Inpatient	57.2 (31.9)	58.7 (32.1)	1.56 (1.04, 2.07)
Outpatient	59.2 (31.4)	60.3 (31.4)	1.03 (0.69, 1.36)

Abbreviations: CI, confidence interval; SD, standard deviation.
[a]*p*-value <.05 is indicative where CI does not include 0.

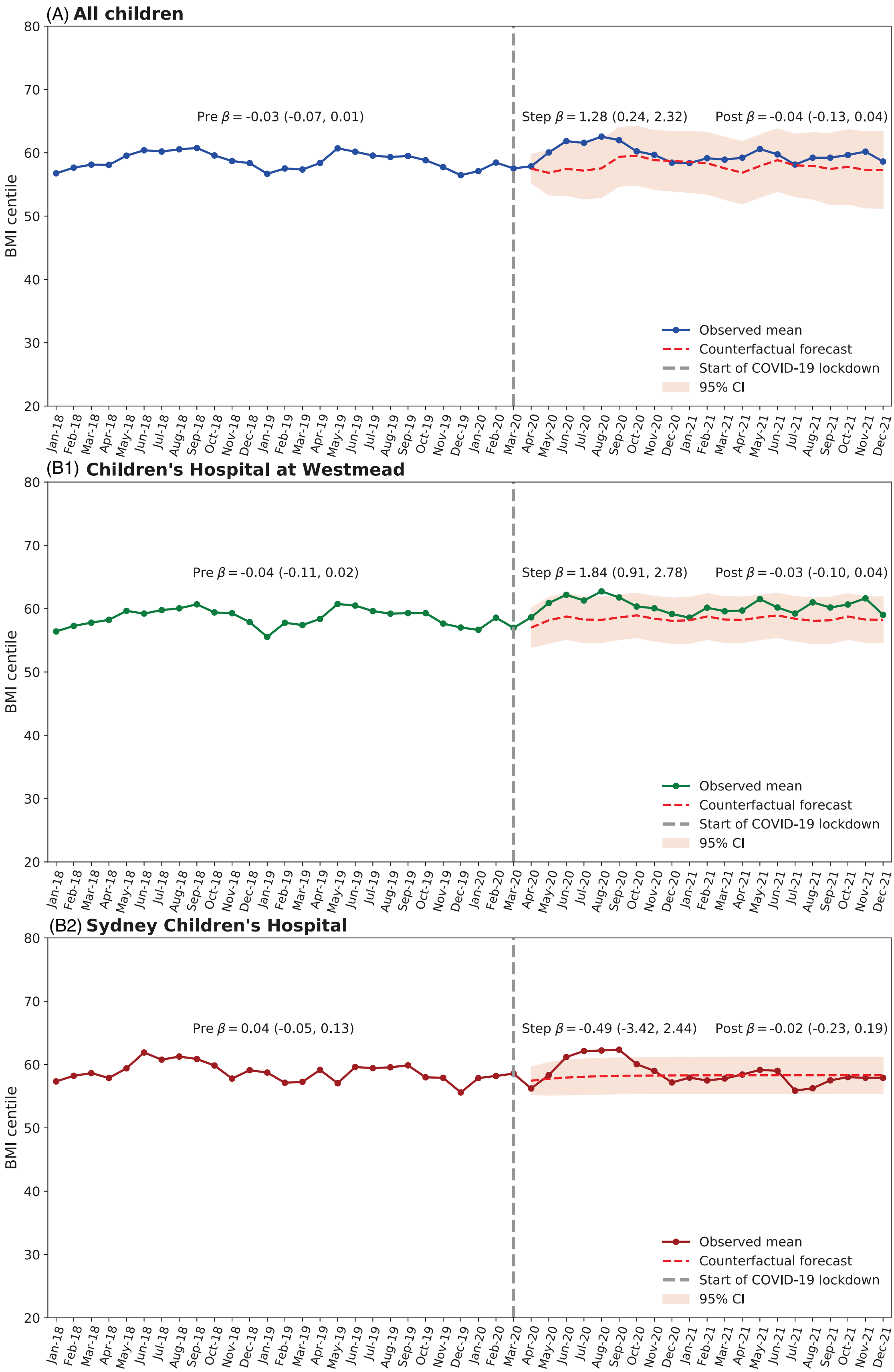

FIGURE 1 Time-series analysis comparing BMI percentiles pre- and post- COVID-19 restrictions (A) overall and (B) stratified by facility.

characteristics pre/post COVID-19 restrictions were similar, except children post-restrictions had greater admissions and fewer outpatient visits (Table 1).

Overall, two-thirds of children had normal BMI, nearly one-third (30%) were classified with overweight or obesity and 6% with underweight. Compared to pre-COVID-19, the percentage of children with overweight or obesity increased by 5.5% post-COVID-19 restrictions (obesity alone 6.3%) and the mean BMI percentile increased from 58.7 (SD 31.6) to 59.8 (SD 31.7) (mean difference [MD] 1.08 [95% CI 0.80, 1.36]). The difference in mean BMI percentiles was more pronounced when analysed by children with a pre- and post-measurement (MD 2.38 [95% CI 2.04, 2.73]). The average weight also increased from 31.6 (SD 22.1) to 33.4 (22.8) kg and change in weight percentile increased from 54.2 (SD 32.6) to 55.8 (32.8) (MD 1.56 [95% CI 1.30, 1.83]) (Table 2). Children aged 2–4 and 5–11 years, in the lower socioeconomic groups, residing in remote areas and attending CHW had the greatest increase in BMI percentile (Table 3). After adjusting for age, sex, socioeconomic status and facility, the post-COVID-19 restrictions BMI changes were translated into a 7% increase in overweight (aRR 1.07 [95% CI 1.03, 1.11]) and 12% increase in obesity (aRR 1.12 [95% CI 1.07, 1.17]) (Table S2). Overall, females were more likely than males to be in the overweight category (aRR 1.11 [95% CI 1.05, 1.17]), but less likely to be in the obesity category (aRR 0.82 [95% CI 0.77, 0.88]). Children from lower socioeconomic backgrounds (quintile 1) had a 40% higher risk of being classified with overweight (aRR 1.41 [95% CI 1.30, 1.52]) and 2.7 times the risk of being classified with obesity (aRR 2.70 [95% CI 2.44, 2.99]) compared to those from higher socioeconomic backgrounds (Table S2).

The overall monthly trend in BMI percentiles showed periodic increases corresponding to the winter months from June to August in Australia, followed by decreases in the summer months from December to February (Figure 1). Overall, there was no increase in BMI percentile pre-COVID-19 ($\beta = -0.03$ [95% CI -0.07, 0.01]) but an increase in the period immediately following the COVID-19 restrictions ($\beta = 1.28$ [95% CI 0.24, 2.32]), followed by a decrease and levelling off to just above pre-pandemic levels ($\beta = -0.04$ [95% CI -0.13, 0.04]). When stratified by facility, the increase immediately after the restriction (step) was primarily seen at CHW ($\beta = 1.84$ [95% CI 0.91, 2.78]) compared to none at SCH ($\beta = -0.49$ [95% CI -3.42, 2.44]). By the end of 2021, the trend in BMI returned to pre-pandemic levels at both sites (Figure 1).

4 | DISCUSSION

This study showed an increase in mean BMI percentile in children and adolescents post-COVID-19 restrictions predominantly in children aged 2–11 years and among those of a lower socioeconomic status. Although results showed a 5.5% increase in the proportion of children with overweight and obesity after the start of the pandemic, this peaked in the first few months following COVID-19 restrictions, particularly among children attending CHW. Within a year, the BMI at both sites returned to pre-pandemic levels.

Our results are comparable to previous studies showing an increase in weight/ BMI in the immediate period following COVID-19 lockdown.[17–20] Increases in obesity alone ranged from 5.3% pre-pandemic to 7.2% post-pandemic in three US studies, comparable to 6.3% in our study.[17,18,20] However, a systematic review not inclusive of these studies reported a higher weight increase of 2.7 kg[16] compared to an increase of 1.9 kg seen in our study. This may be explained by the small sample size in their included studies ($N = 37$–2824) compared to ours (245 836 measurements in 86 794 children). Nevertheless, the increased BMI may be reflective of the social changes and restrictions that occurred during the pandemic with families being home full-time, reduced outdoor activity and the potential for increased boredom and psychosocial stress leading to increased snacks, meals, inactive screen time and altered sleep cycles.[28–30]

Although previous studies showed an increase in BMI and weight in the immediate period following COVID-19, these were limited by the length of follow-up, with most reporting outcomes for 2–4 months.[14,16] and 3 up to 9–11 months post-pandemic.[17–19] Despite the initial increase in the BMI percentile in the months immediately following the start of the pandemic as seen by other studies, our longer-term follow-up period of 21 months highlighted the return to rates and trends similar to pre-pandemic levels, although this differed by facility, with the rates at CHW remaining slightly higher. This may be explained by children attending the CHW being more likely to be from lower sociodemographic backgrounds, and who also had higher mean BMI percentiles and increases compared to children attending SCH. Comparison of the demographics of the areas where the two facilities are located show a 41% higher mean income for families residing in the SCH area, and almost double the number of people born overseas in the CHW area, as well as a higher rate of overweight and obesity in adults (55% vs. 42.8%).[31,32] Recent studies in the US and Germany also reported the disproportionate increase of obesity in disadvantaged sub-populations.[20,33,34] The greater impact of the pandemic on overweight and obesity among families from a lower socioeconomic background may reflect a greater likelihood of larger households and smaller living spaces in areas with less access to parks and green spaces, nutritious foods and other material conditions conducive to a healthy lifestyle.[20]

The longer-term recovery of children and adolescent's weight/ BMI to pre-pandemic levels in our study may be explained by implementation of congruent state-wide health policies. In NSW, the most populous state of Australia, the prevalence of overweight and obesity among all children aged 5–16 years has been relatively stable since 2007 at approximately 24%.[35] In 2017, the NSW Health Premier's Priority Childhood Overweight and Obesity Delivery Plan, 'Tackling Childhood Obesity' was implemented, which aimed to reduce childhood overweight and obesity rates by 5% over 10 years (i.e. to 16.5% in 2025). This involved routine data collection of weight and height measurements by local area health services to support strategies to combat childhood obesity. In addition, in 2018, the state government implemented a 4-year 'Active Kids' voucher program to support the cost of structured physical activity and sport among children and adolescents in NSW.[36] Preliminary evaluation of the response to the uptake and effect of the program in the first year demonstrated increased physical activity and decreased BMI among the participants.[37,38] However, among the 55% of NSW schoolchildren who registered for the program, only 16% were from the most disadvantaged areas compared to 34% of the least disadvantaged areas.[39] This highlights the importance of ongoing evaluation and targeted strategies to ensure equitable access and uptake of prevention programs.

The major strengths of this population-based study were the large sample size assessing the weight status of children pre- and post-COVID-19 restrictions and the longer-term analysis including nearly 2 years after the beginning of the COVID-19 pandemic, providing the ability to assess trends and recovery. We were also able to compare two facilities located in demographic and socioeconomic diverse areas. Measurement of height and weight during routine healthcare was also more rigorous than self-reported measures,[16] and was standardized by age and sex to ensure validity of findings. While our study was limited by the inclusion of only those children and adolescents who attended hospital and may not be representative of healthy young people, our overall rates of overweight and obesity were comparable to the general NSW population,[35] and somewhat less than those reported in two US cohorts of children,[17,19] one that excluded youth with chronic complex conditions. Information on comorbid conditions was unavailable in our data and may have been helpful in exploring whether weight/BMI may have differed by children with specific types of health conditions. However, a recent study investigating the trend in paediatric emergency department and hospital admissions at the same two study hospitals (as ours) found that while there was an initial decrease in healthcare use for paediatric acute and chronic conditions, there was a return to pre-COVID-19 levels for most chronic conditions except mental health disorders following the restrictions.[40] Another limitation was that height and/or weight data were only collected for 18.7% of all visits to health services, and mostly for admissions and outpatients as compared to ED presentations. Despite this, the socio-demographic characteristics of children were similar for those with and without data. Finally, although we could determine socioeconomic status based on postcode of residential address, we did not have data to evaluate other measures of sociodemographic status such as ethnicity, parental income or education.

5 | CONCLUSION

The COVID-19 pandemic resulted in age-sex adjusted BMI and weight increases among children and adolescents, particularly among children under 12 and those from lower socioeconomic backgrounds. However, this was attributable to initial restrictions with longer-term follow-up highlighting a return to pre-pandemic rates and trends. Routine measurement of height and weight among children is critical to enable ongoing monitoring and evaluation of the weight status of children, and identification of those at risk. This ensures the development and implementation of targeted strategies to reduce excessive weight gain in vulnerable populations to ensure a positive start and safeguard of future health and well-being.

AUTHOR CONTRIBUTIONS

Natasha Nassar, Radhika Seimon, Louise A. Baur, Maria Craig, Shirley Alexander, Sarah P. Garnett and Joanne Henderson conceptualized and designed the study protocol. Diana M. Bond and Natasha Nassar provided oversight of ethics submissions. Diana M. Bond and Francisco J. Schneuer conducted statistical analysis and Diana M. Bond drafted the manuscript for publication. All authors reviewed and provided important intellectual content and critical feedback of the manuscript, and after revisions approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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