Received: 28 September 2022 | Revised: 20 November 2022 | Accepted: 28 November 2022

DOI: 10.1002/osp4.648

ORIGINAL ARTICLE

Obesity Science and Practice Open Access WILEY

# More than just body mass index: Using the Edmonton obesity staging system for pediatrics to define obesity severity in a multi-ethnic Australian pediatric clinical cohort

Faye Southcombe[1,2] | Sinthu Vivekanandarajah[1] | Slavica Krstic[1,2] | Fang Lin[1,2] | Paul Chay[1] | Mandy Williams[1] | Jahidur Rahman Khan[3] | Nan Hu[3,4] | Valsa Eapen[1,4,5] | Sarah Dennis[1,2,5] | Elizabeth Denney-Wilson[2] | Raghu Lingam[3,5]

[1]South Western Sydney Local Health District, Sydney, New South Wales, Australia

[2]Faculty of Medicine and Health, The University of Sydney, Sydney, New South Wales, Australia

[3]School of Clinical Medicine, University of NSW, Sydney, New South Wales, Australia

[4]School of Psychiatry, Faculty of Medicine, University of NSW, Sydney, New South Wales, Australia

[5]Ingham Institute of Applied Medical Research, Liverpool, New South Wales, Australia

**Correspondence**

Faye Southcombe, Primary and Community Health, South Western Sydney Local Health District, Sydney, NSW 2560, Australia.
Email: faye.southcombe@health.nsw.gov.au

## Abstract

**Background:** Despite advancements in the use of body mass index (BMI) to categorize obesity severity in pediatrics, its utility in guiding individual clinical decision making remains limited. The Edmonton Obesity Staging System for Pediatrics (EOSS-P) provides a way to categorize the medical and functional impacts of obesity according to the severity of impairment. The aim of this study was to describe the severity of obesity among a sample of multicultural Australian children using both BMI and EOSS-P tools.

**Methods:** This cross-sectional study included children aged 2–17 years receiving obesity treatment through the Growing Health Kids (GHK) multi-disciplinary weight management service in Australia between January to December 2021. BMI severity was determined using the 95th percentile for BMI on age and gender standardized Centre for Disease Control and Prevention (CDC) growth charts. The EOSS-P staging system was applied across the four health domains (metabolic, mechanical, mental health and social milieu) using clinical information.

**Results:** Complete data was obtained for 338 children (age 10.0 $\pm$ 3.66 years), of whom 69.5% were affected by severe obesity. An EOSS-P stage 3 (most severe) was assigned to 49.7% of children, the remaining 48.5% were assigned stage 2 and 1.5% were assigned stage 1 (least severe). BMI predicted health risk as defined by EOSS-P overall score. BMI class did not predict poor mental health.

**Conclusion:** Used in combination, BMI and EOSS-P provide improved risk stratification of pediatric obesity. This additional tool can help focus resources and develop comprehensive multidisciplinary treatment plans.

KEYWORDS
child, health risk, obesity, pediatric, treatment

Elizabeth Denney-Wilson and Raghu Lingam: Joint senior authors.

## 1 | INTRODUCTION

Childhood obesity affects 158 million children (aged 5–19 years) worldwide and remains one of the most serious global public health challenges of the 21st century.[1,2] In Australia, childhood obesity affects 8.2% of children and adolescents aged 2–17 years.[3] Moreover, the proportion of those affected by severe obesity is rising among those with obesity.[4,5] There are also considerable variations in the prevalence of childhood obesity among sub-populations, with a disproportionately higher burden felt among children residing in low socio-economic settings (SES), Indigenous children and those with developmental comorbidities.[6,7] Childhood obesity is strongly linked to morbidity and mortality in adulthood.[8] For most children (aged 7–14 years) obesity will persist into adulthood.[8,9] This presents an immediate and lasting physical, social, and psychological toll on the individual, as it increases medical costs, limits productivity, and reduces life expectancy.[1] As childhood obesity disproportionately affects children with vulnerabilities such as low SES, and some ethnic minority groups, it also contributes to many of the growing health disparities affecting Australia today.

Clinically, obesity among children and adolescents is classified by a body mass index (BMI) greater than the 95th percentile for age and gender using the 2000 CDC growth charts.[10] One limitation of these growth charts is their inability to accurately plot children and adolescents with very high BMI.[10–12] This has led to the use of 120% of the 95th percentile of BMI (BMI95pct) for the classification of severe obesity among children.[13] The BMI95pct evaluates a child's BMI by comparing to the expected BMI at the 95th percentile for the child's age and gender, the cut point for obesity.[5] This classification system is increasingly being used to predict health risk factors and complications in children with severe obesity. Studies have found that children with class II obesity (120% to <140% BMI95pct) demonstrated greater risk for abnormal levels of HDL cholesterol, systolic blood pressure, and glucose, and those with class III obesity (140% BMI95pct or greater) had significantly worse levels of triglycerides, diastolic blood pressure, and health-related quality of life compared to children with class II obesity.[14]

Despite these advancements in the representation of obesity at an individual level, BMI remains a simplistic approximation of excess body fat, as, does not consider the various other clinical and management complexities of pediatric obesity and fails to provide information on the presence or extent of comorbidities, functional (physical, psychological, social) limitations, or factors that may complicate management and guide clinical decision making. Effective delivery of obesity based clinical services requires detailed assessment tools which not only approximate overall excess body fat, but also captures other relevant metabolic, functional and psychological sequelae. These other data may allow for integrated multidisciplinary clinical solutions.[15] In 2016, Hadjiyannakis and colleagues proposed the Edmonton Obesity Staging System for Pediatrics (EOSS-P) which was based on the Edmonton Obesity Staging System for Adults.[16] The EOSS-P categorizes the medical and functional impacts of obesity according to severity of impairment across four health domains: metabolic health, mental health, mechanical health, and social milieu (Table 1). Each of the four health domains is scored across a 4-point staging system of increasing severity (stage 0–3).

Previous research has assessed the clinical utility of EOSS in adult populations.[17,18] The EOSS adult staging system, correlates with the relative risk for all-cause mortality and morbidity, independent of BMI, indicating that obesity-related comorbidities increase the mortality risk.[17,18] The EOSS-P has only been used to stratify obesity risk among two pediatric cohorts in Canada and one in Greece.[19–21] These studies showed that the use of BMI class alone to define disease severity underestimated disease burden in a substantial proportion of children with class I obesity and overestimated health risk in some with class III obesity.[19] However, EOSS-P has never been assessed in combination with the BMI95pct approach in a pediatric cohort, and neither tool has been used to describe obesity severity among a multicultural cohort of children in this case based in Australia.

This study aimed to fill this research gap by systematically describing obesity severity by looking at the association between BMI (expressed in terms of the 95th percentile), and the EOSS-P clinical staging system in a multi-ethnic cohort of Australian children enrolled in the Growing Healthy Kids (GHK) weight management service in South West Sydney, New South Wales, Australia.

## 2 | METHODS

### 2.1 | Study design and participants

The participants in this study consisted of children who were accessing clinical services for obesity treatment at a multidisciplinary pediatric weight management service, GHK, based in South Western Sydney, Australia. South West Sydney is one of poorest and most ethnically diverse areas in NSW. Participants were enrolled into the GHK service between January 2019 and December 2021. Referral to the GHK service was by healthcare practitioner only and required a measured weight and height. Eligibility for the GHK service consisted of children aged between 2 and 17 years with a BMI equal to or greater than the 95th percentile on CDC BMI for age- and sex-specific charts. Children were triaged based on referral BMI and any obesity-related comorbidity noted on referral. Waiting times for services varied by triage category. Demographic information received through referral was used to calculate the child's age, to identify Aboriginality and culturally and linguistically diverse (CALD) children. CALD status was defined as children born in non-English speaking countries, and those who did not speak English at home.[22] Standardized data collection occurred for all children at the initial appointment. Data collection was undertaken by a combination of Allied Health, Nursing and Staff Specialist clinicians. All staff were trained, and competency assessed, prior to undertaking the standardized assessment.

**TABLE 1** Edmonton obesity staging scale for pediatrics (EOSS-P)

| | Stage | | | |
|---|---|---|---|---|
| **Domain** | **0** | **1** | **2** | **3** |
| Metabolic | No metabolic concern | Acanthosis nigricans | T2D without diabetes-related complications | T2D with diabetes-related complications, hemoglobin A1c ≥8% |
| | | Impaired glucose tolerance (7.8–11.0 mmol/L) | | |
| | | Impaired fasting glucose (6.1–6.9 mmol/L) | | |
| | | [a]**Insulin resistance (fasting insulin >10 mIU/L)** | | |
| | | Prehypertension | Hypertension [a]**(HTN stage 1 and stage 2)** | Uncontrolled hypertension onpharmacotherapy |
| | | | | Focal segmental glomerulosclerosis |
| | | Lipids at upper end of normal range | Lipids modestly elevated | Elevated lipids requiring pharmacotherapy |
| | | LDL-C or non-hdl-c: 3.4–4.1 mmol/L | LDL-C or non-hdl-c: >4.2 mmol/L | |
| | | HDL-C: 0.8–1.03 mmol/L | HDL-C: <0.80 mmol/L | |
| | | TG: 1.5–4.0 mmol/L | Tg: >4.0 mmol/L | |
| | | ALT: 1.5–2.0× normal | ALT: 2–3× normal | ALT: >3× normal |
| | | Ultrasound: Mild to moderate fatty infiltration of the liver | Ultrasound: Severe fatty infiltration of the liver | Liver dysfunction |
| | | | PCOS | Cardiomegaly |
| Mechanical | No functional limitations | Mild OSA not requiring BiPAP or CPAP | OSA requiring BiPAP or CPAP | OSA requiring BiPAP or CPAP and supplementary oxygen overnight; pulmonary hypertension |
| | | Mild MSK pain that does not interfere with activities of daily living | MSK pain and/or complications limiting physical activity | Limited mobility; Blount's disease; slipped capital femoral epiphysis; osteoarthritis |
| | | | Gastroesophageal reflux disease | Peripheral edema |
| Mental health | No psychopathology | Mild depression or anxiety that does not interfere with functioning [a]**(not medicated, not interfering with ADLs)** | Major depression or anxiety disorder [a]**(medicated or limiting ADLs)** | Uncontrolled psychopathology [a]**(requiring acute care, recent suicide attempt, suicide ideology)** |
| | | Mild body image preoccupation/concern [a]**(occasional, not interfering with ADLs)** | Significant body image disturbance [a]**(frequent, limits ADLs)** | Self/physical loathing[a] **(daily, interferes with functioning)** |
| | | Mild emotional/binge eating (occasional) | Moderate binge eating (frequent) | Severe binge eating (daily) |
| | | Developmental delay with mild impact on weight management | Developmental delay with moderate impact on weight management [a]**(moderate GDD, ID, ASD level 3 (and greater), ODD, OCD)** | Developmental delay with severe impact on weight management [a]**(severe GDD, ID)** |
| | | [a]**(Mild GDD, ID, ASD level 1/2)** | | |
| | | ADHD or learning disability | | |
| Social milieu | No parental, familial, or social-environment concerns | Occasional bullying at school or at home | Significant bullying at school or at home; poor school attendance | School refusal/absenteeism |
| | | Minor problems in the relationships of the child with one or more family members | Moderate problems with parents, siblings or other family members, frequent arguing, difficulty maintaining positive relationships | Severe problems with parent, sibling or other family members, constant arguing or family violence |

(Continues)

TABLE 1 (Continued)

| | Stage | | | |
|---|---|---|---|---|
| Domain | 0 | 1 | 2 | 3 |
| | | Caregiver is generally knowledgeable of child's needs/ strengths but may require information or support in parenting skills | Need for information on parenting skills; current lack of information interfering with ability to parent effectively | Unable to monitor or discipline child |
| | | Caregiver has minimal difficulty organizing household to support needs of child | Moderate difficulty organizing household to support needs of child | Unable to organize household to support needs of child; experienced recent periods of homelessness |
| | | Caregiver is recovering from medical/physical, mental health and/or substance use problems | Medical/physical problems that interfere with parenting; has some mental health, substance use and/or developmental challenges that interfere with parenting | Medical/physical, mental health, substance use or developmental challenges that make it impossible for caregiver to parent effectively |
| | | Mild financial limitations [a]**(SEIFA decile 4 and 5)** | Moderate financial limitations [a]**(SEIFA decile 2 and 3)** | Severe financial limitations [a]**(SEIFA decile 1)** |
| | | | | Dangerous home environment; current child protection involvement |

Abbreviations: ADLs, activities of daily living; CPAP, continuous positive airway pressure; MSK, musculoskeletal; OSA, obstructive sleep apnea; PCOS, polycystic ovarian syndrome; T2D, type 2 diabetes mellitus.

[a]Denotes variations in criteria from the recommended criteria published by Hadjiyannakis et al.

## 2.2 | BMI classification

To classify obesity severity a physical assessment of BMI routinely collected at referral and the initial appointment was extracted from the participant's medical records. Body mass index (BMI) was calculated as a percentile (using the CDC Growth Reference Charts) using weight and standing height measured using standardized procedures. Standing height was measured to the nearest 0.1 cm and body weight to the nearest 10 g. The BMI95pct was calculated for each child by dividing their measured BMI by the corresponding BMI at the 95th percentile for their age and gender using the standardized CDC Growth Reference Charts.[23] Using the BMI95pct class I obesity is defined as BMI ≥95% and <120% BMI95pct, class II obesity BMI ≥120% BMI95pct and <140% BMI95pct, and class III obesity is BMI ≥140% BMI95pct.

## 2.3 | EOSS-P staging

The EOSS-P criteria, outlined in Table 1, was used for staging obesity complications in each of the four domains using routinely collected clinical data extracted from the participant's medical record. The four EOSS-P domains and criteria within[16] were applied with some modification to the original methods (Table 1). Variation occurred for two reasons, firstly, not all data required for the EOSS-P was routinely collected in the GHK cohort. In these instances, the criteria were omitted, or a clinically appropriate substitute measure was applied across the staging system. Secondly, in the domain of mental health further information was needed for the clinical service and to ensure consistent scoring between team members.

The metabolic health domain was assigned using the criteria outlined in Table 1. Blood pressure (BP) was staged according to the systolic BP percentile tables.[24] A metabolic health stage 0 was applied if a participant's systolic BP was classified as normative, stage 1 for prehypertension, and stage 2 for hypertension stage 1 and hypertension stage 2. Routinely collected pathology; lipid profile, fasting glucose homeostasis, and transaminases was staged as recommended.[16] Fasting insulin was routinely collected for all children and adolescents attending the service, however acanthosis nigricans was only noted among those children where the physical assessment was undertaken by a pediatrician. As a result, a fasting insulin of greater than 10 mIU/L or presence of acanthosis nigricans were used as proximate measures of insulin resistance and were scored as stage 1 metabolic risk factor. The domain of mechanical health was applied as recommended except for dyspnea, which was not systematically assessed and for the purposes of this study was removed from the criteria.[16]

To assist in consistent stage scoring of the mental health risk factors further definitions were applied. Clinically diagnosed depression or anxiety was allocated stage 1 if it did not interfere with daily functioning and was not medicated. Stage 2 was allocated for depression and anxiety requiring pharmacotherapy or that interfered with daily functioning. Stage 3 was assigned to children

requiring acute mental health management. Body image dissatisfaction which occurred occasionally (monthly or less) was classed as stage 1, frequent (weekly) and interfering with functioning was classed as stage 2 and occurring daily and limiting functioning was stage 3. Binge eating disorder was only assessed for children and adolescents with clinical indications of the condition and severity was assigned by a clinical psychologist using the Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) criteria.[25] Developmental disability was scored based on the level of impact of the associated behavioral difficulties on weight management using clinical judgment. Stage 1 developmental disability was scored for children whose developmental disability was felt to have a mild influence on weight management. This was usually mild levels of global developmental delay (GDD) or mild intellectual disability (ID), autism spectrum disorder (ASD) level 1 and level 2 and attention deficit hyperactivity disorder (ADHD).[25] Stage 2 was assigned when the developmental difficulties were felt to have moderate impacts on weight management. This tended to be moderate GDD or ID as well as ASD level 3 and greater, oppositional defiance disorder (ODD), and obsessive compulsive disorder (OCD). Stage 3 was scored when developmental disability was felt to have severe impacts on weight management (e.g., severe GDD or ID). Socio-Economic Index for Areas (SEIFA) by residential suburb was used to assess socio-economic status. An overall EOSS-P score corresponds with the highest score observed in any of the four domains. For example, a child presenting with no metabolic or mechanical concerns, a stage 1 for mental health and a stage 2 for social milieu, would be assigned an overall EOSS-P score of stage 2.[16]

## 2.4 | Statistical analysis

The primary analysis included only participants who had complete data as recommended by Hadjiyannakis et al.[16] The EOSS-P staging system assigns a stage based on the most severe score observed across the fout health domains. As such, missing data could result in misclassification, and the most accurate evaluation of EOSS-P is made for individuals with complete data.[16]

Data was analyzed across the four EOSS-P domains by BMI class. Descriptive statistics, means (with standard deviations, SDs) or counts (with percentages) were tabulated. Change in BMI95pct between referral and initial assessment were tabulated and compared using Wilcoxon signed rank test (paired two sample case).

Associations between BMI class and EOSS-P stages 2–3 were assessed using a multivariable binary logistic regression model. These models were adjusted for age and sex, and the strengths of associations were presented as adjusted odds ratios (with 95% confidence intervals [CIs]) of EOSS-P stages 2–3 for class II or III obesity compared with class I obesity. Statistical significance was set at $p$ value of 0.05. All analyses were done with R version R-4.1.2.[26]

This study was approved by the South Western Sydney Local Health District Human Research and Ethics Committee (2019/ETH12871).

# 3 | RESULTS

Data was available for 397 children with a mean age of 10.0 years (range 2–18 years). Of these children 86.9% ($n$ = 343) had complete data. Children excluded due to incomplete data were older (average age 11.7 years), had a greater proportion of class III obesity ($n$ = 16) and were more likely to identify as Aboriginal ($n$ = 6). Five children were further excluded due to Trisomy 21, a condition for which the CDC growth charts do not apply. Thus, a total of 84.7% ($n$ = 338) children were included in the primary analysis. Among these 338 children, 57.1% ($n$ = 193) were male and 35.5% ($n$ = 120) were culturally and linguistically diverse (CALD) (Supporting Information S1). Severe obesity (120%95pct or greater) affected 69.5% ($n$ = 235) children of which 45.2% ($n$ = 153) class II severe obesity and 24.2% ($n$ = 82) had class III severe obesity. There was no significant difference in the age or gender distribution across the BMI classes.

A significant worsening in the BMI95pct was observed across all BMI classes between referral and initial assessment (Table 2). Despite a shorter waiting time, children with severe class III obesity experienced the greatest deterioration while waiting for services, with an observed change in BMI95pct six times greater than experienced among children affected by obesity (class I). When considered by EOSS-P Stage and BMI class, BMI95pct at referral remained the strongest predictor of deterioration between referral and initial assessment (Table 2).

Serious weight-related comorbidities, as defined by the EOSS-P staging system, were observed in all children, with no children assigned an EOSS-P stage 0 in this study sample. An EOSS-P stage 3 was assigned to half of all children (49.7%, $n$ = 168), the remaining 48.5% ($n$ = 164) were assigned stage 2 and 1.8% ($n$ = 6) were assigned stage 1. Of the children classified as EOSS-P stage 1, three were affected by class III severe obesity, one by class II severe obesity, and 2 by obesity (Table 3). Among children with class III obesity, 58.5% ($n$ = 48) were EOSS-P stage 3. Alarmingly, 39.8% ($n$ = 41) of children affected by class I obesity were also assigned EOSS-P stage 3, indicating the presence of serious weight-related comorbidity at lower BMI values (Table 3). There were no significant differences in the distribution of EOSS-P stage by age (Table 4).

Poor metabolic health, defined as a metabolic EOSS-P score of 1 or greater, were observed among 87.4% ($n$ = 297) children (Table 3). Pre-diabetes was observed among 75% ($n$ = 255) of children, and an additional 1.8% ($n$ = 6) of children had markers of type 2 diabetes. More than half (52.1%, $n$ = 176) of all children had an abnormal lipid profile. Elevated BP affected 30.2% ($n$ = 102) children, of which 20.1% ($n$ = 68) were prehypertensive, 8.9% ($n$ = 30) were hypertensive, and 0.9% ($n$ = 3) were hypertensive requiring pharmacotherapy (Supporting Information S1). Class III obesity increased the risk of dyslipidemia, hypertension, liver dysfunction, acanthosis and abnormal HbA1c (Supporting Information S1). Insulin resistance, a high normal lipid profile and prehypertension was also observed in most children with Class I obesity (Table 3).

**TABLE 2** Change in BMI95pct from referral to initial assessment by BMI class and EOSS-P stage

| | Referral (BMI95pct) | | Initial assessment (BMI95pct) | | BMI95pct | | Average waiting time (months) | |
|---|---|---|---|---|---|---|---|---|
| | mean | SD | Mean | SD | Difference from referral to initial assessment | *p*-value* | Mean | SD |
| Overall | 128.44 | 26.58 | 135.87 | 29.14 | 7.43 | <0.001 | 9.30 | 5.91 |
| Class I | 109.04 | 8.86 | 110.73 | 6.03 | 1.69 | 0.0217 | 9.77 | 5.23 |
| Class II | 125.21 | 13.32 | 134.44 | 19.95 | 9.23 | <0.001 | 9.78 | 5.75 |
| Class III | 158.84 | 32.75 | 170.12 | 27.31 | 11.28 | <0.001 | 7.80 | 6.75 |
| Overall EOSS-P stage 3 | | | | | | | | |
| Overall | 133.33 | 30.03 | 141.52 | 35.61 | 8.19 | <0.001 | 9.09 | 6.36 |
| Class I | 109.20 | 8.97 | 110.86 | 5.85 | 1.66 | 0.0686 | 9.00 | 4.96 |
| Class II | 125.90 | 14.27 | 135.18 | 26.67 | 9.28 | <0.001 | 9.70 | 6.03 |
| Class III | 166.17 | 33.10 | 178.14 | 32.24 | 11.97 | <0.001 | 8.17 | 7.81 |
| Overall EOSS-P stages 1 and 2 | | | | | | | | |
| Overall | 123.61 | 21.68 | 130.28 | 19.43 | 6.67 | <0.001 | 9.5 | 5.43 |
| Class I | 108.94 | 8.85 | 110.64 | 6.20 | 1.7 | 0.1738 | 10.27 | 5.38 |
| Class II | 124.47 | 12.28 | 133.64 | 8.22 | 9.17 | <0.001 | 9.86 | 5.48 |
| Class III | 148.51 | 29.74 | 158.80 | 11.14 | 10.29 | <0.001 | 7.29 | 4.96 |

*Note*: **p*-value for the test to see if referral and initial assessment groups are significantly different.

Abbreviation: BMI, body mass index; EOSS-P, Edmonton obesity staging system for pediatrics; SD, standard deviation.

Although mechanical health complications were the least common EOSS-P domain reported among the study population, 12.7% ($n = 43$) children reported obstructive sleep apnea (OSA) and 7.7% ($n = 26$) children experienced musculoskeletal pain (Supporting Information S1). Both these health issues appeared more commonly with Class III obesity. Limited mobility was reported by 0.9% ($n = 3$) children, however, was not always secondary to obesity.

A mental health stage 1–3 was reported by 45.6% ($n = 154$) children, of which 39.3% ($n = 133$) were reported to have multimorbid mental health concerns. Attention deficit hyperactivity disorder was the most reported mental health concern affecting 25.1% ($n = 85$) children, followed by depression and anxiety affecting 21.5% ($n = 72$) children. Developmental delay was reported in 19.2% ($n = 65$) children, 3.8% ($n = 13$) children were affected by binge eating disorder, and 3.5% ($n = 12$) by body image dissatisfaction. A range of serious mental health conditions not included in the EOSS-P were reported among the participants. Psychosocial trauma associated with a refugee experience was reported among 18.2% ($n = 62$) children, while bipolar affective disorder and borderline personality disorder affected 1% ($n = 3$) of children.

A complex social milieu, social EOSS-P domain of 1–3, was ubiquitous among participants with 46.1% ($n = 156$) classified as stage 3, 51.5% ($n = 174$) as stage 2, and 1.8% ($n = 6$) stage 1. The majority (75.7%, $n = 256$) of children lived in areas of relative socio-economic disadvantage and reported relationship difficulties with their caregiver (68.3%, $n = 231$). Bullying affected 24.9% ($n = 84$) children, 11.5% ($n = 39$) of whom reported occasional bullying, 11.5% ($n = 39$) reported significant bullying and 1.8% ($n = 6$) reported bullying resulting in school absenteeism. Limitations in caregiver ability to organize the household was reported among the majority (66.7%, $n = 227$) of children. Social risk factors were equally distributed across all BMI classes (Table 3, Supporting Information S1).

Compared to class I obesity, class III obesity was associated with a greater odd of an overall EOSS-P stage 3 (adjusted odds ratio [AOR] 2.15, 95% confidence interval [CI] 1.19, 3.91, *p*-value 0.011), and an almost 2-fold increase in odds of social milieu stage 3 (AOR 1.98, 95% CI 1.10, 3.60, *p*-value 0.023) (Table 5). In metabolic, mechanical, and mental health domains, stages 2 and 3 were merged owing to a very low count in stage 3 before performing regression analysis. Class III obesity was associated with a 3.86 fold increase in odds of metabolic stages 2–3 (AOR 3.86, 95% CI 1.92, 8.05, *p*-value <0.001), and a 4.44 fold increase in odds of mechanical stages 2–3 (AOR 4.44, 95% CI 1.48, 16.4, *p*-value 0.013). For the mental domain, class II obesity was marginally associated with a greater odds of mental stages 2–3 (AOR 1.95, 95% CI 1.01, 3.94, *p*-value 0.053), but class III obesity was not significantly related to mental stages 2–3.

## 4 | DISCUSSION

This study is the first to assess the relationship between BMI class, based on BMI95pct and EOSS-P in a pediatric sample. Severity of obesity, defined by BMI, was observed to predict overall health risk as defined by the EOSS-P. Stratifying clinical risk in pediatric obesity

**TABLE 3** Participant demography and Edmonton obesity staging system for pediatrics (EOSS-P) stages overall and by domain across body mass index (BMI) classes

| | BMI class (severity of obesity) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Overall | | Class I | | Class II | | Class III | |
| Demography | *n* | Column % | *n* | Column % | *n* | Column % | *n* | Column % |
| Female | 145 | 42.9 | 47 | 45.6 | 65 | 42.5 | 33 | 40.2 |
| Male | 193 | 57.1 | 56 | 54.4 | 89 | 58.2 | 48 | 58.5 |
| CALD | 120 | 35.5 | 31 | 30.1 | 60 | 39.2 | 29 | 35.4 |
| Aboriginal | 12 | 3.6 | 5 | 4.9 | 3 | 2.0 | 4 | 4.9 |
| | BMI class (severity of obesity) | | | | | | | |
| | Overall | | Class I | | Class II | | Class III | |
| Initial assessment | mean | SD | mean | SD | mean | SD | mean | SD |
| Age (years) | 10 | 3.7 | 10 | 3.8 | 9.7 | 3.6 | 10.6 | 3.7 |
| BMI (kg/m$^2$) | 31.5 | 8.8 | 25.7 | 4 | 30.7 | 7.2 | 40.2 | 9.2 |
| BMI95pct | 135.9 | 29 | 110.7 | 6 | 134.4 | 19.9 | 170.1 | 27.3 |

| | | BMI class (severity of obesity) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Overall | | Class I | | Class II | | Class III | |
| EOSS-P domain | | *n* | Column % | *n* | Column % | *n* | Column % | *n* | Column % |
| Overall EOSS-P | Stage 0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | Stage 1 | 6 | 1.8 | 2 | 1.9 | 1 | 0.7 | 3 | 3.7 |
| | Stage 2 | 164 | 48.5 | 60 | 58.3 | 73 | 47.7 | 31 | 37.8 |
| | Stage 3 | 168 | 49.7 | 41 | 39.8 | 79 | 51.6 | 48 | 58.5 |
| Metabolic health | Stage 0 | 41 | 12.1 | 19 | 18.4 | 17 | 11.1 | 5 | 6.1 |
| | Stage 1 | 221 | 65.4 | 69 | 67.0 | 108 | 70.6 | 44 | 53.7 |
| | Stage 2 | 74 | 21.9 | 15 | 14.6 | 27 | 17.6 | 32 | 39.0 |
| | Stage 3 | 2 | 0.6 | 0 | 0.0 | 1 | 0.7 | 1 | 1.2 |
| Mechanical health | Stage 0 | 237 | 70.1 | 84 | 81.6 | 113 | 73.9 | 40 | 48.8 |
| | Stage 1 | 70 | 20.7 | 15 | 14.6 | 26 | 17.0 | 29 | 35.4 |
| | Stage 2 | 22 | 6.5 | 3 | 2.9 | 10 | 6.5 | 9 | 11.0 |
| | Stage 3 | 12 | 2.7 | 1 | 1.0 | 4 | 2.6 | 4 | 4.9 |
| Mental health | Stage 0 | 184 | 55.4 | 69 | 67.0 | 74 | 50.3 | 41 | 50.0 |
| | Stage 1 | 80 | 24.1 | 19 | 18.4 | 38 | 25.9 | 23 | 28.0 |
| | Stage 2 | 47 | 14.2 | 11 | 10.7 | 23 | 15.6 | 13 | 15.9 |
| | Stage 3 | 21 | 6.3 | 4 | 3.9 | 12 | 8.2 | 5 | 6.1 |
| Social milieu | Stage 0 | 2 | 0.6 | 1 | 1.0 | 0 | 0.0 | 1 | 1.2 |
| | Stage 1 | 6 | 1.8 | 2 | 1.9 | 2 | 1.3 | 2 | 2.4 |
| | Stage 2 | 174 | 51.5 | 61 | 59.2 | 79 | 51.6 | 34 | 41.5 |
| | Stage 3 | 156 | 46.2 | 39 | 37.9 | 72 | 47.1 | 45 | 54.9 |

is, however, highly complex and although BMI class predicted overall health risk, heterogeneity among individuals was observed. A small number of children with class III obesity had EOSS-P stage 1, suggesting some children with a high BMI had a relatively low health risk. At the same time most children with class I obesity were classified as EOSS-P stage 3 (40%) and stage 2 (59%), suggesting a high health risk may exist at these lower BMI values. These findings, consistent with previous research in Canada and Greece, illustrates

the importance of wholistic assessment for the needs of young people that accounts not only on excess body fat, but also incorporating all the various comorbidities and perpetuating factors to enable the provision of integrated care across health, psychological and social service providers delivering treatment and prevention services.[19,20,27]

In pediatrics, the EOSS-P has been shown to be predictive of poor medical and functional status, as well as complex social circumstances, and poorer quality of life.[19–21] Studies have not yet confirmed the clinical utility of the EOSS-P in predicting complications following intervention. Although medical, and functional status and a complex social milieu are known to mediate health outcomes, traditional anthropometric measurements often remain the sole aspects that guide the treatment of individuals with obesity.[28] The EOSS-P provides a systematic way to shift the narrative from weight loss toward treatment based on the individual pathophysiology and needs of persons with obesity.[29] To do this, investment in systems that support prospective data capture and scoring in the real-world setting are required. To date all studies reporting on the EOSS-P have applied the clinical staging in retrospect. In the current study, attempts to implement prospective EOSS-P clinical staging for individual children was inhibited by a lack of integration clinical data systems, medical records systems, and reporting systems. Interestingly, we found BMI95pct at referral predicted deterioration while waiting for services, independent of EOSS-P. This is important, as BMI is commonly used in the clinical setting, field surveys and population health screening and provides a simple solution to referral and triage for weight management services.

Among the four domains of EOSS-P, complex social concerns were most prevalent. The extremes of social disadvantage, including relationship breakdown, financial hardship, school absenteeism, family violence, limited caregiver capacity and homelessness were observed among 98% of children in this study and were predicted by BMI class. Given the level of influence and dependence of the social environment in predisposing, perpetuating and improving obesity and associated comorbidity, it is essential that obesity classification tools assess the social context and clinicians apply this information to treatment decisions.[30] The higher burden of social and economic disadvantage in children with obesity, especially for those from sociodemographically disadvantaged backgrounds, also underscore the need for integrated psychosocial supports, social work and psychology, in multi-disciplinary weight management services.[31] Not doing so will likely contribute to the burden of disease and health inequity.

Poor metabolic health was observed in most participants and, consistent with previous research, BMI class differentiated the degree of metabolic disease.[17,19,21] Most participants had metabolic indicators of early disease development, including prehypertension, insulin resistance and raised blood fats. Class III obesity increased the risk of established metabolic disease, however 15% of children with class I obesity also scored stage 2 in the metabolic domain. Children in this study were not evenly distributed across the 4 metabolic EOSS-P stages, with less than 1% scored as stage 3. A score of stage 3 in the metabolic health domain is consistent with established and unmanaged chronic disease. A larger sample set would enable further exploration of the metabolic staging system in a pediatric cohort. The broad co-existence of metabolic disease in children with obesity, however, does highlights the importance of routine metabolic screening. Unmanaged metabolic concerns can have immediate and long-lasting health impacts and can act as a barrier to treatment efficacy.[32] Despite recommendations for their inclusion, few services report metabolic screening as a routine clinical measure.[28,33]

Children affected by obesity in this study reported a high degree of mental health burden and in particular, a high burden of developmental comorbidity. Developmental comorbidity conveys a

**TABLE 4** Distribution of the overall EOSS-P scoring by age group

| | Overall EOSS-P score | | |
|---|---|---|---|
| **Age group** | **Average** | **Median** | **SD** |
| Preschool 2–5 years | 2.58 | 3 | 0.50 |
| Primary school 6–11 years | 2.44 | 2 | 0.54 |
| Secondary school 12–18 years | 2.50 | 3 | 0.53 |

Abbreviations: EOSS-P, Edmonton obesity staging system for pediatrics; SD, standard deviation.

**TABLE 5** Association between BMI class and EOSS-P stages 2–3 adjusted for age and sex

| | Overall EOSS-P stage 3 | Metabolic health stages 2 or 3 | Mechanical health stages 2 or 3 | Mental health stages 2 or 3 | Social milieu stage 3 |
|---|---|---|---|---|---|
| Class I | Reference | Reference | Reference | Reference | Reference |
| Class II | 1.62, (0.98, 2.69), 0.063 | 1.37, (0.70, 2.80), 0.368 | 2.66, (0.91, 9.68), 0.095 | 1.95, (1.01, 3.94), 0.053 | 1.37, (0.82, 2.3), 0.228 |
| Class III | 2.15, (1.19, 3.91), 0.011 | 3.86, (1.92, 8.05), <0.001 | 4.44, (1.48, 16.4), 0.013 | 1.57, (0.73, 3.42), 0.251 | 1.98, (1.10, 3.60), 0.023 |

*Note*: Data presented as adjusted odds ratio (95% CI), *p* value.

Abbreviations: BMI, body mass index; EOSS-P, Edmonton obesity staging system for pediatrics.

heightened risk of obesity and related comorbidity.[34] For these children, obesity increases the risk of secondary conditions related to their primary disability, such as fatigue, chronic pain, muscular deconditioning, social isolation, depression, and difficulty performing activities of daily living.[35–37] Despite evidence of an increased prevalence, little attention has been paid to the treatment of obesity among children with developmental comorbidity.[38] Where evidence is available, efficacy in weight management is achieved through adaptations of existing treatment models.[39] This notion requires further understanding, especially around the clinical skills required by treatment teams to adequately modify treatment approaches. Consistent with previous reports, BMI class did not seem to discern the degree of mental health risk in children with obesity.[19] Interestingly, the criteria included in the EOSS-P mental health domain combine three heterogeneous dimensions; internalizing problems (e.g., depression, body self-image), ADHD and developmental disability. This multi-dimensionality combined with a small sample size in this paper is likely to have contributed to non-significant outcomes. Despite this, at an individual clinical level of the EOSS-P offers a means of identifying mental health concerns, as well as the need for multi-disciplinary weight management services being equipped with the specialist skills to support patients with mental health concern and developmental comorbidity, within multi-disciplinary weight management services.

Mechanical complications of OSA, musculoskeletal pain and gastroesophageal reflux disorder most often affected children with class III obesity. These concerns were, however, the least likely issue to be reported overall. This finding might be due to measurement bias as non-documentation of mechanical concerns was interpreted as the absence of concern. The exclusion of dyspnea, which was not routinely assessed, will also have influenced this outcome. Obesity is a major risk factor for respiratory disease.[1] Like other weight-related comorbidity, obesity and respiratory diseases, including asthma and OSA perpetuate one another.[40] Children with obesity display poorer asthma control which has been linked to reduced participation in physical activity and greater sedentary behavior.[40] Assessment of, and support in the management of, mechanical complications must be an essential part of the health-care plan for children with severe obesity.

The level of severe obesity observed in this cohort is of concern. Severe obesity was noted in 57% at referral increasing to 69.5% at the time of initial assessment, following an average waiting time of 9 months. Further research is required to understand why children are not being identified and referred to services in a timely manner. Additionally, adequate resourcing of effective multi-disciplinary care models is required to reduce time waiting for services. This is important, given that treatment outcomes are improved when children are referred younger and at a lower BMI.[4,41] In Australia and abroad, unequal service access and high demand for multi-disciplinary pediatric weight management services further contributes to the problem by increasing service waiting times.[28,42] In Australia, only 16 multi-disciplinary weight management services exist, most of which are based in metropolitan centers and operate in a part-time capacity.[28] Such supply and demand mismatches are problematic as long waits for treatment have been linked to decreased engagement and adherence, and increased attrition, and a worsening of obesity severity.[43] By providing a more detailed understanding of clinical risk, the EOSS-P used in combination with BMI, may improve early referral to weight management services and service access of weight management through improved triage.

A strength of this study is the availability of data to stage children across the full EOSS-P. A further strength is the use of BMI expressed as percentage of the 95th percentile. The combination of these two enables a more accurate description of clinical risk in this pediatric cohort. This study also has limitations. In this is a referral-based clinic sample health care practitioners were encouraged to identify obesity-related co-morbidities at the time of referral. This may have resulted in a higher prevalence of co-morbidity among the sample and may explain the higher staging score observed among children in the lower BMI classes. The small sample size did not allow for staging across the four stages with sufficient numbers to find significant outcomes. Further research is required on a larger cohort to determine the spread of children across the four stages in each of the four domains. Children excluded from analysis due to incomplete data were more likely to be affected by Class III severe obesity. Incomplete data was most often due to loss to follow-up, and evidence suggests that loss to follow-up in children is associated with low socio-economic status.[44] This study found a high degree of low socioeconomic status and complex social circumstances among children with Class III obesity. The exclusion of this data is a source of selection bias and further exploration into the causes of loss to follow-up among this small group may strengthen further clinical and research work. Consistent scoring of the EOSS-P domains of mental health and social milieu was aided by standardized definitions but would have been further strengthened by an assessment of inter-rater reliability, which was not undertaken in this study. In this study data was in part limited by the tool itself. Without integration of the tool into electronic medical systems, collating and scoring of the EOSS-P remains time consuming. Further consideration of the performance of the EOSS-P tool in resource limited setting is required. This should include learning from the integration of this tool in the management of adult obesity and consideration for its application in broader settings, outside specialist services.

Understanding comorbidity profile is crucial to understanding clinical risk and helping to decide on the most appropriate intervention for weight management, thereby influencing the urgency with which services should be received. The EOSS-P tool is a useful tool for clinical staging that circumvents the under or over estimation of risk that can occur with using BMI class alone. Use of the EOSS-P in combination with BMI class provides a more accurate framework for capture of clinical risk and fairer triaging of clients being referred to pediatric weight management services. This is important for appropriate allocation and targeting of resources at population health, primary, secondary and tertiary level care for these children. We advocate for broader familiarity with such a clinical staging

system to prompt clinicians to adopt a more holistic and systematic approach to aid the assessment and management of these children.

## AUTHOR CONTRIBUTIONS

Faye Southcombe, Sarah Dennis, Raghu Lingam, Elizabeth Denney-Wilson, Nan Hu, Paul Chay, Mandy Williams, and Valsa Eapen contributed to study design. Faye Southcombe, Slavica Krstic, Nan Hu, and Jahidur Rahman Khan completed data collection, data analysis, data interpretation, and generation of figures. Authors Faye Southcombe, Sinthu Vivekanandarajah, Slavica Krstic, Paul Chay, Mandy Williams, Valsa Eapen, Sarah Dennis, Elizabeth Denney-Wilson, and Raghu Lingam contributed to writing of the manuscript.

## ACKNOWLEDGMENTS

We would like to thank the children and adolescents for participating in this study. We would also like to thank our authorship group for their time and commitment to this important work.

## CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

## ORCID

*Faye Southcombe* https://orcid.org/0000-0002-4061-9014

## REFERENCES

1. World Health Organisation. *Consideration of the Evidence on Childhood Obesity for the Commission on Ending Childhood Obesity: Report of an Ad Hoc Working Group on Science and Evidence for Ending Childhood Obesity*. World Health Organistion; 2016.
2. Abarca-Gómez L, Abdeen ZA, Hamid ZA, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet*. 2017;390(10113):2627-2642.
3. Australian Institute of Health and Welfare. *A Picture of Overweight and Obesity in Australia 2017*. AIHW; 2017. Contract No. PHE 216.
4. Ells LJ, Rees K, Brown T, et al. Interventions for treating children and adolescents with overweight and obesity: an overview of Cochrane reviews. *Int J Obes*. 2019;43(8):1653. https://doi.org/10.1038/s41366-019-0358-4
5. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999–2016. *Pediatrics*. 2018;141(3):e20173459. https://doi.org/10.1542/peds.2017-3459
6. Chung A, Backholer K, Wong E, Palermo C, Keating C, Peeters A. Trends in child and adolescent obesity prevalence in economically advanced countries according to socioeconomic position: a systematic review. *Obes Rev*. 2016;17(3):276-295. https://doi.org/10.1111/obr.12360
7. Maiano CHO, Morin AJ, Moullec G. Prevalence of overweight and obesity among children and adolescents with intellectual disabilities: a systematic review and meta-analysis. *Obes Rev*. 2016;17(7):599-611. https://doi.org/10.1111/obr.12408
8. Brisbois TD, Farmer AP, McCargar LJ. Early markers of adult obesity: a review. *Obes Rev*. 2012;13(4):347-367. https://doi.org/10.1111/j.1467-789x.2011.00965.x
9. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa heart study. *J Pediatr*. 2007;150(1):12-17. https://doi.org/10.1016/j.jpeds.2006.08.042
10. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC growth charts for the United States: methods and development. *National Center for Health Statistics Vital Health Stat*. 2002;11(246):1-190. PMID: 12043359.
11. Flegal KM, Wei R, Ogden CL, Freedman DS, Johnson CL, Curtin LR. Characterizing extreme values of body mass index-for-age by using the 2000 Centers for Disease Control and Prevention growth charts. *Am J Clin Nutr*. 2009;90(5):1314-1320. https://doi.org/10.3945/ajcn.2009.28335
12. Gulati AK, Kaplan DW, Daniels SR. Clinical tracking of severely obese children: a new growth chart. *Pediatrics*. 2012;130(6):1136-1140. https://doi.org/10.1542/peds.2012-0596
13. Freedman DS, Butte NF, Taveras EM, Goodman AB, Ogden CL, Blanck HM. The limitations of transforming very high body mass indexes into z-scores among 8.7 million 2- to 4-year-old children. *J Pediatr*. 2017;188:50-56.e1. https://doi.org/10.1016/j.jpeds.2017.03.039
14. Black WR, Borner KB, Beauchamp MT, et al. Health-related quality of life across recent pediatric obesity classification recommendations. *Children*. 2021;8(4):303. https://doi.org/10.3390/children8040303
15. Wolfe I, Satherley RM, Scotney E, Newham J, Lingam R. Integrated care models and child health: a meta-analysis. *Pediatrics*. 2020;145(1). https://doi.org/10.1542/peds.2018-3747
16. Hadjiyannakis S, Buchholz A, Chanoine JP, et al. The Edmonton obesity staging system for pediatrics: a proposed clinical staging system for pediatric obesity. *Paediatr Child Health*. 2016;21(1):21-26. https://doi.org/10.1093/pch/21.1.21
17. Kuk JL, Ardern CI, Church TS, et al. Edmonton obesity staging system: association with weight history and mortality risk. *Appl Physiol Nutr Metabol*. 2011;36(4):570-576. https://doi.org/10.1139/h11-058
18. Padwal RS, Pajewski NM, Allison DB, Sharma AM. Using the Edmonton obesity staging system to predict mortality in a population-representative cohort of people with overweight and obesity. *CMAJ (Can Med Assoc J)*. 2011;183(14):e1059-e1066. https://doi.org/10.1503/cmaj.110387
19. Hadjiyannakis S, Ibrahim Q, Li J, et al. Obesity class versus the Edmonton obesity staging system for pediatrics to define health risk in childhood obesity: results from the CANPWR cross-sectional study. *Lancet Child Adolesc Health*. 2019;3(6):398-407. https://doi.org/10.1016/s2352-4642(19)30056-2
20. Kakon GA, Hadjiyannakis S, Sigal RJ, et al. Edmonton obesity staging system for pediatrics, quality of life and fitness in adolescents with obesity. *Obes Sci Pract*. 2019;5(5):449-458. https://doi.org/10.1002/osp4.358
21. Grammatikopoulou MG, Chourdakis M, Gkiouras K, et al. Edmonton obesity staging system among pediatric patients: a validation and obesogenic risk factor analysis. *J Endocrinol Invest*. 2018;41(8):947-957. https://doi.org/10.1007/s40618-017-0821-9
22. Pham TTL, Berecki-Gisolf J, Clapperton A, O'Brien KS, Liu S, Gibson K. Definitions of culturally and linguistically diverse (CALD): a literature review of epidemiological research in Australia. *Int J Environ Res Publ Health*. 2021;18(2):737. https://doi.org/10.3390/ijerph18020737
23. Kelly AS, Barlow SE, Rao G, et al. Severe obesity in children and adolescents: identification, associated health risks, and treatment approaches. *Circulation*. 2013;128(15):1689-1712. https://doi.org/10.1161/cir.0b013e3182a5cfb3
24. U. S. Department of Health and Human Services. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004;114(Suppl 2):555-576. https://doi.org/10.1542/peds.114.2.s2.555
25. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. American Psychiatric Association; 2000.

26. R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing; 2021. https://www.R-project.org/
27. Zullig K, Ubbes VA, Pyle J, Valois RF. Self-reported weight perceptions, dieting behavior, and breakfast eating among high school adolescents. *J Sch Health*. 2006;76(3):87-92. https://doi.org/10.1111/j.1746-1561.2006.00074.x
28. McMaster CM, Calleja E, Cohen J, Alexander S, Denney-Wilson E, Baur LA. Current status of multi-disciplinary pediatric weight management services in Australia. *J Paediatr Child Health*. 2021;57(8):1259-1266.
29. Rodríguez-Flores M, Goicochea-Turcott EW, Mancillas-Adame L, et al. The utility of the Edmonton obesity staging system for the prediction of COVID-19 outcomes: a multi-centre study. *Int J Obes*. 2022;46(3):661-668. https://doi.org/10.1038/s41366-021-01017-8
30. Lee A, Cardel M, Donahoo WT. Social and environmental factors influencing obesity. In: Feingold KR, Anawalt B, Boyce A, Chrousos G, de Heredr WW, et al., eds. *Endotext* [Internet]. MDText.com; 2000. Updated 2019.
31. Yang RZ, Blumenthal JB, Glynn NM, et al. Decrease of circulating SAA is correlated with reduction of abdominal SAA secretion during weight loss. *Obesity*. 2014;22(4):1085-1090. https://doi.org/10.1002/oby.20657
32. Skinner AC, Perrin EM, Moss LA, Skelton JA. Cardiometabolic risks and severity of obesity in children and young adults. *N Engl J Med*. 2015;373(14):1307-1317. https://doi.org/10.1056/nejmoa1502821
33. Styne DM, Arslanian SA, Connor EL, et al. Pediatric obesity-assessment, treatment, and prevention: an endocrine society clinical practice guideline. *J Clin Endocrinol Metab*. 2017;102(3):709-757. https://doi.org/10.1210/jc.2016-2573
34. Levy SE, Pinto-Martin JA, Bradley CB, et al. Relationship of weight outcomes, Co-occurring conditions, and severity of autism spectrum disorder in the study to explore early development. *J Pediatr*. 2019;205:202-209. https://doi.org/10.1016/j.jpeds.2018.09.003
35. Irby MB, Kolbash S, Garner-Edwards D, Skelton JA. Pediatric obesity treatment in children with neurodevelopmental disabilities: a case series and review of the literature. *Infant Child Adolesc Nutr*. 2012;4(4):215-221. https://doi.org/10.1177/1941406412448527
36. Saner CSG, Wühl E, Mullis PE, Janner M. Circadian and ultradian cardiovascular rhythmicity in obese children. *Eur J Pediatr*. 2016;175(8):1031-1038. https://doi.org/10.1007/s00431-016-2736-4
37. Dong B, Wang Z, Wang HJ, Ma J. The association between resting heart rate and blood pressure among children and adolescents with different waist circumferences. *Eur J Pediatr*. 2015;174(2):191-197. https://doi.org/10.1007/s00431-014-2377-4
38. Bennett EA, Kolko RP, Chia L, Elliott JP, Kalarchian MA. Treatment of obesity among youth with intellectual and developmental disabilities: an emerging role for telenursing. *West J Nurs Res*. 2017;39(8):1008-1027. https://doi.org/10.1177/0193945917697664
39. Winkler MR, Moore ED, Bennett GG, Armstrong SC, Brandon DH. Parent-adolescent influences on everyday dietary practices: perceptions of adolescent females with obesity and their mothers. *Matern Child Nutr*. 2017;13(4):e12416. https://doi.org/10.1111/mcn.12416
40. di Palmo E, Filice E, Cavallo A, et al. Childhood obesity and respiratory diseases: which link? *Children*. 2021;8(3):177. https://doi.org/10.3390/children8030177
41. Dalla Valle M, Laatikainen T, Lehikoinen M, Nykänen P, Jääskeläinen J. Pediatric obesity treatment had better outcomes when children were younger, well motivated and did not have acanthosis nigricans. *Acta Pediatrica*. 2017;106(11):1842-1850. https://doi.org/10.1111/apa.13953
42. Wittmeier K, Brockman GH, Garcia AP, et al. Access to multidisciplinary care for pediatric weight management: exploring perspectives of the health care team within Canada and the United States. *Child Obes*. 2019;15(6):363-370. https://doi.org/10.1089/chi.2019.0011
43. Walker JL, Malley R, Littlewood R, Capra S. The need for early referral: characteristics of children and adolescents who are overweight and obese attending a multidisciplinary weight management service. *Children*. 2017;4(11):93. https://doi.org/10.3390/children4110093
44. Atger-Lallier L, Guilmin-Crepon S, Boizeau P, et al. Factors affecting loss to follow-up in children and adolescents with chronic endocrine conditions. *Horm Res Paediatr*. 2019;92(4):254-261. https://doi.org/10.1159/000505517


## SUPPORTING INFORMATION

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

**How to cite this article:** Southcombe F, Vivekanandarajah S, Krstic S, et al. More than just body mass index: using the Edmonton obesity staging system for pediatrics to define obesity severity in a multi-ethnic Australian pediatric clinical cohort. *Obes Sci Pract*. 2023;9(3):285-295. https://doi.org/10.1002/osp4.648