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Changes in body mass index and health related quality of life from childhood to adolescence

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Abstract

Objective. To determine longitudinal relationships between body mass index (BMI) and health-related quality of life (HRQoL) in an adolescent population sample. *Design.* Data collected in 2000 and 2005 within the Health of Young Victorians longitudinal cohort study. *Setting.* Originally a community sample of elementary school students in Victoria, Australia. Follow-up occurred in either secondary schools or individuals homes. *Participants.* Cohort recruited in 1997 via a random sampling design from Victorian elementary schools. Originally comprising 1 943 children, 1 569 (80.8%) participated in 2000 (wave 2, 8–13 years) and 851 (54%) in 2005 (wave 3, 13–19 years). *Main outcome measures.* In both waves participants and their parents completed the PedsQL, a 23-item child HRQoL measure, and BMI z-scores and status (non-overweight, overweight or obese) were calculated from measured height and weight. Associations were tested cross-sectionally and longitudinally (linear regression, adjusted for baseline values) *Results.* A total of 81.6% remained in the same BMI category, while 11.4% and 7.0% moved to higher and lower categories, respectively. Cross-sectional inverse associations between lower PedsQL and higher BMI categories were similar to those for elementary school children. Wave 2 BMI strongly predicted wave 3 BMI and wave 2 PedsQL strongly predicted wave 3 PedsQL. Only parent-reported Total PedsQL score predicted higher subsequent BMI, though this effect was small. Wave 2 BMI did not predict wave 3 PedsQL. *Conclusions.* This novel study confirmed previous cross-sectional associations, but did not provide convincing evidence that BMI is causally associated with falling HRQoL or vice versa across the transition from childhood to adolescence.

Key words: *Adolescent, child, health, obesity, health-related quality of life, longitudinal studies*

Introduction

The increasing prevalence of childhood obesity represents a major global public health epidemic (1,2), because overweight children often become the overweight adults (3,4) who will incur substantial future physical and economic health costs. However, increased morbidity is not delayed until adulthood (5). Obese adolescents are more likely than others to experience metabolic abnormalities, such as hypertension and adverse insulin, lipid and glucose profiles, and a raft of overt physical symptoms (6), such as heat intolerance, intertrigo, heat rash, tiredness, shortness of breath on exercise, joint pain, headaches and, according to some studies, asthma (7,8). Psychosocial correlates include lower self esteem and higher rates of sadness, loneliness and nervousness (9–11).

However, the impact of obesity on overall adolescent health is much less clear. Health-related quality of life (HRQoL), the subset of overall quality of life directly related to an individual's health, is viewed by the World Health Organization as combining physical, mental and social wellbeing (12). It is thus a unifying construct that pulls together multiple strands

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of functioning to summarise the overall burden of specific health problems. The advent of robust, generic measures, such as the Pediatric Quality of Life Scale (PedsQL) (13), have made it possible over the last decade to investigate how obesity relates to HRQoL in large-scale studies (e.g., (10,14–16)).

A 2009 systematic review examining associations between HRQoL and weight status identified 22 cross-sectional and 6 intervention studies published since 2001 (17). Pooling study estimates from the 13 papers that used the PedsQL, it reported a strong inverse relationship between HRQoL and body mass index (BMI). This review may, however, have overestimated the strength of the associations, because it combined community with tertiary clinical samples who may be seeking help *because* of problems that do not affect all obese children but that substantially reduce HRQoL in those affected. More importantly, this systematic review identified an absence of longitudinal studies reporting HRQoL, meaning that the causal direction (if any) of the observed associations remains unknown. Specifically, it is not clear whether poorer childhood HRQoL predicts rising adolescent BMI, or vice versa – whether childhood obesity predicts falling HRQoL.

We have previously reported an inverse cross-sectional association between 8–12-year-olds' BMI categories and parent and self-reported HRQoL in the second wave of the population-based Health of Young Victorians Study (HOYVS, one of the studies (16) cited by the review). With the third wave complete, we are now able to examine these longitudinal relationships from late childhood to early adolescence.

Our first aim for this paper was to test our hypothesis that cross-sectional inverse relationships between HRQoL and BMI category would persist in mid-adolescence. Our second aim was to investigate the temporal nature of any observed associations. Aim 2 was more exploratory, as both possible causal directions are plausible and we did not therefore specify *a priori* one temporal direction as more likely than the other.

Methods

Design and sample

This study draws on the second and third waves (2000 and 2005) of HOYVS, a longitudinal population-based cohort study established in 1997 whose sampling and methods have been reported previously (18). Briefly, a representative sample of elementary school children was selected from 24 schools in Victoria, Australia, in a 2-stage sampling design based on education sector (government, Catholic and independent) and class level. The baseline response rate for prep (first school year) to third grade students in 1997 was 83.2% (1 943 of 2 336 identified children with age range: 5.0 to 10.7 years). The achieved sample mirrored Victorian census data for age distribution, sex, ethnicity (parental country of birth), and proportion of indigenous persons.

Children were resurveyed three years later when in grades three to six (HOYVS 2000; age range: 8.4 to 13.8 years; retention rate 80.8% (1 569 of the 1 943 children in 1997, plus 30 children who were not included in 1997)). Wave 3 (HOYVS 2005) was conducted from September 2005–December 2006. A total of 960 parents consented for their child to participate again (58% of the 1 662 located; mean age 15.9 years; age range 13.6 to 19.4 years); the main reasons for non-participation were parent refusal (n = 357) and parent consent not being obtained (n = 345).

Procedures

At both waves 2 (2000) and 3 (2005), parents were sent a package containing a cover letter, a questionnaire about their child and a consent form. Children were visited by a researcher at their school or in their home, at which time the child/adolescent also completed a questionnaire and had anthropometric measurements taken.

HOYVS was approved at each wave by the Royal Children's Hospital Ethics in Human Research Committee and the authorities responsible for each education sector, and parents provided written consent (plus written adolescent consent for wave 3).

Questionnaires

In waves 2 and 3, self-reported questionnaires were completed by both the children/adolescents and their parents. In wave 2 the children reported basic demographic information (age, sex and postcode of residence) and completed the age-appropriate versions of the PedsQL 4.0, and the parent questionnaires included the parent-proxy version of the PedsQL 4.0. These same measures were collected again in wave 3.

The PedsQL 4.0 was used to assess child/adolescent Physical and Psychosocial functioning. This validated (13,19) 23-item questionnaire provides a Total Scale Score representing overall health-related functioning, as well as Physical and Psychosocial Health Summary Scores, with higher scores representing better health. The Psychosocial Summary Score can be further broken down into subscale scores for Emotional, Social and School Functioning. The Total Scale Score has excellent reliability

(Cronbach's alpha = 0.88 child; 0.90 parent), as do the Physical (Cronbach's alpha = 0.80 child; 0.88 parent) and Psychosocial Health Summary Scores (Cronbach's alpha = 0.83 child; 0.86 parent).

Anthropometric measures

Trained research staff measured the participants' height to the nearest 0.1 cm using rigid stadiometers (Invicta (Leicester, UK), Model IPO955) and weight (in light clothing) to the nearest 100 g using digital scales (Tanita (Tokyo, Japan), Model 1597 in 2000, Model THD-646 in 2005), both without shoes. Height was measured once in 2000; in 2005, two height measurements were averaged and, if they differed by >0.5 cm, the median of three measurements was used in analyses.

BMI (kg/m^2) was analysed in two different ways. First, for descriptive and categorical analyses, the sex- and age-specific cut points developed by the International Obesity Task Force (20) were used to classify participants by BMI into not overweight, overweight and obese categories (the few adolescents ≥19 years of age at wave 3 were classified as non-overweight (<25 kg/m^2), overweight (≥25 and <30 kg/m^2) or obese (≥30 kg/m^2). Second, for continuous analyses, BMI was transformed to externally-standardised (z) scores based on gender and age using the Centres for Disease Control and Prevention (CDC) 2000 Growth Chart data (21), to adjust for right skew in the BMI distribution and physiological changes that occur in child BMI with age.

Socio-economic status

Following each 5-year population census in Australia, socio-economic indices for areas (SEIFA) are calculated for various geographic regions (22). The disadvantage index (national population mean 1 000, SD 100) is based on 27 variables, including income, employment rate, home ownership, number of bedrooms in the home, number of registered motor vehicles, and proportion of single parent families; a higher score indicates a less disadvantaged neighbourhood. The 2001 index was used to assign a measure of neighbourhood socio-economic status based on each participant's postal code of residence.

Statistical analyses

Demographic characteristics of those for whom BMI category was available in 2000 but not in 2005 were compared with those for whom BMI category was available in both years. T-tests were used to compare means of continuous variables (e.g., SEIFA disadvantage scores and age) and chi-square tests for categorical variables (e.g., sex). For descriptive purposes, we summarized continuities and changes in BMI categories between 2000 and 2005 by cross-tabulations.

Cross-sectional analyses (Aim 1). Linear regression models were fitted with 2005 PedsQL Total, Physical and Psychosocial scales (parent-proxy and child-self reported) as outcomes and 2005 BMI category as a categorical predictor, adjusting for age, gender, and SEIFA disadvantage index. Adjusted mean (standard error) summary and subscale scores were calculated from these models to examine the cross-sectional relationships between PedsQL scores and BMI category in adolescence (Wave 3).

Longitudinal analyses (Aim 2). All analyses were adjusted for age, gender and quartile of SEIFA disadvantage index. First, we summarized the adjusted means and standard errors of 2000 PedsQL subscales across the 2000 and 2005 BMI categories as a preliminary exploration of the longitudinal relationship between PedsQL scores and BMI across the five years. We then performed four separate linear regression analyses. First, we determined whether earlier HRQoL predicts later BMI, using BMI z-score in 2005 as the outcome and child or parent-rated 2000 Total PedsQL score as the primary exposures in the respective models; these two models included BMI z-score at 2000 as an additional baseline predictor. Second, to assess the converse relationship (i.e., whether earlier BMI z-score predicts later HRQoL), two regression analyses with child-rated 2005 Total PedsQL as the outcome and BMI z-score at 2000 as the primary exposure were conducted, including child or parent-rated 2000 Total PedsQL as additional baseline predictors in the respective models.

For skewed outcomes, such as Total and subscale PedsQL scores, bias-corrected accelerated bootstrap confidence intervals (CIs) were used to validate the model-based 95% CIs from all the linear regression analyses; as all results were similar to the non-bootstrap intervals, the latter are presented. All analyses were conducted using Stata release 10.0 (Statacorp (Texas, USA), 2007).

Results

Participant characteristics

Table I shows the wave 2 baseline (2000) characteristics of those retained and lost by wave 3. In wave 2, the 851 wave 3 participants were similar to those lost to wave 3 follow-up in terms of gender, PedsQL Total Scale Score, BMI category and socioeconomic

Table I. Characteristics (measured in 2000) of non-participants (those with BMI in 2000 but not 2005) and participants (BMI available in both 2000 and 2005).

Characteristics in 2000	2005 Participation Yes (n = 851)	2005 Participation No (n = 715)	*p*-value[a]
Male (%)	49.9	50.8	0.74
Age in years (mean (SD))	10.7 (1.2)	10.9 (1.2)	<0.001
PedsQL Total Score (mean (SD))	80.0 (12.4)	79.9 (12.3)	0.97
BMI Category (%)			
Not overweight	76.6	73.7	0.06
Overweight	19.5	19.9	
Obese	3.9	6.4	
SEIFA Disadvantage Index[b] (mean (SD))	1 029 (61)	1 023 (65)	0.10

[a]Based on the χ^2 test for the categorical variable and the t-test for the continuous variables.
[b]Based on SEIFA index from the 2001 census and the postcode of residence in 2000.
Numbers may vary due to missing data.
BMI: Body mass index; SD: Standard deviation.

disadvantage score; however, those retained were slightly younger. All further analyses included only those children with BMI data in both 2000 and 2005.

Table II summarizes movement between BMI category in 2000 and 2005; 694 (81.6%) children remained in the same category, while 150 (17.6%) moved either up (N = 93, 10.9%) or down (N = 57, 6.7%) a single category. Only seven children moved two categories. Overall, 97 (11.4%) moved into a higher category and 60 (7.1%) moved into a lower category. Viewed as a continuous variable, change in BMI z-score 2000–2005 was normally distributed, centering around 0 with a range of approximately –2 to +2 population standard deviation (SD) units.

Wave 3 cross-sectional relationships between HRQoL and BMI category (Aim 1)

Table III shows strikingly similar parent and adolescent perceptions. Except for marginally lower self-reported school functioning in overweight adolescents, obese adolescents had the lowest values for all summary and sub-scale scores. Significantly lower PedsQL scores were seen with higher BMI category for all three parent-reported (Total, Physical and Psychosocial) and for two (Total and Physical) of the three self-reported summary scores. Regarding the psychosocial subscales, higher BMI status was most strongly associated with poorer social functioning, while the association with school functioning was significant for parent but not adolescent self-reported data. Emotional functioning was not associated with BMI category.

Table II. Longitudinal movements between body mass index (BMI) categories from 2000 to 2005.

BMI category in 2000	BMI category in 2005 (N (row %)) Non-overweight	Overweight	Obese
Non-overweight	580 (89.0%)	68 (10.4%)	4 (0.6%)
Overweight	49 (29.5%)	92 (55.4%)	25 (15.1%)
Obese	3 (9.1%)	8 (24.2%)	22 (66.7%)

Longitudinal relationships between HRQoL and BMI (Aim 2)

Table IV shows that, in general, children who moved into a higher BMI category over the subsequent five years tended to have poorer mean PedsQL scores preceding the weight gain than those who remained in the same BMI category. Conversely, those children who moved down a BMI category between 2000 and 2005 generally had better PedsQL scores in 2000 compared with those who remained in the higher category. In striking contrast, the three participants who moved down two BMI categories reported the lowest baseline Total PedsQL scores and the lowest scores on all sub-scales except for school functioning.

Table V shows the various longitudinal predictive relationships between child and parent-reported PedsQL and BMI z-score. BMI z-score in late elementary school (2000) was an extremely strong predictor of having a higher BMI z-score 5 years later. After adjusting for baseline BMI z-score, lower parent-reported (but not child-reported) Total PedsQL score predicted a higher subsequent BMI z-score, though this effect was small. The SEIFA disadvantage index coefficients show that those living in less disadvantaged neighbourhoods were less likely to have an increase in BMI z-score.

Table V also shows that although Total PedsQL score in 2000 was strongly predictive of Total PedsQL score five years later, BMI z-score in 2000 was not. Being female significantly increased the likelihood of a decrease in HRQoL from late elementary school to adolescence and, according to child-report, HRQoL decreased significantly with increasing age.

Discussion

Cross-sectional associations between lower health-related quality of life and higher BMI category from late childhood (16) are very stable from late elementary school to the early and middle high school years. The associations are consistent in magnitude and nature across this five-year span; according to both the parents and the adolescents themselves, the dimensions most affected are physical and social

Table III. Estimated marginal mean[a] PedsQL scores by BMI category: cross-sectional 2005 data.

PedsQL Scale	N	Estimated marginal mean (SE)			p-value[b]
		Non-overweight	Overweight	Obese	
Child self-report					
Total score	832	80.4 (0.4)	79.1 (0.8)	75.6 (1.5)	0.007
Physical summary	843	86.4 (0.4)	85.9 (0.8)	79.6 (1.5)	<0.001
Psychosocial summary	832	77.2 (0.5)	75.5 (1.0)	73.6 (1.8)	0.06
Emotional	843	73.5 (0.7)	71.9 (1.3)	71.5 (2.4)	0.47
Social	843	86.0 (0.6)	84.4 (1.1)	78.3 (2.0)	<0.001
School	832	72.1 (0.6)	70.0 (1.2)	71.9 (2.3)	0.33
Parent-proxy report					
Total score	794	82.0 (0.6)	80.4 (1.1)	74.3 (1.9)	<0.001
Physical summary	804	86.1 (0.7)	83.4 (1.3)	76.3 (2.3)	<0.001
Psychosocial summary	794	79.9 (0.6)	78.9 (1.1)	73.0 (2.1)	0.006
Emotional	802	77.1 (0.7)	75.7 (1.3)	74.9 (2.4)	0.50
Social	802	86.6 (0.7)	85.9 (1.3)	75.4 (2.4)	<0.001
School	796	75.9 (0.7)	75.1 (1.4)	68.7 (2.6)	0.03

[a]Marginal means were estimated using linear regression analyses. All F tests had 2 degrees of freedom.
[b]Overall p from regression analyses, adjusted for 2005 age, gender and disadvantage index.
BMI: Body mass index; SE: Standard error.

functioning, with a mixed picture for school functioning and emotional functioning largely spared.

With regard to the causal nature of these associations, we found no evidence that higher BMI in late childhood predicts falling HRQoL across adolescence. Conversely, poorer childhood HRQoL predicted rising BMI, and those who moved up a BMI category already had lower HRQoL by late elementary school. However, this effect was small, and was statistically strong only for the parent-proxy reports. This raises the question as to exactly when the cross-sectional associations evident by late elementary school first develop. Obesity is not strongly associated with either mental health (23) or HRQoL (24) in preschoolers, despite their already-high prevalence of overweight and obesity (25). We speculate that preschool obesity may initially drive falling HRQoL in the early school years, with the lower HRQoL then potentiating and exacerbating obesity by adolescence. However, confirmation must await the availability of longitudinal studies with repeated measures of HRQoL and BMI from early childhood to adolescence.

Table IV. Estimated marginal means (SE) child-rated PedsQL scores in 2000 by BMI category in 2000 and 2005.

Child-rated PedsQL Scale	BMI status in 2000	Mean (SE) 2000 PedsQL score by 2005 BMI category		
		Non-overweight	Overweight	Obese
Total	Non-overweight	81.1 (0.5)	77.6 (1.5)	77.2 (5.9)
	Overweight	79.0 (1.8)	80.0 (1.3)	73.1 (2.6)
	Obese	65.0 (6.2)	82.4 (3.9)	72.4 (2.4)
Physical summary	Non-overweight	85.9 (0.5)	83.2 (1.5)	80.2 (6.3)
	Overweight	82.7 (1.8)	84.8 (1.3)	77.3 (2.6)
	Obese	71.6 (8.4)	87.0 (5.3)	73.9 (3.3)
Psychosocial summary	Non-overweight	78.5 (0.6)	74.6 (1.7)	75.7 (6.7)
	Overweight	76.9 (2.0)	77.4 (1.5)	70.8 (2.9)
	Obese	61.4 (6.5)	80.0 (4.1)	71.6 (2.6)
Emotional	Non-overweight	73.8 (0.7)	69.3 (2.0)	67.2 (8.4)
	Overweight	71.7 (2.5)	72.4 (1.8)	71.0 (3.6)
	Obese	49.8 (9.8)	76.9 (6.2)	69.4 (3.8)
Social	Non-overweight	83.5 (0.6)	79.4 (2.0)	84.3 (7.9)
	Overweight	79.8 (2.4)	81.5 (1.7)	66.6 (3.4)
	Obese	56.5 (9.0)	83.5 (5.6)	73.7 (2.8)
School	Non-overweight	78.1 (0.6)	75.0 (1.8)	75.8 (7.5)
	Overweight	79.2 (2.3)	78.6 (1.6)	74.9 (3.2)
	Obese	78.0 (8.5)	79.6 (5.3)	71.6 (4.0)

[a]All adjusted for age (2005), gender and SEIFA disadvantage index quartile (2005).
In 2000, 645–6 were not overweight, 164 were overweight, and 33 were obese.
BMI: Body mass index; SE: Standard error.

Table V. Regression analyses of BMI z-score, PedsQL Total score, gender, SEIFA disadvantage score and age (in years) in 2000 on BMI z-score in 2005 and PedsQL Total in 2005.

	Outcome variables (2005)					
	BMI z-score			PedsQL Total		
Predictor variables (2000)	Coefficient	95% CI	p-value	Coefficient	95% CI	p-value
Child self-report						
BMI z-score	0.78	0.73 to 0.82	<0.001	−0.13	−0.95 to 0.70	0.76
PedsQL Total	−0.002	−0.005 to 0.001	0.19	0.26	0.20 to 0.32	<0.001
Female sex	0.05	−0.03 to 0.13	0.20	−2.33	−3.83 to −0.83	0.002
SEIFA disadvantage score	−0.0008	−0.0014 to−0.0001	0.02	0.009	−0.003 to 0.021	0.16
Age	0.01	−0.02 to 0.05	0.45	−0.83	−1.48 to −0.18	0.01
Parent-proxy report						
BMI z-score	0.77	0.73 to 0.82	<0.001	−0.05	−0.89 to 0.78	0.90
PedsQL Total	−0.005	−0.009 to −0.002	0.002	0.25	0.18 to 0.31	<0.001
Female sex	0.05	−0.02 to 0.13	0.17	−2.86	−4.38 to −1.36	<0.001
SEIFA disadvantage score	−0.0007	−0.0014 to −0.0001	0.02	0.008	−0.005 to 0.020	0.21
Age	0.01	−0.02 to 0.05	0.42	−0.44	−1.08 to 0.20	0.18

NB: The sample size for these four linear regression analyses ranged from 746 to 760.
BMI: Body mass index; CI: Confidence interval.

The most striking longitudinal finding was the strength of the associations *within* the repeated measures of HRQoL and BMI. In other words, HRQoL and BMI both tracked strongly over this five-year period. We have previously reported that BMI category tracks very strongly through the elementary school years, with 83% remaining in the same BMI category between waves 1 and 2 (14). Similarly, 82% remained in the same BMI category in the five years between waves 2 and 3. We are confident that the PedsQL can capture change in HRQoL, both because of its pedigree and because the significant HRQoL decline seen in this sample's girls mirrors that seen in girls elsewhere for more nuanced measures of mental health, such as social anxiety, anxiety, and depressive symptoms (26). We measured BMI rigorously, and the inverse relationship we found between socio-economic status and weight is synonymous with previous studies (27,28).

The main limitation was the relatively high sample attrition over the 5 years. However, those who did and did not participate in 2005 were very similar at baseline, other than a weak trend towards lower participation by those obese in 2000. While this may have strengthened tracking within the two key measures (as obese young people report lower HRQoL and are also the most likely to remain in the same BMI category over time), this is unlikely to have altered our conclusions.

Strengths include the population-derived nature of our sample, its relatively large sample size, the repeated measures of both key constructs, and the synchronicity between the parallel parent-proxy and self reports of child HRQoL. Despite the within-measure tracking, there was a wide range of change in both BMI and PedsQL scores between the two waves, such that we would have expected to detect important predictive relationships between these two measures had they existed. In order to quantify whole-person impacts of obesity we focused on the generic construct of HRQoL, rather than its individual components or more specific obesity-related symptoms. While newly-available weight-related quality of life measures (e.g., (29,30)) would likely show specific impacts of obesity, the strength of our approach is that it enables a quantification of the impact of obesity within a rubric relevant to the entire population.

Conclusion

While the most important predictor of adolescent overweight/obesity is previous BMI, lower HRQoL in late elementary school may play a small causal role. However, it does not appear that higher BMI causes HRQoL to fall in this age group. The pathways to the highly stable relationship between high BMI and low HRQoL will likely only be untangled by longitudinal studies spanning children's entire lifespan. However, it is clear that adolescent overweight is influenced by a multitude of factors, each contributing only a small amount to the variance. Multidisciplinary strategies to reduce adolescent obesity may be supported by measuring quality of life in late elementary school, as this may help to identify individuals or groups who are more likely to experience an increase in weight during this developmental period.

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