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Body composition: Population epidemiology and concordance in 11-12 year old Australians and their parents

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Keywords:	Body composition, Adiposity, Reference values, Children, Inheritance patterns, Epidemiologic studies

Body composition: Population epidemiology and concordance in 11-12 year old Australians and their parents

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Keywords: body composition, adiposity, reference values, children, inheritance patterns, epidemiologic studies, parents, correlation studies, cross-sectional studies

Abbreviations: ABS: Australian Bureau of Statistics; BIA: bioimpedence analysis; BMI: Body mass index; CC: correlation coefficient; CDC: Centres for Disease Control and Prevention; CI: confidence interval; DOB: date of birth; IOTF: International Obesity Task Force; LSAC: Longitudinal Study of Australian Children; REDCap: Research Electronic Data Capture; SD: standard deviation; UK: United Kingdom; UK90: United Kingdom 1990; USA: United States of America; USB: Universal Serial Bus; WHO: World Health Organisation.

Word count: 3882

ABSTRACT

Objectives: Overweight and obesity remain at historically high levels, cluster within families, and are established risk factors for multiple diseases. We describe the epidemiology and cross-generational concordance of body composition amongst Australian 11-12 year olds and their parents.

Design: The population-based cross-sectional Child Health CheckPoint study, nested within the Longitudinal Study of Australian Children (LSAC).

Setting: Assessment Centres in seven major Australian cities and eight regional cities, or home visits; February 2015-March 2016.

Participants: Of all participating CheckPoint families (n=1,874), body composition data were available for 1,872 children (49% girls) and 1,852 parents (mean age 43.7 years; 88% mothers), including 1830 biological parent-child pairs.

Measures: Height, weight, body mass index (BMI), waist circumference and waist-height ratio for all participants; body fat and fat-free mass by four-limb bioimpedence analysis (BIA) at Assessment Centres, or body fat percentage by two-limb BIA at home visits. *Analysis:* Parent-child concordance was assessed using (i) Pearson's correlation coefficients, and (ii) partial correlation coefficients adjusted for age, sex and socioeconomic disadvantage. Survey weights and methods accounted for LSAC's complex sample design.

Results: 20.7% of children were overweight and 6.2% obese, as were 33.5% and 31.6% of parents. Boys and girls showed similar distributions for all body composition measures but, despite similar BMI and waist-height ratio, mothers had higher proportions of total and truncal fat than fathers. Parent-child partial correlations were greatest for height (0.37, 95% CI 0.33 to 0.42). Other anthropometric and fat/lean measures showed strikingly similar partial correlations, ranging from 0.25 (95% CI 0.20 to 0.29) for waist circumference to 0.30 (95% CI 0.25 to 0.34) for fat-free percentage. Whole-sample and sex-specific percentile values are provided for all measures.

Conclusions: Excess adiposity remains prevalent in Australian children and parents. Moderate cross-generational concordance across all measures of leanness and adiposity is already evident by late childhood.

ARTICLE SUMMARY

Strengths and limitations of this study

- The nation-wide, population-based cohort was recruited using a two-stage random sampling design, enhancing generalizability of estimates.
- Multiple body composition attributes were objectively measured in children and parents, including body mass index and more detailed measures of segmental fat and fat-free mass and distribution from bio-electrical impedance analysis.
- Only one parent of each child was included in the cross-generational concordance analyses, so we so cannot formally estimate heritability.
- Our parent sample comprised mostly mothers, so estimates of fathers' body composition are less precise.
- Our findings may not generalise to Australian adults who are not parents.

INTRODUCTION

While the proximal cause of overweight is a sustained energy imbalance, overweight clusters in families and clearly both genetic heritability and shared environmental factors contribute to this clustering. Although genetic polymorphisms associated with body composition are being identified,[1 2] the degree of heritability of body mass index (BMI) between parents and children is surprisingly unclear, with estimates ranging from 0.21 to 0.81 between studies.[3] Likewise, parent-child concordance (reflecting both shared genetic and environmental contributions) in two key drivers of body composition – physical activity[4] and dietary patterns[5] – have shown substantial heterogeneity between cohorts in recent meta-analyses.

The epidemiology of obesity – and of body composition more broadly – continues to evolve rapidly. Following steep rises starting around 1980 in all age groups,[6] childhood overweight and obesity has plateaued since around 2005 and increments in adults have slowed, but both remain at historically high levels. For example, 2014-15 Australian estimates are that 27% of 5-17 year olds are overweight (including 7% obese), as are 63% of adults (including 28% obese),[7] with nearly 60% of today's children likely be obese by age 35 years.[8] Population dietary, eating, activity and fitness patterns also continue to evolve – all of which could impact lean and fat mass in different ways, and all of which show varying degrees of environmental and genetic influences.

It is therefore surprising that, while many studies have looked at individual body composition measures (most commonly BMI) in parent-child pairs,[9-12] few have considered a broad range of whole-of-body and segmental body composition measures in a contemporary population-representative sample. Multiple measures are required as fat has differential health impacts depending on where it is deposited throughout the body;[13] for example, abdominal fat measures (e.g. waist circumference, waist-to-height ratio) more strongly predict cardiovascular and all-cause mortality than BMI.[14 15] The few studies with multiple body composition measures in both parents and children have assessed body fat using DXA or skinfold thickness[16 17 18] (used in research but not clinical settings). We have identified no parent-child concordance studies incorporating bioimpedence analysis (BIA, commonly used in population and household settings) for assessing body fat and lean tissue mass and distribution.

Parent-child correlations in body composition differ by sex, parent and offspring ages, and specific aspect of body composition measured.[3] Height (correlation coefficient (CC) 0.29 to

0.51[9 16 17 19]) and fat-free mass (CC 0.21 to 0.48[17 20]) may be more strongly correlated than BMI (CC 0.19 to 0.44[10 17-22]) and weight (CC 0.29 to 0.42[10 17 22]), although estimates vary and overlap to a great extent between studies. Estimates of parent-child correlation on measures of body fat are slightly lower but again overlap with all other measures (body fat percentage CC 0.23 to 0.34,[17 20] waist circumference 0.14 to 0.32[19-21] and fat mass 0.16 to 0.30[17 20]). Longitudinal studies with repeated parent-child BMI concordance report that associations strengthen with child age (from CC 0.15 to 0.28 between ages 5 and 9[9], CC 0.25 to 0.34 between ages 6-9 and 10-11,[22] CC 0.31 to 0.36 between ages 9-10 and 15-16[18], and CC 0.33 to 0.43 between ages 15 and 22 years[23]), presumably reflecting puberty-related changes towards a more adult-like physiology in the offspring.[22] Offspring may not come to resemble parents more beyond this age; in the Midspan Family Study of Scottish parents aged 45–64 years and offspring at ages 30–59 years, regression coefficients for BMI concordance ranged from 0.26 to 0.35 depending on sex of parent and child.[24] Several studies have reported mother-child concordance in BMI to be higher than father-child concordance,[9 11 18] postulating intrauterine environmental effects, but other studies report no difference[10 19] or stronger father-child associations.[21] There is also mixed evidence for[24 25] and against[26] gender-assortative concordance in body composition, that is, a stronger association in mother-daughter and father-son pairs than mother-son and father-daughter pairs. Sex differences in the concordance of body compositional measures other than BMI remain relatively unexplored.

The Child Health CheckPoint, a cross-sectional biophysical wave nested within the Longitudinal Study of Australian Children (LSAC), provided an opportunity to include multiple measures of body composition in a broadly-focused population-based health assessment of parent-child dyads at child age 11-12 years. Here, we aimed to describe, in a population-derived sample of Australian 11-12 year olds and their parents, the (i) population prevalence and epidemiology of body composition measures, and (ii) parent-child concordance in these measures.

METHODS

Study design and participants: Detailed information about the initial LSAC recruitment and study design is available elsewhere.[27 28] Briefly, a population-representative sample of 0-1 and 4-5 year olds were recruited into LSAC's B and K cohort, respectively. A two-stage random sampling design was employed, using postcode as the primary sampling unit. For the B cohort, 8921 families were invited to participate, of which 5107 (57.2%) were recruited into the first data collection wave in 2004. Additional data collection waves have occurred every two years since.

The Child Health CheckPoint was a physical health and biomarkers module offered to the B cohort between LSAC Waves 6 and 7. The CheckPoint data collection spanned February 2015 to March 2016. A more detailed description of the CheckPoint study design is available elsewhere.[29 30] During the 2014 Wave 6 visit, B cohort families (n=3764) were introduced to the upcoming CheckPoint and asked to consent to their contact details being shared with the CheckPoint team. From late 2014, consenting families (n=3515) received an information pack and recruitment phone call (Figure 1).

Ethics and Consent: The Child Health CheckPoint study protocol was approved by The Royal Children's Hospital, Melbourne, Human Research Ethics Committee (33225D) and Australian Institute of Family Studies Ethics Committee (14-26). Parents provided informed written consent for their child's and their own study participation.

Patient and Public Involvement: Because LSAC is a population-based longitudinal study, no patient groups were involved in its design or conduct. To our knowledge, the public was not involved in the study design, recruitment or conduct of LSAC study or its CheckPoint module. Parents received a summary health report for their child and themselves at or soon after the CheckPoint assessment visit. They consented to take part knowing that they would not otherwise receive individual results about themselves or their child.

Procedure: The main CheckPoint data collection mechanism was the 'pop-up' Assessment Centre. Families completed a 3½ hour visit at an Assessment Centre set up sequentially in seven major Australian cities, or a 2¾ hour visit as a Mini-Assessment Centre set up in eight regional cities. Families unable to attend an Assessment Centre were offered a 1½ hour home visit. All centre and home visits began with anthropometry measurements. Children completed a brief questionnaire administered on an iPad using the Research Electronic Data Capture (REDCap) tool[31] during downtime throughout the visit, or at the end of the visit.

Measures: Height, weight, bioimpedence (BIA) and waist circumference were measured using standard protocols similar to previous LSAC waves, which are described in Table 1. These data were used to derive BMI (kg/m^2), total fat mass percentage, truncal fat percentage and waist-to-height ratio. For children, we also generated BMI and waist z-scores for age and sex using historical reference datasets. As child height, weight and waist circumference are expected to change throughout development, it is common practice within the paediatric literature to analyse z-scores, which allow tracking of an individual child's adiposity over time and comparison between children of different ages. The *Measure Up* data collection and management Standard Operating Procedures, available from the CheckPoint team, provide more detailed information.

An estimate of 300 g was subtracted from measured body weight for two children wearing a plaster cast. Two parents with pacemakers were weighed but BIA analysis was not conducted as the BIA electrical current may affect the operation of the device. Five pregnant women, and five parents who refused measurement but instead self-reported their height and weight, were excluded from our analyses.

Age, sex, socioeconomic disadvantage and (for the child) pubertal status were collected via questionnaire, linkage to administration databases or provided by the Australian Bureau of Statistics (Table 1).

Table 1. Study measures and protocols

Measure	Equipment/instrument	Data collection and data capture	Data derivation
Body composition			
Standing height [32 33]	Portable rigid stadiometer (Invicta IP0955, Leicester, UK).	In light clothing, without shoes or socks, participants stood straight with their heels, back and shoulders against the stadiometer and their head in the Frankfort plane. Height was measured twice (to nearest 0.1 cm); a third measurement was taken if first two measures differed by ≥ 0.5 cm. Staff recorded each height measurement into the participant's REDCap[31] data entry form.	**Mean height:** average of all height measurements.
Weight and bioelectrical impedence analysis (BIA)[32 33]	Four-limb segmental body composition scales (InBody230, Biospace, Seoul, Korea). If not available, two-limb body composition scales (Tanita BC-351, Kewdale, Australia).	Participants wore light clothing and no shoes or socks. Weight was measured once (to the nearest 0.1 kg), and entered into REDCap. Staff entered participant ID, age, sex and mean height into the scales. BIA was measured once with the participant standing on the scale footplates (and also holding two horizontal handles, in the case of four-limb BIA). *Four limb BIA*: Staff entered weight and total body fat mass (to the nearest 0.1 kg) into REDCap, and exported BIA data to USB daily. *Two limb BIA*: Staff entered weight and total body fat percentage (to the nearest 0.1%) into REDCap.	*Four-limb BIA:* **Total body fat %:** (total fat in kg/weight in kg) ×100. **Total body fat-free mass %:** ((weight in kg - total fat in kg)/ weight in kg) ×100. **Truncal fat %:** (truncal fat in kg/ weight in kg) ×100. **Non-truncal fat %:** (right arm + left arm + right leg + left leg fat in kg)/ weight in kg) ×100. *Two-limb BIA:* **Total body fat in kg**: (weight in kg × total body fat %)/100 **Total body fat-free mass in kg**: weight in kg - total fat in kg **Total body fat-free mass %:** As above. Two-limb scales did not generate segmental body composition information.
Body Mass Index (BMI), z-scores and categories.	Derived from height and weight, above.	Derived from height and weight, above.	**BMI:** weight in kg/(mean height in cm^2). **BMI z-score (children only):** BMI transformed into z-scores using both CDC[34] and UK90[35] population normative data. **Weight status**: BMI categorised into underweight, normal weight, overweight and obese using IOTF cut-points for children,[36] and WHO cut-points for adults.[37]
Waist circumference[32 33]	Steel anthropometric measuring tape (Lufkin Executive Diameter W606PM, Maryland, USA).	Waist circumference was measured twice on the skin (to the nearest 0.1cm), at the narrowest point between the 10^{th} rib and iliac crest. If no narrowing was present, the measurement was taken at the midpoint between these two landmarks. A third measure was taken if the first two measures differed by ≥1cm. Staff recorded each waist measurement into REDCap.	**Mean waist circumference**: average of all measurements. **Waist circumference z-score (children only)**: Waist circumference transformed into z-score using the UK90[38] population normative data. **Waist-to-height ratio**: mean waist circumference in cm/mean height in cm.

Measure	Equipment/instrument	Data collection and data capture	Data derivation
Potential confounders			
Age	*Children*: Medicare Australia database. *Parents*: self-reported	*Children*: LSAC provided date of birth (DOB), which was originally exported from the Medicare Australia database. *Parents*: Self-reported in the CheckPoint questionnaire.	**Age in years:** (Date of CheckPoint assessment – DOB)/365.
Sex	*Children*: Medicare Australia database. *Parents*: self-reported	*Children*: LSAC provided sex, which was originally exported from the Medicare Australia database. *Parents*: Self-reported in the CheckPoint questionnaire.	Data used as collected.
Pubertal status (children only)	Pubertal Development Scale.[39]	Five questions about the pubertal development: growth spurt, body hair growth, skin changes/pimples, deepening of voice (male version only), facial hair (male version only), breast growth (female version only) and menstruation (female version only). Four point response scale: 'has not started yet' (coded as 1) 'has barely started' (2), 'has definitely started' (3) and 'seems complete' (4).	*Boys:* Responses were summed for body hair, deepening of voice and facial hair responses, then grouped into pubertal development categories: Prepubertal (3), early pubertal (4-5), midpubertal (6-8), or late-post pubertal (9-12). *Girls:* Body hair and breast growth responses summed. Pubertal categories created using score and menstruation response: Prepubertal (2, not yet menstruating), early pubertal (3, not yet menstruating), midpubertal (≥4, not yet menstruating), late-post pubertal (menstruation started).
Disadvantage index	Socio-Economic Indexes for Areas Index of Relative Socioeconomic Disadvantage 2011 (Disadvantage index)[40]	LSAC provided contact details of families consenting to be contacted by CheckPoint The family's residential postcode was confirmed during the CheckPoint recruitment phone call and updated, if required.	The disadvantage index score of postcode was used to summarise neighbourhood socioeconomic position. Generated by the ABS from the 2011 national Census, the index numerically summarises the social and economic conditions of Australian neighbourhoods; national mean 1000, standard deviation 100; higher scores indicate less disadvantage.[40]

ABS: Australian Bureau of Statistics; BIA: bioimpedence analysis; BMI: Body mass index; CDC: Centres for Disease Control and Prevention; DOB: date of birth; IOTF: International Obesity Task Force; LSAC: Longitudinal Study of Australian Children; REDCap; Research Electronic Data Capture; UK: United Kingdom; UK90: United Kingdom 1990; USA: United States of America; USB: Universal Serial Bus; WHO: World Health Organisation.

Statistical analysis: For Aim 1, we described **t**he distributions of body composition domains in children and parents using mean values and standard deviations (SD), as well as key percentiles. These population summary statistics were calculated using weighted multi-level survey analyses that took clustering in the sampling frame and stratification into account. The analytic sample comprised all study children and attending parents (any adult who attended with the study child) with data for at least one measure of height, weight, BIA or waist circumference.

For Aim 2, concordance between parents and children was quantified for (i) the sample overall and (ii) subgroups by child and parent sex, using Pearson's correlation coefficients (CC) with 95% confidence intervals, and partial correlation coefficients, adjusted for child and parent age, disadvantage index, and for child and parent sex in models including both sexes; with 95% bootstrapped confidence intervals (CI). In addition, Aim 2 analyses were repeated using weighted multi-level survey analyses.[41] The unweighted and weighted results were similar, so we present the unweighted analyses. The Aim 2 analytic sample consisted of all biological parent-child pairs with complete data for at least one measurement.

All analyses were performed using Stata version 14.2 (StataCorp, College Station, Texas, USA).

RESULTS

A total of 1874 parent-child pairs participated in the Child Health CheckPoint module. Figure 1 summarises the sample size and reasons for non-response at various stages of the study, and reasons for missing body composition data within the CheckPoint module. Data for at least one body composition measure are available for 1872 children and 1852 parents, including 1830 biological parent-child pairs.

There was a similar proportion of boys and girls, but 88% of parents were mothers (Table 2). The average age of children was 12.0 years, and fathers were three years older than mothers, on average. A greater proportion of girls (89%) than boys (48%) were in the mid-late stages of pubertal development. The sample was somewhat less socioeconomically disadvantaged than the general population, with 26% of the sample in the least disadvantaged national quintile but only 12% in the most disadvantaged quintile.

Table 2. Sample characteristics, stratified by sex, of children and parents; values are mean (standard deviation), except where specified as %.

Characteristic	All	Male	Female
Child	**n=1731-1872**	**n=898-954**	**n=833-918**
Age, years	12.0 (0.4)	12.0 (0.4)	12.0 (0.4)
Pubertal status, %			
Prepubertal	8.5	12.0	4.5
Early pubertal	24.4	40.0	6.7
Mid pubertal	52.5	42.2	64.1
Late-postpubertal	14.6	5.8	24.6
Parent	**n=1847-1852**	**n=226-229**	**n=1621-1623**
Age, years	43.7 (5.6)	46.4 (7.1)	43.3 (5.3)
Disadvantage index	1009 (61)	1005 (69)	1009 (61)
Disadvantage index quintile, %			
1 (Most disadvantaged)	12.3	13.8	12.2
2	18.1	22.7	17.5
3	21.3	21.9	21.2
4	22.6	14.9	23.7
5 (Least disadvantaged)	25.6	26.7	25.5

Sample weights applied to data.

Approximately one quarter of children and two thirds of parents were overweight or obese (children: overweight 20.7%, obese 6.2%; parents: overweight 33.5%, obese 31.6%). Table 3 shows that, compared to fathers, mothers had a mean waist circumference approximately 12 cm less, similar waist-to-height ratio and BMI, and higher proportions of total body fat (36% compared to 26%) and truncal fat (18% compared to 14%). Sex differences in these measures were much smaller in children. In regards to fat distribution, children had a greater proportion of their fat in the non-truncal regions than adults.

Table 3. Distribution of body composition markers in Australian children and parents.

Body composition measure	All				Males				Females			
	n	Mean	SD	95% CI	n	Mean	SD	95% CI	n	Mean	SD	95% CI
Children												
Raw												
Height, cm	1872	153.7	8.0	153.3 to 154.2	954	153.3	8.2	152.7 to 153.9	918	154.3	7.7	153.7 to 154.8
Weight, kg	1872	46.5	11.4	45.9 to 47.2	954	45.9	11.6	45.0 to 46.8	918	47.2	11.2	46.3 to 48.1
BMI, kg/m^2	1872	19.5	3.7	19.3 to 19.7	954	19.4	3.8	19.0 to 19.7	918	19.7	3.7	19.4 to 20.0
Waist circumference, cm	1869	66.9	9.0	66.4 to 67.4	952	67.6	9.2	66.9 to 68.4	917	66.1	8.7	65.4 to 66.8
Waist-to-height ratio	1869	0.44	0.05	0.43 to 0.44	952	0.44	0.06	0.44 to 0.45	917	0.43	0.05	0.42 to 0.43
Total body fat, kg	1859	11.2	7.0	10.8 to 11.6	945	10.4	7.2	9.8 to 11.1	914	12.0	6.7	11.5 to 12.6
Total body fat-free mass, kg	1859	35.3	6.3	34.9 to 35.6	945	35.4	6.6	34.9 to 35.9	914	35.1	6.0	34.6 to 35.6
Truncal fat mass, kg	1478	5.0	3.8	4.7 to 5.2	736	4.6	3.9	4.2 to 5.0	742	5.4	3.8	5.1 to 5.7
Non-truncal fat mass, kg	1478	6.2	2.9	6.0 to 6.3	736	5.9	3.1	5.6 to 6.2	742	6.4	2.8	6.1 to 6.6
Z-scores												
BMI z-score (CDC)	1872	0.37	1.05	0.31 to 0.43	954	0.35	1.09	0.26 to 0.44	918	0.39	0.99	0.31 to 0.46
BMI z-score (UK90)	1872	0.56	1.22	0.49 to 0.64	954	0.62	1.25	0.52 to 0.73	918	0.50	1.19	0.41 to 0.59
Waist circumference z-score	1869	0.90	1.13	0.84 to 0.97	952	0.83	1.08	0.75 to 0.92	917	0.98	1.17	0.89 to 1.07
Percentages												
Total body fat percentage	1859	22.5	8.8	22.1 to 23.0	945	21.1	9.2	20.3 to 21.9	914	24.0	8.1	23.4 to 24.7
Total fat-free mass percentage	1859	35.3	6.3	34.9 to 35.6	945	35.4	6.6	34.9 to 35.9	914	35.1	6.0	34.6 to 35.6
Truncal fat mass percentage	1478	9.9	5.5	9.5 to 10.2	736	9.1	5.6	8.6 to 9.7	742	10.6	5.3	10.2 to 11.0
Non-truncal fat mass percentage	1478	13.0	3.3	12.8 to 13.2	736	12.6	3.5	12.3 to 13.0	742	13.3	3.1	13.1 to 13.6
Parents												
Height, cm	1852	165.7	7.8	165.3 to 166.2	229	177.8	7.4	176.6 to 178.9	1623	164.1	6.3	163.7 to 164.5
Weight, kg	1852	77.9	18.8	76.8 to 79.0	229	91.5	17.3	88.7 to 94.3	1623	76.1	18.3	75.0 to 77.2
BMI, kg/m^2	1852	28.3	6.3	27.9 to 28.7	229	28.9	4.9	28.1 to 29.7	1623	28.2	6.5	27.8 to 28.7
Waist circumference, cm	1838	87.7	14.9	86.8 to 88.6	227	98.1	13.3	95.9 to 100.3	1611	86.2	14.5	85.3 to 87.2
Waist-to-height ratio	1838	0.53	0.09	0.52 to 0.53	227	0.55	0.07	0.54 to 0.56	1611	0.53	0.09	0.52 to 0.53
Total body fat, kg	1837	28.2	13.2	27.4 to 29.0	227	24.7	11.0	22.9 to 26.5	1610	28.8	13.4	27.8 to 29.6
Total body fat-free mass, kg	1837	49.6	9.5	49.0 to 50.1	227	66.8	9.3	65.3 to 68.3	1610	47.2	6.7	46.8 to 47.6

Truncal fat mass, kg	1479	14.3	6.3	13.9 to 14.8	192	13.6	6.0	12.5 to 14.7	1287	14.4	6.4	14.0 to 14.9
Non-truncal fat mass, kg	1479	13.7	7.2	13.2 to 14.2	192	11.3	5.5	10.3 to 12.2	1287	14.1	7.3	13.5 to 14.6
Percentages												
Total body fat percentage	1837	34.9	9.4	34.3 to 35.5	227	26.1	7.4	25.0 to 27.3	1610	36.1	9.1	35.5 to 36.6
Total body fat percentage	1837	49.6	9.5	49.0 to 50.1	227	66.8	9.3	65.3 to 68.3	1610	47.2	6.7	46.8 to 47.6
Truncal fat-mass percentage	1479	17.8	4.7	17.4 to 18.1	192	14.3	4.1	13.5 to 15.0	1287	18.3	4.6	18.0 to 18.6
Non-truncal fat mass percentage	1479	16.9	5.1	16.5 to 17.3	192	11.8	3.7	11.2 to 12.5	1287	17.6	4.8	17.3 to 18.0

Sample weights applied to data. Reduced sample size for truncal and non-truncal fat due to the two-limb BIA scales not generating these data.

BMI: body mass index; CDC: Centers for Disease Control; CI: confidence interval; SD: standard deviation; UK90: British 1990 Growth Reference.

The distributions of BMI, waist circumference, total body fat mass and truncal fat mass are plotted in figures 2 and 3. For reference purposes, supplementary table 1 shows the distribution of these body composition markers at key percentiles (from 5th to 95th). Amongst children, there were no notable sex differences in the distribution of BMI or waist z-scores, but the distribution of total and truncal fat was slightly shifted to the right (i.e. greater proportion of fat) in girls compared to boys.

Adults showed more striking sex differences. While mothers' and fathers' mean BMI were similar (table 3), the distribution in mothers was flatter and shifted to the left (i.e. lower BMI) compared to fathers. The distribution of men's and women's waist circumference were similar in shape, but shifted to the left (i.e. smaller waists) in women. National Australian guidelines recommend waist circumference below 94 cm and 80 cm cut-points for men and women respectively.[42 43] The median waist circumference for men and women exceeded these cut-points (supplementary table 1); that is, 57% (95% CI 50 to 65) of men and 61% (95% CI 58 to 63) of women in the parent sample exceeded recommendations.

Mothers and fathers had different distributions of total body and truncal fat mass. The mothers had a wider range of fat than fathers, and the distribution was shifted to the right (i.e. greater proportion of fat mass). Overlap in the distributions of mothers' and fathers' fat was less than for other body composition measures.

Unadjusted correlations between child and parent body composition in the cohort overall were moderate and remarkably consistent (table 4); concordance was highest for height (CC 0.30, 95% CI 0.25 to 0.34) and lowest for waist circumference (CC 0.23, 95% CI 0.19 to 0.28). Table 4 also shows that mother-child and father-child correlations were similar for each measure, although there was a tendency for father-child waist, fat and fat-free mass estimates to be higher (but with wider confidence intervals) than mother-child correlations. While we did not conduct formal statistical tests, sex-matched pairs (i.e. mother-daughter, father-son) appeared to show similar concordance to sex-mixed pairs (i.e. mother-son, father-daughter; supplementary table 2).

On adjustment for age, sex and disadvantage index, parent-child height correlations strengthened to be clearly greater than the remaining correlations, which remained relatively unchanged and tightly clustered.

Table 4. Parent-child concordance in body composition characteristics

	Parent-child			Mother-child			Father-child		
	n	CC	95% CI	n	CC	95% CI	n	CC	95% CI
Pearson's Correlation (unadjusted)									
Height	1830	0.30	0.25 to 0.34	1605	0.36	0.32 to 0.40	225	0.30	0.18 to 0.42
Weight	1830	0.27	0.23 to 0.32	1605	0.29	0.24 to 0.33	225	0.28	0.16 to 0.40
BMI / BMI z-score*	1830	0.27	0.23 to 0.32	1605	0.28	0.23 to 0.32	225	0.27	0.14 to 0.38
Waist circumference/z-score#	1814	0.23	0.19 to 0.28	1592	0.24	0.19 to 0.29	222	0.31	0.18 to 0.42
Waist-to-height ratio	1814	0.28	0.24 to 0.32	1592	0.28	0.23 to 0.32	222	0.34	0.22 to 0.45
Total body fat percentage	1810	0.28	0.24 to 0.32	1587	0.28	0.25 to 0.32	223	0.36	0.24 to 0.47
Total body fat-free mass percentage	1810	0.29	0.25 to 0.33	1587	0.29	0.25 to 0.34	223	0.35	0.23 to 0.46
Truncal fat percentage	1430	0.27	0.22 to 0.33	1244	0.26	0.20 to 0.31	186	0.37	0.24 to 0.49
Non-truncal fat percentage	1430	0.28	0.23 to 0.33	1244	0.28	0.22 to 0.33	186	0.32	0.18 to 0.44
Partial correlation (adjusted for covariates)†									
Height	1825	0.37	0.33 to 0.42	1603	0.38	0.34 to 0.42	222	0.36	0.23 to 0.48
Weight	1825	0.28	0.23 to 0.32	1603	0.28	0.22 to 0.33	222	0.30	0.14 to 0.47
BMI / BMI z-score*	1825	0.27	0.23 to 0.31	1603	0.27	0.22 to 0.32	222	0.28	0.11 to 0.45
Waist circumference/z-score#	1809	0.25	0.20 to 0.29	1590	0.24	0.19 to 0.29	219	0.31	0.18 to 0.45
Waist-to-height ratio	1809	0.28	0.24 to 0.33	1590	0.28	0.22 to 0.33	219	0.36	0.23 to 0.50
Total body fat percentage	1805	0.29	0.25 to 0.34	1585	0.28	0.23 to 0.32	220	0.36	0.24 to 0.48
Total body fat-free mass percentage	1805	0.30	0.25 to 0.34	1585	0.29	0.25 to 0.34	220	0.35	0.24 to 0.47
Truncal fat percentage	1426	0.26	0.21 to 0.31	1242	0.25	0.20 to 0.30	184	0.36	0.22 to 0.50
Non-truncal fat percentage	1426	0.27	0.24 to 0.34	1242	0.26	0.23 to 0.34	184	0.30	0.17 to 0.45

Sample weights not applied to data. Reduced sample size for total and truncal fat mass due to 2-limb BIA scales used at Home Visits not generating these data. Sample restricted to children and parents whose relationship was biological child/parent (n = 20 child-parent pairs with body composition data available were excluded).
* UK 90 BMI z-score for children and raw BMI for parents
# UK 90 waist circumference z-score for children and raw waist circumference for parents
[4]Adjusted for child and parent age, and disadvantage index. The 'all biological child-parent pairs' model additionally adjusted for child and parent sex.
BMI: Body Mass Index; CC: correlation coefficient; CI: confidence interval.

DISCUSSION

Principal findings: We describe the epidemiology of BMI, waist, fat and fat-free mass measures in a large population-based Australian cohort of parents and children, at two stages of the life course (11-12 years of age and mid-adulthood). A quarter of children and two thirds of adults were overweight or obese on BMI criteria. We confirm known sex differences between men's and women's body composition.[44 45] Parent-child concordance in body composition measures were moderate and strikingly similar for all measures tapping into leanness and adiposity, with partial correlations ranging from 0.25 to 0.30; the exception was higher concordance for height (0.37). Mother-child and father-child concordance patterns were similar, although estimates appeared slightly stronger for fathers than for mothers.

Strengths and weaknesses of the study: Body composition was measured in a large nation-wide cohort of children and their parents originally selected to be population-representative.[46] Dyads underwent multiple measures of body composition at the same time and using the same equipment and protocols, maximising generalisability and minimising biases reflecting these factors. Our BIA scales captured segmental, as well as whole-of-body, fat mass. Although the smaller numbers of fathers reduced the precision of father-child estimates, this is one of few studies to provide population estimates both for mother-child and father-child concordance for any anthropometric measurement.

Limitations included under-representation of very disadvantaged families due to selective uptake of CheckPoint and attrition in LSAC, partly mitigated by our use of survey weights (although this showed no meaningful influence on the results). We cannot extend conclusions outside the narrow child age range (11-12 years) and, as we examined parent-child dyads rather than triads, we cannot formally estimate heritability.

Comparisons with other studies: As expected, exact estimates vary across different samples, however, our results are very similar to recent local studies. The prevalence of overweight and obesity in our child (27%) and parent (65%) samples were similar to those reported in the 2014-15 Australian National Health Survey (27% of 5-17 year olds, and 63% of adults 18+ years) three years earlier.[7] Our child waist circumference (mean 66.9cm, standard deviation 9.0cm) was slightly smaller than that of the 11-12 year old Australian children measured in the 2007 National Children's Nutrition and Physical Activity survey (mean 69.1cm, standard deviation 10.3cm; unpublished data, provided by Prof T. Olds). 57% (95% CI 50 to 65) of our fathers and 61% (95% CI 58 to 63) of our mothers exceeded the recommended waist cutpoints of 94 cm and 80 cm cut-points for men and women respectively,[42 43] compared to 60% of Australian men and 65% of women aged ≥18 years in the 2014-15 survey. Total body fat percentage in our child sample are similar to, but slightly higher than, values reported for the 9-11 year olds in the Australian subsample of the 2011-2013 ISCOLE study.[47 48]

As previous studies have examined parent-child concordance in a single or limited number of body composition measures, ours is one of the first to show the consistency in concordance (correlation coefficients 0.23 to 0.30) across a broad range of body composition measures spanning leanness to adiposity. Our concordance estimates generally fell within the ranges previously reported for each measure, except that our concordance for height fell on the lower end of the range,[9] and weight just below the lower boundary reported in previous literature.[9 10 16-22] Previous studies collectively show parent-child concordance in BMI strengthens with child age; our estimate of 0.29 at child age 11-12 years is consistent with previous estimates of 0.31 to 0.34 for 9-10 and 10-11 year olds, respectively.[18 22]

Meaning and implications for clinicians and policymakers: This study updates summary population data on multiple body composition measures across two generations. Prevalence data for overweight and obesity are not novel, but contribute to within- and between- country population monitoring. Population monitoring should track a range of body composition measures, not BMI alone, as these may have independent health benefits (e.g. lean mass) and risk (e.g. truncal fat) and can vary in the face of stable BMI in children[49] and adults.[50] This dataset is available to researchers from mid-2018 (see the data access statement at the end of the article). Uses may include statistical power calculation and exploration of the shared and unique contributions of each of the body composition measures to outcomes of choice, to inform which of the multiple measures would be most appropriate for future trials.

Taken with other studies, our moderate concordances support both genetic and environmental influences on body composition measures. Older children share only some of the latter with their parents. On the one hand, parents are to some extent nutritional gatekeepers for their children; on the other, children spend a substantial amount of time at school and with peers, in homogenising environments not shared with their parents. While extreme environmental restrictions (such as body building, gastric banding[51] and the Cuban blockade[52]) show very real malleability of body composition, long-term change is nonetheless profoundly difficult for most individuals.[53] Given that each aspect of body composition likely falls under different genetic influences, it is striking that our parent-child concordances across all body compartments were nearly identical (except for height, known to be strongly genetically influenced). The modest concordances between parents and children may challenge a general pessimism about the ability of children to follow healthier trajectories than their overweight parents, and suggest that far more than the family environment drives the current obesity epidemic.

Unanswered questions and future research: Establishing national and international repositories of representative body composition data would allow near-real time detection of shifts in prevalence in response to policy changes and other levers, and support future healthcare provision and economic modelling. The ultimate goal remains interventions – whether driven by politics, policy or practice – that not only reduce obesity but lead to healthier body composition. Unfortunately, at the present time, the 'optimal' body composition at differing stages of the lifecourse remains unknown as it relates to a range of important outcomes. Defining this requires large longitudinal population studies incorporating family triads, biospecimens, and relevant exposures and disease outcomes/proxies, including the potential for Mendelian randomisation studies. Novel intervention strategies may be informed by parents and children non-concordant for adiposity.

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DATA SHARING STATEMENT: Dataset and technical documents available from Growing Up in Australia: The Longitudinal Study of Australian Children via low-cost license for bone fide researchers. More information is available at www.growingupinaustralia.gov.au

SUPPLEMENTARY DOCUMENTS:

Supplementary Table 1. Percentile values for body composition measures.

Supplementary Table 2. Parent-child concordance in body composition measures, by child and parent sex.

FIGURE CAPTIONS AND FOOTNOTES:

Figure 1. Participant flow.

Figure 2. Distribution of child body composition measures

Sample weights applied to data.

Figure 3. Distribution of parent body composition measures.

Sample weights applied to data.

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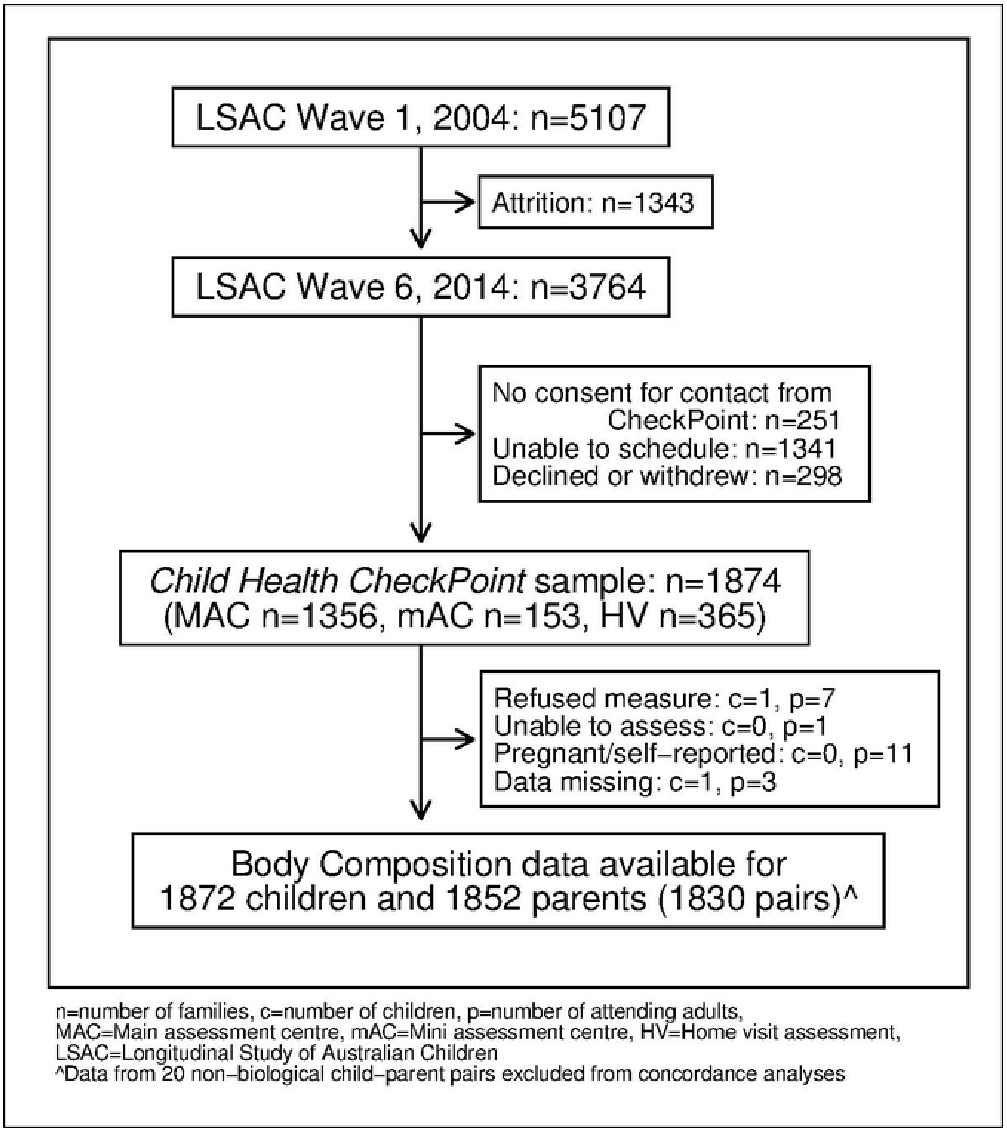

Figure 1. Participant flow

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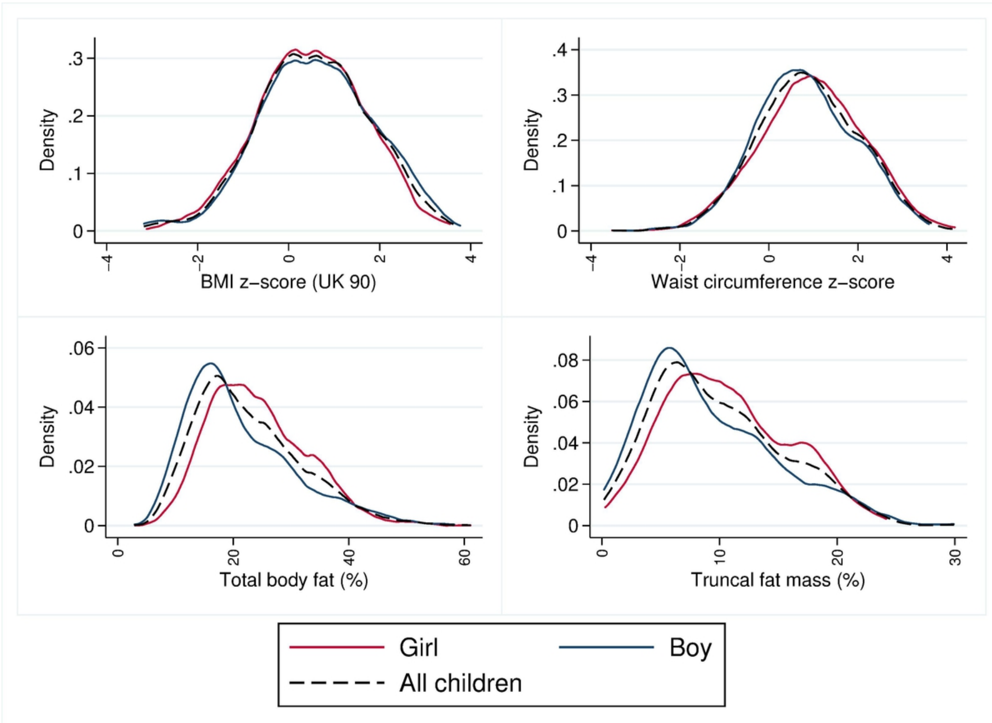

Figure 2. Distribution of child body composition measures. Sample weights applied to data.

101x73mm (300 x 300 DPI)

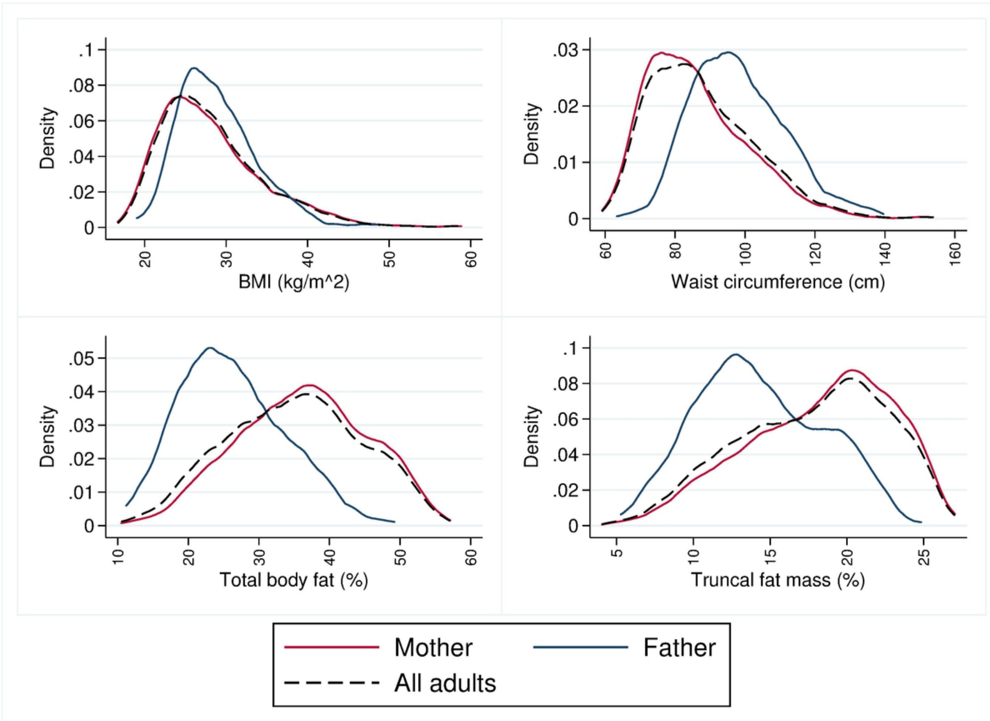

Figure 3. Distribution of parent body composition measures. Sample weights applied to data.

101x73mm (300 x 300 DPI)

Supplementary Table 1. Percentile values for body composition measures.

Characteristic	Child							Parent						
	P5	P10	P25	P50	P75	P90	P95	P5	P10	P25	P50	P75	P90	P95
Height, cm														
Male	140.1	143.0	147.8	153.0	159.0	164.0	167.7	167.0	169.0	173.6	178.0	182.0	187.0	190.0
Female	142.0	145.0	149.0	154.0	160.0	164.3	167.0	153.6	156.0	160.0	164.0	168.0	172.0	174.0
All	141.0	144.0	148.0	153.0	159.0	164.0	167.0	154.0	156.8	160.9	165.0	170.0	176.0	180.0
Weight, kg														
Male	31.2	33.6	37.9	43.1	51.6	61.5	69.1	67.5	72.0	79.8	88.6	102.1	114.6	127.1
Female	32.5	34.4	39.4	45.5	53.2	62.5	67.2	52.9	56.2	63.2	72.3	85.9	101.3	110.6
All	31.9	33.8	38.5	44.5	52.5	62.1	68.1	53.5	57.1	64.3	74.3	88.5	104.1	113.9
BMI, kg/m^2														
Male	14.9	15.6	16.7	18.4	21.1	24.6	26.9	22.9	23.6	25.3	28.0	31.3	35.1	38.1
Female	15.0	15.8	17.1	18.9	21.6	24.8	26.2	20.2	21.3	23.5	26.9	31.5	37.6	41.0
All	15.0	15.7	16.9	18.7	21.3	24.7	26.5	20.3	21.4	23.8	27.1	31.4	37.1	40.3
BMI z-score (CDC)														
Male	-1.45	-1.00	-0.37	0.41	1.13	1.76	2.07	-	-	-	-	-	-	-
Female	-1.30	-0.96	-0.25	0.44	1.11	1.68	1.83	-	-	-	-	-	-	-
All	-1.36	-0.99	-0.30	0.43	1.13	1.71	1.95	-	-	-	-	-	-	-
BMI z-score (UK 90)														
Male	-1.35	-0.90	-0.23	0.62	1.48	2.29	2.74	-	-	-	-	-	-	-
Female	-1.42	-1.06	-0.30	0.49	1.34	2.12	2.32	-	-	-	-	-	-	-
All	-1.39	-0.98	-0.26	0.54	1.40	2.18	2.56	-	-	-	-	-	-	-
Waist circumference, cm														
Male	56.8	58.5	61.1	65.4	71.8	81.6	86.5	80.8	82.9	87.9	96.6	107.1	114.4	122.9
Female	55.2	56.9	60.3	64.3	70.4	77.4	81.3	67.7	70.3	75.1	83.8	95.2	106.4	112.9
All	56.0	57.7	60.7	64.8	71.0	79.3	84.4	68.0	70.6	76.0	85.2	96.9	108.3	114.3

Characteristic	Child							Parent						
	P5	P10	P25	P50	P75	P90	P95	P5	P10	P25	P50	P75	P90	P95
Waist circumference z-score														
Male	-0.86	-0.52	0.07	0.80	1.58	2.33	2.68	-	-	-	-	-	-	-
Female	-0.96	-0.53	0.22	0.96	1.75	2.50	2.80	-	-	-	-	-	-	-
All	-0.92	-0.53	0.12	0.87	1.69	2.40	2.76	-	-	-	-	-	-	-
Waist-to-height ratio														
Male	0.38	0.39	0.40	0.43	0.46	0.52	0.55	0.45	0.46	0.50	0.54	0.60	0.65	0.68
Female	0.37	0.37	0.39	0.42	0.45	0.50	0.52	0.41	0.42	0.46	0.51	0.58	0.65	0.69
All	0.37	0.38	0.40	0.42	0.46	0.51	0.54	0.41	0.43	0.46	0.51	0.58	0.65	0.69
Total body fat, kg														
Male	3.5	4.2	5.6	8.0	12.9	19.6	26.1	11.3	13.0	16.6	22.1	30.6	41.4	46.4
Female	4.4	5.4	7.1	10.3	15.4	21.3	23.6	11.6	13.9	18.9	26.0	35.5	47.7	54.6
All	3.8	4.6	6.2	9.2	14.0	20.9	24.7	11.5	13.7	18.6	25.6	35.0	47.3	53.8
Total body fat percentage														
Male	9.7	11.2	14.5	18.6	26.4	34.7	39.5	15.4	17.1	20.7	25.0	30.8	37.2	39.7
Female	12.6	14.5	18.0	23.3	28.9	35.5	37.7	20.8	23.8	29.5	36.4	42.5	48.2	50.5
All	10.6	12.4	15.8	20.8	28.1	35.3	38.7	19.6	22.0	28.1	35.0	41.6	47.6	50.2
Total body fat-free mass, kg														
Male	26.3	27.8	30.9	34.4	39.0	43.9	46.4	52.4	55.8	61.1	66.5	72.9	79.2	81.9
Female	26.1	27.6	31.0	34.9	38.7	42.5	45.5	37.0	39.3	43.0	46.7	51.0	55.5	58.8
All	26.2	27.6	30.9	34.7	38.8	43.5	46.2	37.5	39.9	43.5	47.7	53.8	62.9	68.7
Truncal fat mass, kg														
Male	0.6	1.1	1.9	3.3	6.2	10.2	13.3	6.0	6.8	9.2	12.4	17.2	22.7	26.2
Female	1.0	1.5	2.6	4.5	7.2	10.8	12.2	5.5	6.8	9.5	13.6	18.3	23.6	25.9
All	0.8	1.2	2.2	3.9	6.6	10.7	12.6	5.7	6.8	9.4	13.5	18.2	23.5	25.9

Characteristic	Child							Parent						
	P5	P10	P25	P50	P75	P90	P95	P5	P10	P25	P50	P75	P90	P95
Truncal fat mass percentage														
Male	1.7	3.0	5.0	7.7	12.6	17.8	20.2	8.2	8.9	11.2	13.9	17.4	20.4	21.0
Female	2.9	4.4	6.5	10.0	14.2	18.0	19.5	10.0	11.5	15.0	19.1	21.7	24.0	24.6
All	2.2	3.5	5.6	8.9	13.4	17.9	19.9	9.4	10.9	14.1	18.4	21.4	23.8	24.5
Non-truncal fat mass, kg														
Male	3.2	3.5	4.0	4.9	6.7	10.0	12.6	5.5	6.0	7.5	9.6	13.8	19.1	21.1
Female	3.5	3.8	4.3	5.6	7.6	10.2	11.3	6.1	7.0	9.0	12.2	17.1	23.7	27.8
All	3.3	3.6	4.1	5.2	7.2	10.1	12.2	6.0	6.8	8.8	11.8	16.7	23.1	27.5
Non-truncal fat mass percentage														
Male	8.1	8.9	10.1	11.7	14.5	17.6	19.5	7.1	8.1	9.1	11.3	14.1	16.6	18.4
Female	9.2	9.9	11.1	12.8	15.3	17.5	19.0	10.7	11.7	14.2	17.0	20.6	24.1	26.8
All	8.6	9.3	10.6	12.4	14.8	17.6	19.3	9.3	10.7	13.3	16.4	20.2	23.7	26.1

PX: value of Xth percentile, eg P50 = median
BMI: body mass index; CDC: Centers for Disease Control; UK90: British 1990 Growth Reference.

Supplementary Table 2. Parent-child concordance in body composition measures, by child and parent sex.

	Mother-daughter		Mother-son		Father-daughter		Father-son	
	n	**CC (95% CI)**	**n**	**CC (95% CI)**	**n**	**CC (95% CI)**	**n**	**CC (95% CI)**
Pearson's Correlation (unadjusted)								
Height	804	0.36 (0.30 to 0.42)	801	0.36 (0.30 to 0.42)	95	0.51 (0.34 to 0.64)	130	0.16 (-0.02 to 0.32)
Weight	804	0.29 (0.22 to 0.35)	801	0.28 (0.22 to 0.35)	95	0.31(0.11 to 0.48)	130	0.29 (0.12 to 0.44)
BMI / BMI z-score*	804	0.29 (0.22 to 0.35)	801	0.27 (0.21 to 0.34)	95	0.30 (0.10 to 0.47)	130	0.28 (0.11 to 0.43)
Waist circumference/z-score#	800	0.24 (0.18 to 0.31)	792	0.24 (0.18 to 0.31)	93	0.31 (0.11 to 0.48)	129	0.33 (0.16 to 0.47)
Waist-to-height ratio	800	0.31 (0.25 to 0.37)	792	0.24 (0.18 to 0.31)	93	0.39 (0.20 to 0.55)	129	0.36 (0.20 to 0.50)
Total body fat percentage	798	0.32 (0.25 to 0.38)	789	0.26 (0.19 to 0.32)	94	0.36 (0.16 to 0.52)	129	0.37 (0.21 to 0.51)
Total body fat-free mass percentage	798	0.34 (0.27 to 0.40)	789	0.27 (0.20 to 0.33)	94	0.36 (0.16 to 0.52)	129	0.35 (0.19 to 0.49)
Truncal fat percentage	640	0.30 (0.22 to 0.36)	604	0.22 (0.15 to 0.30)	84	0.30 (0.10 to 0.49)	102	0.42 (0.25 to 0.57)
Non-truncal fat percentage	640	0.31 (0.23 to 0.37)	604	0.25 (0.17 to 0.32)	84	0.27 (0.06 to 0.46)	102	0.36 (0.18 to 0.52)
Partial correlation (adjusted for covariates)†								
Height	803	0.39 (0.34 to 0.45)	800	0.36 (0.30 to 0.42)	95	0.50 (0.35 to 0.65)	127	0.29 (0.11 to 0.46)
Weight	803	0.27 (0.20 to 0.34)	800	0.28 (0.22 to 0.35)	95	0.29 (0.10 to 0.49)	127	0.33 (0.12 to 0.53)
BMI / BMI z-score*	803	0.27 (0.22 to 0.35)	800	0.27 (0.21 to 0.34)	95	0.30 (0.12 to 0.48)	127	0.27 (0.07 to 0.51)
Waist circumference/z-score#	799	0.23 (0.17 to 0.32)	791	0.24 (0.17 to 0.30)	93	0.30 (0.10 to 0.50)	126	0.33 (0.15 to 0.50)
Waist-to-height ratio	799	0.31 (0.24 to 0.40)	791	0.24 (0.16 to 0.31)	93	0.37 (0.17 to 0.57)	126	0.36 (0.18 to 0.54)
Total body fat percentage	797	0.31 (0.25 to 0.37)	788	0.25 (0.18 to 0.31)	94	0.35 (0.17 to 0.54)	126	0.38 (0.21 to 0.55)
Total body fat-free mass percentage	797	0.33 (0.27 to 0.39)	788	0.26 (0.19 to 0.32)	94	0.35 (0.17 to 0.54)	126	0.36 (0.20 to 0.53)

Truncal fat percentage	639	0.28 (0.20 to 0.35)	603	0.21 (0.14 to 0.29)	84	0.30 (0.08 to 0.52)	100	0.40 (0.22 to 0.59)
Non-truncal fat percentage	639	0.29 (0.25 to 0.39)	603	0.23 (0.17 to 0.32)	84	0.26 (0.14 to 0.51)	100	0.33 (0.09 to 0.51)

Sample weights not applied to data. Reduced sample size for truncal fat mass due to 2-limb BIA scales used at Home Visits not generating these data. Sample restricted to children and parents whose relationship was biological child/parent (n = 20 child-parent pairs with body composition data available were excluded).
*UK 90 BMI z-score for children and raw BMI for parents
#UK 90 waist circumference z-score for children and raw waist circumference for parents
[4]Adjusted for child and parent age, and disadvantage index.
BMI: body mass index; CDC: Centers for Disease Control; CI: confidence interval; SD: standard deviation; UK90: British 1990 Growth Reference.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	*Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up for the choice of cases and controls	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-9
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	10
		(*e*) Describe any sensitivity analyses	N/A

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	✓
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	12-13
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	5-6, Fig 1
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	12-13
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-13, 15
		(*b*) Report category boundaries when continuous variables were categorized	12-13, 15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-15, Supp T1
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Body composition: Population epidemiology and concordance in 11-12 year old Australians and their parents

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Manuscripts

Body composition: Population epidemiology and concordance in 11-12 year old Australians and their parents

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Keywords: body composition, adiposity, reference values, children, inheritance patterns, epidemiologic studies, parents, correlation studies, cross-sectional studies

Abbreviations: ABS: Australian Bureau of Statistics; BIA: bioimpedence analysis; BMI: Body mass index; CC: correlation coefficient; CDC: Centres for Disease Control and Prevention; CI: confidence interval; DOB: date of birth; IOTF: International Obesity Task Force; LSAC: Longitudinal Study of Australian Children; REDCap: Research Electronic Data Capture; SD: standard deviation; UK: United Kingdom; UK90: United Kingdom 1990; USA: United States of America; USB: Universal Serial Bus; WHO: World Health Organisation.

Word count: 3738

ABSTRACT

Objectives: Overweight and obesity remain at historically high levels, cluster within families, and are established risk factors for multiple diseases. We describe the epidemiology and cross-generational concordance of body composition amongst Australian 11-12 year olds and their parents.

Design: The population-based cross-sectional Child Health CheckPoint study, nested within the Longitudinal Study of Australian Children (LSAC).

Setting: Assessment Centres in seven major Australian cities and eight regional cities, or home visits; February 2015-March 2016.

Participants: Of all participating CheckPoint families (n=1,874), body composition data were available for 1,872 children (49% girls) and 1,852 parents (mean age 43.7 years; 88% mothers), including 1830 biological parent-child pairs.

Measures: Height, weight, body mass index (BMI), waist circumference and waist-height ratio for all participants; body fat and fat-free mass by four-limb bioimpedence analysis (BIA) at Assessment Centres, or body fat percentage by two-limb BIA at home visits. *Analysis:* Parent-child concordance was assessed using (i) Pearson's correlation coefficients, and (ii) partial correlation coefficients adjusted for age, sex and socioeconomic disadvantage. Survey weights and methods accounted for LSAC's complex sample design.

Results: 20.7% of children were overweight and 6.2% obese, as were 33.5% and 31.6% of parents. Boys and girls showed similar distributions for all body composition measures but, despite similar BMI and waist-height ratio, mothers had higher proportions of total and truncal fat than fathers. Parent-child partial correlations were greatest for height (0.37, 95% CI 0.33 to 0.42). Other anthropometric and fat/lean measures showed strikingly similar partial correlations, ranging from 0.25 (95% CI 0.20 to 0.29) for waist circumference to 0.30 (95% CI 0.25 to 0.34) for fat-free percentage. Whole-sample and sex-specific percentile values are provided for all measures.

Conclusions: Excess adiposity remains prevalent in Australian children and parents. Moderate cross-generational concordance across all measures of leanness and adiposity is already evident by late childhood.

ARTICLE SUMMARY

Strengths and limitations of this study

- The nation-wide, population-based cohort was recruited using a two-stage random sampling design, enhancing generalizability of estimates.
- Multiple body composition attributes were objectively measured in children and parents, including body mass index and more detailed measures of segmental fat and fat-free mass and distribution from bio-electrical impedance analysis.
- Only one parent of each child was included in the cross-generational concordance analyses, so we so cannot formally estimate heritability.
- Our parent sample comprised mostly mothers, so estimates of fathers' body composition are less precise.
- Our findings may not generalise to Australian adults who are not parents.

INTRODUCTION

While the proximal cause of overweight is a sustained energy imbalance, overweight clusters in families and clearly both genetic heritability and shared environmental factors contribute to this clustering. Although genetic polymorphisms associated with body composition are being identified,[1 2] the degree of heritability of body mass index (BMI) between parents and children is surprisingly unclear, with estimates ranging from 0.21 to 0.81 between studies.[3] Likewise, parent-child concordance (reflecting both shared genetic and environmental contributions) in two key drivers of body composition – physical activity[4] and dietary patterns[5] – have shown substantial heterogeneity between cohorts in recent meta-analyses.

The epidemiology of obesity – and of body composition more broadly – continues to evolve rapidly. Following steep rises starting around 1980 in all age groups,[6] childhood overweight and obesity has plateaued since around 2005 and increments in adults have slowed, but both remain at historically high levels. For example, 2014-15 Australian estimates are that 27% of 5-17 year olds are overweight (including 7% obese), as are 63% of adults (including 28% obese),[7] with nearly 60% of today's children likely be obese by age 35 years.[8] Population dietary, eating, activity and fitness patterns also continue to evolve – all of which could impact lean and fat mass in different ways, and all of which show varying degrees of environmental and genetic influences.

It is therefore surprising that, while many studies have looked at individual body composition measures (most commonly BMI) in parent-child pairs,[9-12] few have considered a broad range of whole-of-body and segmental body composition measures in a contemporary population-representative sample. Multiple measures are required as fat has differential health impacts depending on where it is deposited throughout the body;[13] for example, abdominal fat measures (e.g. waist circumference, waist-to-height ratio) more strongly predict cardiovascular and all-cause mortality than BMI.[14 15] The few studies with multiple body composition measures in both parents and children have assessed body fat using DXA or skinfold thickness[16 17 18] (used in research but not clinical settings). We have identified no parent-child concordance studies incorporating bioimpedence analysis (BIA, commonly used in population and household settings) for assessing body fat and lean tissue mass and distribution.

Parent-child correlations in body composition differ by sex, parent and offspring ages, and specific aspect of body composition measured.[3] Height (correlation coefficient (CC) 0.29 to 0.51[9 16 17 19]) and fat-free mass (CC 0.21 to 0.48[17 20]) may be more strongly correlated than BMI (CC 0.19 to 0.44[10 17-22]) and weight (CC 0.29 to 0.42[10 17 22]), although estimates vary and overlap to a great extent between studies. Estimates of parent-child correlation on measures of body fat are slightly lower but again overlap with all other measures (body fat percentage CC 0.23 to 0.34,[17 20] waist circumference 0.14 to 0.32[19-21] and fat mass 0.16 to 0.30[17 20]). Longitudinal studies with repeated parent-child BMI concordance report that associations strengthen with child age (from CC 0.15 to 0.28 between ages 5 and 9[9], CC 0.25 to 0.34 between ages 6-9 and 10-11,[22] CC 0.31 to 0.36 between ages 9-10 and 15-16[18], and CC 0.33 to 0.43 between ages 15 and 22 years[23]), presumably reflecting puberty-related changes towards a more adult-like physiology in the offspring.[22] Offspring may not come to resemble parents more beyond this age; in the Midspan Family Study of Scottish parents aged 45–64 years and offspring at ages 30–59 years, regression coefficients for BMI concordance ranged from 0.26 to 0.35 depending on sex of parent and child.[24] Several studies have reported mother-child concordance in BMI to be higher than father-child concordance,[9 11 18] postulating intrauterine environmental effects, but other studies report no difference[10 19] or stronger father-child associations.[21] There is also mixed evidence for[24 25] and against[26] gender-assortative concordance in body composition, that is, a stronger association in mother-daughter and father-son pairs than mother-son and father-daughter pairs. Sex differences in the concordance of body compositional measures other than BMI remain relatively unexplored.

The Child Health CheckPoint, a cross-sectional biophysical wave nested within the Longitudinal Study of Australian Children (LSAC), provided an opportunity to include multiple measures of body composition in a broadly-focused population-based health assessment of parent-child dyads at child age 11-12 years. Here, we aimed to describe, in a population-derived sample of Australian 11-12 year olds and their parents, (i) the epidemiology (population prevalence and distributional statistics) of body composition measures, and (ii) parent-child concordance in these measures.

METHODS

LSAC study design and participants: Detailed information about the initial LSAC recruitment and study design is available elsewhere.[27 28] Briefly, a population-representative sample of 0-1 and 4-5 year olds were recruited into LSAC's B and K cohort, respectively. A two-stage random sampling design was employed, using postcode as the primary sampling unit. For the B cohort, 8921 families were invited to participate, of which 5107 (57.2%) were recruited into the first data collection wave in 2004. Additional data collection waves have occurred every two years since.

CheckPoint study design and participant recruitment: The Child Health CheckPoint was a physical health and biomarkers module offered to the B cohort between LSAC Waves 6 and 7. The CheckPoint data collection spanned February 2015 to March 2016. During the 2014 Wave 6 visit, B cohort families (n=3764) were introduced to the upcoming CheckPoint and asked to consent to their contact details being shared with the CheckPoint team. From late 2014, consenting families (n=3515) received an information pack and recruitment phone call (Figure 1). A more detailed description of the CheckPoint study design is available elsewhere.[29 30]

Ethics and Consent: The Child Health CheckPoint study protocol was approved by The Royal Children's Hospital, Melbourne, Human Research Ethics Committee (33225D) and Australian Institute of Family Studies Ethics Committee (14-26). Parents provided informed written consent for their child's and their own study participation.

Patient and Public Involvement: Because LSAC is a population-based longitudinal study, no patient groups were involved in its design or conduct. To our knowledge, the public was not involved in the study design, recruitment or conduct of LSAC study or its CheckPoint module. Parents received a summary health report for their child and themselves at or soon after the CheckPoint assessment visit. They consented to take part knowing that they would not otherwise receive individual results about themselves or their child.

Procedure: The main CheckPoint data collection mechanism was the 'pop-up' Assessment Centre. Families completed a 3½ hour visit at an Assessment Centre set up sequentially in seven major Australian cities, or a 2¾ hour visit as a Mini-Assessment Centre set up in eight regional cities. Families unable to attend an Assessment Centre were offered a 1½ hour home visit. At the Assessment Centre, participants completed numerous measurements of multiple body systems in a standard sequence that differed slightly for children and parents. Participants advanced every 15 minutes from one station to the next, starting with the body composition station '*Measure Up'*. Children and parents completed a brief questionnaire administered on an iPad using the Research Electronic Data Capture (REDCap) tool[31] during downtime throughout the visit, or at the end of the visit.

Measures: Height, weight, bioimpedence (BIA) and waist circumference were measured at the beginning of the CheckPoint centre/home visit, using standard protocols similar to previous LSAC waves (CheckPoint protocols are described in Table 1). These data were used to derive BMI (kg/m^2), total fat mass percentage, truncal fat percentage and waist-to-height ratio. For children, we also generated BMI and waist z-scores for age and sex using historical reference datasets. As child height, weight and waist circumference are expected to change throughout development, it is common practice within the paediatric literature to analyse z-scores, which allow tracking of an individual child's adiposity over time and comparison between children of different ages. The *Measure Up* data collection and management Standard Operating Procedures, available from the CheckPoint team, provide more detailed information.

An estimate of 300 g was subtracted from measured body weight for two children wearing a plaster cast. Two parents with pacemakers were weighed but BIA analysis was not conducted as the BIA electrical current may affect the operation of the device. Five pregnant women, and five parents who refused measurement but instead self-reported their height and weight, were excluded from our analyses.

Covariates: Age and sex were self-reported in the questionnaire (parents) or LSAC provided these data exported from administrative databases (children). Neighbourhood socioeconomic disadvantage was linked to publicly-available Australian Bureau of Statistics Census data. Child pubertal status was self-reported in the questionnaire. These covariates were measured at the CheckPoint visit (see Table 1); no LSAC data are analysed in this study.

Table 1. Study measures and protocols

Measure	Equipment/instrument	Data collection and data capture	Data derivation
Body composition			
Standing height [32 33]	Portable rigid stadiometer (Invicta IP0955, Leicester, UK).	In light clothing, without shoes or socks, participants stood straight with their heels, back and shoulders against the stadiometer and their head in the Frankfort plane. Height was measured twice (to nearest 0.1 cm); a third measurement was taken if first two measures differed by ≥ 0.5 cm. Staff recorded each height measurement into the participant's REDCap[31] data entry form.	**Mean height:** average of all height measurements.
Weight and bioelectrical impedence analysis (BIA)[32 33]	Four-limb segmental body composition scales (InBody230, Biospace, Seoul, Korea). If not available, two-limb body composition scales (Tanita BC-351, Kewdale, Australia).	Participants wore light clothing and no shoes or socks. Weight was measured once (to the nearest 0.1 kg), and entered into REDCap. Staff entered participant ID, age, sex and mean height into the scales. BIA was measured once with the participant standing on the scale footplates (and also holding two horizontal handles, in the case of four-limb BIA). *Four limb BIA*: Staff entered weight and total body fat mass (to the nearest 0.1 kg) into REDCap, and exported BIA data to USB daily. *Two limb BIA*: Staff entered weight and total body fat percentage (to the nearest 0.1%) into REDCap.	*Four-limb BIA:* **Total body fat %:** (total fat in kg/weight in kg) ×100. **Total body fat-free mass %:** ((weight in kg - total fat in kg)/ weight in kg) ×100. **Truncal fat %:** (truncal fat in kg/ weight in kg) ×100. **Non-truncal fat %:** (right arm + left arm + right leg + left leg fat in kg)/ weight in kg) ×100. *Two-limb BIA:* **Total body fat in kg**: (weight in kg × total body fat %)/100 **Total body fat-free mass in kg**: weight in kg - total fat in kg **Total body fat-free mass %:** As above. Two-limb scales did not generate segmental body composition information.
Body Mass Index (BMI), z-scores and categories.	Derived from height and weight, above.	Derived from height and weight, above.	**BMI:** weight in kg/(mean height in cm^2). **BMI z-score (children only):** BMI transformed into z-scores using both CDC[34] and UK90[35] population normative data. **Weight status**: BMI categorised into underweight, normal weight, overweight and obese using IOTF cut-points for children,[36] and WHO cut-points for adults.[37]
Waist circumference[32 33]	Steel anthropometric measuring tape (Lufkin Executive Diameter W606PM, Maryland, USA).	Waist circumference was measured twice on the skin (to the nearest 0.1cm), at the narrowest point between the 10th rib and iliac crest. If no narrowing was present, the measurement was taken at the midpoint between these two landmarks. A third measure was taken if the first two measures differed by ≥1cm. Staff recorded each waist measurement into REDCap.	**Mean waist circumference**: average of all measurements. **Waist circumference z-score (children only)**: Waist circumference transformed into z-score using the UK90[38] population normative data. **Waist-to-height ratio**: mean waist circumference in cm/mean height in cm.
Potential confounders			

Measure	Equipment/instrument	Data collection and data capture	Data derivation
Age	*Children*: Medicare Australia database. *Parents*: self-reported	*Children*: LSAC provided date of birth (DOB), which was originally exported from the Medicare Australia database. *Parents*: Self-reported in the CheckPoint questionnaire.	**Age in years:** (Date of CheckPoint assessment – DOB)/365.
Sex	*Children*: Medicare Australia database. *Parents*: self-reported	*Children*: LSAC provided sex, which was originally exported from the Medicare Australia database. *Parents*: Self-reported in the CheckPoint questionnaire.	Data used as collected.
Pubertal status (children only)	Pubertal Development Scale.[39]	Five questions about the pubertal development: growth spurt, body hair growth, skin changes/pimples, deepening of voice (male version only), facial hair (male version only), breast growth (female version only) and menstruation (female version only). Four point response scale: 'has not started yet' (coded as 1) 'has barely started' (2), 'has definitely started' (3) and 'seems complete' (4).	*Boys:* Responses were summed for body hair, deepening of voice and facial hair responses, then grouped into pubertal development categories: prepubertal (3), early pubertal (4-5), midpubertal (6-8), or late-post pubertal (9-12). *Girls:* Body hair and breast growth responses summed. Pubertal categories created using score and menstruation response: Prepubertal (2, not yet menstruating), early pubertal (3, not yet menstruating), midpubertal (≥4, not yet menstruating), late-post pubertal (menstruation started).
Disadvantage index	Socio-Economic Indexes for Areas Index of Relative Socioeconomic Disadvantage 2011 (Disadvantage index)[40]	LSAC provided contact details of families consenting to be contacted by CheckPoint The family's residential postcode was confirmed during the CheckPoint recruitment phone call and updated, if required.	The disadvantage index score of postcode was used to summarise neighbourhood socioeconomic position. Generated by the ABS from the 2011 national Census, the index numerically summarises the social and economic conditions of Australian neighbourhoods; national mean 1000, standard deviation 100; higher scores indicate less disadvantage.[40]

ABS: Australian Bureau of Statistics; BIA: bioimpedence analysis; BMI: Body mass index; CDC: Centres for Disease Control and Prevention; DOB: date of birth; IOTF: International Obesity Task Force; LSAC: Longitudinal Study of Australian Children; REDCap; Research Electronic Data Capture; UK: United Kingdom; UK90: United Kingdom 1990; USA: United States of America; USB: Universal Serial Bus; WHO: World Health Organisation.

Statistical analysis: For Aim 1, we described the distributions of body composition domains in children and parents using mean values and standard deviations (SD), as well as key percentiles. These population summary statistics were calculated using weighted multi-level survey analyses that took clustering in the sampling frame and stratification into account. The analytic sample comprised all study children and attending parents (any adult who attended with the study child) with data for at least one measure of height, weight, BIA or waist circumference.

For Aim 2, concordance between parents and children was quantified for (i) the sample overall and (ii) subgroups by child and parent sex, using Pearson's correlation coefficients (CC) with 95% confidence intervals, and partial correlation coefficients, adjusted for child and parent age, disadvantage index, and for child and parent sex in models including both sexes; with 95% bootstrapped confidence intervals (CI). In addition, Aim 2 analyses were repeated using weighted multi-level survey analyses.[41] The unweighted and weighted results were similar, so we present the unweighted analyses. The Aim 2 analytic sample consisted of all biological parent-child pairs with complete data for at least one measurement.

All analyses were performed using Stata version 14.2 (StataCorp, College Station, Texas, USA).

RESULTS

A total of 1874 parent-child pairs participated in the Child Health CheckPoint module. Figure 1 summarises the sample size and reasons for non-response at various stages of the study, and reasons for missing body composition data within the CheckPoint module. Data for at least one body composition measure are available for 1872 children and 1852 parents, including 1830 biological parent-child pairs.

There was a similar proportion of boys and girls, but 88% of parents were mothers (Table 2). The average age of children was 12.0 years, and fathers were three years older than mothers, on average. A greater proportion of girls (89%) than boys (48%) were in the mid-late stages of pubertal development. The sample was somewhat less socioeconomically disadvantaged than the general population, with 26% of the sample in the least disadvantaged national quintile but only 12% in the most disadvantaged quintile.

Table 2. Sample characteristics, stratified by sex, of children and parents; values are mean (standard deviation), except where specified as %.

Characteristic	All	Male	Female
Child	**n=1731-1872**	**n=898-954**	**n=833-918**
Age, years	12.0 (0.4)	12.0 (0.4)	12.0 (0.4)
Pubertal status, %			
Prepubertal	8.5	12.0	4.5
Early pubertal	24.4	40.0	6.7
Mid pubertal	52.5	42.2	64.1
Late-postpubertal	14.6	5.8	24.6
Parent	**n=1847-1852**	**n=226-229**	**n=1621-1623**
Age, years	43.7 (5.6)	46.4 (7.1)	43.3 (5.3)
Disadvantage index	1009 (61)	1005 (69)	1009 (61)
Disadvantage index quintile, %			
1 (Most disadvantaged)	12.3	13.8	12.2
2	18.1	22.7	17.5
3	21.3	21.9	21.2
4	22.6	14.9	23.7
5 (Least disadvantaged)	25.6	26.7	25.5

Sample weights applied to data.

Approximately one quarter of children and two thirds of parents were overweight or obese (children: overweight 20.7%, obese 6.2%; parents: overweight 33.5%, obese 31.6%). Table 3 shows that, compared to fathers, mothers had a mean waist circumference approximately 12 cm less, similar waist-to-height ratio and BMI, and higher proportions of total body fat (36% compared to 26%) and truncal fat (18% compared to 14%). Sex differences in these measures were much smaller in children. In regards to fat distribution, children had a greater proportion of their fat in the non-truncal regions than adults.

Table 3. Distribution of body composition markers in Australian children and parents.

Body composition measure	All				Males				Females			
	n	Mean	SD	95% CI	n	Mean	SD	95% CI	n	Mean	SD	95% CI
Children												
Raw												
Height, cm	1872	153.7	8.0	153.3 to 154.2	954	153.3	8.2	152.7 to 153.9	918	154.3	7.7	153.7 to 154.8
Weight, kg	1872	46.5	11.4	45.9 to 47.2	954	45.9	11.6	45.0 to 46.8	918	47.2	11.2	46.3 to 48.1
BMI, kg/m²	1872	19.5	3.7	19.3 to 19.7	954	19.4	3.8	19.0 to 19.7	918	19.7	3.7	19.4 to 20.0
Waist circumference, cm	1869	66.9	9.0	66.4 to 67.4	952	67.6	9.2	66.9 to 68.4	917	66.1	8.7	65.4 to 66.8
Waist-to-height ratio	1869	0.44	0.05	0.43 to 0.44	952	0.44	0.06	0.44 to 0.45	917	0.43	0.05	0.42 to 0.43
Total body fat, kg	1859	11.2	7.0	10.8 to 11.6	945	10.4	7.2	9.8 to 11.1	914	12.0	6.7	11.5 to 12.6
Total body fat-free mass, kg	1859	35.3	6.3	34.9 to 35.6	945	35.4	6.6	34.9 to 35.9	914	35.1	6.0	34.6 to 35.6
Truncal fat mass, kg	1478	5.0	3.8	4.7 to 5.2	736	4.6	3.9	4.2 to 5.0	742	5.4	3.8	5.1 to 5.7
Non-truncal fat mass, kg	1478	6.2	2.9	6.0 to 6.3	736	5.9	3.1	5.6 to 6.2	742	6.4	2.8	6.1 to 6.6
Z-scores												
BMI z-score (CDC)	1872	0.37	1.05	0.31 to 0.43	954	0.35	1.09	0.26 to 0.44	918	0.39	0.99	0.31 to 0.46
BMI z-score (UK90)	1872	0.56	1.22	0.49 to 0.64	954	0.62	1.25	0.52 to 0.73	918	0.50	1.19	0.41 to 0.59
Waist circumference z-score	1869	0.90	1.13	0.84 to 0.97	952	0.83	1.08	0.75 to 0.92	917	0.98	1.17	0.89 to 1.07
Percentages												
Total body fat percentage	1859	22.5	8.8	22.1 to 23.0	945	21.1	9.2	20.3 to 21.9	914	24.0	8.1	23.4 to 24.7
Total fat-free mass percentage	1859	35.3	6.3	34.9 to 35.6	945	35.4	6.6	34.9 to 35.9	914	35.1	6.0	34.6 to 35.6
Truncal fat mass percentage	1478	9.9	5.5	9.5 to 10.2	736	9.1	5.6	8.6 to 9.7	742	10.6	5.3	10.2 to 11.0
Non-truncal fat mass percentage	1478	13.0	3.3	12.8 to 13.2	736	12.6	3.5	12.3 to 13.0	742	13.3	3.1	13.1 to 13.6
Parents												
Height, cm	1852	165.7	7.8	165.3 to 166.2	229	177.8	7.4	176.6 to 178.9	1623	164.1	6.3	163.7 to 164.5
Weight, kg	1852	77.9	18.8	76.8 to 79.0	229	91.5	17.3	88.7 to 94.3	1623	76.1	18.3	75.0 to 77.2
BMI, kg/m²	1852	28.3	6.3	27.9 to 28.7	229	28.9	4.9	28.1 to 29.7	1623	28.2	6.5	27.8 to 28.7
Waist circumference, cm	1838	87.7	14.9	86.8 to 88.6	227	98.1	13.3	95.9 to 100.3	1611	86.2	14.5	85.3 to 87.2
Waist-to-height ratio	1838	0.53	0.09	0.52 to 0.53	227	0.55	0.07	0.54 to 0.56	1611	0.53	0.09	0.52 to 0.53
Total body fat, kg	1837	28.2	13.2	27.4 to 29.0	227	24.7	11.0	22.9 to 26.5	1610	28.8	13.4	27.8 to 29.6
Total body fat-free mass, kg	1837	49.6	9.5	49.0 to 50.1	227	66.8	9.3	65.3 to 68.3	1610	47.2	6.7	46.8 to 47.6

Truncal fat mass, kg	1479	14.3	6.3	13.9 to 14.8	192	13.6	6.0	12.5 to 14.7	1287	14.4	6.4	14.0 to 14.9
Non-truncal fat mass, kg	1479	13.7	7.2	13.2 to 14.2	192	11.3	5.5	10.3 to 12.2	1287	14.1	7.3	13.5 to 14.6
Percentages												
Total body fat percentage	1837	34.9	9.4	34.3 to 35.5	227	26.1	7.4	25.0 to 27.3	1610	36.1	9.1	35.5 to 36.6
Total body fat percentage	1837	49.6	9.5	49.0 to 50.1	227	66.8	9.3	65.3 to 68.3	1610	47.2	6.7	46.8 to 47.6
Truncal fat-mass percentage	1479	17.8	4.7	17.4 to 18.1	192	14.3	4.1	13.5 to 15.0	1287	18.3	4.6	18.0 to 18.6
Non-truncal fat mass percentage	1479	16.9	5.1	16.5 to 17.3	192	11.8	3.7	11.2 to 12.5	1287	17.6	4.8	17.3 to 18.0

Sample weights applied to data. Reduced sample size for truncal and non-truncal fat due to the two-limb BIA scales not generating these data.

BMI: body mass index; CDC: Centers for Disease Control; CI: confidence interval; SD: standard deviation; UK90: British 1990 Growth Reference.

The distributions of BMI, waist circumference, total body fat mass and truncal fat mass are plotted in figures 2 and 3. For reference purposes, supplementary table 1 shows the distribution of these body composition markers at key percentiles (from 5th to 95th). Amongst children, there were no notable sex differences in the distribution of BMI or waist z-scores, but the distribution of total and truncal fat was slightly shifted to the right (i.e. greater proportion of fat) in girls compared to boys.

Adults showed more striking sex differences. While mothers' and fathers' mean BMI were similar (table 3), the distribution in mothers was flatter and shifted to the left (i.e. lower BMI) compared to fathers. The distribution of men's and women's waist circumference were similar in shape, but shifted to the left (i.e. smaller waists) in women. National Australian guidelines recommend waist circumference below 94 cm and 80 cm cut-points for men and women respectively.[42 43] The median waist circumference for men and women exceeded these cut-points (supplementary table 1); that is, 57% (95% CI 50 to 65) of men and 61% (95% CI 58 to 63) of women in the parent sample exceeded recommendations.

Mothers and fathers had different distributions of total body and truncal fat mass. The mothers had a wider range of fat than fathers, and the distribution was shifted to the right (i.e. greater proportion of fat mass). Overlap in the distributions of mothers' and fathers' fat was less than for other body composition measures.

Unadjusted correlations between child and parent body composition in the cohort overall were moderate and remarkably consistent (table 4); concordance was highest for height (CC 0.30, 95% CI 0.25 to 0.34) and lowest for waist circumference (CC 0.23, 95% CI 0.19 to 0.28). Table 4 also shows that mother-child and father-child correlations were similar for each measure, although there was a tendency for father-child waist, fat and fat-free mass estimates to be higher (but with wider confidence intervals) than mother-child correlations. While we did not conduct formal statistical tests, sex-matched pairs (i.e. mother-daughter, father-son) appeared to show similar concordance to sex-mixed pairs (i.e. mother-son, father-daughter; supplementary table 2).

On adjustment for age, sex and disadvantage index, parent-child height correlations strengthened to be clearly greater than the remaining correlations, which remained relatively unchanged and tightly clustered.

Table 4. Parent-child concordance in body composition characteristics

	Parent-child			Mother-child			Father-child		
	n	CC	95% CI	n	CC	95% CI	n	CC	95% CI
Pearson's Correlation (unadjusted)									
Height	1830	0.30	0.25 to 0.34	1605	0.36	0.32 to 0.40	225	0.30	0.18 to 0.42
Weight	1830	0.27	0.23 to 0.32	1605	0.29	0.24 to 0.33	225	0.28	0.16 to 0.40
BMI / BMI z-score*	1830	0.27	0.23 to 0.32	1605	0.28	0.23 to 0.32	225	0.27	0.14 to 0.38
Waist circumference/z-score#	1814	0.23	0.19 to 0.28	1592	0.24	0.19 to 0.29	222	0.31	0.18 to 0.42
Waist-to-height ratio	1814	0.28	0.24 to 0.32	1592	0.28	0.23 to 0.32	222	0.34	0.22 to 0.45
Total body fat percentage	1810	0.28	0.24 to 0.32	1587	0.28	0.25 to 0.32	223	0.36	0.24 to 0.47
Total body fat-free mass percentage	1810	0.29	0.25 to 0.33	1587	0.29	0.25 to 0.34	223	0.35	0.23 to 0.46
Truncal fat percentage	1430	0.27	0.22 to 0.33	1244	0.26	0.20 to 0.31	186	0.37	0.24 to 0.49
Non-truncal fat percentage	1430	0.28	0.23 to 0.33	1244	0.28	0.22 to 0.33	186	0.32	0.18 to 0.44
Partial correlation (adjusted for covariates)†									
Height	1825	0.37	0.33 to 0.42	1603	0.38	0.34 to 0.42	222	0.36	0.23 to 0.48
Weight	1825	0.28	0.23 to 0.32	1603	0.28	0.22 to 0.33	222	0.30	0.14 to 0.47
BMI / BMI z-score*	1825	0.27	0.23 to 0.31	1603	0.27	0.22 to 0.32	222	0.28	0.11 to 0.45
Waist circumference/z-score#	1809	0.25	0.20 to 0.29	1590	0.24	0.19 to 0.29	219	0.31	0.18 to 0.45
Waist-to-height ratio	1809	0.28	0.24 to 0.33	1590	0.28	0.22 to 0.33	219	0.36	0.23 to 0.50
Total body fat percentage	1805	0.29	0.25 to 0.34	1585	0.28	0.23 to 0.32	220	0.36	0.24 to 0.48
Total body fat-free mass percentage	1805	0.30	0.25 to 0.34	1585	0.29	0.25 to 0.34	220	0.35	0.24 to 0.47
Truncal fat percentage	1426	0.26	0.21 to 0.31	1242	0.25	0.20 to 0.30	184	0.36	0.22 to 0.50
Non-truncal fat percentage	1426	0.27	0.24 to 0.34	1242	0.26	0.23 to 0.34	184	0.30	0.17 to 0.45

Sample weights not applied to data. Reduced sample size for total and truncal fat mass due to 2-limb BIA scales used at Home Visits not generating these data. Sample restricted to children and parents whose relationship was biological child/parent (n = 20 child-parent pairs with body composition data available were excluded).
* UK 90 BMI z-score for children and raw BMI for parents
\# UK 90 waist circumference z-score for children and raw waist circumference for parents
[4]Adjusted for child and parent age, and disadvantage index. The 'all biological child-parent pairs' model additionally adjusted for child and parent sex.
BMI: Body Mass Index; CC: correlation coefficient; CI: confidence interval.

DISCUSSION

Principal findings: We describe the epidemiology of BMI, waist, fat and fat-free mass measures in a large population-based Australian cohort of parents and children, at two stages of the life course (11-12 years of age and mid-adulthood). A quarter of children and two thirds of adults were overweight or obese on BMI criteria. We confirm known sex differences between men's and women's body composition.[44 45] Parent-child concordance in body composition measures were moderate and strikingly similar for all measures tapping into leanness and adiposity, with partial correlations ranging from 0.25 to 0.30; the exception was higher concordance for height (0.37). Mother-child and father-child concordance patterns were similar, although estimates appeared slightly stronger for fathers than for mothers.

Strengths and weaknesses of the study: Body composition was measured in a large nation-wide cohort of children and their parents originally selected to be population-representative.[46] Dyads underwent multiple measures of body composition at the same time and using the same equipment and protocols, maximising generalisability and minimising biases reflecting these factors. Our BIA scales captured segmental, as well as whole-of-body, fat mass. Although the smaller numbers of fathers reduced the precision of father-child estimates, this is one of few studies to provide population estimates both for mother-child and father-child concordance for any anthropometric measurement.

Limitations included under-representation of very disadvantaged families due to selective uptake of CheckPoint and attrition in LSAC, partly mitigated by our use of survey weights (although this showed no meaningful influence on the results). We cannot extend conclusions outside the narrow child age range (11-12 years) and, as we examined parent-child dyads rather than triads, we cannot formally estimate heritability.

Comparisons with other studies: As expected, exact estimates vary across different samples, however, our results are very similar to recent local studies. The prevalence of overweight and obesity in our child (27%) and parent (65%) samples were similar to those reported in the 2014-15 Australian National Health Survey (27% of 5-17 year olds, and 63% of adults 18+ years) three years earlier.[7] Our child waist circumference (mean 66.9cm, standard deviation 9.0cm) was slightly smaller than that of the 11-12 year old Australian children measured in the 2007 National Children's Nutrition and Physical Activity survey (mean 69.1cm, standard deviation 10.3cm;

unpublished data, provided by Prof T. Olds). 57% (95% CI 50 to 65) of our fathers and 61% (95% CI 58 to 63) of our mothers exceeded the recommended waist cutpoints of 94 cm and 80 cm cut-points for men and women respectively,[42 43] compared to 60% of Australian men and 65% of women aged ≥18 years in the 2014-15 survey. Total body fat percentage in our child sample are similar to, but slightly higher than, values reported for the 9-11 year olds in the Australian subsample of the 2011-2013 ISCOLE study.[47 48]

As previous studies have examined parent-child concordance in a single or limited number of body composition measures, ours is one of the first to show the consistency in concordance (correlation coefficients 0.23 to 0.30) across a broad range of body composition measures spanning leanness to adiposity. Our concordance estimates generally fell within the ranges previously reported for each measure, except that our concordance for height fell on the lower end of the range,[9] and weight just below the lower boundary reported in previous literature.[9 10 16-22] Previous studies collectively show parent-child concordance in BMI strengthens with child age; our estimate of 0.29 at child age 11-12 years is consistent with previous estimates of 0.31 to 0.34 for 9-10 and 10-11 year olds, respectively.[18 22]

Meaning and implications for clinicians and policymakers: This study updates summary population data on multiple body composition measures across two generations. Prevalence data for overweight and obesity are not novel, but contribute to within- and between- country population monitoring. Population monitoring should track a range of body composition measures, not BMI alone, as these may have independent health benefits (e.g. lean mass) and risk (e.g. truncal fat) and can vary in the face of stable BMI in children[49] and adults.[50] This dataset is available to researchers from mid-2018 (see the data access statement at the end of the article). Uses may include statistical power calculation and exploration of the shared and unique contributions of each of the body composition measures to outcomes of choice, to inform which of the multiple measures would be most appropriate for future trials.

Taken with other studies, our moderate concordances support both genetic and environmental influences on body composition measures. Older children share only some of the latter with their parents. On the one hand, parents are to some extent nutritional gatekeepers for their children; on the other, children spend a substantial amount of time at school and with peers, in homogenising environments not shared with their parents. While extreme environmental restrictions (such as body building, gastric banding[51] and the Cuban blockade[52]) show very real malleability of body composition, long-term change is nonetheless profoundly difficult for most individuals.[53] Given that each aspect of body composition likely falls under different genetic influences, it is striking that our parent-child concordances across all body compartments were nearly identical (except for height, known to be strongly genetically influenced). The modest concordances between parents and children may challenge a general pessimism about the ability of children to follow healthier trajectories than their overweight parents, and suggest that far more than the family environment drives the current obesity epidemic.

Unanswered questions and future research: Establishing national and international repositories of representative body composition data would allow near-real time detection of shifts in prevalence in response to policy changes and other levers, and support future healthcare provision and economic modelling. The ultimate goal remains interventions – whether driven by politics, policy or practice – that not only reduce obesity but lead to healthier body composition. Unfortunately, at the present time, the 'optimal' body composition at differing stages of the lifecourse remains unknown as it relates to a range of important outcomes. Defining this requires large longitudinal population studies incorporating family triads, biospecimens, and relevant exposures and disease outcomes/proxies, including the potential for Mendelian randomisation studies. Novel intervention strategies may be informed by parents and children non-concordant for adiposity.

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DATA SHARING STATEMENT: Dataset and technical documents available from Growing Up in Australia: The Longitudinal Study of Australian Children via low-cost license for bone fide researchers. More information is available at www.growingupinaustralia.gov.au

SUPPLEMENTARY DOCUMENTS:

Supplementary Table 1. Percentile values for body composition measures.

Supplementary Table 2. Parent-child concordance in body composition measures, by child and parent sex.

FIGURE CAPTIONS AND FOOTNOTES:

Figure 1. Participant flow.

Figure 2. Distribution of child body composition measures

Sample weights applied to data.

Figure 3. Distribution of parent body composition measures.

Sample weights applied to data.

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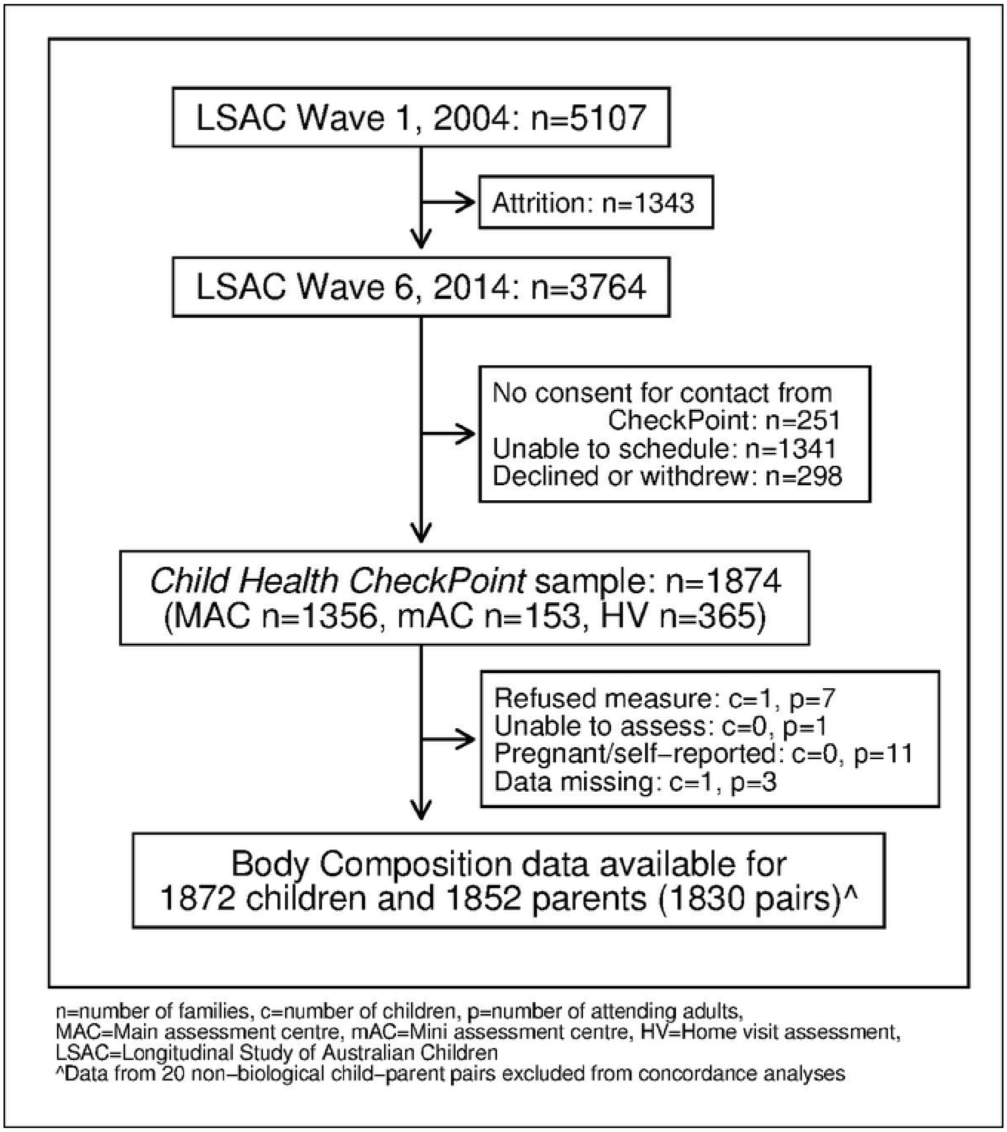

Figure 1. Participant flow

57x64mm (300 x 300 DPI)

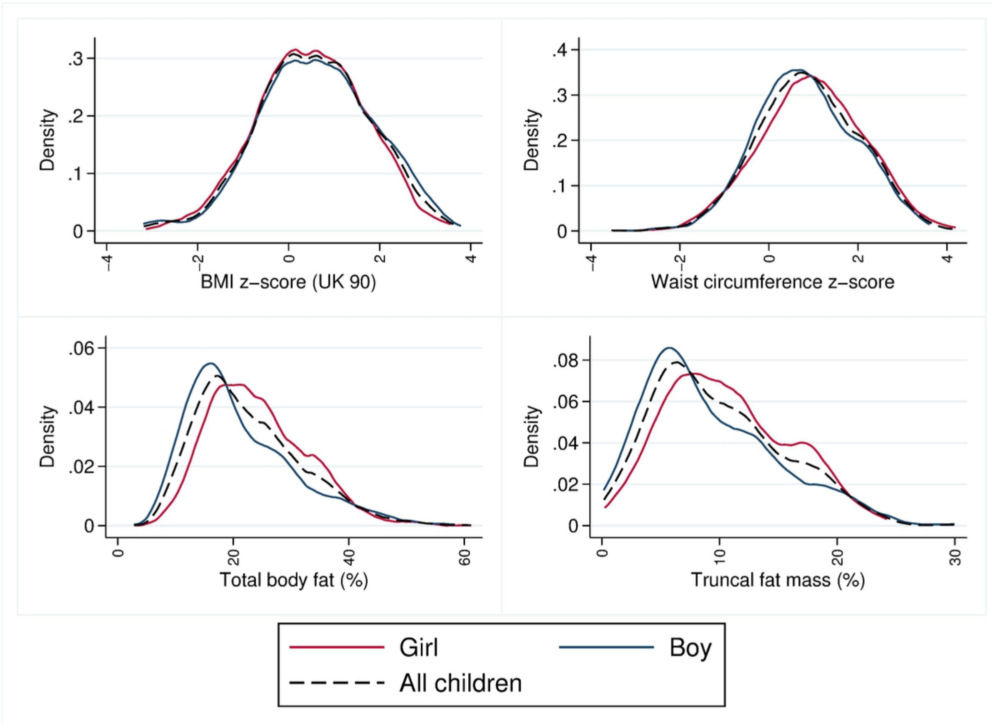

Figure 2. Distribution of child body composition measures. Sample weights applied to data.

101x73mm (300 x 300 DPI)

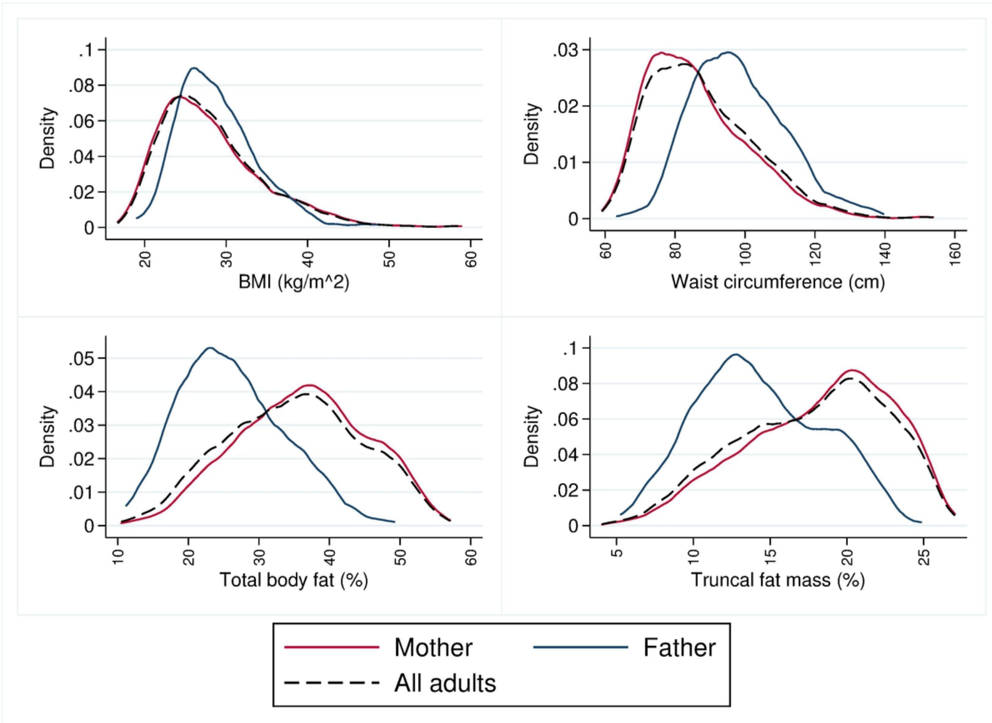

Figure 3. Distribution of parent body composition measures. Sample weights applied to data.

101x73mm (300 x 300 DPI)

Supplementary Table 1. Percentile values for body composition measures.

Characteristic	Child							Parent						
	P5	P10	P25	P50	P75	P90	P95	P5	P10	P25	P50	P75	P90	P95
Height, cm														
Male	140.1	143.0	147.8	153.0	159.0	164.0	167.7	167.0	169.0	173.6	178.0	182.0	187.0	190.0
Female	142.0	145.0	149.0	154.0	160.0	164.3	167.0	153.6	156.0	160.0	164.0	168.0	172.0	174.0
All	141.0	144.0	148.0	153.0	159.0	164.0	167.0	154.0	156.8	160.9	165.0	170.0	176.0	180.0
Weight, kg														
Male	31.2	33.6	37.9	43.1	51.6	61.5	69.1	67.5	72.0	79.8	88.6	102.1	114.6	127.1
Female	32.5	34.4	39.4	45.5	53.2	62.5	67.2	52.9	56.2	63.2	72.3	85.9	101.3	110.6
All	31.9	33.8	38.5	44.5	52.5	62.1	68.1	53.5	57.1	64.3	74.3	88.5	104.1	113.9
BMI, kg/m^2														
Male	14.9	15.6	16.7	18.4	21.1	24.6	26.9	22.9	23.6	25.3	28.0	31.3	35.1	38.1
Female	15.0	15.8	17.1	18.9	21.6	24.8	26.2	20.2	21.3	23.5	26.9	31.5	37.6	41.0
All	15.0	15.7	16.9	18.7	21.3	24.7	26.5	20.3	21.4	23.8	27.1	31.4	37.1	40.3
BMI z-score (CDC)														
Male	-1.45	-1.00	-0.37	0.41	1.13	1.76	2.07	-	-	-	-	-	-	-
Female	-1.30	-0.96	-0.25	0.44	1.11	1.68	1.83	-	-	-	-	-	-	-
All	-1.36	-0.99	-0.30	0.43	1.13	1.71	1.95	-	-	-	-	-	-	-
BMI z-score (UK 90)														
Male	-1.35	-0.90	-0.23	0.62	1.48	2.29	2.74	-	-	-	-	-	-	-
Female	-1.42	-1.06	-0.30	0.49	1.34	2.12	2.32	-	-	-	-	-	-	-
All	-1.39	-0.98	-0.26	0.54	1.40	2.18	2.56	-	-	-	-	-	-	-
Waist circumference, cm														
Male	56.8	58.5	61.1	65.4	71.8	81.6	86.5	80.8	82.9	87.9	96.6	107.1	114.4	122.9
Female	55.2	56.9	60.3	64.3	70.4	77.4	81.3	67.7	70.3	75.1	83.8	95.2	106.4	112.9
All	56.0	57.7	60.7	64.8	71.0	79.3	84.4	68.0	70.6	76.0	85.2	96.9	108.3	114.3

Characteristic	Child							Parent						
	P5	P10	P25	P50	P75	P90	P95	P5	P10	P25	P50	P75	P90	P95
Waist circumference z-score														
Male	-0.86	-0.52	0.07	0.80	1.58	2.33	2.68	-	-	-	-	-	-	-
Female	-0.96	-0.53	0.22	0.96	1.75	2.50	2.80	-	-	-	-	-	-	-
All	-0.92	-0.53	0.12	0.87	1.69	2.40	2.76	-	-	-	-	-	-	-
Waist-to-height ratio														
Male	0.38	0.39	0.40	0.43	0.46	0.52	0.55	0.45	0.46	0.50	0.54	0.60	0.65	0.68
Female	0.37	0.37	0.39	0.42	0.45	0.50	0.52	0.41	0.42	0.46	0.51	0.58	0.65	0.69
All	0.37	0.38	0.40	0.42	0.46	0.51	0.54	0.41	0.43	0.46	0.51	0.58	0.65	0.69
Total body fat, kg														
Male	3.5	4.2	5.6	8.0	12.9	19.6	26.1	11.3	13.0	16.6	22.1	30.6	41.4	46.4
Female	4.4	5.4	7.1	10.3	15.4	21.3	23.6	11.6	13.9	18.9	26.0	35.5	47.7	54.6
All	3.8	4.6	6.2	9.2	14.0	20.9	24.7	11.5	13.7	18.6	25.6	35.0	47.3	53.8
Total body fat percentage														
Male	9.7	11.2	14.5	18.6	26.4	34.7	39.5	15.4	17.1	20.7	25.0	30.8	37.2	39.7
Female	12.6	14.5	18.0	23.3	28.9	35.5	37.7	20.8	23.8	29.5	36.4	42.5	48.2	50.5
All	10.6	12.4	15.8	20.8	28.1	35.3	38.7	19.6	22.0	28.1	35.0	41.6	47.6	50.2
Total body fat-free mass, kg														
Male	26.3	27.8	30.9	34.4	39.0	43.9	46.4	52.4	55.8	61.1	66.5	72.9	79.2	81.9
Female	26.1	27.6	31.0	34.9	38.7	42.5	45.5	37.0	39.3	43.0	46.7	51.0	55.5	58.8
All	26.2	27.6	30.9	34.7	38.8	43.5	46.2	37.5	39.9	43.5	47.7	53.8	62.9	68.7
Truncal fat mass, kg														
Male	0.6	1.1	1.9	3.3	6.2	10.2	13.3	6.0	6.8	9.2	12.4	17.2	22.7	26.2
Female	1.0	1.5	2.6	4.5	7.2	10.8	12.2	5.5	6.8	9.5	13.6	18.3	23.6	25.9
All	0.8	1.2	2.2	3.9	6.6	10.7	12.6	5.7	6.8	9.4	13.5	18.2	23.5	25.9

Characteristic	Child							Parent						
	P5	**P10**	**P25**	**P50**	**P75**	**P90**	**P95**	**P5**	**P10**	**P25**	**P50**	**P75**	**P90**	**P95**
Truncal fat mass percentage														
Male	1.7	3.0	5.0	7.7	12.6	17.8	20.2	8.2	8.9	11.2	13.9	17.4	20.4	21.0
Female	2.9	4.4	6.5	10.0	14.2	18.0	19.5	10.0	11.5	15.0	19.1	21.7	24.0	24.6
All	2.2	3.5	5.6	8.9	13.4	17.9	19.9	9.4	10.9	14.1	18.4	21.4	23.8	24.5
Non-truncal fat mass, kg														
Male	3.2	3.5	4.0	4.9	6.7	10.0	12.6	5.5	6.0	7.5	9.6	13.8	19.1	21.1
Female	3.5	3.8	4.3	5.6	7.6	10.2	11.3	6.1	7.0	9.0	12.2	17.1	23.7	27.8
All	3.3	3.6	4.1	5.2	7.2	10.1	12.2	6.0	6.8	8.8	11.8	16.7	23.1	27.5
Non-truncal fat mass percentage														
Male	8.1	8.9	10.1	11.7	14.5	17.6	19.5	7.1	8.1	9.1	11.3	14.1	16.6	18.4
Female	9.2	9.9	11.1	12.8	15.3	17.5	19.0	10.7	11.7	14.2	17.0	20.6	24.1	26.8
All	8.6	9.3	10.6	12.4	14.8	17.6	19.3	9.3	10.7	13.3	16.4	20.2	23.7	26.1

PX: value of Xth percentile, eg P50 = median
BMI: body mass index; CDC: Centers for Disease Control; UK90: British 1990 Growth Reference.

Supplementary Table 2. Parent-child concordance in body composition measures, by child and parent sex.

	Mother-daughter		Mother-son		Father-daughter		Father-son	
	n	**CC (95% CI)**	**n**	**CC (95% CI)**	**n**	**CC (95% CI)**	**n**	**CC (95% CI)**
Pearson's Correlation (unadjusted)								
Height	804	0.36 (0.30 to 0.42)	801	0.36 (0.30 to 0.42)	95	0.51 (0.34 to 0.64)	130	0.16 (-0.02 to 0.32)
Weight	804	0.29 (0.22 to 0.35)	801	0.28 (0.22 to 0.35)	95	0.31(0.11 to 0.48)	130	0.29 (0.12 to 0.44)
BMI / BMI z-score*	804	0.29 (0.22 to 0.35)	801	0.27 (0.21 to 0.34)	95	0.30 (0.10 to 0.47)	130	0.28 (0.11 to 0.43)
Waist circumference/z-score#	800	0.24 (0.18 to 0.31)	792	0.24 (0.18 to 0.31)	93	0.31 (0.11 to 0.48)	129	0.33 (0.16 to 0.47)
Waist-to-height ratio	800	0.31 (0.25 to 0.37)	792	0.24 (0.18 to 0.31)	93	0.39 (0.20 to 0.55)	129	0.36 (0.20 to 0.50)
Total body fat percentage	798	0.32 (0.25 to 0.38)	789	0.26 (0.19 to 0.32)	94	0.36 (0.16 to 0.52)	129	0.37 (0.21 to 0.51)
Total body fat-free mass percentage	798	0.34 (0.27 to 0.40)	789	0.27 (0.20 to 0.33)	94	0.36 (0.16 to 0.52)	129	0.35 (0.19 to 0.49)
Truncal fat percentage	640	0.30 (0.22 to 0.36)	604	0.22 (0.15 to 0.30)	84	0.30 (0.10 to 0.49)	102	0.42 (0.25 to 0.57)
Non-truncal fat percentage	640	0.31 (0.23 to 0.37)	604	0.25 (0.17 to 0.32)	84	0.27 (0.06 to 0.46)	102	0.36 (0.18 to 0.52)
Partial correlation (adjusted for covariates)†								
Height	803	0.39 (0.34 to 0.45)	800	0.36 (0.30 to 0.42)	95	0.50 (0.35 to 0.65)	127	0.29 (0.11 to 0.46)
Weight	803	0.27 (0.20 to 0.34)	800	0.28 (0.22 to 0.35)	95	0.29 (0.10 to 0.49)	127	0.33 (0.12 to 0.53)
BMI / BMI z-score*	803	0.27 (0.22 to 0.35)	800	0.27 (0.21 to 0.34)	95	0.30 (0.12 to 0.48)	127	0.27 (0.07 to 0.51)
Waist circumference/z-score#	799	0.23 (0.17 to 0.32)	791	0.24 (0.17 to 0.30)	93	0.30 (0.10 to 0.50)	126	0.33 (0.15 to 0.50)
Waist-to-height ratio	799	0.31 (0.24 to 0.40)	791	0.24 (0.16 to 0.31)	93	0.37 (0.17 to 0.57)	126	0.36 (0.18 to 0.54)
Total body fat percentage	797	0.31 (0.25 to 0.37)	788	0.25 (0.18 to 0.31)	94	0.35 (0.17 to 0.54)	126	0.38 (0.21 to 0.55)
Total body fat-free mass percentage	797	0.33 (0.27 to 0.39)	788	0.26 (0.19 to 0.32)	94	0.35 (0.17 to 0.54)	126	0.36 (0.20 to 0.53)
Truncal fat percentage	639	0.28 (0.20 to 0.35)	603	0.21 (0.14 to 0.29)	84	0.30 (0.08 to 0.52)	100	0.40 (0.22 to 0.59)
Non-truncal fat percentage	639	0.29 (0.25 to 0.39)	603	0.23 (0.17 to 0.32)	84	0.26 (0.14 to 0.51)	100	0.33 (0.09 to 0.51)

Sample weights not applied to data. Reduced sample size for truncal fat mass due to 2-limb BIA scales used at Home Visits not generating these data. Sample restricted to children and parents whose relationship was biological child/parent (n = 20 child-parent pairs with body composition data available were excluded).
*UK 90 BMI z-score for children and raw BMI for parents
#UK 90 waist circumference z-score for children and raw waist circumference for parents
[4]Adjusted for child and parent age, and disadvantage index.
BMI: body mass index; CDC: Centers for Disease Control; CI: confidence interval; SD: standard deviation; UK90: British 1990 Growth Reference.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	*Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up for the choice of cases and controls	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-9
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	10
		(*e*) Describe any sensitivity analyses	N/A

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	✓
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	12-13
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	5-6, Fig 1
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	12-13
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-13, 15
		(*b*) Report category boundaries when continuous variables were categorized	12-13, 15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-15, Supp T1
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.