Child Health CheckPoint: cohort summary and methodology of a physical health and biospecimen module for the Longitudinal Study of Australian Children

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ABSTRACT

Objectives 'Growing Up in Australia: The Longitudinal Study of Australian Children' (LSAC) is Australia's only nationally representative children's longitudinal study, focusing on social, economic, physical and cultural impacts on health, learning, social and cognitive development. LSAC's first decade collected wide-ranging repeated psychosocial and administrative data; here, we describe the Child Health CheckPoint, LSAC's dedicated biophysical module.

Design, setting and participants LSAC recruited a cross-sequential sample of 5107 infants aged 0–1 year and a sample of 4983 children aged 4–5 years in 2004, since completing seven biennial visits. CheckPoint was a cross-sectional wave that travelled Australia in 2015–2016 to reach LSAC's younger cohort at ages 11–12 years between LSAC waves 6 and 7. Parent–child pairs participated in comprehensive assessments at 15 Assessment Centres nationwide or, if unable to attend, a shorter home visit.

Measures CheckPoint's intergenerational, multidimensional measures were prioritised to show meaningful variation within normal ranges and capture non-communicable disease (NCD) phenotype precursors. These included anthropometry, physical activity, fitness, time use, vision, hearing, and cardiovascular, respiratory and bone health. Biospecimens included blood, saliva, buccal swabs (also from second parent), urine, hair and toenails. The epidemiology and parent–child concordance of many measures are described in separate papers.

Results 1874 (54% of eligible) parent–child pairs and 1051 second parents participated. Participants' geographical distribution mirrored the broader Australian population; however, mean socioeconomic position and parental education were higher and fewer reported non-English-speaking or Indigenous backgrounds. Application of survey weights partially mitigates that the achieved sample is less population representative than previous waves of LSAC due to non-random attrition. Completeness was uniformly high for phenotypic data (>92% of eligible), biospecimens (74%–97%) and consent (genetic analyses 98%, accessing neonatal blood spots 97%, sharing 96%).

Conclusions CheckPoint enriches LSAC to study how NCDs develop at the molecular and phenotypic levels before overt disease emerges, and clarify the underlying dimensionality of health in childhood and mid-adulthood.

INTRODUCTION

Worldwide there is a large and growing burden of non-communicable diseases (NCD). Many have their genesis in early life, and develop over decades of cumulative exposures. This provides opportunities to prevent, slow or alter disease trajectories at multiple points of the life course. Wide gradients within the normal range of phenotypes relevant to many...
later NCDs are already measurable across many body systems from childhood.

It is evident that family, social and other environmental factors interact with an individual’s innate biology (including genetic profile) to create modifiable pathways (such as chronic inflammation) common to multiple NCDs. Shonkoff’s biodevelopmental framework of life-course determinants of health and their mechanisms proposes that health-promoting and health-threatening environmental effects interact with genes and affect later health, via physiological adaptions during sensitive periods and cumulative effects over time. These physiological adaptions are the key intermediary step, which may be measured years or decades before overt ill health develops.

‘Big picture’ research into physiological adaptions and objective health outcomes has shifted from narrowly focused hypothesis-driven studies with a single outcome, towards multidisciplinary and/or multidimensional research with outcomes across multiple domains that recognise the interconnectedness of health. Around the start of the millennium, many countries launched large-scale birth cohort studies (eg, UK Millennium Cohort, Growing Up in Ireland, New Zealand, Singapore). Australia’s study, Growing Up in Australia: The Longitudinal Study of Australian Children (LSAC) was intended to provide a strong evidence base for policy development and service delivery on a wide range of issues relating to children’s development and lifetime well-being.

LSAC is a population-based cohort study from early childhood, and is the country’s only nationally representative children’s longitudinal study. It is broad in scope, surveying lifetime pathways in health, learning and development. Its design incorporates frequent (biennial) and ongoing data collection; multiple study respondents; linkage to lifetime universal parent and child administrative data including healthcare (eg, lifetime primary health services, medication prescriptions dispensed), education (eg, national literacy and numeracy exam results) and census data sets; and open access to the data sets for researchers. The federal government investment into LSAC is yielding major returns that influence policy, with several hundred publications in the first decade of the study (listed at http://flosse.fahcsia.gov.au/). Adopting a dual cross-sequential design, LSAC recruited two cohorts in 2004, each comprising ~5000 children. At recruitment, the K cohort children were aged 4–5 years (n=4984 families, 50.4% uptake), and B cohort were aged 0–1 year (n = 5107 families , 57.2 % uptake; figure 1). A two-stage random sampling design was applied, first randomly selecting 10% of postcodes (stratified by state and urban/rural locations), then in-age children within those postcodes (stratified by state and urban/rural locations), then in-age children within those postcodes from the Medicare database. Medicare is an Australian government programme within the universal healthcare system that reduces or covers medical visit and medication costs, into which 98% of children are enrolled by their first birthday. Very remote postcodes and those with <20 children (n=874 postcodes, 3.2% of population) were excluded. At wave 6 (child age 10–11 years), 74% of the original B cohort were retained; families with Indigenous or non-English-speaking backgrounds, or incomes less than $1000 per week were under-represented in later waves.

Like other government-implemented children’s studies internationally, LSAC has mainly focused on psychosocial and demographic exposures, with all health items except anthropometry and blood pressure being parent-reported or self-reported. A physical health and biocollection module was beyond the scope of the original study design. There was also uncertainty as to how such a biomarker module might impact (whether positively or negatively) on cohort retention and engagement.

To address this gap, we recently introduced an intergenerational physical health and biomarkers module, the Child Health CheckPoint. This one-off cross-sectional wave, nested between LSAC waves 6 and 7, was offered to the B cohort at child age 11–12 years. CheckPoint’s intergenerational, multidimensional measures were prioritised to show meaningful variation within normal ranges and capture NCD phenotype precursors both in
ultimately encompassed a much wider range of health and philanthropic funding, such that the CheckPoint competitive (NHMRC Project Grant 1109355, 2016-2020) spirothetic measures and leveraged additional institutional, 2013-17). This core funding enabled the child cardiore- cation to the Australian National Health and Medical Research Council (NHMRC Project Grant 1041352, 2016-2017). In 2012, researchers at the Murdoch Chil- tigators at the University of South Australia, University dren’s Research Institute (MCRI) partnered with inves- expertise. In 2012, researchers at the Murdoch Chil- to LSAC with physical health and biomarkers content ments at an Assessment Centre or home visit. Choice of parent and whether or not biological was determined by the family; in practice this 'attending parent' was usually the mother. Second biological parents living with the child, if available, were also invited to participate after the visit by contributing a buccal swab.

Participants
LSAC B cohort families who completed a wave 6 home interview were eligible. The study child and one parent were invited to participate in comprehensive health assessments at an Assessment Centre or home visit. Choice of parent and whether or not biological was determined by the family; in practice this 'attending parent' was usually the mother. Second biological parents living with the child, if available, were also invited to participate after the visit by contributing a buccal swab.

Ethical approval and consent
The CheckPoint study was approved by The Royal Child- ren’s Hospital Melbourne Human Research Ethics Committee (33225D) and the Australian Institute of Family Studies Ethics Committee (14-26); the latter also provides ethical review and approval for LSAC at every wave. A parent or guardian provided written consent for their own and their child’s participation in the study. Optional consent was requested for the collection, storage and non-genetic analysis of biospecimens; genetic analyses of these samples; sharing images and samples with other researchers; and access to the child’s birth data and dried newborn heel-prick blood samples that are stored indefinitely by most Australian states. Non-attending biological parents provided written consent for the storage and non-genetic analysis of their buccal swab, and optional consent for genetic analysis was requested. Participants were aware that no health, genetic or other information would be returned to them, beyond a summary of physical health measurements (eg, body mass index, blood pressure) provided at the end of the visit.

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 the LSAC study or its CheckPoint module. Parents received a summary

METHODS
Study design
LSAC is a longitudinal child cohort study conducted in partnership between the Australian Government Department of Social Services, the Australian Institute of Family Studies and the Australian Bureau of Statistics. It is funded by the Australian Government.

The Child Health CheckPoint was conducted between February 2015 and March 2016 at child age 11-12 years. The CheckPoint was offered to the B cohort because: (A) it contains more detailed pregnancy and birth data; (B) LSAC’s data collections span the children’s entire postnatal lives; (C) by this child age, there is a wide range in normal values of risk factors predicting adult preclinical markers of disease; and (D) experience suggested that the health measurements would be of greater interest (and so attract higher uptake) to children and parents at this age than to the K cohort aged 15–16 years, an age when many birth cohorts experience heightened attrition.

Study development
In 2007, the Department of Social Services commis- sioned a scoping report on the potential value, content and cost of a physical health and biomarkers module. A partnership was formed between LSAC senior management, LSAC researchers and child health researchers new to LSAC with physical health and biomarkers content expertise. In 2012, researchers at the Murdoch Children’s Research Institute (MCRI) partnered with inves- tigators at the University of South Australia, University of Adelaide and Deakin University to form the Check- Point Investigator Team and to lead a successful application to the Australian National Health and Medical Research Council (NHMRC Project Grant 1041352, 2013-17). This core funding enabled the child cardiore- spiatory measures and leveraged additional institutional, competitive (NHMRC Project Grant 1109355, 2016-2020) and philanthropic funding, such that the CheckPoint ultimately encompassed a much wider range of health domains underpinning NCDs across two generations.

Feasibility of core CheckPoint assessments were tested in 2014 within the ‘3C’ study; a longitudinal study of 378 aged 7–17 years in the MCRI’s existing Parent Education and Support (PEAS), Live, Eat and Play 2 (LEAP2) and Shared Care Obesity Trial in Children (HopSCOTCH) cohorts examining cardiovascular outcomes of life course growth, diet and activity.

Late in 2014, we tested the CheckPoint protocol with a vanguard of 52 Victorian LSAC families to fine-tune recruitment, visit flow, timing and feasibility, and test acceptability of the centre-based suite of measures ahead of the much larger bulk of children due to attend in 2015–2016. Child and parent participants prospectively rated enjoyment of each assessment and overall impres- sions (scored out of 10). Participants were also asked to rate how the CheckPoint module changed their feeling about being in LSAC overall, from 0 (Now I like it much less) to 10 (Now I like it much more).

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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

Participation in the CheckPoint involved (1) an Assessment Centre or home visit for the child and attending parent, (2) follow-up phone interview for the child, (3) a week of wearing an accelerometer (physical activity monitor) for the child and attending parent, and (4) a buccal (DNA) sample collection at home for the non-attending parent. Assessments and phone interviews were conducted by trained research assistants and students.

Sample recruitment: B cohort families were briefly introduced to the upcoming Child Health CheckPoint during the LSAC wave 6 home interview in 2014. A total of 3513 families (93% of wave 6 families and 69% of original cohort, see figure 1) gave written consent to be contacted by the CheckPoint Team.

Assessment visit types and locations: The core CheckPoint data collection mechanism was the ‘pop-up’ Main Assessment Centre, set up in seven major Australian cities (online supplementary figure 1) sequentially for between 2 and 8 weeks before being packed up and transported by road to the next location. On each operating day, up to 24 families were invited to attend the Assessment Centre for a 3.5-hour visit.

Road transport between Australian cities can take days. To maximise the size and geographic reach of the sample, ‘pop-up’ Mini Assessment Centres operated in eight regional cities for up to a week while the bulk of equipment was in transit. The 2.75-hour Mini Assessment Centre visit included most of the assessments offered at the Main Assessment Centres, except those requiring large equipment unable to be checked in as personal luggage on commercial flights. Those unable to attend an Assessment Centre were offered a 1.5-hour home visit.

The visit started with the parent providing consent, while the child wrote their story at Life at 25. At Assessment Centres, participants were then given a carry bag containing an iPad to complete the questionnaire, water bottle and urine sample collection kit, and a lanyard showing the order of data collection stations to visit. Participants advanced every 15 min from one station to the next (except child Lung Fun which was 30 min duration), following the previous participant in their journey around the Centre. Most stations were conducted one-to-one, but in some the study child and attending parent were both present (CheckPoint Check-in, Measure Up, Tooth Booth, Bone Zone, child Young Bloods and Endgames, see figure 2), and two children could be present at any one time for Life at 25, Jumping Beans and Bike Hike.

Prior to the last station Endgames, participants could take extra time to complete their questionnaire or provide a urine sample. At Endgames, a staff member explained the contents of a take-home pack. The child and parent were fitted with their wrist-worn accelerometers, and a follow-up phone interview was booked/confirmed for the child to complete additional time-use diaries. The take-home pack also included a reply-paid express post satchel, child and parent activity log cards, non-attending parent buccal sample collection kit (as applicable), summary of health results collected on the day, and thank you gifts and token reimbursement for travel.

Home visit consent, assessments and take-home packs used the same protocol as the Assessment Centres and included at least one measure from every major health domain; however, some assessments were omitted (table 1). The home visit sequence generally mirrored the centre flow, with minor adjustments to allow one staff member to assess both child and parent within the available time. Dried blood spot, urine and buccal swabs were obtained, and urine processing was delayed when local laboratory facilities were not available.

Research assistants and students were trained by experts, and real-time quality checks were undertaken throughout the data collection period. These checks included data range checks integrated into the data entry forms; dynamic data completeness checks for each participant during and at the end of their visit, with gaps redressed by a dedicated staff member before departure; weekly completeness checks for the study overall and ongoing process modifications to address all causes of missing data identified; random visual checks of the data to identify and fix any developing departures from protocol.

Table 1 reports the assessments offered at each visit type, and figure 1 the sample size per visit type.

Assessment sequence: Participants completed the assessments in a standard sequence (figure 2), designed to minimise interdependencies between measures. Bronchodilator administration (which may alter cardiovascular parameters) followed cardiovascular measures, and the snack station was scheduled after saliva and semi-fast ing blood collection, but before exercise.

Assessment Centre and 20% completed a home visit. The visit started with the parent providing consent, while the child wrote their story at Life at 25. At Assessment Centres, participants were then given a carry bag containing an iPad to complete the questionnaire, water bottle and urine sample collection kit, and a lanyard showing the order of data collection stations to visit. Participants advanced every 15 min from one station to the next (except child Lung Fun which was 30 min duration), following the previous participant in their journey around the Centre. Most stations were conducted one-to-one, but in some the study child and attending parent were both present (CheckPoint Check-in, Measure Up, Tooth Booth, Bone Zone, child Young Bloods and Endgames, see figure 2), and two children could be present at any one time for Life at 25, Jumping Beans and Bike Hike.

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| Construct and measure                          | Main Station | Mini Station | Home Station | Station Equipment/instrument* | Data/sample collection protocol in brief |
|----------------------------------------------|--------------|--------------|--------------|------------------------------|------------------------------------------|
| **Anthropometry**                            |              |              |              |                              |                                          |
| Height                                       | Ch           | P            | Ch           | P                            | Portable rigid stadiometer (Invicta IP0955, Leicester, UK) | Standing height without shoes or socks, measured ×2, or ×3 if first two measures differed by ≥0.5 cm. |
| Weight and body composition                  | Ch           | P            | Ch           | P                            | 4-limb segmental (InBody230, Biospace, Seoul, Korea) or 2-limb (Tanita BC-351, Kewdale, Australia) body composition scales | Weight and body composition wearing light clothing without shoes or socks, measured once. |
| Waist circumference                          | Ch           | P            | Ch           | P                            | Steel anthropometric measuring tape (Lufkin Executive Diameter W606PM, Maryland, USA) | Waist circumference at the narrowest point between the 10th rib and iliac crest, or midpoint between if no visible narrowing. Measured ×2, or ×3 if first two differed by ≥1 cm. |
| **Pubertal status**                          |              |              |              |                              |                                          |
| Pubertal development                         |              |              |              |                              | Sexual Maturity Scale50                  | Sexual maturity assessed using three sets of images (1 male and 2 female) showing stages of puberty. Pubertal progress assessed using five sex-specific questions. |
|                                              |              |              |              |                              | Pubertal Development Scale51             |                                          |
| Menstruation                                 |              |              |              |                              | Study-designed questions about menstruation | Self-reported current menstruation (females only). Age of menstruation onset (girls only). |
| Acne                                         |              |              |              |                              | Modified Comprehensive Acne Severity Scale for the face52 | Current acne severity assessed using a sex-specific 5-point pictorial scale. |
| **Bone and muscle measures**                 |              |              |              |                              |                                          |
| Bone and muscle morphology, bone density     | Ch           | P            | Ch           | P                            | Peripheral quantitative CT (pQCT, Stratec XCT 2000L scanner and XCT 2000 software, Birkenfeld, Germany) | Two pQCT scans of the non-dominant lower leg to image bone and muscle density and morphology. Scans taken at 4% (above ankle) and 66% (mid-calf) length of the tibia. |
### Table 1 Continued

| Construct and measure | Main Ch | Mini Ch | Home Ch | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|-----------------------|---------|---------|---------|---------|------------------------|------------------------------------------|
| Cardiovascular measures | **Carotid intima-media thickness and distensibility**<sup>55 56</sup> | ● ● ● ● | ● ● ● || Portable ultrasound (GE Healthcare Vivid / BT06 with 10 MHz linear array probe, Little Chalfont, UK) with ECG | Performed in supine position with head turned 45° to the left. Probe applied to right side of the neck to capture carotid artery wall images, with concurrent ECG trace. |
| | **Arterial stiffness and blood pressure**<sup>57</sup> | ● ● ● ● | ● ● ● | | SphygmoCor XCEL (AtCor Medical, West Ryde, AUS) | Aortic-femoral pulse wave velocity measured ×3, supine, using a tonometer on the neck and blood pressure (BP) cuff on the thigh. Pulse wave analysis (including BP) measured ×3, 1 min apart, using a BP cuff on the arm. |
| | Microvascular structure<sup>58</sup> | ● ● | ● | | Retinal camera (Canon CR-DGi, Tokyo, Japan), fitted with a digital SLR camera (Canon EOS 60D, Tokyo, Japan) | In a darkened room without mydriasis, two retinal photographs were taken per eye, one focused on the macula and one focused on the optic disc. |
| Respiratory measures | **Lung function** | ● ● ● ● ● | ● ● ● | | Spirometer<sup>59</sup> (Vyntus, CA, USA) and Sentry Suite software (CA, USA) for collection (V.2.10) and download (V.2.17) | Children and parents perform 3–8 maximal exhalation manoeuvres. Children inhale 4 puffs of bronchodilator (Ventolin), wait 10 min and repeat test. |
| Language | **Expressive and receptive language** | ● ● ● ● | ● ● ● | | Recalling Sentences subtest, Pearson Clinical Evaluation of Language Fundamentals–fourth edition, Australian version,<sup>59</sup> iPad (Apple, CA, USA) and headphones | Participant recalls and repeats up to 32 recorded spoken sentences of varying length and syntactic complexity. |
| | **Receptive vocabulary** | ● ● ● ● ● | ● ● ● | | National Institutes of Health Picture Vocabulary test<sup>61</sup> (NIH Toolbox software with Cognition package), iPad and headphones | Participant hears word and selects picture best representing the word’s meaning. Adaptive test using computer-based algorithms to quickly approximate and then precisely pinpoint participant ability. |
| Construct and measure | Main | Mini | Home | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|-----------------------|------|------|------|---------|-----------------------|------------------------------------------|
| Hearing               |      |      |      |         |           | In a soundproof booth with headphones, participant presses button on hearing sound. Adaptive test: sound presented at increasing and decreasing volume at 4 frequencies (1, 2, 4, 8 kHz). Each ear tested separately. |
| Hearing threshold     | ● ●  | ● ●  | ● ●  |         | Audiometer (Oscilla USB-330, V.3.3.4, Taastrup, Denmark) and Oscilla headphones. Data exported using V.4.0.0 |
| Middle ear function   | ● ●  | ● ●  | ● ●  |         | Tympanometer (Oscilla TSM300) and AudioConsole software (V.3.3.4) |
| Speech reception      |      |      |      |         | Listening in Spatialised Noise–Sentences Test v1.104 65 66 (Phonak, NSW, Australia), laptop and headphones (Sennheiser HD215, Wedemark, Germany) |
| threshold             |      |      |      |         | In a soundproof booth with headphones, participant repeats sentences at varying volume against fixed-volume background conversation. Adaptive test; computer algorithms pinpoint threshold. |
| Diet and food choices |      |      |      |         |          | Participant provided with a food box with prepacked snack food items to eat during a 15 min break. Boxes on different days randomised to differ by box size and food amount. Uneaten food weighed at end of session. |
| Food choices          | ● ●  | ● ●  | ● ●  |         | Digital weight scales accurate to 1 g (Breville, BSK500BSS) |
| Physical activity and |      |      |      |         |          | Wrist-worn accelerometer (GENEActiv Original, Cambs, UK) and self-report activity log |
| time use              |      |      |      |         | Triaxial accelerometer worn on non-dominant wrist for 8 days. Participant records type of day (school, non-school), sleep times and activities with device off. |
| Physical activity,    | ● ●  | ● ●  | ● ●  |         | Multimedia Activity Recall for Children and Adults55 68 69 programme |
| sedentary behaviour,  |      |      |      |         | Activities recalled from the previous 24–48 hours, in increments of ≥5 min. 2–3 days recalled, including one school and one non-school day. |
| sleep                 |      |      |      |         |          |
| Time use              | ● ●  | ● ●  | ● ●  |         | About Time |
| Strength and fitness  |      |      |      |         | Gym mat and measuring tape (Lufkin L610CME, Maryland, USA) |
| Eurofit broad jump    | ● ●  | ● ●  | ● ●  |         | Jumping Stones |
|                       |      |      |      |         | Participant jumps horizontally from a standing start with double-leg take-off. After a practice jump, the distances of 3 jumps (measured in cm) are recorded. |
| Construct and measure | Main | Mini | Home | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|-----------------------|------|------|------|---------|-----------------------|---------------------------------------|
| PWC170 VO\textsubscript{2} max test\textsuperscript{71} | ♦ | | | | Exercise bike (Monark 928G3, Manila, Philippines) and chest-worn heart rate monitor (Polar FT4, Smeaton Grange, Australia) | Warm up, then cycle at 60 RPM for 3×2 min bouts. Resistance increases as per heart rate at end of each bout. Aerobic work capacity (VO\textsubscript{2}max) estimated. |
| Vision | | | | | | |
| Visual acuity | ♦ | ♦ | ♦ | | Computerised adaptive Freiburg Visual Acuity and Contrast Test\textsuperscript{72} with Landolt C optotypes (FrACT V3.8.2, Breisgau, Germany) | Participant identifies optotypes (shapes) from 3 m. Right and left eyes tested separately, without glasses or contact lenses. Adaptive test: computer algorithms adjust size of optotypes presented to determine visual acuity. If visual acuity <1.0, test repeated with pinhole lens. |
| 2D and 3D oral photography | | | | | | |
| 2D and 3D oral photography | ♦ | ♦ | ♦ | | 2D photography–Digital SLR camera (Canon 70D, Tokyo, Japan) 3D photography–3-pod 3D camera (3dMD Trio System, Georgia, USA) | 2D photos of the dorsum of extruded tongue; then with lip retractors in place, teeth in occlusion and slightly apart with lower incisal edges visible. 3D photo of teeth in occlusion with lip retractors in place. |
| 3D facial photography | ♦ | ♦ | | | 3-pod 3D camera (3dMD Trio System) | 3D photo of the face (neutral expression, hair pulled back in net to show hairline), ears and under chin. |
| Written story | | | | | Pen, paper. Using protocol adapted from 1958 National Child Development Study (UK)\textsuperscript{73} | Child writes a short story about what they think their life will be like when they are 25 years old. |
| Well-being and quality of life | | | | | | |
| General well-being | ♦ | ♦ | | | International Survey of Children’s Well-Being\textsuperscript{74 75} Pediatric Quality of Life (PedsQL) 4.0 General Well-Being Scale\textsuperscript{76} | 6-item measure of subjective well-being. 7-item measure of quality of life and general well-being. |
| Health-related quality of life | ♦ | ♦ | | | PedsQL 4.0 Generic Core Scale\textsuperscript{76} | 23-item measure of physical and psychosocial health, yielding total, physical and psychosocial summary scores. |

Continued
| Construct and measure | Main Ch P | Mini Ch P | Home Ch P | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|-----------------------|-----------|----------|-----------|---------|-----------------------|------------------------------------------|
| Assessments of Quality of Life 8D Scale | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | 35-item measure of health-related quality of life. Overall utility score and dimension scores calculated. |
| Child Health Utility 9D | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | 9-item measure of health-related quality of life. Overall utility score calculated. |
| Pain | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | Pain severity questions with pain manikin adapted for online administration. |
| Diet | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | Adapted National Secondary Students’ Diet and Activity questions, supplemented with adapted International Study of Childhood Obesity, Lifestyle and Environment items. |
| Allergy and eczema | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | Allergy and pet exposure questions from the HealthNuts study, parent reported. |
| Colouring | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | Questions adapted to self-report format from Paediatric Autoimmune Disease study colour chart; parent reported. |
| Medications and supplements | ● ● ● ● | ● ● ● ● | ● ● ● ● | ● ● ● ● | Medications and supplement questions modified from LSAC; parent reported. |

Continued
### Table 1  Continued

| Construct and measure                                      | Main | Mini | Home | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|------------------------------------------------------------|------|------|------|---------|------------------------|----------------------------------------|
| **Health, welfare and community services**                 |      |      |      |         |                        |                                        |
| Hospital admissions and health insurance                   | ●    | ●    | ●    |         | Child lifetime hospitalisations, healthcare card and insurance coverage questions modified from LSAC; parent reported | Branched questionnaire items about child’s lifetime hospital admissions (including age, diagnosis), and concession card/private health insurance coverage. |
| Health service use                                          | ●    | ●    | ●    |         | Use of service questions modified from LSAC; parent reported | Branched questionnaire items about child’s health service use and parent time spent on service use. |
| Community participation                                    | ●    | ●    | ●    |         | Community activity use questions modified from LSAC; parent reported | Branched questionnaire on community activity participation (e.g., team sports, music) in last year. |
| **Biological samples**                                     |      |      |      |         |                        |                                        |
| Venous blood                                               | ●    | ●    | ●    | ●      | S-Monovette Vacutainer: 2.7 mL K3 EDTA (05.1167.001), 9 mL K3 EDTA (02.1066.001), 7.5 mL lithium heparin liquid (01.1608.001), 9 mL serum gel with clotting activator (02.1388.001), Sarstedt, Australia | Approximately 28 mL blood from non-dominant arm of semireclining (45°), semifasted participants, processed into 0.5 mL aliquots. Up to 6 EDTA plasma, 6 EDTA buffy coat, 6 LiH plasma, 6 LiH buffy coat (viable cells) and 6 sera per participant. In addition, either a whole blood clot or 3 whole blood aliquots and a dried blood spot (see next row). All serum, plasma and clot samples frozen directly at −80°C on site, while buffy coat aliquots were prepared in a freeze mix (10% fetal bovine serum +10% dimethyl sulfoxide +80% basal medium eagle) and placed within CoolCells (BioTools, Australia) prior to control the rate of freezing at −80°C to maximise cell viability. |
| Dried blood spot                                           | ●    | ●    | ●    | ●      | Lancet (1.6 mm (No 85.1018) or 1.8 mm (No 85.1016) depth, Sarstedt Australia), Guthrie card | Card used for newborn screening is blotted with four drops of blood, collected via either a finger prick or pipetting a small amount of the venous whole blood sample. Stored at room temperature. |
| Construct and measure | Main | Mini | Home | Station | Equipment/instrument* | Data/sample collection protocol in brief |
|-----------------------|------|------|------|---------|-----------------------|------------------------------------------|
| **Urine**             | ●    | ●    | ●    | ●       | 70 mL screw cap polypropylene sterile pot (No 75.9922.731, Sarstedt, Australia) | Participant collects random urine sample into sterile urine pot, pipetted into 12×0.7 mL aliquots. Stored at −80°C on site. |
| **Saliva**            | ●    | ●    | ●    | ●       | 50 mL polypropylene sterile tube (FAL352070, Falcon, Corning, NY, USA) | 5 min passive saliva drool into sterile tube. Sample weighed, then pipetted into 6×0.5 mL aliquots. Stored at −80°C on site. |
| **Buccal swab**       | ○    | ●    | ●    | ●       | Buccal swab (Oracollect DNA OCR-100, The Hague, Netherlands. If not available, FloqSwab, COPAN Flock Technologies, Brescia, Italy was used). | Participant rubs swab over gums/inner cheeks. OCR-100: immerses swab in the preserving liquid, seals tube. Aliquotted into 2×0.5 mL aliquots. FloqSwab: seals swab in air-tight container. Stored at room temperature then −80°C. |
| **Hair**              | ●    | ●    | ●    | ●       | String, aluminium foil, envelope, scissors | Two locks of hair (4 mm in diameter) tied with string and cut close to the scalp from the occipital area under the crown. Hair wrapped in aluminium foil (scalp end identified) and stored in a barcoded envelope at room temperature. |
| **Toenails**          | ●    | ●    | ●    | ○       | Scissors, envelope | Clean toenails >3 mm trimmed from right big toe (if not available, left big toenail or fingernails) and stored at room temperature in barcoded envelope. |

Questionnaire measures are self-reported, unless indicated they were parent reported.

*All questionnaire items administered by iPad or laptop, except the pain manikin, which was completed on paper at home visits. For brevity, iPad or laptop is not listed for every questionnaire item. Open circles indicate sample collected from non-attending parent.

2D, two dimensional; 3D, three dimensional; Ch, data/sample collected relates to child participant; FrACT, Freiburg Visual Acuity and Contrast Test; LiH, lithium heparin; LSAC, Longitudinal Study of Australian Children; NIH, National Institutes of Health; P, data/sample collected relates to parent participant; VO₂max, maximum volume of oxygen consumed.
and ongoing staff training, time trials and testing knowledge of standard operating procedures. Inter-rater and intrarater reliability for data transcription and scoring was calculated, where relevant and possible. Data collection reliability was not available as the participant flow precluded repeated measures of same individual.

**Measures**

Measures and biological samples collected are briefly described in table 1. Other papers of this *BMJ Open Special Issue* provide greater detail, epidemiological description and parent-child concordance for many of these; and their rationale has been previously published. Data were collected electronically via specialist medical equipment/software or, where not possible, staff entered data into REDCap (Research Electronic Data Capture) electronic data collection tools. REDCap was also used to administer the child and parent questionnaires on iPads. Data collection and data processing standing operating procedures are available (see http://www.checkpoint-lsb.mcrl.edu.au). Measures were offered to both children and parents; however, the parent flow omitted the exercise stations (*Bike Hike* and *Jumping Beans*), time-use diary, postbronchodilator spirometry and toenail samples. Instead, parents completed a more detailed questionnaire about their child's healthcare (including hospitalisations), medications and use of community services; and their own health-related quality of life.

**Biospecimen collection and repository:** Biospecimens collected are described in table 1. Samples (except buccal swabs) were processed within hours in an on-site laboratory set up at all Main Assessment and most Mini Assessment Centres. Blood and saliva samples were generally processed within an hour (blood: range 1 min to 3.8 hours, median 53 min; saliva: range 1 min to 5.7 hours, median 44 min). Urine sample processing was delayed if collected away from a laboratory; 56% of urine samples processed within 3 hours (range 1 min to 9 days, median 71 min). At the completion of each Assessment Centre, a single batch of all frozen samples was shipped on dry ice to the Melbourne Children's Bioresource Centre (at the MCRI) for long-term storage at −80°C (except buffy coat aliquots are stored in vapour phase liquid nitrogen). A
temperature data logger was included in each shipment to confirm optimal temperature throughout. All other samples, kept at room temperature, were transported at the same time. All samples are stored in a deidentified manner and are only identified for extraction from the repository. Newly derived biospecimen data are linked to the participant by an external staff member using a linkage key. Samples were tracked using QR code scanners and FreezerPro Enterprise (RuRo, Maryland, USA) software. Frozen samples are stored in boxes of 96 aliquots, and aliquot picking is undertaken by hand (ie, not automated by robot). As of April 2019, completed biomarker analyses for all parents and children with relevant samples were serum metabolomics (http://www.nightingalehealth.com),22 39 40 urinary albumin-creatinine ratio,16 telomere length16 and genotyping; micronutrient and one-carbon pathway analyses were underway.

Data access
The LSAC data are available to researchers under licence, and from early 2019 include the first tranche of completed parent and child CheckPoint data. The LSAC website explains access to these data (http://www.growingupinaustralia.gov.au/data/data-accessmenu.html).

It is intended that all further CheckPoint data and biospecimens will also be accessible to all researchers. Applications to undertake new data extraction and biosamples, or to collaborate with CheckPoint investigators on in-train funded new data, are considered by CheckPoint's Data/Biospecimens Access Committees (see http://www.checkpoint-lsac.mcri.edu.au).

Statistical analyses
Sample characteristics, sample size and consent rates were described as counts, proportions, means and SDs. Baseline demographic characteristics of LSAC families who did and did not participate in CheckPoint were compared to consider the representativeness of the maintained CheckPoint sample in relation to preceding LSAC waves.

Survey weights
CheckPoint survey weights were created41 using methods similar to those used for previous waves of LSAC, and are provided in the CheckPoint data set. These methods account for the selection probability of each child to establish the target design sample, initial non-response to the baseline survey and subsequent loss to follow-up. LSAC and CheckPoint survey weights have been estimated to reflect the likelihood of participation from wave to wave within the limits of the information available from study measures.

Applying LSAC survey weights produces analyses that will be as representative as possible for all Australian children born in 2004 and their parents. CheckPoint differs in that, for the majority of measures, only the attending parent (usually the mother) was assessed, and thus weighted analyses of the parent data are more difficult to interpret because the weighting does not estimate a representative sample of all parents.

RESULTS
Below we summarise the vanguard participants' evaluation of the CheckPoint module. We then describe B cohort recruitment and reasons for non-participation in the CheckPoint module, and demographic characteristics of CheckPoint participants and non-responders. Lastly, we summarise data completeness for each measure, and biospecimen collection and consent rates.

In 2014, ahead of the main data collection wave, the vanguard families reported high levels of enjoying the CheckPoint visit (mean of 10: children 8.8, parents 8.2), recommending it to others (children 7.7, parents 9.0) and valuing the child health report provided on the day (children 7.7, parents 8.2). Children and parents were also asked if participating in the CheckPoint had changed how they feel about being in the LSAC study (from 1 'Like it much less' to 10 'Like it much more'); on average, participants liked LSAC more after their CheckPoint visit (mean: children 8.4, parents 7.7).

The CheckPoint sample size was fixed by LSAC retention to wave 6. Of a total of 3764 families who participated in wave 6, there were 3513 (93%) consented to CheckPoint contact, 3152 (84%) provided valid contact details and were invited into CheckPoint and 1875 (50%) participated (figure 1). One family withdrew consent after assessment. Thus, the CheckPoint analytic sample included 1874 parent–child pairs, plus 1051 non-attending resident parents.

Most non-participation (60%) was due to inability to attend or reschedule a visit during the short period CheckPoint was in each location. Far fewer families declined (18%).

Demographic characteristics of the CheckPoint sample and non-responders are summarised in table 2. Within the CheckPoint sample, 90% of attending parents and all non-attending participants were a biological parent of the study child. There was an equal distribution of boys and girls. However, the sample of attending parents did not equally or randomly comprise mothers and fathers, since each family decided which parent or guardian attended and most (88%) attending parents were mothers. Almost 90% of attending parents were nominated 'Parent 1’ (ie, the parent who knows the child best and completes the main questionnaire) in previous LSAC waves. The majority of CheckPoint families lived in major cities, with a distribution across the states and territories similar to the Australian population. Larger proportions of families were in the higher socioeconomic position quintiles than in the Australian population. Detailed comparisons of the LSAC sample to the Australian population have been published previously.11 42

Compared with B cohort families who did not take part in the CheckPoint, table 2 shows that participating families...
Table 2  Child Health CheckPoint sample characteristics

| Characteristic Values are %, unless indicated | Sample characteristics at CheckPoint (2015–2016)* n=1874 families | Baseline characteristics (2004)† In CheckPoint n=1874 families | Not in CheckPoint n=3233 families |
|---------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|----------------------------------|
| Child age in years, mean (SD)              | 12.4 (0.4)                                                    | 0.8 (0.2)                                                     | 0.8 (0.2)                        |
| Parent age in years, mean (SD)             | 44.4 (5.2)                                                    | 32.1 (4.9)                                                   | 30.4 (5.7)                       |
| Female child                               | 49.0                                                         | 49.0                                                          | 48.9                             |
| Female parent                              | 87.7                                                         | 98.7                                                          | 98.5                             |
| Child accompanied by biological parent     | 98.9                                                         | 99.7                                                          | 99.7                             |
| Child has indigenous background            | 2.0                                                          | 2.0                                                           | 6.0                              |
| Parent born in Australia                   | 79.0                                                         | 79.3                                                          | 81.2                             |
| Parent home language not English           | 10.8                                                         | 11.2                                                          | 16.3                             |
| Area of residence¶                         |                                                               |                                                               |                                  |
| Major city                                 | 70.3                                                         | 70.5                                                          | 64.0                             |
| Inner regional                             | 20.3                                                         | 18.0                                                          | 20.6                             |
| Outer regional                             | 8.7                                                          | 9.9                                                           | 12.8                             |
| Remote                                     | 0.8                                                          | 1.6                                                           | 2.6                              |
| Australian state/territory of residence   |                                                               |                                                               |                                  |
| Australian Capital Territory               | 2.8                                                          | 2.9                                                           | 1.6                              |
| Northern Territory                         | 1.6                                                          | 2.4                                                           | 1.3                              |
| New South Wales                            | 28.6                                                         | 29.9                                                          | 32.6                             |
| Queensland                                 | 21.5                                                         | 20.0                                                          | 20.1                             |
| South Australia                            | 8.0                                                          | 7.5                                                           | 6.4                              |
| Tasmania                                   | 3.3                                                          | 3.2                                                           | 1.6                              |
| Victoria                                   | 22.5                                                         | 22.2                                                          | 25.8                             |
| Western Australia                          | 11.8                                                         | 11.8                                                          | 9.7                              |
| Socioeconomic position,** mean (SD)        | 0.2 (1.0)                                                    | 0.3 (1.0)                                                     | −0.2 (1.0)                       |
| Neighbourhood disadvantage index††, mean (SD) and % in national quintiles | 1023 (60) | 1019 (61) | 1003 (59) |
| 1 (least disadvantaged quintile)           | 34.8                                                         | 29.0                                                          | 18.9                             |
| 2                                          | 23.4                                                         | 20.3                                                          | 19.8                             |
| 3                                          | 18.8                                                         | 19.3                                                          | 21.6                             |
| 4                                          | 14.8                                                         | 19.8                                                          | 21.7                             |
| 5 (most disadvantaged quintile)            | 8.2                                                          | 11.6                                                          | 18.1                             |
| Parent’s highest level of education        |                                                               |                                                               |                                  |
| Did not complete high school               | 20.1                                                         | 21.4                                                          | 39.0                             |
| High school                                | 44.4                                                         | 42.3                                                          | 39.9                             |
| Undergraduate degree (Bachelor)            | 23.6                                                         | 26.6                                                          | 15.5                             |
| Postgraduate degree                        | 11.9                                                         | 9.7                                                           | 5.7                              |
| Attending parent’s employment status       |                                                               |                                                               |                                  |
| Working full time (≥30 hours/week)         | 46.9                                                         | 31.8                                                          | 22.4                             |
| Working part-time                          | 37.4                                                         | 2.7                                                           | 1.6                              |
| Not currently working                      | 15.7                                                         | 65.5                                                          | 76.0                             |
| Parent has a spouse/partner                | 88.1                                                         | 95.7                                                          | 91.3                             |

*Data collected in CheckPoint 2015–2016 wave, except child Indigenous background collected at wave 1 (2004), and parent birth country, home language, educational qualifications and employment status; and family socioeconomic position collected at wave 6 (2014). Parent data=CheckPoint ‘attending parent’.†Data collected in wave 1 (2004). Parent data=‘Parent 1’. CheckPoint attending parent is the wave 1 Parent 1 for 89.3% of families.¶Australian Bureau of Statistics (ABS) Remoteness Area Code.86 **Longitudinal Study of Australian Children (LSAC)-derived family socioeconomic position z-score.87 Higher scores=greater advantage.††ABS Socio-Economic Indexes for Areas Index of Relative Socio-Economic Disadvantage.88
at baseline (2004) reported higher socioeconomic position and parental education, and lower likelihood of non-English-speaking or indigenous backgrounds.

Data completeness for each measure was high (table 3) at >92% of participants eligible for each measure, except for accelerometry and child pain. A shortage of accelerometers at certain points over the data collection period meant physical activity data were available for 74% of children and 77% of parents. Initial problems with the branching architecture of questions meant pain data were available for only 85% of children (but 99% of parents). The most common reasons for missing data were the measure not being included in all visit types, followed by equipment unavailability, participant refusal and erroneous data removed in the preparation of the data set. Data from all of the measures listed in table 3 are included in the first CheckPoint data release in early 2019, except the handwritten story; retinal, oral and facial photographs; and telomere length.

Biospecimen collection rates were also high (table 4) for blood (venous or finger prick, 91% of children and 96% of attending parents) and other biological samples (>70%). Most (95%) of children and parents had either a saliva (collected when laboratory facilities were available) or buccal swab (stable for 60 days before processing) sample. Consent was obtained for ≥97% of samples to be shared with other researchers and used for genetic analyses, and for ≥94% of participants’ digital images to be shared with other researchers and child perinatal birth data and neonatal blood spots be accessed. Buccal samples were also collected from 1051 non-attending parents (of whom 94% consented to share, and 98% to undertake genetic analyses). In total, 1021 (55%) families have at least one sample available for the child and both biological parents.

DISCUSSION

Principal findings

The Child Health CheckPoint provides a paired cross-generational snapshot of the health of Australian children aged 11–12 years and their parents who took part in the CheckPoint assessment (mostly mothers). Data completeness was high among the nearly 2000 families who participated. The utility of the data and biospecimens is further enhanced by near-universal consent for genetic analysis and sharing with other researchers. Enriching LSAC’s lifelong environmental data with CheckPoint’s biological data strengthens the utility of LSAC to address important questions on how NCDs develop phenotypically before overt disease is evident, and shed light on the underlying dimensionality of health at different life stages.

Key logistic challenges faced by the CheckPoint were its short-time window both to plan and conduct (a fixed 12 months from February 2015), the sheer size of Australia (approximately the same as continental USA) and the limited funding allowing for only one set of heavy equipment and thus curtiling the period during which the CheckPoint was available to participants in each city.

Strengths and limitations

Strengths of LSAC include its large population-based sample, data linkage, historical repeated measures and open data access. Strengths of the CheckPoint module include the sophistication of its health assessments, and the cross-generational child–parent assessments paired on time of assessment, protocols and equipment. Utility of the CheckPoint data is strengthened by its timing relative to child age (ie, adolescence onset) and LSAC duration (ie, 10 years of data already available); and its timely release of curated data to researchers (within 3 years of data collection), with more to come as data scoring and biomarker analyses are completed. The CheckPoint is led by diverse and specialty-based researchers, who continue to develop multisystem hypotheses and discovery research. We have prioritised harmonisation of methods with other internationally significant cohorts (eg, utilisation of the Nightingale metabolomics and Illumina Global Screening Array genotyping platforms). Finally, the CheckPoint module was enjoyable for participants, and its impact on participant retention in future LSAC waves will be examined.

The sample reflects the broader Australian population in many attributes, including state/territory of residence. A limitation (that can be partly addressed by using survey weights) is that families were more likely to live in major cities and have a higher socioeconomic status than non-participants and Australians in general. The limitation that the majority of the parent sample are mothers reflects the design of the study and cannot be addressed using survey weights so should be considered and noted in all analyses of parents. Due to sample attrition, the final number of parent–child dyads was only around 1900, limiting power for rare exposures and outcomes; this is partly offset by LSAC’s common exposures, and CheckPoint’s focus on continuous outcome measures. Almost all measures were collected from only one of the child’s parents, although family studies will be possible for the 55% of families for whom we collected a DNA sample from both parents. A further potential limitation is that LSAC does not have prospective prenatal data on the children, although it does include prospective data from very early life (child age at wave 1 spanned 3–19 months) and permission to link to birth data.

Implications and future research

The wealth and depth of longitudinal LSAC data available gives important context to CheckPoint’s health and biomarker data. To commence a brand-new cohort incorporating these measures is exceptionally expensive and would have set back the availability of such data by decades, at a time when other prominent efforts to do so internationally have failed. Other internationally significant efforts, such as the US Environmental Influences On Child Health Outcomes (ECHO) Program,
Table 3  Sample size by measure and participant group

| Construct          | Measure                                      | Children n=1874 | Parents n=1874 | Biological n=1854 | 2019 Data release |
|--------------------|----------------------------------------------|-----------------|-----------------|-------------------|-------------------|
|                    |                                              | Study n=1874    | All n=1874      | All n=1854        |                   |
| Anthropometry      | Height, weight                               | 1873 (99.9)     | 1865 (99.5)     | 1845 (98.5)       | 1864 (99.5)       |
|                    | Body composition*                           | 1859 (99.2)     | 1844 (98.4)     | 1824 (97.3)       | 1837 (98.0)       |
| Pubertal status    | Puberty Development, Sexual Maturity scales | 1807 (96.4)     | –               | –                 | –                 |
|                    | Menstruation†                                | 844 (45.0)      | 1610 (85.9)     | 1598 (85.3)       | 740 (39.5)        |
|                    | Modified Comprehensive Acne Severity Scale  | 1762 (84.0)     | –               | –                 | –                 |
| Bone, muscle       | Peripheral quantitative CT                   | 1271 (67.8)     | 1250 (66.7)     | 1240 (66.2)       | 1231 (65.7)       |
| Cardiovascular     | Carotid intima-media thickness              | 1489 (79.5)     | 1476 (78.8)     | 1463 (78.1)       | 1462 (78.0)       |
|                    | Pulse wave velocity, pulse wave analysis    | 1836 (98.0)     | 1790 (95.5)     | 1773 (94.6)       | 1769 (94.4)       |
|                    | Blood pressure                              | 1777 (94.8)     | 1749 (93.3)     | 1732 (92.4)       | 1682 (89.8)       |
|                    | Microvascular structure (retinal photography)| 1307 (69.7)     | 1317 (70.3)     | 1307 (69.7)       | 1292 (68.9)       |
| Respiratory        | Spirometry                                   | 1759 (93.9)     | 1774 (94.7)     | 1754 (93.6)       | 1688 (90.1)       |
| Language           | Expressive and receptive language (Recall' Sent) | 1441 (76.9) | 1446 (77.2)     | 1433 (76.5)       | 1415 (75.5)       |
|                    | Receptive vocabulary (NPVT)                 | 1443 (77.0)     | 1457 (77.7)     | 1444 (77.1)       | 1401 (74.8)       |
| Hearing            | Pure tone audiometry                         | 1488 (79.4)     | 1493 (79.7)     | 1480 (79.0)       | 1480 (79.0)       |
|                    | Tympanometry                                 | 1099 (58.6)     | 1101 (58.8)     | 1092 (58.3)       | 1065 (56.8)       |
|                    | Speech reception threshold (LiSN-S)          | 1483 (79.1)     | 1482 (79.1)     | 1469 (78.4)       | 1466 (78.2)       |
| Diet and food      | National Secondary Students’ Diet and Activity | 1846 (98.5) | 1862 (99.4)     | 1846 (98.5)       | 1837 (98.0)       |
| choices            | Snack observation                            | 1294 (69.1)     | 1246 (66.5)     | 1235 (65.9)       | 1205 (64.3)       |
|                    | Physical activity, time use                 | 1382 (73.7)     | 1440 (76.8)     | 1424 (76.0)       | 1223 (65.3)       |
|                    | Time-use diary (MARCA)                       | 1830 (97.7)     | –               | –                 | –                 |
| Strength and       | Eurofit broad jump                           | 1771 (94.5)     | –               | –                 | –                 |
| fitness            | PWC170 VO,max test                           | 1301 (69.4)     | –               | –                 | –                 |
| Vision             | Freiburg Visual Acuity Test                 | 1494 (79.7)     | 1491 (79.6)     | 1478 (78.9)       | 1481 (79.0)       |
| 2D and 3D          | 2D and 3D photos of teeth and tongue         | 1486 (79.3)     | 1480 (79.0)     | 1467 (78.3)       | 1478 (78.9)       |
| photography        | 3D photos of face                            | 1331 (71.0)     | 1316 (70.2)     | 1305 (69.6)       | 1313 (70.1)       |
| Handwriting,       | Handwritten story about life at age 25       | 1811 (96.6)     | –               | –                 | –                 |
| written language   |                                              |                 |                 |                   |                   |
| General well-being | ISCW and PedsQL General Well-Being          | 1860 (99.3)     | –               | –                 | –                 |
| Health-related     | PedsQL, Child Health Utility 9D, AQoL-8D‡   | 1854 (98.9)     | 1871 (99.8)     | 1853 (98.9)       | 1854 (98.9)       |
| quality of life    |                                              |                 |                 |                   |                   |
| Pain               | Pain§                                         | 1586 (84.6)     | 1859 (99.2)     | 1843 (98.3)       | 1576 (84.1)       |
| Natural colouring  | Skin, hair and eye colour                    | 1859 (99.2)     | 1859 (99.2)     | 1843 (98.3)       | 1859 (99.2)       |
| Medications,       | Current medications and supplements          | 1853 (98.9)     | –               | –                 | –                 |
| supplements        |                                              |                 |                 |                   |                   |

Continued
Table 3

| Construct/Measure | Children n=1874 | Parents | Biological n=1854 | Parent–child pairs |
|-------------------|----------------|---------|------------------|--------------------|
|                   | All n=1874    | All n=1874 | All n=1874       | 2019 Data release |
| Health, welfare and community services | Health service use, hospital admissions | 1874 (100.0) | – | – | – | – | ● |
|                   | Community participation and services | 1822 (97.2) | – | – | – | – | ● |
| Serum metabolites | NMR metabolomics platform | 1180 (63.0) | 1325 (70.7) | 1313 (70.1) | 1139 (60.8) | 1133 (60.5) | ● |
| Renal function    | Urinary albumin and creatinine concentration | 1579 (84.3) | 1671 (89.2) | 1653 (88.2) | 1535 (81.9) | 1518 (81.0) | ● |
| Biological ageing | Telomere length | 1206 (64.4) | 1343 (71.7) | 1330 (71.0) | 1151 (61.4) | 1143 (61.0) |

Values are n (%) of participants or pairs with data available. These may differ slightly from sample sizes presented in other CheckPoint papers in this BMJ Open Special Issue, where authors have restricted analyses to participants meeting specified levels of data quality or completeness. ‘All parents’ and ‘all parent–child pairs’ include biological and non-biological (eg, step, adoptive or biological relatives other than mother or father) parent–child relationships. Parent–child pairs include families where both the child and the parent have data available for that measure.

*381 children and 344 parents have body fat % measured using a two-limb BIA scale at home visits; the remainder have detailed body composition measured using a four-limb BIA scale.
†Girls were asked ‘has menstruation started’ and ‘are you menstruating today?’ and women were asked ‘are you menstruating today?’
‡Children completed the PedsQL; parents completed the AQoL-8D and both children and parents completed the Child Health Utility 9D.
§Parents completed a subset of the pain questions completed by children.

AQoL-8D, Assessment of Quality of Life 8D; BIA, bioelectrical impedance analysis; ISCW: International Survey of Children’s Well-Being; LiSN-S, Listening in Spatialised Noise–Sentence Test; MARCA, Multimedia Activity Recall for Children and Adults; NMR, nuclear magnetic resonance; NPVT, National Institute of Health Picture Vocabulary Test; PedsQL, Pediatric Quality of Life.

Table 4

| Measure or sample | Children n=1874 | Attending parents n=1874 |
|-------------------|----------------|-------------------------|
|                   | Data/sample collected | Consent to share | Consent to genetic analyses | Data/sample collected | Consent to share | Consent to genetic analyses |
| Digital images (photos) | | | | | | |
| 2D and 3D teeth | 1486 (79.3) | 1398 (94.1) | – | 1480 (79.0) | 1397 (94.4) | – |
| 3D face | 1331 (71.0) | 1251 (94.0) | – | 1316 (70.2) | 1241 (94.3) | – |
| Retinal | 1307 (69.7) | 1229 (94.0) | – | 1317 (70.3) | 1240 (94.2) | – |
| Perinatal birth data* | 1838 (98.1) | – | – | – | – | – |
| Newborn Guthrie card* | 1810 (96.6) | 1760 (97.2) | 1775 (98.1) | – | – | – |
| Blood | 1701 (90.8) | 1646 (96.8) | 1673 (98.4) | 1792 (95.6) | 1731 (96.6) | 1762 (98.3) |
| Plasma | 1230 (65.6) | 1196 (97.2) | 1211 (98.5) | 1371 (73.2) | 1331 (97.1) | 1353 (98.7) |
| Serum | 1192 (63.6) | 1160 (97.3) | 1174 (98.5) | 1336 (71.3) | 1297 (97.1) | 1319 (98.7) |
| Whole blood/clot | 1223 (65.3) | 1189 (97.2) | 1204 (98.4) | 1358 (72.5) | 1318 (97.1) | 1340 (98.7) |
| Guthrie card | 1424 (76.0) | 1382 (97.1) | 1405 (98.7) | 1468 (78.3) | 1421 (96.8) | 1446 (98.5) |
| Urine | 1595 (85.1) | 1548 (97.1) | 1571 (98.5) | 1686 (90.0) | 1637 (97.1) | 1662 (98.6) |
| Saliva | 1375 (73.4) | 1327 (96.5) | 1350 (98.2) | 1392 (74.3) | 1347 (96.8) | 1370 (98.4) |
| Buccal | 398 (21.2) | 385 (96.7) | 392 (98.5) | 390 (20.8) | 378 (96.9) | 383 (98.2) |
| Hair | 1390 (74.2) | 1343 (96.6) | 1365 (98.2) | 1439 (76.8) | 1397 (97.1) | 1418 (98.5) |
| Toenail | 1586 (84.6) | 1534 (96.7) | 1561 (98.4) | – | – | – |

Values are n (%). Data/sample collected % is the proportion of the sample (√/1874). Consent % is the proportion of participants who provided data/sample(s).

*Access to these data has been consented to by participants, but not yet attempted by the study team as of April 2019.
are now taking a similar approach to CheckPoint. For example, ECHO is enriching existing traditional child cohorts with additional cutting-edge biophysical modules and forward harmonisation. This will add great value to these cohorts and to knowledge that can be generated from their interrogation.

In the study's first decade, over 500 papers have been published using LSAC data. Child health is one of the most common topics of LSAC papers, and many of these health-related research questions could be extended on now that the CheckPoint data are available. For example, research papers on the parent-reported health comorbidities of overweight or short sleep duration published by our group could be extended to include comprehensive objective measures of segmental body composition, 24 hours' time use including sleep and a range of health outcomes (eg, serum blood parameters, arterial structure and function). The greater precision brought by using these measures may reveal nuances in the associations not detectable using reported measures. Many new health-related questions are also now able to be examined, as LSAC's broad range of early life exposures is reflected in peripubertal metabolic health and development of a wide range of body systems. In addition, the CheckPoint data set will be augmented with genetic data in late 2019, which will facilitate gene-environment analyses for the first time in this cohort.

In summary, the efficient addition of objective health measures and biospecimens into the open-access LSAC repository greatly increases the utility of this widely used data set. Analysis of the CheckPoint data holds great promise in integrating cutting-edge measures of mid-childhood physiology with lifetime trajectories of mental and physical health, growth, behaviour and healthcare within a single population study. The data’s utility will continue to grow as ongoing waves of the main LSAC study accrue into adulthood, when CheckPoint health data will be able to be examined both as outcomes of early life exposures (LSAC waves 1–6) and predictors of later life health (LSAC wave 7 onwards).

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REFERENCES

1. Shonkoff JP. Building a new biodevelopmental framework to guide the future of early childhood policy. Child Dev 2010;81:357–67.
2. Khoury MJ, Lam TK, Ioannidis JP, et al. Transforming epidemiology for 21st century medicine and public health. Cancer Epidemiol Biomarkers Prev 2013;22:508–16.
3. Lauer MS, Gordon D, Wei G, et al. Efficient design of clinical trials and epidemiological research: is it possible? Nat Rev Cardiol 2017;14:493–501.
4. Connelly R, Platt L. Cohort profile: UK Millennium Cohort Study (MCS). Int J Epidemiol 2014;43:1719–25.
5. Greene S, Williams J, Layte R, et al. Growing Up in Ireland: Background and Conceptual Framework. Dublin, Ireland: Office of the Minister for Children and Youth Affairs, Department of Health and Children, 2010.
6. Morton SM, Atabaa Carr PE, Grant CC, et al. Cohort profile: Growing Up in New Zealand. Int J Epidemiol 2013;42:65–75.
7. Sot SE, Tint MT, Gluckman PD, et al. Cohort profile: Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. Int J Epidemiol 2014;43:1401–9.
8. Sanson A, Johnstone R. The LSAC Research Consortium & FaCS LSAC Project Team. Growing Up in Australia takes its first steps. Family Matters 2004;67:46–53.
9. Wake M. Tracking the health of the next generation: Sax Institute. 2016 https://www.saxinstitute.org.au/news/tracking-the-health-of-the-next-generation/.
10. Soloff C, Lawrence D, Johnstone R. LSAC technical paper number 1: Sample design. Melbourne: Australian Institute of Family Studies, 2005.
11. Cusack B, Defina R. LSAC technical paper number 10: Wave 5 weighting and non response. Melbourne: Australian Institute of Family Studies, 2013.
12. Welsh L, Kathirasevong G, Raheem T, et al. Spironometry: population epidemiology and concordance in 11-12 year old Australian children and their parents. BMJ Open 2019;9(suppl 3):53–62.
13. Vlokh J, Simm PJ, Clifford SA, et al. qQCT bone geometry and strength: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):63–74.
14. Vivarini P, Kerr JA, Grobler AC, et al. Food choices: concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):147–56.
15. Smith J, Wang J, Grobler AC, et al. Hearing, speech reception, vocabulary and language: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):118–26.
16. Matricciani L, Frayssie F, Grobler AC, et al. Sleep: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):127–35.
17. Liu RS, Dunn S, Grobler AC, et al. Carotid artery intima-media thickness, distensibility, and elasticity: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):23–33.
18. Larkins NG, Kim S, Carlin JC, et al. Albuminuria: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):136–46.
19. Dascaliu J, Lui M, Lycett K, et al. Retinal microvasculature: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):44–52.
20. Clifford SA, Gillespie AN, Olds TS, et al. Body composition: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):106–17.
21. Catchpool M, Gold L, Grobler AC, et al. Health-related quality of life: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):95–105.
22. Ellul S, Wake M, Clifford SA, et al. Metabolomics: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):34–43.
23. Ellul S, Wake M, Clifford SA, et al. Vascular function and stiffness: population epidemiology and concordance in Australian children aged 11-12 years and their parents. BMJ Open 2019;9(suppl 3):3–43.
24. Boyd A, Golding J, Macleod J, et al. Cohort Profile: the ‘Children of the 90s’—the index offspring of the Avon Longitudinal Study of Parents and Children. Int J Epidemiol 2013;42:111–27.
25. Straker L, Mountain J, Jacques A, et al. Cohort Profile: The Western Australian Pregnancy Cohort (Raine) Study—Generation 2. Int J Epidemiol 2017;46:dyw308–35.
26. Australian Institute of Family Studies. Longitudinal Study of Australian Children Data User Guide. Melbourne: Australian Institute of Family Studies, 2015.
27. Wake M, Canterford L, Nicholson J, et al. Options for physical and psychomotor augmentation in LSAC: Discussion paper, 2008.
28. Wake M, Gallagher S, Poulakis Z, et al. The Parent Education and Support (PEAS) Program: Final report. Melbourne, Australia: Centre for Community Child Health, Royal Children’s Hospital, 2003.
29. Wake M, Baur LA, Gernen B, et al. Outcomes and costs of primary care surveillance and intervention for overweight or obese children: the LEAP2 randomised controlled trial. BMJ 2009;339:b3308.
30. Wake M, Lycett K, Sabin MA, et al. A shared-care model of obesity treatment for 3-10 year old children: protocol for the HopSCOTCH randomised controlled trial. BMJ Paediatrics Open 2012;2:35–39.
31. Harvey AN, Mensah FK, Clifford SA, et al. Adolescent cardiovascular functional and structural outcomes of growth trajectories from infancy: prospective community-based study. Child Obes 2017;13:154–63.
32. Harvey AN, Clifford SA, Mensah FK, et al. Which body composition measures are associated with cardiovascular function and structure in adolescence? Obes Med 2016;3:20–7.
33. Olds TS, Ridley K, Dollman J, et al. The validity of a computerized use of time recall, the Multimedia Activity Recall for Children and Adolescents. Pediatr Exerc Sci 2010;22:34–43.
34. Dascaliu J, Clifford SA, Gillespie AN, et al. Longitudinal Study of Australian Children’s Child Health CheckPoint Data Issues Paper - December 2018. Melbourne, Australia: Murdoch Children’s Research Institute, 2018.
35. Wake M, Clifford SA, York E, et al. Introducing Growing Up in Australia’s Child Health CheckPoint, Family Matters 2014;35:15–23.
36. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377–81.
37. Soh SE, Tint MT, Gluckman PD, et al. Cohort profile: Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. Int J Epidemiol 2014;43:1401–9.
40. Kettunen J, Tukiainen T, Sarin AP, et al. Genome-wide association study identifies multiple loci influencing human serum metabolite levels. *Nat Genet* 2012;44:269–76.

41. Ellul S, Hiscock R, Mensah FK, et al. Longitudinal Study of Australian Children’s Child Health CheckPoint Technical Paper 1: Weighting and Non-Response. Melbourne: Murdoch Children’s Research Institute, 2018.

42. Edwards B. Growing Up in Australia: The Longitudinal Study of Australian Children: Entering adolescence and becoming a young adult. Family Matters 2014:95–5.

43. Pearson H. Massive UK baby study cancelled. *Nature* 2015;526:620–1.

44. Landrigan PJ, Baker DB. The National Children’s Study—end or new beginning? *N Engl J Med* 2015;372:1466–7.

45. Scherdt DW. Rowing a New Study: Environmental Influences on Child Health Outcomes. *Environ Health Perspect* 2015;123:A260–3.

46. Wake M, Clifford SA, Patton GC, et al. Morbidity patterns among the overweight, obese and obese between 2 and 18 years: population-based cross-sectional analyses. *Int J Obes* 2013;37:86–93.

47. Price AMH, Quarach J, Wake M, et al. Cross-sectional sleep thresholds for optimal health and well-being in Australian 4-9-year-olds. *Sleep Med* 2016;22:83–90.

48. Marfell-Jones M, Olds T, Stewart A, et al. International Standards for Anthropometric Assessment. Potchefstroom, RSA: North-West University, 2006.

49. World Health Organization. Physical status: The use of and interpretation of anthropometry: report of a WHO expert committee. *WHO Technical Report Series*. Geneva, 2000;854.

50. Morris NM, Udry JR. Validation of a self-administered instrument to assess stage of adolescent development. *J Adolesc* 1989;80:271–80.

51. Petersen AC, Crockett L, Richards M, et al. A self-report measure of pubertal status: Reliability, validity, and initial norms. *J Youth Adolesc* 1988;17:117–33.

52. Tan JK, Tang J, Fung K, et al. Development and validation of a comprehensive acne severity scale. *J Cutan Med Surg* 2007;11:211–6.

53. Moy-Thomas LJ, Quick JL, Murray MA. Peripheral quantitative computed tomography of the tibia: pediatric reference values. *J Clin Densitom* 2008;11:283–94.

54. Zemel BS. Quantitative computed tomography and computed tomography in children. *Curr Osteoporos Rep* 2011;9:284–90.

55. Stein JH, Korczac CE, Hurst RT, et al. Use of carotid ultrasound to identify subclinical vascular disease and evaluate cardiovascular disease risk: a consensus statement from the American Society of Echocardiography Carotid Intima-Media Thickness Task Force. Endorsed by the Society for Vascular Medicine. *J Am Soc Echocardiogr* 2008;21:93–111.

56. Clifford SA, et al. BMJ Open 2019;9:3–22. doi:10.1136/bmjopen-2017-020261

60. Cameron S, Glyde H, Dillon H. Listening in Spatialized Noise-Sentences Test (LISN-S): normative and retell reliability data for adolescents and adults up to 60 years of age. *J Am Acad Audiol* 2011;22:697–709.

61. National Acoustic Laboratories. Listening in Spatialised Noise Sentences Test (LISN-S). 2015 https://www.nal.gov.au/products/licensed-products/listening-in-spatialized-noise-sentences-test-lisn-s.

62. Eslinger DW, Rowlands AV, Hurst TL, et al. Validation of the GENEA Acoustic Accelerometer. *Med Sci Sports Exerc* 2011;43:1095–83.

63. Ridley K, Ainsworth BE, Olds TS. Development of a compendium of energy expenditures for youth. *Int J Behav Nutr Phys Act* 2008;5:45.

64. Foley LS, Maddison R, Rush E, et al. Doubly labeled water validation of a computerized use-of-time recall in active young people. *Med Sci Sports Exerc* 2007;39:1576–83.

65. Ortega FB, Ruiz JR, Castillo MJ, et al. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes* 2008;32:1–11.

66. Boreham CA, Paliczkka VJ, Nichols AK. A comparison of the PWC170 and 20-MST tests of aerobic fitness in adolescent schoolchildren. *J Sports Med Phys Fitness* 1990;30:19–23.

67. Bach M. The Freiburg Visual Acuity test--automatic measurement of visual acuity. *Optom Vis Sci* 1996;73:49–53.

68. Ellis J, Morrow V. Imagining the Future: Preliminary analysis of NCDS essays written by children at age 11. London: Centre for Longitudinal Studies, 2007.

69. Seligson JL, Huebner ES, Valois RF. Preliminary Validation of the Brief Multidimensional Students’ Life Satisfaction Scale (BMSLSS). *Soc Indic Res* 2003;61:121–45.

70. Children’s Worlds. International Survey of Children’s Well-Being. 2017. Available from. http://iscweb.org.

71. Varni JW, Seid M, Kurtin PS. PedsQL 4.0: reliability and validity of the Pediatric Quality of Life Inventory version 4.0 generic core scales in healthy and patient populations. *Med Care* 2001;39:800–12.

72. Richardson J, Iezzi A, Khan MA, et al. Validity and reliability of the Assessment of Quality of Life (AQoL)-BD multi-attribute utility instrument. *Patient* 2014;7:85–94.

73. Stevens K. Assessment of performance of a new generic measure of health-related quality of life for children and refining it for use in health state valuation. *Appl Health Econ Health Policy* 2011;9:157–69.

74. Derogatis LR, Lipman RS, Covi L. SCL-90: an outpatient psychiatric rating scale—preliminary report. *Psychopharmacol Bull* 1973;9:13–28.

75. Jones GT, Watson KD, Silman AJ, et al. Predictors of low back pain in British schoolchildren: a population-based prospective cohort study. *Pain* 2003;111(4 Pt 1):822–8.

76. Flood VM, Webb K, Rangan A. Recommendations for short questions to assess food consumption in children for the NSW Health Surveys, 2005.

77. Saloheimo T, Gonzalez SA, Erkko M, et al. The reliability and validity of a short food frequency questionnaire among 9–11-year-olds: a multinational study on three middle-income and high-income countries. *Int J Obes Suppl* 2015:5:S22–S28.

78. Koplin JJ, Wake M, Dharmage SC, et al. Cohort Profile: The HealthNuts Study: Population prevalence and environmental/ genetic predictors of food allergy. *Int J Epidemiol* 2015;44:116–71.

79. Peters RL, Koplin JJ, Gurrin LC, et al. The prevalence of food allergy and other allergic diseases in early childhood in a population-based study: HealthNuts age 4-year follow-up. *J Allergy Clin Immunol* 2017.

80. Peczic A, Ponsoby AL, Cameron FJ, et al. Constitutive and relative facultative skin pigmentation among Victorian children including comparison of two visual skin charts for determining constitutive melanin density. *Photochem Photobiol* 2013;89:714–23.

81. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS): Volume 5 - Remoteness Structure, July 2011 (cat. no. 1270.0.55.005) Australian Bureau of Statistics, 2011.

82. Blakemore T, Strazdins L, Gibbins J. Measuring family socioeconomic position. *Australian Social Policy* 2009;9:121–68.

83. Australian Bureau of Statistics. Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA) Australia 2011 (cat. no. 2033.0.55.001). http://www.abs.gov.au/websitedbs/censushome/nsw/ home/seifa2011.