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Profile of the PLAY spaces & environments for children's physical activity, sedentary behaviour and sleep (PLAYCE) cohort study, Western Australia

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Abstract

Background Childhood is a critical period for the development of movement behaviours such as physical activity, sleep and sedentary behaviour. The PLAYCE Cohort was established to investigate how movement behaviours change over early to middle childhood, across key behaviour settings and relationships with health and development. An overview of the PLAYCE cohort, summary of key findings to date, and future research opportunities are presented.

Methods Children were recruited at 2–5 years of age (preschool; Wave 1) via early childhood education and care (ECEC) services and were followed up in junior primary school (5–7 years; Wave 2) at 8–10 years (Wave 3) and again at 11–13 years (Wave 4; in progress). Children's movement behaviours were measured via parent-report and accelerometry. Social-emotional development, motor development, weight status, diet, and child and family socio-demographics were parent-reported. Physical environmental features of children's key behaviour settings (home, neighbourhood, ECEC and school) were collected using geo-spatial and audit data.

Results to date At wave 1 (2–5 years), only 8% of children met all three recommendations of the Australian 24-hour Movement Guidelines for the Early Years. Meeting all recommendations (8%) was positively associated with boys social-emotional development. Physical environment features of the home yard (size, play equipment, natural features) were positively associated with preschool children's physical activity. Tree canopy and more portable play equipment in ECEC outdoor areas was also positively associated with children's outdoor time and physical activity.

Conclusions Wave 4 (11–13 years) data collection will be completed in early 2026. Traditional longitudinal and compositional data analysis of the PLAYCE cohort will be undertaken. Four waves of data will provide detailed patterns of movement behaviours and their effect on child health and development as well as the environmental influences on children's movement behaviours across early to middle childhood. The findings can be used to inform national and international 24-Hour Movement Guidelines and behaviour setting-specific as well as population-level interventions to benefit child health and wellbeing across early to middle childhood.

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Keywords Child, Cohort, Movement behaviour, Physical activity, Sedentary, Sleep, Diet, Obesity, Development, Environment

Background

Childhood is a critical period for the development of key movement behaviours such as regular physical activity, adequate sleep, and minimising sedentary behaviour. The establishment of such behaviours provides the foundation for lifelong health [1, 2] and impacts child health and development outcomes including weight status, cardiorespiratory fitness, the musculoskeletal system, and cognitive and psychosocial development [3–8].

Along with Canada, Australia released the first 24-hour Movement Guidelines for the Early years in 2018 [9, 10]. These guidelines consider physical activity, sedentary behaviour (including screen time), and sleep as three co-dependent behaviours. Meeting all three movement behaviour recommendations is optimal for child health and development compared with the attainment of a single recommendation [5, 11–15]. A large proportion of young Australian children do not achieve movement behaviour guidelines [16, 17]. However, estimates vary substantially by age, guideline, and data collection methods. For instance, parent-reported surveillance data suggests 61% of Australian children aged 2–5 years achieve the recommended daily 180 min of total physical activity, while only 32% of children aged 5–9 years achieve the recommended daily 60 min of moderate-to-vigorous physical activity [18]. In contrast, using device-based measures between 31 and 93% of Australian children aged between 2 and 5 years achieve physical activity guidelines [19, 20] with fewer than 15% of children meeting all three movement behaviours [19, 20]. Device-based data from 10-12-year-olds indicates 48–65% [21, 22] meet physical activity guidelines and 12–21% [21, 22] meet all three guidelines. To date, most Australian research on children's movement behaviours has been cross-sectional, with a few recent studies publishing findings from longitudinal analyses [23–25]. Thus, it is not known if children who meet movement behaviour guidelines in their early years continue to do so as they progress into middle childhood, and what impact this has on their health (e.g., weight status) and development (e.g., social-emotional, cognitive, motor/physical).

Internationally, a few studies have used device-based measures to track movement behaviours during early to middle childhood. For example, the Sogn og Fjordane Preschool Physical Activity Study (PRESPAS) followed 294 Norwegian preschoolers annually over five years to measure physical activity and sedentary time using accelerometery [26]. Total physical activity was found to peak at age five, whereas boys had a later peak (at eight years) than girls (at seven years) for moderate to vigorous intensity physical activity [26]. Sedentary time increased from the age of three years in girls and four years in boys [26]. Larger early childhood cohort studies are needed to better understand how movement behaviours change across early childhood, the influence of key behaviour settings (i.e., home, neighbourhood, ECEC and school) on young children's movement behaviours and the longitudinal relationship with health and development outcomes.

There is evidence that higher levels of physical activity and lower levels of sedentary behaviour are associated with reduced adiposity, improved motor skills, improved cardiorespiratory fitness, and improved cardiometabolic health among children [10, 27, 28]. However, the relationships between different combinations of physical activity, sedentary behaviour, and sleep and children's development are less clear. Two of the few studies conducted to date have shown meeting all three movement guidelines is associated with improved behavioural outcomes (i.e., strengths and difficulties scores) [13] and some aspects of academic achievement (i.e., literacy and numeracy) [21] in school-aged children. Longitudinal studies are needed to determine the relationship between children's movement behaviours and health and development starting from early childhood.

Another key evidence gap is the longitudinal effects of the environment on movement behaviours across early childhood. Ecological models of behaviour change consider the environmental and policy contexts of behaviour, while incorporating social and psychological influences [29]. How movement behaviours accumulate over time may differ across different temporal contexts such as ECEC, full-time school and home. To date it appears only one small Australian study has examined the impact of sedentary behaviour as young children transition from ECEC to school. It showed that school transition was marked by an increase of 40 min per day of sedentary time and an increase in sedentary bouts during school time [30]. Two small international studies have also reported declines in young children's physical activity as they transition to full-time school [31, 32]. These studies were limited by a single short period of follow up, thus it is unclear if these effects are permanent or transitionary. Longitudinal studies are needed to determine how movement behaviours vary individually (and together) over time across home, ECEC and school to provide necessary evidence of the influence of different time-dependent contexts on young children's movement behaviours.

The overarching aim of the PLAY Spaces and Environments for Children's Physical Activity (PLAYCE) cohort

study is to examine changes in Western Australian children's movement behaviours, the influence of setting-specific (ECEC/school, home, neighbourhood) physical, social, and policy environmental factors, and the impact on child health and development outcomes. The purpose of this 'cohort profile' paper is to provide an overview of the PLAYCE cohort study, summarise key findings to date, and identify future research opportunities. A cohort profile paper is an important step between a study protocol and results paper. It is used to describe the rationale for a cohort's creation, its methods, baseline data and its future research opportunities [33].

Methods

Cohort study design

The PLAYCE cohort study is an observational prospective study of 1,918 young children in Perth, Western Australia. Recruitment occurred from April 2015 to April 2018 (aged 2–5 years; wave 1). Three waves of follow-up occurred: during junior primary school, when aged 5–7 years (wave 2; October 2018 to June 2021) and during middle childhood, when aged 8–10 years (wave 3; July 2021 to December 2023) and again when aged 11–13 years (wave 4; October 2024-present). At all waves, multiple modes of data collection were utilised allowing for comprehensive measurement of children's movement behaviours (through accelerometry and parent surveys), setting-specific environmental factors (through physical environment audits, policy audits, parent surveys, educator practice surveys, and Geographic Information Systems (GIS)), and child health and development outcomes (through anthropometry measurement, parent surveys, observations and assessments).

Eligibility and recruitment

Children were recruited from the ECEC service they attended. ECEC services were randomly sampled and recruited evenly across low, medium and high socioeconomic area and service size (small, medium, large). Service directors were invited to participate and provided consent for their service to take part in the study. Full details are provided in Christian et al. [34]. Overall, 273 ECEC services were invited, with informed consent obtained from 126 service directors (46.2% response rate).

Children attending ECEC services participating in the study were eligible to be part of the PLAYCE cohort if they were aged between 2 and 5 years; did not have a recognised physical, emotional/behavioural or intellectual disability that would affect participation in physical activity; and were not attending full-time school. Children were recruited via parental consent. This occurred in consultation with the ECEC service director. Services were given a variety of study materials (e.g., email and newsletter templates, posters, flyers) to recruit families. Directors distributed recruitment packs to eligible families that contained information about the study, a consent form, and a contact details form.

To be eligible for follow-up at wave 2, children must have transitioned to full-time school, be less than 8 years old, and living in the Perth metropolitan and Peel regions of Western Australia. Similarly, children eligible for wave 3 and 4 follow-up were aged between 8 and 10 (wave 3) and 11 to 13 years (wave 4) and living in the study area. Parents of eligible PLAYCE cohort participants were emailed a letter inviting them to participate in follow-up data collection. Several follow up attempts were made to reach parents through available contact modes, including phone, email and/or SMS. At each wave, parents and children provided verbal re-consent to the study.

Throughout the PLAYCE cohort study, international best-practice follow-up methods and cohort maintenance procedures were employed to retain cohort participants [35]. This has included e-newsletters, social media, events (e.g., Family Days), small thank you gifts for participating children (e.g., stickers) and an individualised report on each child's movement behaviours. The wave 2 retention rate was 39.9% of eligible and contactable participants ($n = 641$, Fig. 1). Furthermore, 16.6% were out of the age scope for wave 2, 14.1% were unreachable, 28.0% were non-respondents and 1.4% actively withdrew from further participation. The wave 3 retention rate was 38.7% of eligible and contactable participants ($n = 603$, Fig. 1). A total of 434 have participated at all three waves (22.6%), 207 (11.0%) at waves 1 and 2 only and 169 (8.8%) at wave 1 and 3 only. To date, data from waves 1,2 and 3 have been cleaned and analysed.

Data collection

At wave 1, researchers attended ECEC services to fit accelerometers on participating children and measure their height and weight. A study pack including the parent survey, accelerometer instructions and accelerometer diary were provided for parents. In addition, at wave 1, educators completed a survey on their practices related to promoting children's physical activity at ECEC and the ECEC physical and policy environment were audited. At waves 2, 3 and 4, participating families were mailed the study pack. Study packs contained the parent survey, accelerometer, accelerometer instructions, accelerometer diary and a tape measure for measuring children's waist circumference and height. Parents were also emailed the link to the survey online. At each wave geospatial measures of the ECEC/school, home and neighbourhood physical environment were created, and information on school-level factors such as school type (government, catholic, private), size, and catchment was obtained through public records.

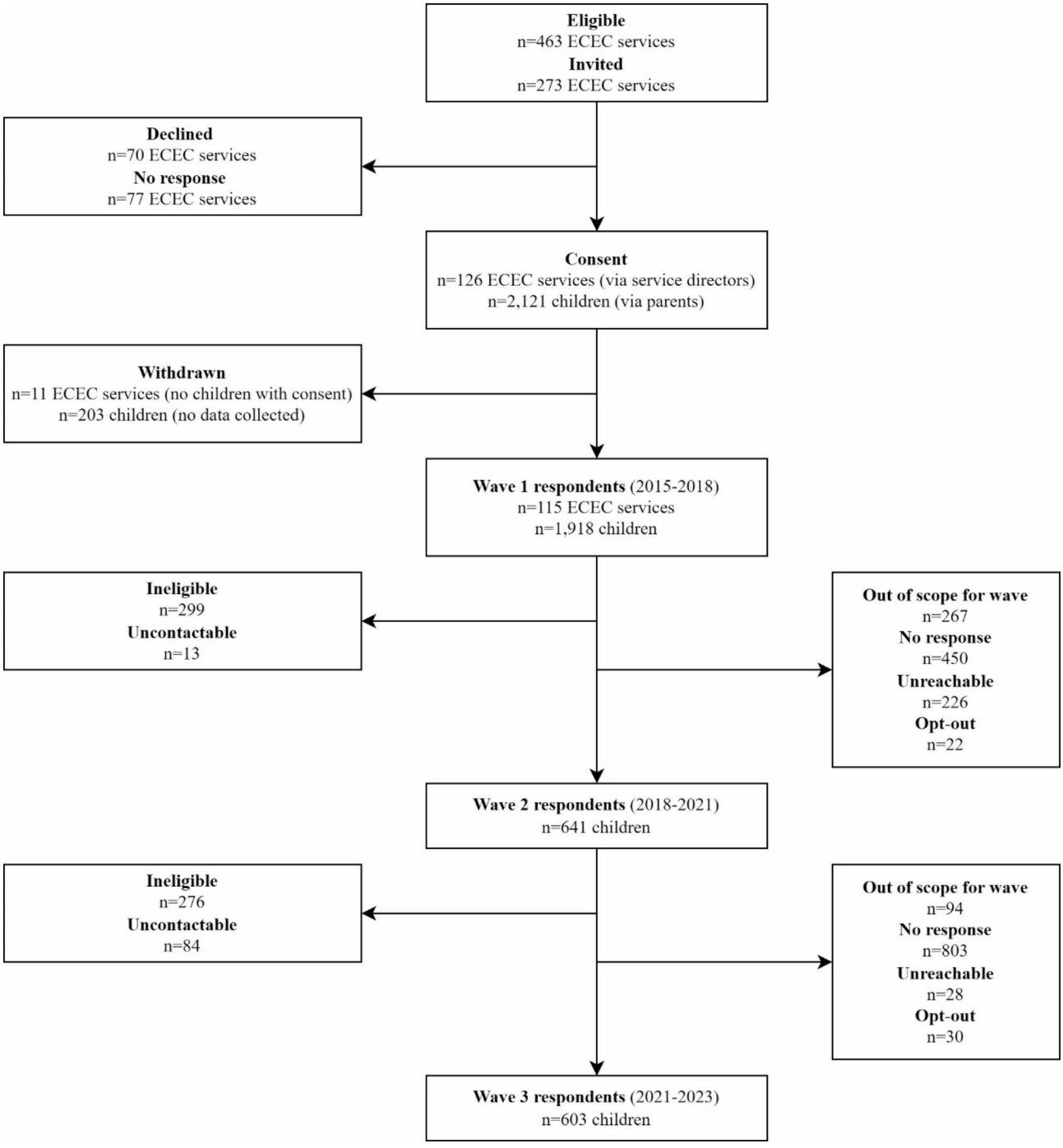

Fig. 1 PLAYCE cohort participant flow chart for wave 1 to wave 3

Multiple data collections have been utilised across four waves of the PLAYCE cohort study to date. The measures are summarised in Table 1 and described in more detail in the following sections.

Accelerometry

Children's movement behaviours were measured using ActiGraph GT3X + accelerometers (ActiGraph Corporation, Pensacola, FL USA). Children wore devices on the right hip over a consecutive 7-day period, excluding water activities and sleep in wave 1. From wave 2, children wore devices across the full 24-hour 7-day period (to capture sleep). Parents also completed a diary to record any times the device was removed, sleep and wake times, and start and end times of ECEC or school attendance. Valid wear time was defined as a minimum

Table 1 Summary of data collected in the PLAYCE cohort study

	Data collection mode	Wave 1	Wave 2	Wave 3	Wave 4
Movement behaviours					
Physical activity	Accelerometry	X	X	X	X
	Parent survey	X	X	X	X
	Global Positioning Systems	X			
Sedentary behaviour	Accelerometry	X	X	X	X
	Parent survey	X	X	X	X
	Global Positioning Systems	X			
Sleep	Accelerometry		X	X	X
	Parent survey	X	X	X	X
Child health and development outcomes					
Weight status	Anthropometry	X	X	X	X
	Parent survey	X	X	X	X
Waist circumference	Anthropometry		X	X	X
Diet	Parent survey		X	X	X
Respiratory symptoms*	Parent survey	X			
Social-emotional development	Parent survey	X	X	X	X
Motor development	Parent survey	X	X	X	X
Self-regulation*	Observation & assessment	X			
Cognitive school readiness*	Observation & assessment	X			
Socio-demographic factors					
Child socio-demographics	Parent survey	X	X	X	X
Parent socio-demographics	Parent survey	X	X	X	X
ECEC educator socio-demographics	Educator survey	X			
Psycho-social environment factors					
Child preference for physical activity	Parent survey	X	X	X	X
Parent importance of physical activity	Parent survey	X	X	X	X
Child physical activity and screen time practices at home	Parent survey	X	X	X	X
Physical activity social support for child	Parent survey	X	X	X	X
Family dog ownership and physical activity	Parent survey	X	X	X	X
Educator-reported amount of physical activity	Educator survey	X			
Educator practices to promote child physical activity	Educator survey	X			
Educator-reported amount of sedentary behaviour	Educator survey	X			
Educator screen time-related practices	Educator survey	X			
Educator physical activity professional development	Educator survey	X			
Educator importance of physical activity*	Educator survey	X			
Educator perceived behavioural control for physical activity*	Educator survey	X			
Educator self-efficacy in promoting child physical activity*	Educator survey	X			
Educator barriers and motivation for promoting child physical activity*	Educator survey	X			
Educator sun protection practices*	Educator survey	X			
Physical environment (home and neighbourhood) factors					
Suburb socio-economic status (SEIFA)	Australian Bureau of Statistics	X	X	X	X
Time lived at address and in neighbourhood	Parent survey	X		X	X
Motor vehicles	Parent survey	X	X	X	X
Household size	Parent survey	X	X	X	
Devices in child's bedroom	Parent survey	X		X	X
Dwelling type	Parent survey	X		X	
Home yard size	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Home yard equipment	Parent survey	X		X	
Home yard vegetation	Parent survey	X		X	
	Geographic Information Systems	X	X	X	X
Crime and traffic-related safety	Parent survey	X		X	X

Table 1 (continued)

	Data collection mode	Wave 1	Wave 2	Wave 3	Wave 4
	Geographic Information Systems	X	X	X	X
Access to services and destinations	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Street connectivity	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Mixed land use	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Residential density	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Green spaces	Parent survey	X		X	X
	Geographic Information Systems	X	X	X	X
Blue spaces	Geographic Information Systems	X			X
Weather	Australian Bureau of Meteorology	X	X	X	X
Physical environment (ECEC and school) factors					
Suburb socio-economic status (SEIFA)	Australian Bureau of Statistics	X	X	X	X
Size	Australian Children's Education and Care Quality Authority/ Australian Curriculum, Assessment and Reporting Authority	X	X	X	X
Green spaces	Geographic Information Systems	X	X	X	X
Traffic exposure	Geographic Information Systems	X	X	X	X
Street connectivity	Geographic Information Systems	X	X	X	X
ECEC play equipment	Educator survey	X			
	Environmental audit	X			
ECEC indoor and outdoor spaces	Educator survey	X			
	Environmental audit	X			
ECEC indoor and outdoor air pollution*	$PM_{2.5}$ using a DustTrak	X			
Policy environment (ECEC and school) factors					
Physical activity policy	Policy audit	X	X	X	X
Screen use policy	Policy audit	X	X	X	X
Sun protection policy	Policy audit	X	X	X	X

* Denotes a PLAYCE cohort sub-study. Data not collected for all children in a wave or for all waves

of eight hours of wear on at least three weekdays and one weekend day. Non-wear periods were identified by summing the 15 s windows in which the standard deviation of the signal vector magnitude was < 13 mg for >= 30 consecutive minutes [36]. A random forest classification model was used to classify raw tri-axial acceleration signals as sedentary behaviours (e.g., sitting or lying down), light intensity activities and games (e.g., standing, slow walking or pottering around, standing arts and crafts), walking, running, and moderate-to-vigorous intensity activities and games (e.g., active games with balls, riding bikes/scooters) [37]. The random forests algorithm has an overall classification accuracy of > 80%, a higher agreement with measured physical activity intensity than cut-point methods, and exhibits equivalence with direct observation [38]. Total energetic play was calculated by summing daily time spent in walking, running, and moderate-to-vigorous activities and games; and total physical activity was calculated by summing daily time spent in energetic play and light intensity activities and games.

Global positioning systems

A subset of 237 wave 1 children from 30 randomly selected ECEC centres also wore the Qstarz Q-1000XT GPS device on their left hip (on the same belt as the accelerometer) for seven consecutive days during waking hours. This GPS device has a median dynamic accuracy of 2.9 m under different environmental conditions [39] and collects X and Y location coordinates, distance, speed, elevation and time for seven days. Data validation for GPS devices were the same as those for accelerometers. As the accelerometer and GPS were worn on the same belt, removing either device meant both were removed for the same period of time.

Anthropometry

At wave 1, the research team visited participating ECEC services to collect data on participating children's height and weight. Height was measured by a portable stadiometer and weight was measured by a calibrated weight scale. At waves 2, 3 and 4, parents provided the height, weight, and waist circumference for their child following a validated protocol using a paper tape measure posted to them in their study pack, and their household scale. Age- and gender-specific z-scores for body mass index (BMI) were derived using the WHO Child Growth Standards [40, 41]. Waist circumference values will be compared against percentiles for Australian children [42].

Parent survey

Parents reported their child's weekly number of activities and total time spent in structured physical activities (e.g., swimming, dance, football/soccer), the weekly frequency of unstructured physical activities (e.g., walking or riding for transport or fun, playing in the yard, playing with a dog), and weekly time spent playing outdoors in the home yard and at parks [43]. Physical activity items were adapted from the Healthy Active Preschool Years Study [44]. Children's usual daily sleep and weekly screen time, parental support for physical activity, perceived importance their child is active, and rules and limits around physical activity and sedentary behaviour were collected using established items [44–46]. Children's diet were measured at waves 2, 3 and 4 using a parent-report short food survey developed and tested for Australian children [47]. The 38-item short food survey provides a consistent estimate of overall compliance to dietary guidelines for children 4–11 years.

Social-emotional development was measured at each wave using the Strengths and Difficulties Questionnaire (SDQ) [48]. The SDQ is a widely used and validated population-based child development questionnaire. Twenty-five items measure five developmental domains: emotional symptoms, peer problems, conduct problems, hyperactivity, and prosocial behaviours. Motor development was measured at each wave using an adapted version of the Athletic Competence subscale of the Self-Perception Profile for Children [49, 50] to measure gross locomotor and object control skills.

Parent perceptions of the neighbourhood environment (e.g., safety, access to services, places for walking) were measured using the Neighbourhood Walkability Scale for Youth (NEWS-Y) [51].

Parents reported their age, sex, education, work status, marital status, country of birth, dwelling type, number of children in the household, and family dog ownership. Education and work status were reported for both parents (where applicable) at wave 1. Parents also provided the study child's sex and date of birth.

Educator survey

Details of the educator survey have been published previously [52]. Briefly, the survey assessed the practices of ECEC staff to promote and support children's physical activity including time provided for physical activity and screen time, educator role in children's physical activity, educator physical activity practices, educator professional development, provision of physical activity equipment and indoor spaces for play. Items were from the Nutrition and Physical Activity Self-Assessment for Child Care (Go NAP SAAC) instruments [53] and were updated, modified and tested for the Australian ECEC context.

Physical and policy environmental audits

Details of these environmental audits have been published previously [52]. Briefly, the audits assessed the physical and policy environment of ECEC centres that may support (or hinder) children's physical activity. The physical environment component assessed the indoor and outdoor environment including spaces, play and media equipment, and built and natural features. The policy environment component of the audit examined the presence and content of any service policies related to children's physical activity, screen time and sun-protection.

Geographic information systems

Geographic Information Systems (GIS) derived built environment measures were calculated at the residential address level at each wave (and ECEC service address at wave 1). GIS measures for each participant were calculated using specified buffer areas of 500 m and 1600 m from home and ECEC service/school. Measures included outdoor space, vegetation, availability and quality of public open space, blue space, traffic exposure, public transport, street connectivity, destination mix, residential density and access to child-relevant services (i.e., ECEC, school, playgroup, child health centre, out of school hours care) [34, 54].

Other data

Several publicly available data sets were included. Suburb-level socio-economic status for the home, ECEC and school were derived from the Socio-Economic Indexes for Areas (SEIFA) [55]. ECEC service data (e.g., number of children, quality ratings, location) were accessed from the Australian Children's Education & Care Quality Authority (ACECQA) [56] at wave 1. Weather data were obtained from the Australian Bureau of Meteorology [57] (waves 1 to 4) and data on the school environment (number of children, location) was downloaded from the Australian Curriculum, Assessment and Reporting Authority (waves 2, 3 and 4) [58]. Small sub-studies

at wave 1 collected data on young children's cognitive school readiness and self-regulation [59]; educator perceived behavioural control, self-efficacy, perceived importance, barriers and enablers related to children's physical activity [60]; and educator sun protection practices with children and air pollution at ECEC services [61].

Impact of COVID-19

On March 15, 2020, Western Australia entered a state of emergency to manage the COVID-19 pandemic which imposed limits on face-to-face gatherings and travel. Families were encouraged to keep children home from school from March 26, 2020 [62]. On March 30, the Australian Federal Government announced the closure of indoor sporting facilities, playgrounds, skate parks, and outdoor gyms in public spaces. In addition, Australians were advised to stay home except for essential purposes. Western Australian schools reopened from April 29, 2020, and all students were required to be back at school from May 18, 2020 [62]. Wave 2 data collection, which began prior to the COVID-19 pandemic, continued during these events. As data collection did not require face-to-face contact or travel, COVID-19 restrictions did not prevent data collection from continuing but may have impacted the wave 2 response rate. This is documented in the PLAYCE cohort dataset and has been highlighted as a future research question.

Patient and public involvement

At the end of wave 1, a community-based research priority setting workshop was held with 40 with parents, ECEC providers and stakeholders to provide input to the direction of the PLAYCE study and related research program. Participants discussed and identified where research was needed to best support young children's health and development, including continued follow up of the cohort. Early in wave 2 a consumer reference group was established with 10 parents of 0-8-year-olds from the Perth/Peel region in the Western Australia community. Members had a two-year appointment on the reference group, and at the start of wave 3, 13 new members were appointed. The consumer reference group provide input to all aspects of the PLAYCE study research including identifying areas where research is needed, research methodology including recruitment and data collection, and the interpretation and translation of findings to positively impact young children's movement behaviours, health and development. Parents provide input through a consultative process, meeting a minimum of three times per year, with face-to-face meetings transitioning to online meetings during COVID-19.

Results to date

Characteristics of study participants

At wave 1, the median age of children was 3.3 years and 53% of children were male (Table 2). The majority of parents were female (91%) and almost all were married or in a de facto relationship (89%). At wave 1, 56% of parents had a university-level education and worked part- or full-time (81%). Two-thirds of children had siblings (67%) and 42% had a dog. At wave 2 and 3, a higher proportion of parents were university educated (67%) and as expected a higher proportion of children had siblings. At wave 3, more parents were in paid full time work and more households had a family dog. For the most part, representativeness of the cohort appears to have been maintained in wave 2 and 3 despite fewer respondents.

Young children's movement behaviours

Child movement behaviours at wave 1 are summarised in Table 3. On average, preschool aged children participated in 373 min per day of total physical activity of which 39.1 min was energetic play. Preschool children did structured physical activity 1.2 times per week, and unstructured physical activity 20.5 times per week. They also accumulated 106.9 min per day of screen time and 11.5 h per day of sleep. Overall, 42% met the physical activity, 67% met the screen time, and 92% met the sleep guidelines in the Australian 24-hour Movement Guidelines for the Early Years.

Movement behaviours and early child development

Preschool children's physical activity, particularly moderate-to-vigorous physical activity, has been shown to be positively associated with their social-emotional development, self-regulation and cognitive school readiness [59, 63]. This was supported by findings showing meeting all three Australian 24-hour Movement Guidelines for the Early Years was positively associated with preschool boy's social-emotional development [19].

Influence of the ECEC setting

Wave 1 findings identified that many young children are not sufficiently active whilst attending ECEC, with only 16% of services including children's physical activity in their policies [64]. Furthermore, in a nested pilot intervention physical activity-related professional development for ECEC educators was effective in improving ECEC educator's self-efficacy to engage children to be active [60]. These findings have been used to develop and test an evidence-informed physical activity policy intervention specific to the time children attend ECEC [65, 66].

In other studies of the ECEC physical environment tree canopy in outdoor spaces was found to be an important sun protection strategy and enabler of children's outdoor

Table 2 Characteristics of PLAYCE cohort participants at wave 1–3

	Wave 1	Wave 2	Wave 3
Total n	1918	641	603
Child age[1] (median years (IQR))	3.3 (2.7–3.9)	6.3 (5.9–6.6)	9.1 (8.7–9.5)
	n (%)	n (%)	n (%)
Child sex[2]			
Male	1011 (52.7)	331 (51.6)	294 (48.8)
Female	906 (47.3)	310 (48.4)	309 (51.2)
Child has siblings[3]			
No	548 (33.2)	106 (17.6)	86 (15.2)
Yes	1103 (66.8)	498 (82.5)	478 (84.8)
Parent 1 sex[4]			
Male	147 (8.9)	50 (8.3)	45 (8.0)
Female	1506 (91.1)	556 (91.8)	520 (92.0)
Parent education[5]			
Secondary school, diploma, certificate	723 (43.7)	199 (32.9)	184 (32.6)
University	932 (56.3)	406 (67.1)	380 (67.4)
Parent work status[6]			
Not in paid work	316 (19.1)	77 (12.7)	49 (8.7)
Paid full time work	553 (33.4)	233 (38.6)	262 (46.4)
Paid part time work	788 (47.6)	294 (48.7)	253 (44.9)
Parent marital status[7]			
Not married or de facto	187 (11.3)	67 (11.7)	77 (13.7)
Married or de facto	1464 (88.7)	538 (88.9)	487 (86.3)
Dog owner[8]			
Yes	686 (41.6)	262 (43.38)	292 (51.8)
No	963 (58.4)	342 (56.6)	272 (48.2)

N and percentages presented for completed responses only; not all participating children completed surveys. Percentages may not sum to 100 due to rounding.

Missing cases: [1]*n*=280 (wave 1), *n* = 11 (wave 2), *n* = 0 (wave 3); [2]*n*= 1 (wave 1), *n* = 0 (wave 2), *n* = 0 (wave 3); [3]*n*=267 (wave 1), *n* = 37 (wave 2), *n* = 39 (wave 3); [4]*n*=265 (wave 1), *n* = 35 (wave 2), *n* = 38 (wave 3); [5]*n*=263 (wave 1), *n* = 36 (wave 2), *n* = 39 (wave 3); [6]*n*=261 (wave 1), *n* = 37 (wave 2), *n* = 39 (wave 3); [7]*n*=267 (wave 1), *n* = 36 (wave 2), *n* = 39 (wave 3); [8]*n*=269 (wave 1), *n* = 37 (wave 2), *n* = 39 (wave 3)

time at ECEC [61]. Using a novel method of combined device-measured physical activity, spatial data and on-site audit data, another study found preschooler physical activity hot spots were common in ECEC open areas and in adjacent outdoor play areas if children could freely move between these areas [67]. The findings of this study provided objective behavioural and spatial information of the types of ECEC outdoor play area designs that promote physical activity in preschoolers. Moreover, in another sub-study, air pollution concentrations in ECECs were observed to be highest when preschool children are likely to be active outdoors at ECEC [68]. Avoiding locating ECEC services in high traffic areas was a key recommendation from this study.

Home setting

An investigation of the relationship between the home yard space and preschool children's outdoor play found physical environment features of the home yard (yard size, play equipment, natural features) were positively associated with preschool children's outdoor play [69]. Two other studies have examined the relationship between family dog ownership and preschooler physical activity and social-emotional development [70, 71]. For example, children from dog-owning households had reduced odds of social-emotional problems, compared with children without a family dog [71]. Moreover, children of dog-owning families who walked or played with their dog more often had improved prosocial behaviours [71].

Neighbourhood setting

Using combined device-measured physical activity (accelerometry), physical activity spatial data (Global Position Systems) as well as data on the neighbourhood physical environment (Geographic Information Systems), preschool children were found to engage in more energetic play in parks and playgrounds and in the homes of others outside their local neighbourhood (e.g., friends and family) [72]. Two studies have highlighted the role of parent's perceptions of the neighbourhood environment on young children's physical activity levels and social-emotional development [73, 74]. For example, using data from wave 1, parents' positive perceptions of traffic safety, crime safety and land use mix were associated with lower odds of pre-schooler social-emotional difficulties

Table 3 Summary of PLAYCE participants' movement behaviours at wave 1

	N	Mean (SD)	Median	IQR
Device-derived movement behaviour (mins/day)				
Sedentary time	1167	292.0 (63.5)	286.7	76.6
Light intensity activities and games	1167	333.9 (46.9)	331.4	59.3
Walking	1167	17.4 (8.3)	16.0	10.0
Running	1167	4.2 (2.9)	3.65	3.7
Moderate-to-vigorous intensity activities and games	1167	17.5 (10.2)	15.5	9.7
Energetic play	1167	39.1 (14.2)	38	16.3
Total physical activity	1167	373.0 (51.5)	370.3	66.5
Parent-report movement behaviour				
Structured physical activity (times/week)	1658	1.2 (1.3)	1.00	2.0
Unstructured physical activity (times/week)	1625	20.5 (10.0)	19.5	14.0
Screen time (mins/week)	1594	748.1 (557.5)	630.0	660.0
Sleep time (hours/day)	1559	11.5 (1.3)	11.5	1.5
Met age-specific movement behaviour guideline	N	n (%)		
Physical activity[1]	1111	471 (42.4)		
Screen time[2]	1594	1073 (32.7)		
Sleep time[3]	1499	1372 (91.5)		

N and percentages presented for completed responses only. Energetic play is the sum of walking, running, and moderate-vigorous activities and games. Total physical activity is the sum of light intensity activities and games and energetic play

[1] Met guideline if child obtained ≥ 180 min of total physical activity and ≥ 60 min of energetic play if aged 3–5 years. Must have valid age recorded to be included in denominator. Derived from accelerometry

[2] Met guideline if child had < 1 h of parent-reported screen time per day

[3] Met guideline if child was 2 years old and had 11–14 h of parent-reported sleep/day or child was 3–5 years old and had 10–13 h of parent-reported sleep/day

[74]. The study concluded that interventions to improve parents' perceptions of built environment features may facilitate opportunities for play and interaction contributing to healthy social-emotional development [74].

Discussion

The PLAYCE study is one of the largest cohort studies of device-measured movement behaviour and environmental data for children from early to middle childhood. The cohort can provide strong longitudinal evidence of the causal relationships between early movement behaviours, key behaviour settings and health and development indicators in children. Device-measured movement behaviours are complemented by parent-report data, providing insights into the role of families, parent perceptions, and the home, neighbourhood, ECEC and school physical environment in forming and modifying these behaviours. Having a strong evidence base for understanding the relationships between movement behaviours and key health and development indicators in children will enable the development of effective targeted interventions to curb the child obesity epidemic and ensure all children have opportunity to lead an active healthy life.

Updates to national and international movement behaviour guidelines have emphasized the need for more rigorous and consistent accelerometer data processing methods to support future guideline development [38, 75]. Through applying machine learning classification methods to existing and new device-measured movement data, the PLAYCE cohort study will provide a more accurate understanding of the optimal dose and combination of movement behaviours to promote healthy weight, and social-emotional, cognitive, and motor development across childhood. Such findings can be used to inform future 24-Hour Movement Behaviour Guideline development and intervention strategies to improve young children's movement behaviours and consideration of the important transitional periods in early childhood (i.e., to full-time school).

Table 4 presents an overview of possible future research questions that can be addressed through the PLAYCE cohort study.

Study limitations

There are some limitations to the PLAYCE cohort study. Despite following best-practice follow-up methods and cohort maintenance procedures to retain cohort participants, there was attrition between waves 1 and 2. Due to the three-year period over which wave 1 participants were recruited and their data collected, some children were not approached at wave 2 as they were already beyond the age range criteria for wave 2 (i.e., not in their first year of full time school). Additionally, the COVID-19 pandemic may have affected response rates due to the timing of wave 2 data collection. Moreover, the time burden on parents from filling out questionnaires may have contributed to attrition at wave 2. While there was attrition between wave 1 and waves 2, the representativeness

Table 4 Possible future studies using the PLAYCE cohort data

Research theme	Question	Outcome
Compositional analyses of movement behaviours	What is the ideal composition of 24-hour movement behaviours for improving child development and weight status? What is the day-to-day variation in children's movement behaviours?	Weight status, social-emotional development, motor development
Impact of transitioning to full-time school	How do young children's movement behaviours change as they transition to full time school?	Change in physical activity, sedentary behaviour and sleep overall and across settings (ECEC, school and home)
Longitudinal patterns of physical activity from pre-school to middle childhood	What are the trajectories of movement behaviours across childhood and what socio-demographic and other family factors are associated with trajectories?	Change in total physical activity, energetic play, sedentary time, sleep
Evaluating natural experiments	What was the impact of COVID-19 restrictions on changes in device-based movement behaviours?	Total physical activity, energetic play

of the sample remained largely unaffected and is sufficiently powered for longitudinal analyses. The study recruited from a single site (Perth, Western Australia) and therefore may not be representative of all Australian children. Additionally, the recruited sample appears to underrepresent families with lower relative socioeconomic status, such as single-parent families and parents with below degree-level education. This is despite the slight over-representation of ECECs recruited from lower socio-economic areas in the original sampling frame [64]. First Nations families, families who are linguistically diverse and members of culturally and racially marginalized groups were also unrepresented and should be the focus of future research.

Conclusion

Four waves (2–13 years) of PLAYCE cohort study data will provide detailed patterns of movement behaviours and their effect on child health and development as well as the environmental influences on children's movement behaviours across early to middle childhood. The findings will inform national and international 24-Hour Movement Guidelines and setting-specific as well as population-level interventions.

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Author contributions
HC: conceptualization, methodology, data curation; investigation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. AN: conceptualization, formal analysis, data curation, writing – original draft, writing – review and editing. SGT: conceptualization, methodology, investigation, data curation, writing – review and editing, funding acquisition. JS: conceptualization, methodology, investigation, writing - review and editing, funding acquisition. BB: conceptualization, methodology, investigation, data curation, writing - review and editing, funding acquisition. EA: formal analysis, data curation, writing – original draft, writing – review and editing. HLM: formal analysis, data curation, writing – original draft, writing – review and editing. PG: writing – original draft, writing – review and editing. AH: data curation, writing – original draft, writing – review and editing.

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Data availability
The de-identified data generated from this study will be available for analytic purposes by academics, research staff and students if approved by the Principal Investigator and relevant ethics committees, from 12 months following the anticipated project end date.

Declarations

Ethics approval and consent to participate
Ethical approval has been granted by The University of Western Australia Human Ethics Research Committee, approval numbers RA/4/1/ 7417 and 2020/ET000353.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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