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Article

Lifestyle clusters and academic achievement in Australian Indigenous children: Empirical findings and discussion of ecological levers for closing the gap

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ABSTRACT

Participation in sport and physical activity can improve academic outcomes and has been identified as a potential mechanism for addressing educational disadvantage and 'closing the gap' in Australian Indigenous communities.

To explore this possibility in relation to sport and lifestyle we performed a cluster analysis on data from the Footprints in Time study (also known as the Longitudinal Study of Indigenous Children), using data from Waves 3–6 (2010–2013, ages 5–9 years) of this cohort study. Cluster inputs were organised according to not only sports participation, but also screen time, sleep duration and unhealthy food intake, as reported in parent surveys. Associations between lifestyle cluster membership and academic outcomes from standardised tests from 2014-5 (Progressive Achievement Tests [PATs] for Maths and Reading, and National Assessment Program for Literacy and Numeracy [NAPLAN]) were examined using linear models. Analyses were adjusted for age, sex, remoteness and parental education.

Three clusters were identified: *Low Sport* (36% of sample), characterised by low sports participation and low sleep duration; *Junk Food Screenies* (21% of sample), with high screen time and high intake of unhealthy foods; and *High Sport* (43% of sample), showing high sports participation and low screen time. Cluster membership was associated with academic performance for NAPLAN Literacy and Numeracy, and for PAT Maths. The *High Sport* cluster consistently performed better on these tests, with effect sizes (standardised mean differences) ranging from 0.10 to 0.38.

We discuss the ecological dynamics potentially contributing to lifestyle cluster membership and ways in which policy can support healthier *High Sport* lifestyles associated with better academic performance.

Introduction

There is an emerging body of research that demonstrates a link between physical activity and improved academic outcomes (Martin, 2010; Singh et al., 2018). Research has demonstrated that physical activity has the capacity to improve cognition and academic achievement (Ardoy et al., 2014; Chen, Yan, Yin, Pan, & Chang, 2014; Coe, Pivarnik, Womack, Reeves, & Melina, 2006; Hillman et al., 2009, 2014; Riley et al., 2017). The US Centres for Disease Control and Prevention have developed the slogan *The More They Burn, The Better They Learn* to highlight the increasing importance of physical activity not just for important public health outcomes but also as a way of improving educational outcomes.

Participation in organised sport is a potential avenue for increasing physical activity. It is evident that shifts in participation in sport occur with age and in conjunction with a range of lifestyle factors (Maher, Olds, & Dollman, 2009). Girls, and children who are older, obese or who come from low-income households are less likely to participate in organised sport (Maher et al., 2009). There are also strong regional patterns in sports participation. Consequently, it is helpful, when examining the relationship between sport and academic achievement, to consider a range of lifestyle factors and the broader developmental

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context of the child. In this paper we take this lifestyle approach and examine how Indigenous Australian children cluster together based on their sport and other lifestyle behaviours, and the relationship these clusters have with education. The study was led by Professor John Evans an Indigenous academic from the Wiradjuri nation. The research was positioned to view sport and physical activity as a strength. This project acknowledges special significance that sport holds within the lives of Indigenous Australians and also the recently identified potential of sport as an important target in efforts to improve the lives of Indigenous Australians.

Analysing data from the *Footprints in Time* study (also known as the Longitudinal Study of Indigenous Children, LSIC) we examine lifestyle cluster of children aged 5–9 years. The data report on children's: participation in organised sport; their screen time; their sleep duration; and consumption of unhealthy food. By coincidence, our approach parallels two recently published studies. A recent study in Nova-Scotia used cross-sectional survey data to analyse the impact of these same lifestyle factors upon the academic achievement of 10 and 11 year olds (Faught et al., 2017). They found that meeting the recommended, or required, levels of each of these (excepting physical activity), had independent positive effects upon the likelihood of children meeting academic expectations on a range of educational measures. Furthermore, by combining these factors Faught and colleagues demonstrated the cumulative, positive effects of multiple healthy lifestyle behaviours. The odds of children meeting expectations on 7 to 9 of the indicators, compared to those meeting 0 to 3, reflected improved probabilities to meet expectations in reading (odds ratio [OR]:3.07), mathematics (OR:1.47) and writing (OR:2.77). These findings were echoed in a study of adolescents in Nevada examining the same, but without a screen time indicator. Burns, Fu, Brusseau, Clements-Nolle, and Yang (2018) found similar cumulative lifestyle effects, but also stronger independent effects for sport participation upon grade outcomes (OR: 1.18). Given the evident interactions between physical activity, diet, sleep and sedentary behaviour, our study uses a similar logic to explore how these factors combine and relate to academic performance among Australian Indigenous children.

Indigenous Australians constitute approximately 3% (649,171) of the total Australian population, and represent diverse cultures, histories, social activities and spiritual mores (Walter, Martin, & Bodkin-Andrews, 2017). Indigenous Australians are under-served relative to their non-Indigenous compatriots. They are generally poorer, less educated, more likely to live in remote areas with less access to facilities, and to suffer intergenerational social and health deficits dating from colonisation. In 2008 the Commonwealth Government entered into a new policy framework known as *Closing the Gap* (CTG). The broad objectives of the CTG approach are to address the equity gaps between Indigenous and non-Indigenous Australians by bringing about generational change to improve the socio-economic conditions faced by Australia's Indigenous population (Commonwealth of Australia, 2013, p. 9). Yet after a decade only modest improvements have been achieved (Commonwealth Government, 2019).

In Australia, sport and physical activity in Indigenous communities has been identified as a potential lever in the *Closing the Gap* approach as outlined in strategies by the Council of Australian Governments (Ware & Meredith, 2013). In Australian Indigenous communities' sport has an important cultural role. It provides a basis for community development as an avenue to address important social challenges (Rossi, 2015; Rossi & Jeanes, 2018). Optimal levels of sport and physical activity have been found to be associated with the reduction of the social disadvantage experienced by these communities (Doyle, Firebrace, Reilly, Crumpen, & Rowley, 2013; Macniven, Canuto, Wilson, Bauman, & Evans, 2019; Macniven et al., 2012).

In 2012, the Australian Commonwealth Government initiated a parliamentary enquiry into the role of sport in Indigenous communities, their report recognised the potential of sport and called for more robust and insightful data relating to its utility and hence its contribution to future policy development (Commonwealth of Australia, 2013). This study addresses that call by reporting on the relationship between sport lifestyles in young Indigenous children and their educational performance in literacy and numeracy, using a cluster analytic approach.

We frame this research using Ecological Systems Theory (EST) (Bronfenbrenner, 1979) which provides an integrated perspective on childhood development explaining how inherent, but often dynamic, factors within a child's environment interact to influence how they will grow and develop. Using EST we consider how family, community and social policy action can shift the ecological circumstances curtailing children's access to sport and healthy lifestyles; thus lifting children out of unhealthy lifestyle clusters and into healthy clusters. Importantly, such actions are understood to impact not only upon health, but holistic childhood development, including educational outcomes. We discuss how community and social policy shifts are likely to affect educational improvements for Australian Indigenous children; and how a lifestyle and ecological analysis approach might be useful more broadly when considering Indigenous and First Nation children in international contexts.

Ecological perspectives on child development

Ecological perspectives on child, and human, development are used to examine the complex, multi-faceted, bi-directional relationships of development across diverse contexts. The theoretical basis used to understand these complex relationships was first established in Bronfenbrenner's *Ecological Systems Theory* (EST) (Bronfenbrenner, 1979). Bronfenbrenner's work has been operationalised in Indigenous communities to theorise about issues associated with childhood development (Atilola, 2017; Manning, 2017; Zubrick et al., 2004) as have other social-ecological approaches (Nelson, Abbott, & Macdonald, 2010).

Bronfenbrenner (1979, 1995) takes a child-centred approach to development, where environmental interactions proximal to the child shape developmental outcomes (see Fig. 1). In the case of this study, we examine a range of lifestyle behaviours (organised sport, sleep duration, unhealthy food, and screen time) and educational outcomes (two different measures of educational attainment) and consider how these develop within the child's ecological context. Literature examining the association between each of these lifestyle factors and educational outcomes is reviewed in Faught et al. (2017) and the cumulative effects of such factors, taken together as lifestyles, have been demonstrated in other populations (Burns et al., 2018; Faught et al., 2017). In our lifestyle study we frame these interactive factors within a broad ecological model.

EST theory is a useful heuristic for understanding children and their developmental outcomes, enabling consideration of the full range of levers available to ameliorate difficulties and optimise positive outcomes. EST is perhaps also particularly useful for consideration of Indigenous children, who live in a diverse set of circumstances, many of which may not be familiar to researchers of different backgrounds and who may consequently be operating on a range of assumptions that are not applicable to the case at hand (Rossi & Rynne, 2013). Atilola (2017) suggests that this acknowledgement that child outcomes are "products of proximal, intermediate and distal factors that influence the care environment of children" (p. 380) is necessary for a holistic understanding and building services for children that are anchored on an integrated platform that can ensure success.

Ecological System's Theory (Bronfenbrenner, 1979, 1995) envisages the child as 'nested' within multiple layers of a complex ecology of relationships, interacting on various levels with the child's physical environment (Bronfenbrenner, 1995). Five levels of influence are modelled in this theory: 1) the ***microsystem*** (the direct impact of relationships at home, school, in childcare, with peers and the wider community), 2) the ***mesosystem*** (interaction between several *microsystems*, such as the school and family environment and how it impacts the child), 3) the ***exosystem*** (environments not in direct contact with the

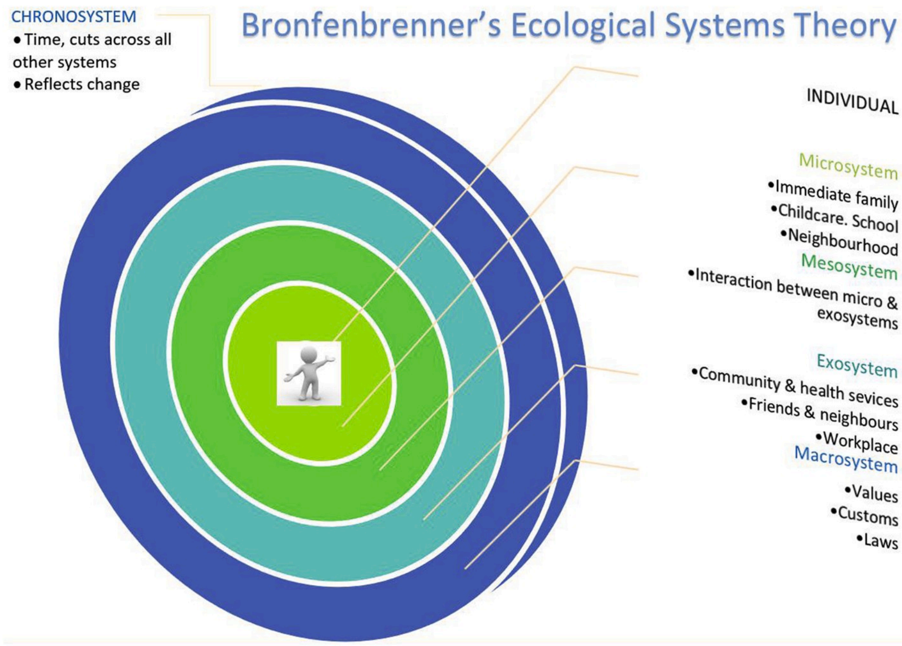

Fig. 1. EST Model graphic (authors' own graphic based on Bronfenbrenner, 1995).

child, including the parents' work place, community centres and facilities; however still indirectly impact upon the child's development) and 4) the ***macrosystem*** (major cultural constructs: cultural values, governmental policies). A final 5) ***chronosystem*** acknowledges shifts in all other systems over time and thus adds an additional and dynamic layer of complexity to the developmental sphere of a child.

The *microsystem* and the *mesosystem* are the only systems the child is directly involved in, however the *exosystem* significantly influences the child through a range of levers, including, financial resources and community programs and cohesion. In terms of sport and healthy lifestyles, policies are implemented within the *exosystem* and have an indirect effect on the child via the mesosystem. Finally, although the *macrosystem* is far removed from the child (see, Fig. 1), it exerts significant influence on the child's development through societal laws and cultural values encompassing acceptable forms of childcare and education. These include the cultural values, customs and laws that provide the background to sport and healthy lifestyle policies. This ecological scheme of influence is bi-directional and multi-factorial, where children are influenced by their environments but also may exercise their own influence (Bronfenbrenner, 1995). While the various system levels are influential, the child's own motivation, which is a product of a wide range of direct and indirect system effects, also has impact upon sport and healthy lifestyles.

Among Indigenous families the cultural valuing of sport is a strong *macrosystem* influence. Research literature has documented and explored the privileged position of sport within Indigenous communities (Bamblett, 2013; Light & Evans, 2018; Norman, 2012). Researchers and policymakers alike have identified the potential of building upon the strong cultural valuing of sport in a strengths-based strategy to redress the disadvantage Indigenous communities experience in other aspects of life (Doyle et al., 2013). However, it is important to remember that, in the *macrosystem* of Australian law and custom, the Indigenous conception of sport and its influence is, at best, diluted; although there have been noted efforts to build on it in social policy for Indigenous communities (Commonwealth of Australia, 2013).

Programs targeting sport via the *exosystem* already abound, with substantial financial and community investment. However, little is known about the impact of these through the *meso-* and *micro-systems* – where there is direct interaction with the child. Thus, considerations regarding both the reach and program fidelity of implementation of programs in the *exosystem* are important unknowns for research in Indigenous communities. The *Sport, More than Just a Game* report, called for more evidence on program implementation and effectiveness (Commonwealth of Australia, 2013).

The importance of the *mesosystem* in relation to this issue should not be underestimated for, among other things, it relates to both the level of access and quality of implementation of policy initiatives experienced by the individual. In the case of Indigenous Australians, policy delivery and implementation fidelity are serious challenges (Commonwealth of Australia, 2013). Whilst there are no simple solutions, awareness of this challenge is important. Effective programs that interact directly, frequently and consistently with the child through the mesosystem are needed to establish healthy lifestyles.

In this study we used EST to explore the relationships between sport, other lifestyle factors and educational outcomes – this is not new, but more productively we use the theory to frame discussion of how action in various systems, including policy led changes to *micro-*, *meso-*, *exo-* and *macro– systems*, might be used to lever lifestyle change, optimise outcomes and *close the gap* for Indigenous Australian children.

Methods

Data sources

This study is part of the larger *Foundation of Sport in Indigenous Communities* (FOSIC) study, which explores the role of sport and physical activity in Australian Indigenous communities. Data for the present study are from the *Footprints in Time* study, also known as the Longitudinal Study of Indigenous Children (LSIC), which commenced across 11 Australian sites in 2008. Sites were strategically chosen to provide even representation of urban, regional and remote areas and to represent the concentration of the Aboriginal and Torres Strait Islander population around Australia. Participants ($n = 1671$ in Wave 1) have been followed up in yearly waves, with an over-time retention rate of 70%. Reasons for non-retention include that families could not be located, they had moved from the area, and that they refused to be interviewed or they could not be interviewed for other reasons. There are two cohorts in the *Footprints in Time* study, a Birth (B) cohort (6–18 months at Wave 1) and a Kinder (K) cohort (3.5–5 years at Wave 1). This study uses data from Waves 3–6 of the K cohort (2010–2013), when the children were 5–9 years old. Compared to children in Wave 1, K cohort children in retained to Wave 6 differed in remoteness of residence (p = 0.02). In Wave 1, 36% were remote; 40% regional and 24% were from cities, whereas in Wave 6, 28% were remote, 45% were regional and 27% were from cities. Between Wave 1 and Wave 6, there were no differences in Index of Relative Indigenous Socioeconomic Outcomes (IRISEO), a measure of community level socioeconomic advantage (p = 0.19).

Measurements

Exposures: Cluster inputs were lifestyle exposures relating to: 1) organised sport; 2) screen time; 3) sleep duration; and 4) unhealthy food. These were reported by the child's parent or caregiver during face-to-face interviews. All four of these lifestyle inputs, are moderated by influences from *micro-, meso-, exo-* and *macro-system* levels.

Data on *organised sports participation* were collected in Waves 3, 4, 5 and 6. In Waves 3 and 6, parents were asked: "In the past month, has (study child) done any organised sport or dancing?". In Waves 4 and 5 they were asked; "Did (study child) do any of these things in the last week? …. Organised sport/dance". Thus, the question referred to sport participation in the previous *week* in Wave 4 and 5, and to the past *month* in Waves 3 and 6. At each wave, sports participation was coded 0/1 for No/Yes. The scores were summed together to create a *Sports Participation* variable ranging from 0 (no sports participation at any wave) to 4 (sports participation at every wave).

Screen time was derived from the question "How many hours on a typical weekday does (study child) watch TV, DVDs or videos?" asked in Waves 3, 4 and 6. Possible responses were [None; Less than an hour; 1 h; About an hour and a half; 2 h; 3 h; 4 h; 5 h; more than 5 h], except in Wave 3, where the lowest possible response was "Less than an hour". Responses were recoded as [0; 0.5; 1; 1.5; 2; 3; 4; 5; 6 h] and the variable was treated as continuous. For Wave 3, the minimum response was coded as 0.44, to reflect the distribution of Wave 4 responses across the "None" and "Less than an hour" categories. Screen time was averaged across the three waves (Waves 3, 4 and 6), to create a mean screen time score per participant, ranging from 0 to 6.

Sleep duration was available only in Wave 5. Parents were asked to indicate "What time does (study child) usually go to bed on weekdays?" and "What time does (study child) usually wake up (get up) on weekdays?" in increments of 15 min. Weeknight sleep duration was derived by subtracting reported waking time from reported sleep onset. Sleep duration ranged from 8 to 15 h.

The sum of *unhealthy food items* consumed on the previous day was obtained from the following set of questions asked at Waves 3–5: "What did (study child) have to eat yesterday morning, including breakfast and during the morning?"; "What did (study child) have to drink yesterday morning, including breakfast and during the morning?"; "What did (study child) have to eat yesterday afternoon, including lunch and during the afternoon?"; and "What did (study child) have to drink yesterday afternoon, including lunch and during the afternoon?". Parents could select from a variety of food and drink items, including hot chips or French fries; packet of chips or salty snacks; biscuits/doughnuts; soft drinks, cordial or sports drinks. The number of unhealthy food items selected was summed at each wave, forming an unhealthy food item score with a range of 0–8. The unhealthy food item score was averaged across Waves 3–5, to create a mean unhealthy food item score for each participant.

Educational Outcomes: Academic performance was measured through National Assessment Program — Literacy and Numeracy (NAPLAN) and also through standardised school tests, the Progressive Achievement Tests (PAT), obtained by data linkage. NAPLAN consists of a series of standardised tests that are administered bi-annually to all Australian students (Commonwealth Department of Education, 2016). These tests assess students' numeracy and literacy. The latter is a composite score obtained by averaging reading, writing, spelling and grammar scores. This study used data from 2015, when the children were in Year 5. PATs are objective, norm-referenced measures of academic achievement used widely in Australian schools (Australian Council for Educational Research, 2018). In this study PAT Reading tests corresponding to Wave 8 (2015), and Maths tests corresponding to Wave 7 (2014) were used.

Covariates: The child's age, sex, parental education and remoteness of residence were used as covariates. The highest education level of the responding parent was used to represent socio-economic status. Responses were collapsed into three categories: Low (up to Year 10 at school); Medium (Year 11–12) at school or trade certificates I or II; and High (anything higher). Remoteness of residence was characterised using the ARIA + system (http://www.abs.gov.au/websitedbs/d3310114.nsf/home/remoteness+structure), and collapsed into three categories: Urban (major cities and outer suburban areas); Regional (medium-sized cities); and Remote (including remote and very remote).

Data analysis

Participants with complete data for all variables required for the analysis were included. Lifestyle behaviour data (cumulative sport participation, average screen time, average unhealthy food items and sleep duration) were used as cluster inputs. The variables were standardised to z-scores prior to clustering. First, data were clustered using a hierarchical agglomerative procedure and plotted in a dendrogram (Supplementary File Fig. S1). From inspection of the dendrogram, a 3-cluster solution was selected. A k-means partitioning algorithm with Euclidean distance was used to determine the final cluster solution.

The influence of multivariate outliers on the cluster solution was checked using principal component analysis (PCA) biplots (Supplementary File Figs. S2 and S3). A total of 7 observations were identified as outlying (beyond the 97.5 percentile on the PCA biplot). These were removed, and the data were re-clustered and visualised on a PCA biplot. Minimal difference was observed between the two cluster solutions. We decided therefore to retain the outliers. To assess the robustness of the cluster solution, a random sub-sample of 200 participants was re-clustered. The agreement between the two cluster solutions was excellent (Cohen's kappa of 0.81; p < 0.001). The clusters were labelled to reflect their distinguishing lifestyle behaviour characteristics.

The next step in the analysis compared academic performance across cluster membership using linear models. The cluster characterised by high cumulative sports participation was used as the reference category in post-hoc pair-wise comparisons. Analyses were adjusted for covariates.

Results

Participant characteristics

From a total of 370 children participating at each wave across Waves 3–6, complete lifestyle behaviour data, socio-demographics and PAT scores were obtained from 294 (79%; PAT Maths) and 268 (72%; PAT Reading) participants. A total of 240 (65%) provided complete lifestyle, socio-demographic and NAPLAN data (Fig. 2).

At Wave 3, participants were aged 6.1 (0.5) years, and 49% were male. The descriptive characteristics of the study children, and of all eligible children, are shown in Table 1. The analytical samples did not differ from the overall sample except in Remoteness (all $p < 0.05$) and higher PAT Maths ($p = 0.02$) and NAPLAN Numeracy ($p = 0.02$).

Lifestyle clusters

Three clusters were identified (Table 2). Cluster 1 consisted of 125 children (36% of the sample) and was characterised by low sports participation and low sleep duration. This group was labelled the *Low Sport* cluster. Cluster 2 (n = 71, 21% of sample) was characterised by high screen time, high intake of unhealthy foods, and high sleep. This

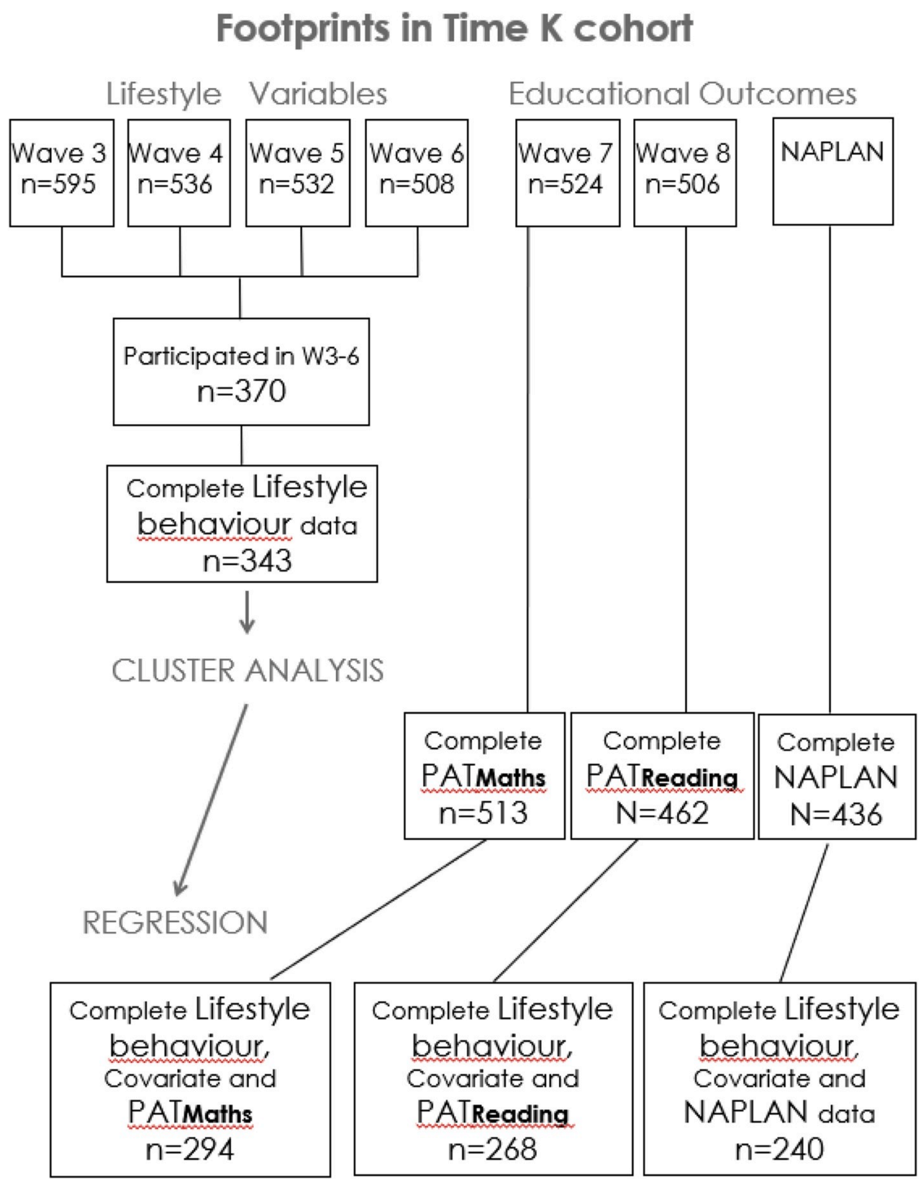

Fig. 2. Participant flow. NAPLAN = National Assessment Program — Literacy and Numeracy; PAT = Progressive Achievement Test.

cluster was labelled the *Junk Food Screenies* cluster. Cluster 3 (n = 147, 43% of the sample) was characterised by low screen time and high sports participation. We labelled this cluster the *High Sport* group.

Socio-demographic characteristics of the clusters

Table 3 shows the socio-demographic and academic characteristics of the three clusters. There were no significant differences across clusters in age, sex, or parental education. Remoteness differed across clusters. The *Low Sport* cluster tended to have more children from remote areas (34% vs 16%).

Cluster membership and academic outcomes

Omnibus tests for association (adjusted for sex, age, parental education and remoteness) showed significant differences between clusters for PAT Maths ($F = 3.9$, $p = 0.02$), NAPLAN Numeracy ($F = 4.8$, $p = 0.01$), and NAPLAN Literacy ($F = 4.5$, $p = 0.01$), and the NAPLAN subscales for Reading ($F = 3.4$, $p = 0.03$) and Grammar ($F = 5.2$, $p = 0.006$). Clusters did not differ for PAT Reading tests ($F = 2.0$, $p = 0.13$), or NAPLAN subscales of Spelling ($F = 2.5$, $p = 0.08$) or Writing ($F = 2.2$, $p = 0.11$).

Table 4 presents adjusted NAPLAN scores of each lifestyle cluster. Post-hoc tests using the *High Sport* cluster as the reference category found significantly higher scores for the *High Sport* cluster compared to the other two clusters for PAT Maths, NAPLAN Numeracy, and NAPLAN Literacy and Grammar. *High Sport* cluster scores on NAPLAN Reading were higher than those for the *Junk Food Screenies* cluster. Relative to the pooled SD for all participants, effect sizes (standardised mean differences) ranged from 0.10 to 0.38 (Fig. 3).

Discussion

This cluster analysis of lifestyle behaviours in Australian Indigenous children identified three distinct clusters characterised by varying amounts of organised sport, screen time, sleep and unhealthy food. One cluster, characterised by high sports participation, exhibited superior performance on standardised tests of academic achievement, particularly in numeracy.

This analysis is based on the largest existing cohort study of Australian Indigenous children, collected over a 5-year period. Because lifestyle characteristics were based on data collected between 2010 and

Table 1
Descriptive characteristics of the sample. All values are mean (SD) unless indicated.

		PAT Maths Sample	PAT Reading Sample	NAPLAN Sample	Overall Sample
N		294	268	240	[b]
Age (y)[a]		6.0 (0.5)	6.0 (0.5)	6.0 (0.4)	6.1 (0.5)$^{n=580}$
Sex (% male)		52	50	48	49$^{n=595}$
Education level (%)	High	23	22	22	20 $^{n=533}$
	Medium	38	40	39	40
	Low	38	38	39	40
Remoteness (n%)	Urban	30	31	30	25 $^{n=580}$
	Regional	50	49	50	41
	Remote	21	20	21	33
Sports Participation		2.3 (1.3)	2.3 (1.3)	2.4 (1.3)	2.2 (1.4) $^{n=353}$
Screen Time		2.2 (1.0)	2.3 (1.0)	2.2 (1.0)	2.2 (1.0) $^{n=370}$
Sleep (h)		10.5 (0.8)	10.6 (0.8)	10.5 (0.8)	10.5 (0.8) $^{n=359}$
Unhealthy Food Items		1.0 (0.7)	1.0 (0.7)	1.0 (0.7)	1.0 (0.7) $^{n=370}$
PAT	Maths	108 (14)			105 (14) $^{n=513}$
	Reading		109 (18)		108 (18) $^{n=462}$
NAPLAN	Numeracy			429 (64)	417 (75) $^{n=436}$
	Literacy			429 (72)	417 (74) $^{n=436}$

NAPLAN = National Assessment Program — Literacy and Numeracy; PAT = Progressive Achievement Test.
[a] Age at baseline (Wave 3).
[b] N with complete data in overall sample presented as superscript to relevant value.

Table 2
Characteristics of the three clusters. Values shown are mean (SD).

Cluster	n	Screen Time (h/day)	Unhealthy Foods (items/day)	No. of waves of sports participation	Sleep (h)
Low Sport	125	2.2 (0.8)	0.9 (0.6)	1.0 (0.8)	10.0 (0.7)
Junk Food Screenies	71	3.3 (1.0)	1.4 (0.8)	1.9 (1.2)	11.1 (0.8)
High Sport	147	1.7 (0.6)	1.0 (0.6)	3.4 (0.7)	10.6 (0.7)

Table 3
Socio-demographic characteristics of clusters.

		Low Sport	Junk Food Screenies	High Sport	P
n		125	71	147	
Age at Baseline [y, mean(SD)]		6.0 (0.5)	6.0 (0.5)	6.1 (0.5)	0.68
Sex (% male)		44	55	55	0.14
Remoteness (%)	City	22	25	38	<0.001
	Regional	43	59	46	
	Remote	34	16	16	
Parental Education (%)	High	19	16	27	0.10
	Medium	39	35	42	
	Low	42	49	31	

2013, and academic achievement from 2014 to 2015, lifestyle was antecedent to academic performance, and appropriately adjusted for age, sex, remoteness and parental education; supporting (but not fully establishing) a causal interpretation. We have used a careful cluster analysis approach, validated by random resampling. The wide range of educational indicators [PAT Maths, Numeracy, PAT Reading and Literacy (grammar, spelling, reading, writing subscales)] in repeated measures provides a more comprehensive account than is feasible in most experimental and cross-sectional studies. The clear trends across outcome measures seen in the radar plot (Fig. 3) suggest strong construct and concurrent validity, even though there were slightly contrasting relationships on some indicators (reading and numeracy) for *low sport* and *Junk Food Screenies* lifestyles. The *High Sport* group, reflecting approximately one in three children in the sample, were consistently superior across the wide range of education outcomes.

These strengths must be weighed against limitations. While the

Table 4
Estimated academic performance outcomes by cluster.

Adjusted mean (SE)		Low Sport	Junk Food Screenies	High Sport (Reference)
PAT Maths		105 (16)[a]	104 (14)[a]	109 (15)
PAT Reading		106 (20)	108 (19)	110 (19)
NAPLAN Numeracy		418 (78)[a]	407 (76)[a]	436 (73)
NAPLAN Literacy	Overall	411 (78)[a]	406 (76)[a]	434 (73)
	Reading	418 (89)	402 (84)[a]	432 (85)
	Writing	426 (101)	427 (101)	449 (97)
	Spelling	401 (101)	389 (101)	417 (97)
	Grammar	400 (101)[a]	405 (101)[a]	436 (97)

Estimates are adjusted for age, sex, parental education level and remoteness.
[a] indicates academic score is significantly different to reference category (*High Sport*). For example, the adjusted PAT Maths score for the *High Sport* cluster was 109, which was significantly higher than the score for the *Junk Food Screenies* cluster (104) or the *Low Sport* cluster (105).

Footprints in Time survey provides data on sport, sleep, screen time and diet, the questions have not been formally validated. Reliability and validity of these parent-reported measures may be compromised due to social desirability bias, communication difficulties and recall errors. Furthermore, only 40–49% of the baseline (Wave 3) participants provided complete lifestyle and academic achievement data (although measured differences between the complete sample and the various subsamples were small, see Table 1). Some questions were not consistent across survey waves, but any bias was reduced by using summary scores. In particular, the sports participation question was different in Waves 4 and 5 (referred to sport in the last week) compared to Waves 3 and 6 (referred to sport in the last month). However, it seems reasonable to assume that organized sports are usually participated in on a weekly basis. Bias may be introduced because lifestyle characteristics were based on different sampling frames as available (e.g. sport participation was collected across four waves, while sleep duration was only collected at one wave and pertaining to weekdays only). In addition, lifestyle data were aggregated across several waves and behaviours across the waves were attributed equal weight. This means we were not able to assess the impact of changes in lifestyle over time, or account for the possibility that more proximal lifestyle behaviours may be more influential on

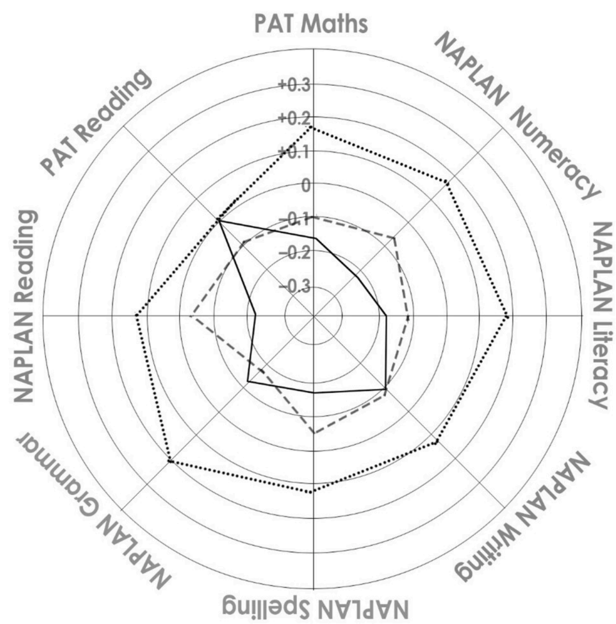

Fig. 3. Radar plot of academic performance of the three clusters, expressed as standardised mean differences relative to the whole sample.
The dotted line … …represents the *High Sport* cluster, the dashed line _ _ _ the *Low Sport* cluster, and the solid line __ the *Junk Food Screenies* cluster.

outcomes. Although academic outcomes were measured later in time than the lifestyle variables, we cannot establish causality due to the observational design.

Interpretation and implications using Ecological Systems theory

The children in this study fell convincingly into three lifestyle clusters. Although there were minimal sociodemographic differences between these clusters (Table 2), their profiles are no doubt the result of a complex mix of child, family, community and environmental factors. We can use EST to consider how these factors may be changed through individual, family, community or social policy actions so that children can move from *low sport/screen junkies* clusters to the healthier *high sport* cluster. Our findings suggest that such a shift is associated with substantial improvements in academic outcomes. Other experimental research supports a causal relationship between sport, physical activity and education (Ardoy et al., 2014; Chen et al., 2014; Coe et al., 2006; Hillman et al., 2009, 2014) and the logic that moving children from low sport, sedentary lifestyles to high sport, healthy diet and low screen lifestyles, may contribute to *closing the gap* in both health and education outcomes for Indigenous communities in Australia.

While this study and many others demonstrate the strong relationship between the physical and cognitive domains in child development, social policy for these domains falls to health and education authorities, and the various authorities regulating the built environment. The need to integrate these authorities has been widely noted (Commonwealth Government, 2019). In Australia bifurcation of school and health policy has been problematic and whilst many government (and also corporate and not-for-profit) authorities for the promotion of sport see schools as sites for their activities, the key drivers of school choice and school diversity operate such that universal optimal participation in sport and physical activity within all schools remains elusive (Hills, Dengel, & Lubans, 2015; Strugnell et al., 2016). Integration of health and education services in Indigenous communities is seen as a key target (Commonwealth Government, 2019) and some efforts have been made to apply this approach to specifically address the challenges in Indigenous communities in Australia. (e.g. through *Connected Communities'* co-situated schools and Indigenous Health Centres).

Referring back to Fig. 1, we now consider the current policy context and potential shifts that can be made in each of the environmental systems to potentially effect positive change. In this analysis we focus specifically on sport and physical activity policy; although similar could be done for dietary and screen use policy. As we have argued there is also scope for further research and service provision work that integrates all three of these lifestyle policy areas.

Targeting the microsystems –schools, families & neighbourhoods

Implementing change from family and community in the *microsystem* may be most effective. Atilola (2017) in their EST analysis child mental health approaches, suggests that "strengthening the micro-/meso system continuum" using direct supports of families should be a priority (p.386). But, while many sport and physical activity programs claim community-based implementation, or even origins, reach is not comprehensive and the fidelity of program implementation varies (Dahlberg, Hamilton, Hamid, & Thompson, 2018). Extant programs, from community or national sporting organisations, for example, situated in the broader *exosystem*, may have poor interaction in the *meso-system* and not make direct impact upon the child, or have limited reach and exert their influence only on a small number. The *Sport, more than just a game* report highlights the fact that few programs have been evaluated in terms of effectiveness (Commonwealth of Australia, 2013). However, it is possible, that a larger problem lies in program reach and implementation. In particular, the multiple barriers that children in financially impoverished and/or remote Indigenous communities, contribute to difficulties in how programs delivered and accessed in a sustainable way. The diversity of Indigenous community contexts, and also cultural barriers, makes effective top-down program implementation, through the *meso-system* an enormous challenge.

Further consideration, and research, is needed to align program and service practice with Indigenous perspectives. While sport, physical activity and recreational activities are important lifestyle and cultural activities in Indigenous communities; funding and implementation of these activities sits outside of community development programs (Commonwealth of Australia, 2013). Furthermore, the agenda for service provision is set according to the *macrosystem* of broader Australian law and customs; and delivered through the *exosystem* of Australian social services. Both these systems are dominated by non-Indigenous cultures and thus may not align with local Indigenous cultural practice.

Schools

One way to address the problems of reach, fidelity, sustainability and cultural appropriateness in current provision, is to build more sport and physical activity into schools and community organisations; and fund these over extended periods. While there are already national curriculum requirements and various state and territory school sport programs, little is known regarding the fidelity of implementation or effectiveness of such approaches in building healthy lifestyles among school students. Indeed, national report card monitoring suggests that despite current school programs Australian students are not active enough and "compare poorly with their international peers" (Schranz et al., 2018, p. 316).

Strengthening school programs would help ensure effective reach and implementation in microsystems where there is direct impact upon children. Strong investment would also enable the systematic monitoring and evaluation of these programs (dose, fidelity, etc). This is needed to establish implementation efficacy against a range of long-term outcomes; and also to build improvements into the programs.

In particular long-term funding, linked to planning in local communities, and delivered across the student cohort at schools with high Indigenous enrolments, has the potential to improve key indicators of education and health: components of the CTG policy goals of successive governments since 2008. The *Connected Communities* (schools as communities model in NSW schools with high Indigenous student numbers) aims for this direct approach (Burgess & Cavanagh, 2016), but not with a specific focus on sport. There is potential for in-school programs to build on established school and club-based sports programs; and also, to include more innovative approaches where sport and physical activity is built into schooling curriculum. Mavilidi et al. (2019), for example, propose a "Thinking by Moving" model where school lessons are more physically active and students better engaged. There are also opportunities for programs including traditional Indigenous sports and games. These are currently acknowledged in the national Australian Curriculum but little is known regarding their uptake (Evans, Wilson, Martin, Man, & Olds, 2018). Secure and long-term sport funding to targeted schools with high Indigenous student numbers, can ensure strong coverage and the potential to build habits through daily integration of sport, which can shift children's lifestyles.

Integration of diet, physical activity and health into *School Policy Frameworks* is a key target for the World Health Organisation (WHO, 2008). WHO suggests careful planning around the school physical environment, increasing the number of physical education classes and supporting extracurricular sport. There is also research evidence supporting the integration of sport and physical activity into school curricula. A study by Käll, Nilsson, and Lindén (2014), shows the potential of regularly scheduled physical activity within the school day. Their study builds upon a range of recent research examining the academic impact of sports programs in schools (Marques, Gómez, Martins, Catunda, & Sarmento, 2017). Käll's quasi-experiment evaluated the Swedish *Schools In Motion* approach with scheduled and mandatory 30–45 min sport activities twice a week delivered by local sports clubs in addition to two hours of curricular physical activity. Outcomes on Swedish national learning goal assessments showed that schools where the program was implemented were twice as likely to meet their learning goals. Given the findings of our study, similar intensity of sport and physical activity programming presents as a possible intervention for schools with Indigenous students – although the nature of that activity needs to be built around community values and needs. A research trial and evaluation would enable the potential of this to be explored.

Families

Families, and extended families, play a critical role in creating and sustaining the conditions that support participation in sport and physical activity. A disproportional number of Indigenous families are low on social and economic capital and rely on wider community support to deliver lifestyle outcomes (Browne-Yung, Ziersch, Baum, & Gallaher, 2014). There is strong evidence that children's levels of sport, fitness and healthiness of lifestyles fall back during school holidays, and differentially across families (Brazendale et al., 2017). It is therefore imperative to partner direct programs at school with family-based support and targeted programs for Indigenous children.

Targeted programs at a family level where parents participate with children on shared activities have been shown to produce positive social, health and education outcomes (Parker et al., 2006). Such programs might be initiated through schools, where programs may involve parent participation, organisation or playing alongside students. Extra-curriculum school or community based family health education programs may also be effective, not only in promoting sport but in informing families on the risks of unhealthy lifestyles and assisting in the development of partnerships for generation of healthy lifestyle habits (Michael, Dittus, & Epstein, 2007).

Neighbourhoods

Indigenous communities face a raft of specific socioeconomic and community challenges that require acknowledgment and EST analysis. The lowest levels of sport participation rates reported here, for example, among children in non-remote areas have been shown elsewhere to be related to socio-economic status (Evans et al., 2018). While there is some evidence that remote communities have strong participation in some sport, neighbourhood barriers in remote areas include a lack of facilities for organised sports and transport difficulties imposed by the combination of large distances, inclement weather and poverty. Surprisingly, in remote areas SES is less of a barrier to sport and physical activity than in urban areas (Evans et al., 2018), where greater opportunities, indeed requirements, exist for activities such as walking and running, and, where communities are large enough to support organised sport, they do so at relatively low cost. In urban areas, by contrast, opportunities/requirements for walking and running may be more limited, however there are more opportunities for organised sport, although costs to participants may be higher. Evans et al. (2018) showed an ecological transition among Indigenous children and youth, whereby SES was positively associated with sport and physical activity in urban areas but negatively associated in remote areas, where higher levels of prosperity translate into access to motor vehicle transport, rather than walking, and also bring more opportunity for sedentary behaviour through screen time.

Support for Indigenous communities needs to acknowledge local issues. For some communities this includes the problem of critical mass. Many isolated communities do not have the numbers to field teams in their preferred sports. Even in urban settings, it may be hard to field teams composed entirely of Indigenous players, where this may be their preference. A lack of critical mass also hinders remote communities in terms of facilities. While some neighbourhoods rely on innovative multipurpose facilities, others make do with school facilities available after hours. There is also the issue of weather, which can be very extreme in some geographical areas, making outdoor sport impossible and making it very hard to maintain grassed areas.

Our findings suggest that community funding and programs to overcome barriers to sport, through infrastructure, transport and secure financing programs, would be a worthy investment for healthy lifestyle returns and the associated benefits in educational outcomes. When considering the scale of investment needed it is also important to acknowledge the protracted and substantial personal and societal costs borne by failure to provide a strong health and education foundation to Indigenous children.

The individual and chronosystem shifts across the lifespan

Actions directly impacting upon the child, from strategies strengthening the *microsystem*, described above, can establish individual traits which in turn make individuals more receptive to sport participation. Thus, over time, sustained *microsystem* programs can establish positive orientations and habits which result in more permanent factors, including attitudes and motivation, related to positive high sport lifestyles. The role of schools, for example, in establishing positive attitudes and habitual sport and physical activity, is well established (Trudeau & Shephard, 2005). However, to optimise the impact upon the individual, programs need to be culturally appropriate and delivered to meet the needs of the individuals. Ongoing evaluation of programs and high-quality empirical research is needed to explore these issues within Indigenous communities.

Finally, policy needs to consider the changes over lifetimes, reflected in the *chronosphere*. Changes in levels of Indigenous sport over childhood and youth have been mapped and illustrate the tendency of some groups, for example 16 year old girls, to disengage (Evans et al., 2018). These trends need to be verified with additional evidence and used to target and sustain resources for those age groups most in need. Research is also needed to explore how effective sport programs, and other healthy lifestyle programs, are at different ages in terms of establishing lifelong habits. Similarly, there needs to be research examining how minimisation of sedentary habit-forming screen activities might be most effective at particular ages. Such approaches would be invaluable in developing economical and sustainable policy initiatives to maximise positive outcomes for Indigenous children. However, they would also require substantial investment in longitudinal research with consistent and objective data collection, allowing trajectory analysis.

Conclusion

This study adds to the emerging body of literature demonstrating the link between participation in physical activity and sport, and improved academic outcomes. Importantly, in this study we do so using a lifestyle approach and ecological framework, rather than examining sport and learning outcomes in isolation. This multifactorial approach sits more comfortably with broader child development literature, which acknowledges the complicated interplay between factors and multiple developmental domains. It also sits comfortably with the need to *close the gap* in multiple domains using community-led approaches (Burgess & Cavanagh, 2016).

Our findings suggest that high sport lifestyles, in tandem with healthy diet and low screen use, among Indigenous children are associated with better performance across a range of educational outcomes. Leaning upon other research establishing a causal relationship between sport and education outcomes, we suggest that careful modification of the ecologies of children can help in shifting their lifestyles toward healthier, active *high sport* ones which may also lead to improved educational outcomes. In particular, we note that given the cultural dissonance of policies that emerge in *Exo-* and *Macro-systems* where Indigenous values are, at the very least, neglected, and quite possibly absent, a more direct approach supporting community action, through *exosystem* support of *microsystem* schools, families and neighbourhoods would be preferable. This would enable culturally appropriate implementation of programs and provide direct shifts supporting sport in the *Microsystems* of children.

Whilst the ecological approach we have taken is applied to child development globally, we present it here as an important tool in analysis of the extremely complex and challenging socio-political and geographical situations that Indigenous communities face. In the Australian context, and likely many others internationally, such an approach may provide insight and clarify ways of addressing disadvantage in vulnerable populations and minority groups, which are culturally distant to many researchers' personal experience. Through ecological approaches research can develop deeper understanding and provide considered alternatives to the, often knee-jerk, tendencies to employ piecemeal initiatives, which are without holistic perspective and therefore restricted in their potential to succeed.

CRediT authorship contribution statement

Rachel Wilson: Funding acquisition, Conceptualization, Methodology, Resources, Writing - original draft, Writing - review & editing. **Dorothea Dumuid:** Formal analysis, Writing - original draft, Writing - review & editing. **Tim Olds:** Funding acquisition, Resources, Methodology, Supervision, Writing - review & editing. **John Evans:** Funding acquisition, Resources, Methodology, Supervision, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2019.100535.

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