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Testing spatial measures of public open space planning standards with walking and physical activity health outcomes: Findings from the Australian national liveability study

Paula Hooper[a,*], Bryan Boruff[b], Bridget Beesley[a], Hannah Badland[c], Billie Giles-Corti[c]

[a] Centre for the Built Environment and Health, School of Agriculture & Environment and School of Human Science, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia
[b] School of Agriculture & Environment, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia
[c] Healthy Liveable Cities Group, Centre for Urban Research, RMIT University, Melbourne, Australia

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ABSTRACT

Green public open spaces (POS) are an important component of healthy, liveable, and sustainable urban environments. Planning policies for POS provision however tend to be evidence-free. A review of Australian state-level POS planning policies and standards was conducted and policy-specific spatial measures generated in GIS. These were linked with health data from the RESIDE survey and relationships examined with weekly walking for recreation and moderate-vigorous physical activity (MVPA). To facilitate the development of a comparable national measure of POS provision, the measures were replicated using a national-level dataset on POS and compared using intra-class correlations.

Sixteen POS policy standards relating to the location, amount, access, and size of POS were identified. Only one POS standard was associated with a health outcome: RESIDE participants living in suburbs where 95% of residents lived within 400 m of a park had a three-fold increased odds of doing weekly MVPA. The national dataset did not appear to align with the types of POS typically addressed by urban POS planning policies and showed a low level of reliability with the finer-grain state layer (ICCs 0.185–0.312).

These findings support existing literature indicating that neighbourhoods with greater access to POS within 400 m are associated with higher odds of physical activity. The current study suggests that not all POS standards are equal, and more research is required to determine whether current planning standards being implemented are achieving their full potential. The development of national evidence-based, policy-relevant POS indicators has the potential to inform future POS planning policies and decisions.

1. Introduction

The provision and availability of green public open spaces (POS) in urban areas is an important component of healthy, liveable and sustainable urban environments and has long been a policy concern of urban planners and policymakers. There are an ever increasing number of biophysical, social and cultural purposes POS is required to fulfil in contemporary urban planning and design (Grose, 2009). This includes provisioning of POS for active and passive recreation; urban water management; biodiversity protection; and reduction of urban heat island effects, to name a few. However, in addition to simple aesthetic value, access to POS such as parks, has been linked to numerous physical, social, and mental health benefits – including increased propensity to engage in physical activity (Giles-Corti et al., 2005; McCormack, Rock, Toohey, & Hignell, 2010), enhancing mental health (Kaplan, 1995; Francis, Wood, Knuiman, & Giles-Corti, 2012), and space for social interaction and cohesion (Francis, Wood et al., 2012; Francis, Giles-Corti, Wood, & Knuiman, 2012).

Despite numerous community benefits associated with the provision of POS, three vital (and still relatively unanswered) questions persist: How much open space should be provided? Of what kind? And where should it be located? (Wilkinson, 1985). Whilst urban planners recognise the complexity involved in answering these questions (Wilkinson, 1985) the use of 'standards' has provided the foundation by which POS planning has progressed in many countries (Wilkinson, 1985; Veal, 2013). These were introduced to ensure a level of consistency and certainty in greenspace planning and to provide a minimum level of service (Veal, 2013). These 'standards' typically

* Corresponding author.
E-mail addresses: paula.hooper@uwa.edu.au (P. Hooper), bryan.boruff@uwa.edu.au (B. Boruff), bridget.beesley@uwa.edu.au (B. Beesley), hannah.badland@rmit.edu.au (H. Badland), billie.giles-corti@rmit.edu.au (B. Giles-Corti).

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provide guidance or targets concerning the amount, type and spatial distribution of (or distances to) POS and parks (as a type of POS) based on longstanding assumptions of park use (Veal, 2013). Three frequently used standard types are: 1) Area percentage: A fixed percentage of land to be reserved for POS; 2) Population-ratio: A prescribed level of provision of open space related to the level of population, typically per 1000 population; and 3) Catchment areas: 'Service areas' for different categories of open space, or maximum distances which residents should have to travel to access a POS (e.g., the percentage of households within a specified distance).

A recent review of the historical origins of POS planning guidelines in Australia revealed that 'standards' in general, are not empirically-derived or evidence-based (Veal, 2013), nor have they been empirically evaluated or scientifically tested (Wilkinson, 1985). Rather, they are based on British or American standards, often with little rationale for their application within the Australian context (Veal, 2013). Veal (2013) indicated that *"even when standards were 'in vogue', there appears to have been no attempt to develop a specific Australian standard based on relevant Australian data"* (p. 231) and *"the lack of authoritative testing and evaluation of early standards is most evident"* (Wilkinson, 1985, p.196). This is not a uniquely Australian problem. Internationally, there is a lack of evidence-based urban design approaches for developing POS as well as policies directing the provision of POS (La Rosa, 2014).

Over the last two decades, a considerable body of scholarly work from the active living research field has been established focusing on the relationship between access (proximity and distance) to POS and the number (counts) or amount (total area) of POS within a neighbourhood with active living outcomes (Kaczynski, Potwarka, & Saelens, 2008). However, very few have based their measurement and analysis of the proximity and size of POS against current planning policies (and their standards) that underpinned the provision of these POS (i.e., the amount and spatial arrangement). Further, despite variations in how it has been conceptualised, measured and quantified, the 'quality' or 'attractiveness' of parks has been shown to be an important factor in encouraging walking and positive physical activity behaviours (Giles-Corti et al., 2005). Analytical approaches have typically looked at the number or mix of different features, facilities and amenities within parks and their associations with park use or increased walking and physical activity. These attributes have then been used to create a "Park Index" (Kaczynski et al., 2016), park quality or attractiveness scores (Giles-Corti et al., 2005, Edwards, Hooper, Knuiman, Foster, & Giles-Corti, 2015).

Today there remains a shortage of research assessing how the application and provision of current POS policies and their standards, guidelines or recommendations are delivered on-the-ground, and how they influence or impact the health and wellbeing of residents − using policy specific measures. Important unanswered questions for policy makers and POS planners include: what policy standards should be recommended from a health perspective? And, are current standards or targets within the POS policies sufficient to bring about positive health and wellbeing outcomes? This has resulted in limited understanding of how current POS planning policies influence the health and wellbeing of residents − despite it being frequently stated as a desirable outcome.

This is also an important question because the provision of POS is currently under intense debate in Australia (Grose, 2009, 2010). With an ever-increasing recognition of the need to create liveable and sustainable cities and urban environments that enhance the health and wellbeing of residents (Badland et al., 2014), it is timely and desirable to examine the extent to which POS policy standards are implemented, and the impact these have on healthy behaviours. In an Australian context, this task is made more difficult as different POS policies and standards have been applied across the nation. However, there is increasing interest and pressure to develop comparative federal analysis of POS across Australian states and cities and provide for national benchmarking (State of the Environment 2011 Committee, 2011) as has been achieved in the US through initiatives such as ParkScore (ParkScore.org) by The Trust for Public Land (2016).

This study sought to gain further insights into these issues. It forms part of the Australian National Liveability Study, which aims to identify the urban planning policies and their standards that are associated with healthy, liveable communities (Giles-Corti et al., 2014). It also aims to respond to government interest to develop and validate a national set of spatially-derived liveability indicators of the built environment that impact on non-communicable disease risk behaviours and/or health outcomes and allow for comparisons across Australian cities and urban areas. Access to quality POS has been identified as one of the components of a liveable community, in this instance, defined as *"a community that is safe and socially cohesive; environmentally sustainable; with affordable housing linked via public transport, walking and cycling to employment, public open space, shops and all the services required for daily living (e.g., schools, health and community)"* (Badland et al., 2014). The specific aims of the study presented here within were to inform urban planning policies related to POS provision by:

1) Identifying existing POS planning policy standards across selected Australian states and territories;
2) Creating spatial measures of these policy standards;
3) Examining which, if any, of these policy standards are associated with recreational walking and physical activity in an urban context; and to
4) Comparing the POS measures developed using state spatial data with those developed using national-level spatial information.

2. Methods

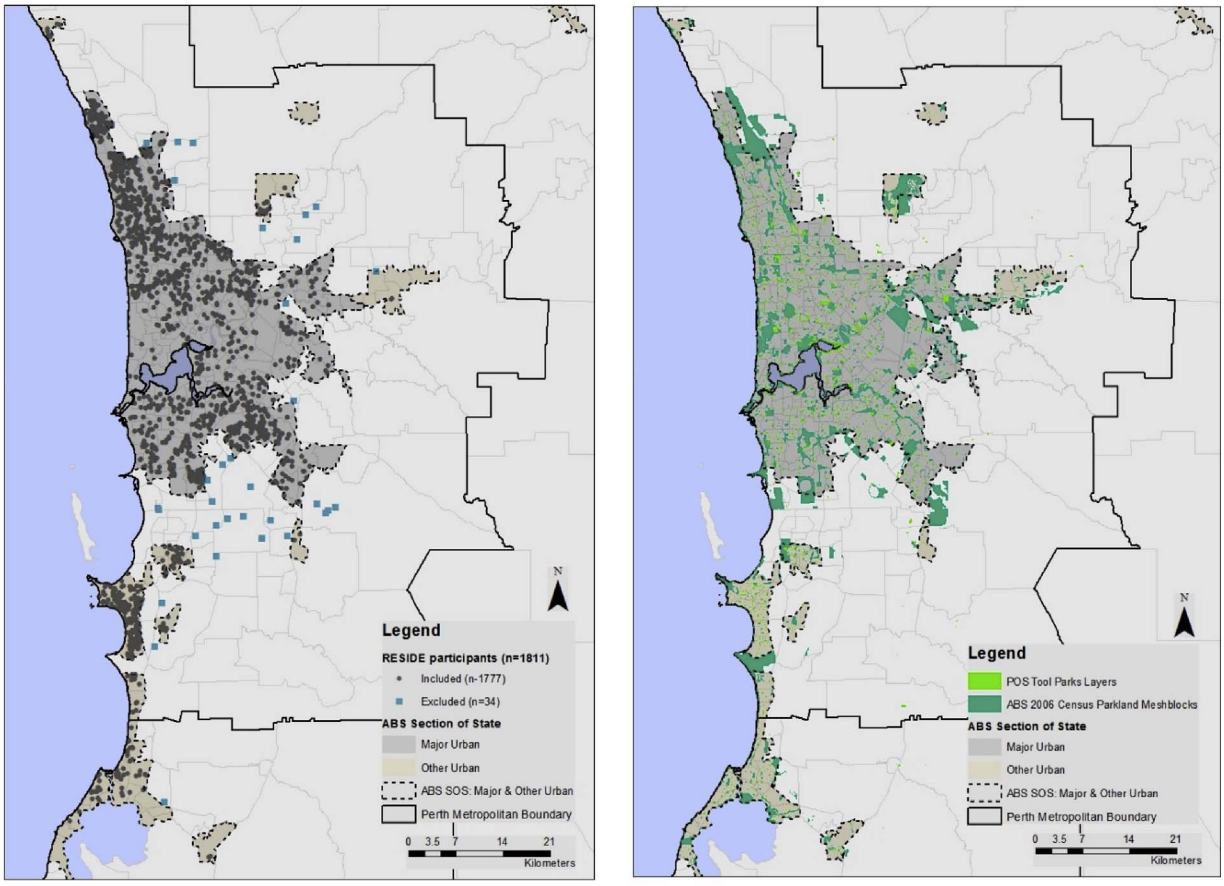
2.1. Study context and participants

The Australian National Liveability Study focussed on metropolitan urban settings throughout the country (Arundel et al., 2017). The sub-study presented here focuses on the 'urban' extent of the Perth metropolitan region classified as either 'Major Urban' (geographical areas with population clusters of 100,000 or more) or 'Other Urban' (population clusters of 1000–99,999) by the Australian Bureau of Statistics (ABS) (Australian Bureau of Statistics) (Fig. 1).

The RESIDE Project was a longitudinal natural experiment of participants relocating to 73 new housing developments across Perth, Western Australia. Participants were invited to take part in the study by the state water authority following land transfer transactions (response rate of 33.4%) in 2005. Participants completed a self-report questionnaire before moving to their new home (baseline n = 1813), and on three occasions after relocation at approximately 12, 36 and 84 months respectively. Full details of the RESIDE recruitment protocols and study design are available elsewhere (Giles-Corti et al., 2008). The current study draws on participants who completed the baseline survey. This time point was chosen as participants were located within the largest number of suburbs across the Perth metropolitan area (247 of the 398 suburbs at the 2006 census) representing a diversity of neighbourhood age structures and POS designs. All RESIDE participants who completed a baseline survey and were residents within the urban extent of Perth were included in this study (n = 1777) (Fig. 1).

2.2. Review of Australian POS planning policy and standards

In 2014, a review of current state-level POS policies and their respective 'standards' was conducted for the states and territories participating in the Australian National Liveability Study (Giles-Corti et al., 2014). These included the Australian Capital Territory (ACT), New South Wales (NSW), Queensland (QLD), Victoria (VIC) and Western Australia (WA). For each policy a set of spatial measures were developed for the associated standards (e.g. amount, location, access, size and facilities/functions). The final list of spatial POS policy measures was reviewed for completeness by the Australian National Liveability



A: RESIDE participants resident with 'urban' areas

B: Comparison of the two POS spatial layers within urban areas of Perth

Fig. 1. RESIDE participants (Fig. 1A), POS Tool 'parks and ABS Census 'parkland' meshblocks located within the 'urban' study area.

Study's Advisory Group, which consisted of state and federal policy-makers, planners, practitioners and non-government organisations.

2.3. POS data

Policy-specific spatial measures of POS were generated in a geographic information system (GIS). Two POS data sets were used to examine the relationship between POS policy and health outcomes: A large scale state-based POS GIS layer (digitised from 10 cm x 10 cm resolution orthorectified imagery) developed initially under the RESIDE study, and a small scale (+/− 1:2000 in urban areas and +/− 1:10,000 in rural areas) national POS GIS layer developed by the ABS. The latter was used to test the feasibility of extending the local analysis across the country using nationally available free POS data.

2.3.1. State-based POS layer

The digital spatial database reflecting the spatial extent of all areas of green POS across the Metropolitan Perth region for 2012 (Centre for the Built Environment and Health, 2013) was initially developed in two stages. First, an initial POS layer for the Perth metropolitan and Peel regions was created using existing vector-based GIS data that identified areas be considered to be POS. This included: 1) 2011 cadastre database (Western Australian Land Information Authority, Landgate); 2) 2012 Vesting reserve report (Western Australian Land Information Authority, Landgate); 3) Planning and land use codes (PLUC) 51 (Public Open Space), 52 (Sporting Infrastructure) and 6 (primary/rural, which includes extractive industries, farming and conservation areas) identified within the Valuer General's Office (VGO) dataset, a point based dataset designed to represent taxable features throughout the state and linked to the 2011 cadastre database mentioned above; and 4) A spatial dataset with the geocoded locations of all primary, secondary and tertiary schools (Department of Education and the Department of Planning 2012). All land uses identified above relate to POS and were combined to create a draft set of potential areas of POS across the Perth and Peel regions. Next, the base POS layer was verified and ground-truthed using high resolution orthoimagery (10 cm × 10 cm) from the corresponding year (circa January 2012) and information from local government authorities on the POS sites and reserves they managed. Any missing areas of POS were added (i.e., manually digitised), POS boundaries modified where appropriate, and unnecessary information removed.

As this study used health outcome information from the RESIDE baseline data collection in 2005, the 2012 POS layer was retrospectively ground-truthed and modified to reflect the on-ground POS landscape in 2005 using high resolution orthoimagery (10 cm × 10 cm) flown in the corresponding year (circa January 2005). Again, any missing areas of POS (i.e., were present in 2005 but not in 2012) were added by manually digitising, POS boundaries modified where appropriate, and unnecessary information removed (i.e., present in 2012 but not 2005).

All areas of POS were then classified into one of four categories: 1) parks, 2) natural and conservation areas, 3) residual green spaces and 4) school grounds. Whilst some policies used the term 'public open space', most refer to formal POS such as 'parks', 'reserves or "ovals" (large oval shaped grassed area for Australian Rules Football and/or cricket). The study was less concerned with the provision of, or access to, natural areas which were therefore excluded from this study. All

areas classified as “parks” were the main focus of this study and were those defined as “areas typically designed for, or able to cater for, a range of different leisure or recreational activities − both active and passive”. These included landscaped, ornamental and manicured gardens or parks (that may or may not include children’s play equipment) as well as publicly accessible (i.e. free to use) sports fields and ovals. Areas of open space, such as ovals or sports courts and facilities with restricted access to the public (i.e. belonged to sports clubs or leisure centres or fenced off school grounds) were not included (Centre for the Built Environment and Health, 2013). For the purposes of this paper, going forward, the term “POS” refers to ‘parks’. These data were used to create spatial measures of the policy standards identified in the POS policy review.

2.3.2. National POS spatial layer

Whilst many Australian states and territories possess spatial information concerning the location of their parks, reserves and POS, the quality and structure of these data are not nationally consistent. Additionally, a lack of uniformity in definition, terminology and descriptions of POS prevents comparability across state data sets for the purpose of national evaluation. In Australia, the Australian Bureau of Statistics (ABS) meshblock dataset provides the only consistent national coverage of POS information. Meshblocks are the smallest geographical area defined by the ABS, containing between 30 and 60 dwellings. Each meshblock is classified by the ABS according to the dominant land-use: i) water; ii) parkland; iii) residential; iv) industrial; v) commercial; vi) education; vii) hospital/medical; viii) agricultural; ix) transport; and x) other.

To facilitate the development of a comparable national measure of POS provision, POS measures were replicated using a national level dataset of POS. All meshblocks from the 2006 census dataset classified as “*parkland*” were extracted and used to measure each spatial POS policy measure. Meshblocks identified as ‘agricultural’ were not considered as ‘parks’, as these areas are not generally accessible by the public for recreation or physical activity. Domestic gardens were also not included in the ‘parkland’ category (Fig. 1).

2.4. POS exposure variables

The POS measures were created to reflect two spatial extents using the state-based POS layer: 1) the suburb in which the participants lived; and 2) service areas (polygons) created along the road network extending 1.6 km in all directions from the participant’s house. This distance was chosen to reflect a 10–15 min walk from home, on the basis that return trips to neighbourhood destinations up to a 15 min walk from participants’ home would meet the recommended 30 min of daily moderate physical activity by walking. Table 1 outlines each of the POS exposure measures that were created for the policy standards at each respective (and applicable) spatial extent. All spatial measures were created in ArcGIS (ESRI v10.2).

2.4.1. Area-percentages

The total area of POS and the ‘subdivisible’ (WA) and ‘net developable’ (VIC) land areas (Table 1) within each participant’s 1.6 km service area and the suburb in which they lived were calculated. Where park polygons crossed (and extended beyond) the 1.6 km service area or fell within adjacent or multiple suburb boundary lines, only the actual area of the park polygon within the suburb or service area was allocated to the respective suburb or service area (Fig. 2). The area of POS was then calculated as a percentage of the ‘subdivisible’ (WA) and ‘net developable’ (VIC) land areas.

2.4.2. Population-ratios

This standard was not appropriate to be tested at the individual household (i.e., 1.6 km road network service area) level and as such was created only for the suburbs participants lived in. Census collection districts (CCDs) are the smallest spatial unit for which data from the 2006 census were collated (Australian Bureau of Statistics, 2011). In urban areas CCDs average approximately 220 dwellings. The CCDs align with, and can be aggregated up to suburb boundaries. Population data for each CCD from the 2006 census was aggregated to their respective suburbs − providing the total ‘usual resident’ population per suburb.

A number of policy ‘standards’ were based on population ratios of POS provision. For the NSW standard the total area of POS present within each suburb was calculated as a measure (area in hectares) of POS per 1000 resident population for the suburb. Again, only the actual area of the park polygon within the suburb was allocated to the respective suburb. The QLD policy identified different population-ratio targets for different size parks (Table 1). All parks were classified based on their size in accordance with the QLD standard. Parks were then selected based on their size and the total summative area of these within in each suburb examined as per 1000 resident population for the suburb. All parks were classified based on the area of their full extent. Where a park crossed a suburb boundary, the original size classification assigned to the park polygon based on the size was used to select it. However, only the area within the suburb was included in the calculation (Fig. 2).

2.4.3. Catchment areas

A number of policy ‘standards’ provided for access to POS within a certain distance of residents. To spatially measure this type of policy first, catchment areas reflecting each policy ‘standard’ were created for each POS. Points were generated at 40 m intervals around all park polygon boundaries to reflect access points into the POS. Service areas extending 400 m along adjacent road networks were then generated for each point. All service areas pertaining to the same park were then dissolved. Individual measures of access to POS within 400 m walking distance (e.g. as per the VIC standard) were generated by identifying and coding the RESIDE participants whose residential (point) location was within a 400 m park catchment.

Furthermore, many planning standards identified targets for the proportion of dwellings that should be within a specified distance from one or more POS − for example the VIC standard states that 95% of dwellings should be within a 400 m walking distance of at least one park. As such, an areal weighting approach was used to identify the number of dwellings within each of the RESIDE participants’ suburbs that had access to a park within 400m. This method assumed equal distribution of dwellings across the CCD. The 2006 census CCD’s provided information on the number of dwellings. A 400 m road network catchment for each POS was intersected with the 2006 CCD’s. The proportion of the CCD land areas that overlapped a catchment was then determined. The number of dwellings for each CCD falling within a 400 m walking distance of at least one park was calculated using an areal weighting approach (e.g., if 50% of the CCD land area fell within a park catchment, 50% of the dwellings within that CCD were counted as being within the POS catchment area). The dwelling data from each CCD was then aggregated to the suburb level and the percentage of the dwellings within a 400 m park catchment for each suburb was calculated.

A core component of the WA POS policy was ensuring residents had access to parks of different sizes within specified distances (Table 1). The same processes as above were thus followed for the WA policies. All park polygons were classified according to their size (area in hectares). Catchment areas were then created using road network distances as appropriate − the size of POS and distances of the catchments each based on policy ‘standards’ for the respective park size and the areal weighting method used to determine the number of proportion of dwellings located within the specified distances (Table 1).

Table 1
POS planning standards and spatial measures developed.

State	Standard Type	Policy Standard	Spatial Measurement: Suburb	Spatial Measurement: Individual 1.6 km road network service	Policy Measures	
					Continuous	Binary
WA	Area-percentage	Public open space equivalent to 10 per cent of the gross subdivisible area: A minimum of eight per cent active and passive recreational purposes.	Total area of all parks within participants' suburb ÷ subdivisible land area of the suburb *(= residential zoned land + POS area)*	Total area of all parks within participants' 1.6 km RNSA[a] ÷ subdivisible land area of the 1.6 km RNSA *(= residential zoned land + POS area)*	% of suburb/ 1.6 km RNSA = POS	< / ≥ 10%
VIC	Area-percentage	In residential areas, approximately 10 per cent of the Net Developable Area (NDA) is to be allocated for public open space	Total area of all parks within participants' suburb ÷ Net Developable Area land area of the suburb *(= gross service area–road cadastre area)*	Total area of all parks within participants' 1.6 km RNSA ÷ Net Developable Area land area of the 1.6 km road network service area *(= gross service area–road cadastre area)*	% of suburb/ 1.6 km RNSA = POS	< / ≥ 10%
	Area-percentage	6 per cent of the "Net developable area" is to be allocated for active open space (NB: active open space = parks ≥ 8 ha in size)	Total area of all ACTIVE parks within participants' suburb ÷ Net Developable Area land area of the suburb *(= gross service area–road cadastre area)*	Total area of all ACTIVE parks within participants' 1.6 km RNSA ÷ Net Developable Area land area of the 1.6 km RNSA *(= gross service area–road cadastre area)*	% of suburb/ 1.6 km RNSA = POS	< / ≥ 6%
NSW	Population-Ratio	All parks = 2.83 ha/1000 persons	(Total area of PARKS within participants suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 2.83 ha/ 1000
QLD	Population-Ratio	'Local recreational' (minimum area = 0.75–1.5 ha) = 1.0–1.2 ha per 1000 residents	(Total area of all parks ≥ 0.75– < 3 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 1.0 ha/1000
QLD	Population-Ratio	'District recreational' (minimum area = 3–6 ha) = 1.0–1.4 ha per 1000 residents	(Total area of all parks ≥ 3 ha ≤ 6 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 1.0 ha/1000
QLD	Population-Ratio	Total recreational (parks 0.75 ha–6 ha) = 2.0–2.6 ha/1000 residents	(Total area of all parks ≥ 0.75– ≤ 6 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 2.0 ha/1000
QLD	Population-Ratio	Local sporting (minimum area = 3–5 ha) = 0.8–1 ha per 1000 residents	(Total area of all parks ≥ 3 ha– < 7 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 0.8 ha/1000
QLD	Population-Ratio	District sporting (minimum area = 7–10 ha) = 1–1.4 ha per 1000 residents	(Total area of all parks ≥ 7 ha– ≤ 10 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 1.0 ha/1000
QLD	Population-Ratio	Total sporting (3–10 ha) 1.8–2.4 ha/1000 residents	(Total area of all parks ≥ 3 ha– ≤ 10 ha within participants' suburb ÷ suburb population) × 1000	Not Applicable	Area (ha)/1000 persons	< / ≥ 1.8 ha/1000
VIC	Catchment Areas	Parks to be within 400 m safe walking distance of at least 95 percent of all dwellings	Number of dwellings within ≥ 1/any 400 m park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥ 1/any park 400 m catchment area	Not Applicable	Participant within ≥ 1/any 400 m park catchment
WA	Catchment Areas	Small parks < 0.4 ha: 200 m from most dwellings	Number of dwellings within ≥ 1/any 200 m small park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥ 1/any small park 200 m catchment area	Not Applicable	Participant within ≥ 1 200 m small park catchment
WA	Catchment Areas	Local parks ≥ 0.4 ha to ≤ 1 ha: ≤ 400 m or 5 min walk from most dwellings	Number of dwellings within ≥ 1/any 400 m local park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥ 1/any local park 400 m catchment area	Not Applicable	Participant within ≥ 1 400 m local park catchment
WA	Catchment Areas	Neighbourhood parks > 1 ha to < 5 ha: ≤ 800 m or 10 min walk from most dwellings	Number of dwellings within ≥ 1/any 800 m neighbourhood park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥ 1/any neighbourhood park 800 m catchment area	Not Applicable	Participant within ≥ 1 800 m neighbourhood park catchment
WA	Catchment Areas	District parks ≥ 5 ha to ≤ 15 ha: ≤ 2 km or 5 min drive from most dwellings	Number of dwellings within ≥ 1/any 2 km district park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥ 1/any district park 2 km catchment area	Not Applicable	Participant within ≥ 1 2 km district park catchment

(*continued on next page*)

Table 1 (*continued*)

State	Standard Type	Policy Standard	Spatial Measurement: Suburb	Spatial Measurement: Individual 1.6 km road network service	Policy Measures	
					Continuous	Binary
WA	Catchment Areas	Regional parks > 15 ha: ≤10 km from most dwellings	Number of dwellings within ≥1/any 10 km regional park catchment area/total number of dwellings	Select and attribute all participants' whose residential location is WITHIN ≥1/any regional park 10 km catchment area	Not Applicable	Participant within ≥1 10 km regional park catchment

[a] RNSA = Road Network Service Area: the area encompassed by all streets that can be reached from the point of origin within a specified distance.

2.5. Outcome measures

The outcomes examined in this paper were walking for recreation and total physical activity undertaken in each participant's home neighbourhood (defined as a 1.6 km road network service area or 10–15 min walk from home). Self-reported walking and physical activity behaviours were measured using the 'Neighbourhood Physical Activity Questionnaire' (NPAQ) (Giles-Corti et al., 2006). Participants reported the frequency and duration of walking within their local neighbourhood in a usual week to get to or from somewhere (i.e., walking for transport) or for recreation, health or fitness. An overall index of physical activity was created by summing the recorded frequency and duration of moderate- and vigorous-intensity activity. Dichotomous variables (yes/no) were computed for > 0 min (any) walking for recreation (WR) in the neighbourhood and any moderate to vigorous physical activity (MVPA).

2.6. Statistical analysis

Logistic regression models with generalised estimating equations (GEE), to account for clustering within residential developments, were used to compare each of the spatial POS policy measures with the odds of doing any walking for recreation and engaging in moderate or vigorous physical activity in a usual week. The models were adjusted for sex, age, education, employment, marital status, household income, and having children under the age of 18 living at home. Analyses were conducted using SPSS version 22.

2.7. Testing the validity of the national indicator dataset

The gross area of POS within each participant's 1.6 km service area was created using both the state-based POS layer and the national meshblock layer. We compared the area of POS within each participant's service area by data source using scatter plots and intra-class correlations (two-way random model with absolute agreement).

3. Results

The review yielded 16 POS policy standards across five states and territories relating to the location, amount, access, and size of POS (Table 1). Planning standards for two states (WA and VIC) specified a fixed percentage of land area to be preserved for POS. However, the land uses included in the denominator of this calculation differed (i.e. operationalised as the residentially zoned land area + the POS area in WA; and the gross service area minus the road cadastre in Victoria). Victoria had a second standard to ensure sufficient amounts of POS were provided for active (i.e., sporting) uses. Both WA and VIC also had catchment-based standards specifying the maximum distance residents should have to travel to access POS. Victoria possessed a single standard requiring 95% of all dwellings to be within 400 m of any POS, while WA specified more ambiguous distance standards such that 'most' residential dwellings should be within a certain distance of POS according to size (and potential function) − for example: most dwellings were required to have a local park (≥ 0.4 ha–≤ 1 ha in size) within 400 m or a five minute walk; and a neighbourhood park (> 1 ha– < 5 ha in size) within a 800 m or 10 min walk. Queensland (QLD) and New South Wales (NSW) both used population-ratio standards. The standard in NSW prescribed a single standard of provision of all/any POS per 1000 population, while the Queensland policy specified standards according to the size and intended functionality (i.e., recreation or sports) of POS.

3.1. POS provision measured by different standard types

Measures based on the standards used across Australia were developed and applied in the Perth context. Both the WA and VIC policies set targets of 10% provision of POS − but the definition and

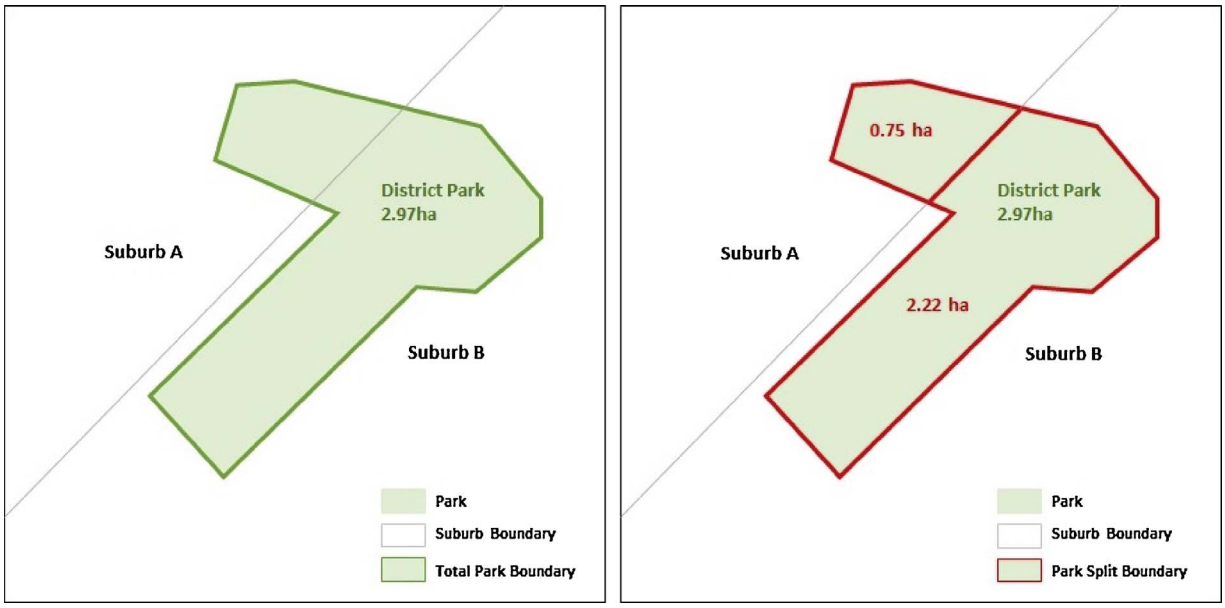


Fig. 2. Methods for dealing with POS polygons split across suburb boundaries.
District Park crosses into two suburb boundaries (suburb A and suburb B).
Left: Park type based on the size classification assigned to the entire extent of the POS polygon − both suburbs are assigned as having a district park.
Right: For POS area statistics the relevant areas of the park that fall within each suburb are assigned to those suburbs.

operationalization of each state's standards differed (see Table 1). Over two thirds (69.6%) of all RESIDE participants had ≥10% of the (subdivisible) land area allocated to POS within their 1.6 km service area (mean = 12.5%) and nearly three-quarters (73.4%) of participants had ≥10% of subdivisible land area allocated to POS within their suburb (mean = 12.4%). However, when this measure of POS provision was applied using the net developable land area as the denominator, only about than one-third (35.5%) of RESIDE participant's service areas had ≥10% land allocated to POS (mean = 8.9%) and less than a quarter (21.8%) had ≥10% POS of the subdivisible land area within their suburb provided as POS (mean = 7.2%). Finally, population-ratios were examined (e.g., hectares per 1000 residents). The average area of all 'parks' within the participants' service areas, was 4.27 ha/1000 residents.

Nearly 80% of the RESIDE participants had access to a park within 400 m road network distance of their home. Using the WA catchment standards, RESIDE participants had high levels of access to neighbourhood, district and regional parks with over three quarters of all participants having POS access as per WA policy standards. Further analyses showed that 42% of participants' closest park was a neighbourhood sized POS (i.e., ≥1.0– < 5 ha), with an average road network distance of just under 300 m from their home.

3.2. Associations between POS policy measures with recreational walking and physical activity

Overall, 1777 of the 1813 RESIDE participants lived in 'urban' or 'other-urban' metropolitan areas of Perth (based on ABS classifications) and were included in the analyses. Participant demographics for each of the outcome variables (any walking for recreation and any moderate-vigorous intensity physical activity per week) are presented in Table 2. Just over one-half (54%) of all participants reported any walking for recreation and under one-half (44%) reported any MVPA within their neighbourhood in a usual week. The majority of participants were female, employed and married. Nearly half of the sample had children under the age of 18 living at home.

There were no significant associations between the area-percentage measures of POS provision, at either the individual service area or suburb extents, or between the population-ratio measures of POS provision and the odds of doing any walking for recreation or MVPA (Table 3). Living in suburbs with ≥95% of dwellings located within a 400 m catchment of any POS (park) was associated with a three-fold increased odds of doing any MVPA in the neighbourhood (OR = 3.17, 1.02–9.81). There was some evidence that the odds of doing any WR was higher for those living within 400 m of a POS, however this did not reach statistical significance. (OR = 1.23, 0.96–1.57 p = 0.098). Having access to a local park (≥0.4– < 1 ha) within 400 m also was

Table 2
Participant demographics and levels of walking for recreation and moderate-vigorous physical activity.

	Any walking for recreation		No walking for recreation		Any MVPA		No MVPA	
	n	%	n	%	n	%	n	%
Total	945	53.8	810	46.2	776	43.8	995	56.2
Sex								
Males	367	38.8	345	42.6	339	43.7	376	37.8
Females	578	61.2	465	57.4	437	56.3	619	62.2
Education								
Secondary or less	360	38.2	328	40.6	275	35.4	419	42.2
Trade/ apprenticeship/ certificate	346	36.7	310	38.4	286	36.9	375	37.8
Bachelor degree or higher	236	25.0	165	20.4	212	27.3	194	19.6
Other	1	0.1	5	0.6	2	0.3	4	0.4
Work Status								
Work	762	80.7	688	85.1	656	84.6	812	81.6
No work	117	12.4	101	12.5	80	10.3	137	13.8
Retired	65	6.9	19	2.4	39	5.0	44	4.4
Marital Status								
Married/DeFacto	778	82.5	653	80.6	613	79.1	830	83.5
Separated/ Divorced/ Widowed	80	8.5	57	12.5	56	7.2	81	8.1
Single	85	9.0	100	2.4	106	13.7	83	8.4
Age		41.0		38.9		38.4		41.3
Children < 18 at home								
Yes	439	46.5	416	51.4	355	45.7	503	50.6

Table 3
Area-Percentage POS measures within RESIDE participants 1.6 km road network service area and suburb and odds of doing any walking for recreation and moderate-vigorous physical activity in the neighbourhood.

		Any Walking for Recreation				Any Moderate-Vigorous Physical Activity			
		Type of Area-Percentage POS Policy Measures							
		% of the subdivisible land area[1]		% of the net developable land area[2]		% of the subdivisible land area[1]		% of the net developable land area[2]	
Spatial Extent	POS Measure	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
1.6 km RNSA	% area = POS	1.004 (0.984–1.024)	0.721	0.988 (0.962–1.015)	0.383	1.007 (0.993–1.021)	0.344	0.998 (0.979–1.017)	0.851
Suburb	% area = POS	0.987 (0.971–1.003)	0.104	0.997 (0.955–1.000)	0.050	1.007 (0.993–1.021)	0.344	0.998 (0.979–1.017)	0.851
1.6 km RNSA	% area < 10%	1.00		1.00		1.00		1.00	
	% area ≥10%	0.871 (0.671–1.10)	0.298	0.932 (0.746–1.163)	0.533	0.992 (0.813–1.211)	0.941	0.992 (0.813–1.211)	0.941
Suburb	% area < 10%	1.00		1.00		1.00		1.00	
	% area ≥10%	0.820 (0.653–1.029)	0.086	0.861 (0.683–1.087)	0.208	0.992 (0.813–1.211)	0.941	0.992 (0.813–1.211)	0.941
1.6 km RNSA	< 6% active POS	–	–	1.00		–	–	1.00	
	≥6% active POS	–	–	0.987 (0.700–1.392)	0.941	–	–	0.878 (0.672–1.148)	0.342
Suburb	< 6% active POS	–	–	1.00		–	–	1.00	
	≥6% active POS	–	–	0.868 (0.573–1.316)	0.506	–	–	0.878 (0.672–1.148)	0.342

[1]subdivisible land area = residential zoned land + POS area; [2]Net developable land area = gross service area − road cadastre area; [3]Active open space = parks ≥8 ha in size.

Table 4
Catchment-based POS measures of RESIDE participants suburb and odds of doing any walking for recreation and MVPA in the neighbourhood[a].

POS Policy Measure			Any Walking for Recreation		Any MVPA	
			OR (95% CI)	p-value	OR (95% CI)	p-value
Individual-level						
VIC	≤400 m any park	No	1.00		1.00	
		Yes	1.230 (0.962–1.573)	0.098	1.077 (0.879–1.319)	0.474
WA	≤200 m pocket park (< 0.4 ha)	No	1.00		1.00	
		Yes	0.952 (0.701–1.292)	0.752	0.993 (0.750–1.314)	0.959
WA	≤400 m local park (≥0.4– < 1 ha)	No	1.00		1.00	
		Yes	1.032 (0.869–1.225)	0.720	1.219 (1.018–1.460)	0.031
WA	≤800 m neighbourhood park (≥1.0– < 5 ha)	No	1.00		1.00	
		Yes	1.142 (0.944–1.382)	0.172	1.144 (0.914–1.431)	0.239
WA	≤2 km district park (≥5.0– < 15 ha)	No	1.00		1.00	
		Yes	0.842 (0.642–1.104)	0.214	1.076 (0.832–1.390)	0.577
WA	≤10 km regional park (≥15.0 ha)	No	1.00		1.00	
		Yes	0.848 (0.644–1.117)	0.240	1.017 (0.824–1.255)	0.873
Suburb-level						
VIC	≥95% dwellings ≤400 m any park	No	1.00		1.00	
		Yes	1.210 (0.480–3.049)	0.687	3.172 (1.025–9.812)	0.045
WA	≥60% dwellings ≤200 m pocket park (< 0.4 ha)	No	1.00		1.00	
		Yes	0.952 (0.701–1.292)	0.752	0.993 (0.750–1.314)	0.959
WA	≥60% dwellings ≤400 m local park (≥0.4– < 1 ha)	No	1.00		1.00	
		Yes	0.589 (0.130–2.678)	0.493	0.207 (0.026–1.612)	0.132
WA	≥60% dwellings ≤800 m neighbourhood park (≥1.0– < 5 ha)	No	1.00		1.00	
		Yes	0.896 (0.719–1.118)	0.331	1.080 (0.868–1.345)	0.490
WA	≥60% dwellings ≤2 km district park (≥5.0– < 15 ha)	No	1.00		1.00	
		Yes	0.753 (0.569–0.949)	0.018	1.098 (0.887–1.361)	0.391
WA	≥60% dwellings ≤10 km regional park (≥15.0 ha)	No	1.00		1.00	
		Yes	0.860 (0.642–1.153)	0.313	1.006 (0.816–1.241)	0.952

[a] Models adjusted for sex, age, education, employment, marital status, household income, and having children under the age of 18 living at home.

associated with a 22% increased odds (OR = 1.219, 1.018–1.460) of doing any MVPA in the neighbourhood (Table 4). However, the odds of WR was nearly 25% lower for those living in suburbs where 60% or more of the residents lived within 2 km of a district park (p = 0.018).

3.3. Validity of the national indicator POS dataset

The final aim of this study, was to explore the feasibility of a POS measure(s) that could be applied nationally. Achieving this aim would require consistent data across all Australian urban areas. Fig. 3a presents scatter-plots comparing the gross area of 'parks' from the RESIDE (state) spatial layer and the nationally available meshblock 'parkland' data within participant's 1.6 km service areas. On average, the areas of POS measured using the meshblock (national) data (31.6 ha, SD = 8.45) were twice that of the 'park' data from the finer grain state-based POS layer (16.0 ha, SD = 12.70) and showed a low level of reliability with intra-class correlation coefficients ICCs ranging from 0.185 (single measures coefficient) to 0.312 (average measures coefficient).

When both data sources were used to create the policy indicator, on

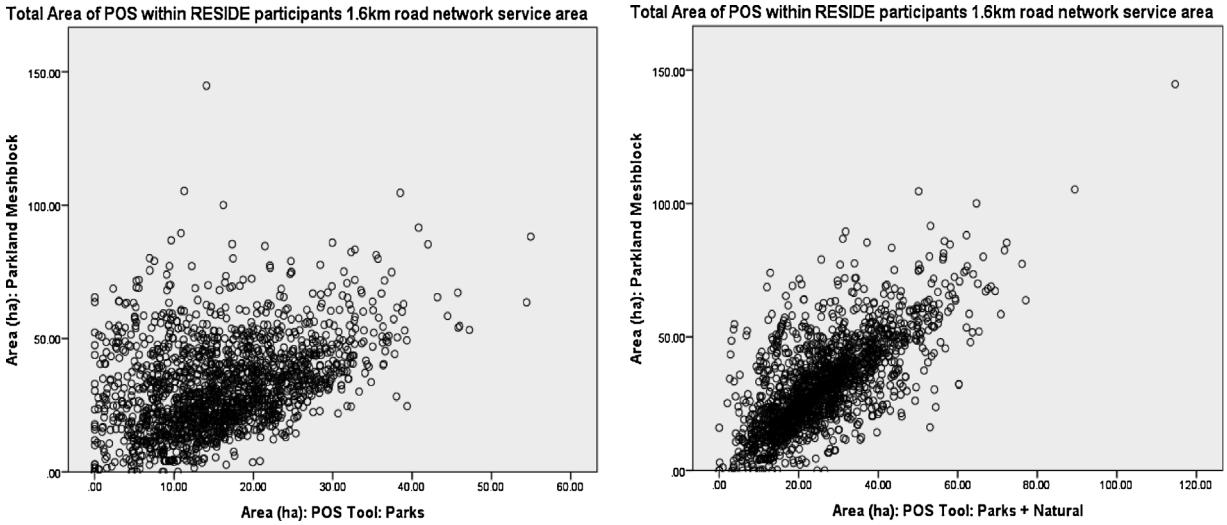


Fig. 3. Scatter-plots comparing values for the area of POS within participants 1.6 km service areas by data source (POS Tool or Meshblock). Left-hand figure includes only POS Tool 'park' categories. Right-hand figure includes POS Tool 'Park + Natural" categories.

average, the percentage area of land provided as parkland within participants 1.6 km RNSA was calculated as 22.21% using the meshblock data. This was double the (average) estimate of 12.24% using the state-level POS data. The intra-class correlation coefficients indicated a low level of reliability, ranging from 0.197 (single measures coefficient) to 0.329 (average measures coefficient).

Given the over-estimates for POS provision observed when using the meshblock data versus that of the 'park' areas from the state layer, we questioned the comparability of the data sets. As such we explored whether the reliability of the comparison between the meshblock layer and the finer grained state data would improve if additional POS categories were included in the state-level data. Fig. 3b presents the scatter-plots comparing values for the area of POS within participants' 1.6 km service areas by data source (state or national) and with addition of the 'natural' categories of POS. Combining 'natural' areas with the 'parks' for state data, improved the similarity of estimates of POS provision between the two different data sources (state = 25.83 ha; meshblock = 31.63 ha) and the reliability of the measures derived from each (i.e., ICCs from 0.285 to 0.323 single measures to 0.634–0.776 average measures).

4. Discussion

Our review, as well as others (Veal, 2013), illustrate that the Australian POS policy environment is complex, with little consistency in policy standards across states and territories, let alone internationally. Furthermore, the planning for POS and the respective policy standards adopted by different states to date, tended to be evidence-free. Little work has been conducted to evaluate which, if any, current POS standards are associated with the health and wellbeing of residents. It is therefore pertinent to investigate further to assist in creating policy–-relevant standards that impact health and wellbeing.

Our policy review identified a range of POS-related urban planning standards across Australian states. We operationalized these spatially to examine their associations with local walking for recreation (WR) and doing moderate to vigorous physical activity (MVPA). To our knowledge, this is the first study comparing measures of various POS policy standards with health-related behaviours. Previous active living research in this area has been hampered by a lack of policy-specific POS measures particularly those based on current POS standards. As such the research evidence to date has not fully reflected the POS policy environment in which the studies were conducted.

4.1. POS policy indicators and health outcomes

The planning policies we identified for Australia provided: geographic-based standards concerning the amount of land that should be allocated for POS; catchment-based standards reflecting proximity to POS; and population-ratio standards based on how much POS should be provided per head of population. In this study, we found that only one standard, based on a Victorian policy, was significantly associated with a health behaviour outcome (95% of residents living within 400 m of a park). RESIDE participants living in suburbs with this level of access, had a three-fold increase in odds of engaging in any MVPA on a weekly basis. Moreover, although it did not reach statistical significance, individuals living within 400 m of a POS had a 23% higher odds of walking for recreation. The positive associations observed with this standard is consistent with the health evidence that (closer) proximity to a park is associated with greater walking and physical activity levels (Giles-Corti et al., 2005; Kaczynski et al., 2008). Neither quantity-based nor geographic-based guidelines related to percentage of POS or population-ratios were found to be associated with recreational walking or MVPA.

Previous research has shown that having access to larger, more attractive, high quality parks, with more facilities and amenities are associated with more walking for recreation (Giles-Corti et al., 2005; Sugiyama and Ward Thompson, 2008; Sugiyama, Francis, Middleton, Owen, & Giles-Corti, 2010). Perhaps somewhat counter intuitively, we found that having a district-sized park within 2 km of a person's home to be negatively associated with doing any walking for recreation in the neighbourhood, whilst having a local park within 400 m was associated with an increased odds of doing any MVPA and to a lesser extent, local recreational walking. However, these measures did not include an indicator of quality as was the case with the aforementioned studies. Another explanation for these findings might be that the 'smaller' parks in Perth were not that small compared with other cities. Whilst 79% of participants had a POS within 400 m of their home, only 10.8% of participants had a small local park (0.4–1 ha) as their closest POS. In fact, nearly one-half of all the RESIDE participant's closest park was a neighbourhood park between 1 and 5 ha in size.

Further, whilst the quality of POS has been shown to be an important predictor of park use (Kaczynski et al., 2016; Giles-Corti et al., 2005), park quality was not measured in the current study as the standards identified were quantity, not quality-based. Whilst some of the policies differentiated between POS for 'sporting' or 'active' and 'passive' or 'recreational' uses, these were still based around a size

standard. No policies reviewed provided standards on the facilities or amenities to be provided within parks and hence, these were not incorporated in our analysis.

The lack of any other findings with walking and physical activity outcomes may be because to encourage health-enhancing behaviours thresholds for the size, number and total area of POS must be reached. Our study did not seek to achieve or test what those thresholds might be. Rather, our focus was on assessing current policy standards used in Australia and their associations with physical activity outcomes.

Another explanation for our findings could be that this study's behavioural outcome measure was very specific (i.e., walking in the neighbourhood). RESIDE participants were asked whether they walked for recreation within their neighbourhood − defined as a 10–15 min walk, or 1.6 km road network service area, from home. The district park requirement we tested, identified that this type of parks was to be located within 2 km of a participants' home. Hence, it is plausible that if district parks were only used by the RESIDE participants; these may have only been included in the walking they did 'outside' the neighbourhood. In addition, we do not know whether the participants actually used parks whilst walking for recreation in the neighbourhood and if so what parks were used and how?

4.2. Development of a national indicator of POS: suitability of the meshblock spatial data?

An objective of this study was to assess the potential for developing a national indicator of POS to allow for comparison across Australian cities and urban areas. Currently, there exists a lack of spatial data with national coverage and a consistent definition of POS and how it is planned − as highlighted by the variety of POS policy standards employed across the nation. At present, the only freely available national-level POS dataset in Australia providing some measure of green POS are the ABS 'parkland' meshblocks. The classification system used is based on an assessment of the primary land use found within each meshblock, however meshblocks are commonly comprised of more than one land use. Whilst the parkland meshblocks do provide the most comprehensive indication of POS nationwide, our results highlight that caution is required when data sets compiled for uses other than required for research.

The types of green spaces classified as 'parkland' in the meshblock data do not align well with how 'park' is described in POS planning policies. The results of our validation analysis found low intra-class correlation coefficients between meshblocks classified as 'parkland' and 'parks' found with the state-basedPOS dataset, as the meshblock data include other types of green space in addition to formal conservation and recreation areas such as state forests and national parks. When additional POS categories found within the state data (e.g. 'natural' areas) were included in the comparison, intra-class correlation coefficients increased. Further, the meshblock layer was also likely to underestimate the presence of smaller parks as by the nature of their size, they were less likely to be classified as the main land use within a meshblock. This also impacted our ability to compute accurate measures of park size where, for example, the QLD policy states that 1–1.2 ha of 'local recreational' space must be provided per 1000 residents. Whilst a meshblock may contain a 'local recreational' space, the meshblock classification is based on the predominant land use found within the administrative unit. Therefore, meshblocks often include additional land uses, which precludes testing of whether the standard was implemented correctly. In addition, by the very nature of how meshblocks are constructed, we were unable to use the meshblock layer to identify the number of individual/discrete parks within a larger administrative unit − because any number of POS could have been included in a single meshblock classified as 'parkland' or present in a meshblock classified as a different land use type altogether (and therefore 'missing').

In the current study, we did not observe significant findings with either our walking or physical activity outcome using the meshblock data. However, meshblock data have been used by some researchers to investigate and observe positive relationships with a number of health outcomes, including walking for recreation and moderate-vigorous physical activity (Astell-Burt, Feng, & Kolt, 2014a), BMI (Astell-Burt, Feng, & Kolt, 2014b), and mental health (Astell-Burt, Feng, & Kolt, 2013). Similar to the current study, Astell-Burt and colleagues (Astell-Burt et al., 2014a) investigated the extent to which neighbourhood green space was associated with weekly participation and frequency of walking and MVPA in a large cross-sectional survey of Australian adults 45 years and older using meshblock data in New South Wales, Australia. They found that compared with participants living in neighbourhoods containing 0–20% green space, those in greener areas were significantly more likely to walk and participate in MVPA at least once a week (trend for both $p < 0.001$). Among those participating at least once a week, participants in neighbourhoods containing 80%+ green space engaged in walking with even greater frequency (incidence rate ratio (IRR) 1.09, 95% CI 1.05–1.13) and MVPA (IRR 1.10, 95% CI 1.05–1.15). The threshold measures used by Astell-Burt and colleagues (2013, 2014a,2014 however bore no resemblance to the current POS standards identified in the policy review.

Whilst the meshblock data represents a measure of total greenness, the results of this study suggests that given the quality of data available in Australia, it may be possible to develop a national measure of the amount of POS. However this indicator would not reflect current POS policy standards, which often specify the presence of certain types of parks and recreational areas categorized by size and distance. The findings of Astell-Burt and colleagues (2013, 2014a,2014 would suggest that such a measure would indicate areas that may produce physical and mental health enhancements, but could not be used to assess the implementation of current Australian POS policies.

4.3. Limitations

There are several limitations with this research. First, because our research focused on state-level policies, urban planning policies or strategies created and administered by local Governments were not identified in the review. Nevertheless, local government POS policies in Australia are generally aligned with the state requirements.

Our modelling approach was to test each policy standard individually with health behaviours in an attempt to understand how each policy related to engagement in walking and physical activity. However, there may be other factors within a neighbourhood's built and social environments that affect an individual's motivation for walking (i.e., street connectivity, aesthetics, safety, social support) that were not controlled for in our analysis. In addition, the behavioural data used in this study were self-reported and there may be measurement error associated with under- or over-representation of walking trips and MVPA.

5. Conclusions

The focus of this study was on creating and testing Australian policy-relevant POS spatial measures related to walking and physical activity. By spatially operationalising these measures, we were able to test which, if any, current POS urban planning policies are associated with recreational walking and physical activity behaviours. Having (any) POS within 400 m was identified as the strongest 'health enhancing' policy standard from the 16 policy measures tested, and was recommended to be used as a national indicator of POS provision and access for health benefits across Australia. These findings support a now extensive body of existing literature indicating that neighbourhoods with greater access to POS are associated with higher odds of physical activity.

The findings of the current study suggest that not all standards are equal, and more research is required to determine whether current

planning standards being implemented are achieving their full potential. Moreover, research should consider under what circumstances, policies are likely to impact health and health behaviour and whether minimum thresholds for POS are required to maximise benefit.

The measures were tested with nationally available spatial data. In Australia, meshblocks classified as 'parkland' do not appear to align with the types of POS typically addressed by urban POS planning policies or guidelines. Nor does it provide an accurate representation of on-ground availability and exposure to formal 'parks' (as a type of POS). While it may be possible to create a national indicator of access to POS that is health-promoting, at this stage in Australia, it would not be possible to assess the delivery of current POS policies nationally. This highlights the need for a more accurate national-level spatial dataset of POS. The next stage of the Australian National Liveability Project will be to create and apply a national urban set of policy-relevant spatial indicators of POS related to recreational walking. This will allow urban regions across Australia to be mapped, benchmarked and monitored over time.

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