

Research Paper

Using participatory GIS to measure physical activity and urban park benefits

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HIGHLIGHTS

- Uses participatory GIS methods to measure physical activities and benefits of urban parks.
- Examines relationship between park activities and benefits with park type, size, and location.
- Park type and size are significantly related to the type and amount of physical activities and community benefits received from urban parks.
- Participatory GIS research methods have limitations but appear useful for examining spatial relationships to inform urban parks planning.

ARTICLE INFO

Article history:

Received 30 March 2013

Received in revised form 8 September 2013

Accepted 12 September 2013

Keywords:

Urban parks

Physical activity

Benefits

Participatory GIS

PPGIS

ABSTRACT

Previous urban park research has used self-reported surveys and physical activity logs to examine associations between physical activity and park features, size, and distance to participants' homes. In this study, we used participatory geographic information systems (GIS) methods to explore potential correlates of physical activity and other health benefits in urban parks. Using an internet-based public participation geographic information system (PPGIS) system, study participants identified the spatial locations where they engaged in various types of physical activity and where they received other park benefits—environmental, social, and psychological health benefits. Using an urban park typology, we found that different urban park types provide different opportunities for physical activity with linear parks providing the greatest overall physical benefit while other park types provided important non-physical community benefits. Distance to park was not a significant predictor of physical activity but park size was correlated with physical activity and other park benefits. We discuss the strengths and limitations of using PPGIS methods for understanding the benefits of urban park systems.

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1. Introduction

Urbanization is a dominant global force with strong implications for human health. Australia, like most countries throughout the world, is becoming increasingly urbanised with 89.1% of Australians now living in urban areas (World Bank, 2010). In cities and towns, the demand for infrastructure to meet the needs of growing populations has been achieved through the development or modification of natural spaces (Byomkesh, Nakagoshi, & Dewan, 2012; DEH, 2008; Kong & Nakagoshi, 2006). Urbanization and the

associated loss of urban green space has been linked to poorer health and decreased quality of life for many city inhabitants (Byomkesh et al., 2012; Maller et al., 2008; The World Bank, 2011). In countries throughout the world, it is increasingly evident that it is detrimental to human health to live without some contact with the natural environment (Maller et al., 2008).

Urban parks and green spaces provide opportunities for people to reconnect with the natural environment which is beneficial to people's health and wellbeing (Chiesura, 2004; Hartig, Evans, Jamner, Davis, & Garling, 2003; Maller et al., 2008; Townsend & Weerasuriya, 2010). Further, parks provide urban inhabitants with opportunities for physical activity, social interaction, escape, and enjoyment of nature (see e.g., Townsend & Weerasuriya, 2010; Weber & Anderson, 2010). Urban parks are valued as places that facilitate physical activity (Wilhelm-Stanis, Schneider, & Pereira, 2010) which is particularly important in urbanized countries such as Australia where physical inactivity leads to the premature deaths

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of thousands of people and costs the economy billions of dollars every year (Medibank Private, 2008).

Understanding the factors that influence the use of urban parks is essential to planning healthy and sustainable communities. For example, residential proximity to parks (Giles-Corti et al., 2005), parks with specific features such as trails (Kaczynski, Potwarka, & Saelens, 2008), aesthetic appeal (Evenson et al., 2006; Giles-Corti et al., 2005), perceived safety (Evenson et al., 2006), as well as temperature and weather (Wolff & Fitzhugh, 2011) appear to be important predictors of park use and leisure-time physical activity. Further, access to urban parks and green spaces has been shown to increase physical activity levels in urban populations (see e.g., Floyd et al., 2011; Giles-Corti et al., 2005; Kaczynski & Henderson, 2007; Sugiyama & Thompson, 2008; Wendel-Vos et al., 2004). In its 2011 report into the health and wellbeing of urban inhabitants, the International Council for Science stressed that the challenge for researchers lies in analysing the complex relationships between urbanization and health and to gain an understanding of the new health challenges that urban areas are likely to face in the future (ICSU, 2011). Positive community health outcomes require providing opportunities and services that assist in reducing the direct burden of avoidable illnesses that are associated with physical inactivity (Maller et al., 2008). For example, Marcus and Forsyth (1999) showed that implementing upstream interventions such as adding parks and walking trails, or providing support for sporting clubs or incentives for healthy lifestyles, have more lasting effects on physical activity levels than downstream (e.g., clinical exercise interventions) or midstream (e.g., media campaigns) interventions. Hence, a focus on urban green space is prudent given it has been shown to facilitate increased physical activity, and improve human health and quality of life in urban areas.

Research methods for assessing urban park use and related health benefits have traditionally involved survey research and/or physical activity logs that include the location of park use and activities relative to study participant domicile. In this study, we present an alternative method for examining park use and associated benefits based on public participation geographic information system (PPGIS) technology. The formal definition of PPGIS remains “nebulous” (Tulloch, 2007) but refers to a diverse set of methods that engage people in the generation of spatially explicit information for a variety of planning and decision-making purposes. In PPGIS, participants identify spatial locations on a map, either hardcopy or digital, using stickers, markers, or digital annotations. Typically, the participants also respond to a set of survey questions that allow the investigator to examine correlations between these responses and the placement of their markers. PPGIS surveys are adaptable to a variety of social survey contexts where measuring perceptions of place is an important research objective. Since the 1990s, the range of PPGIS applications has been extensive, from community and neighbourhood planning to mapping traditional ecological knowledge (see e.g., Brown, 2005; Floredu et al., 2011; Sieber, 2006). With respect to urban parks, PPGIS has been used in urban planning to identify potential green spaces and walking trails of importance to the public (Hawthorne et al., 2006) and to identify the type and location of values people have for urban parks (Brown, 2008).

The qualities of urban parks and green spaces—their variability in size, features, and spatial dispersion within an urban context—makes PPGIS a potentially useful method for studying their potential benefits. The National Parks and Recreation Association (NRPA) developed a typology with guidelines for parks, recreation, open space, and greenways in urban areas (Mertes & Hall, 1996) that describes different park types with size and location parameters (e.g., a neighbourhood park is optimally 2–4 ha at a distance of 400–800 m to the homes being served). Brown (2008) found that people associate different values with the different types of urban parks, but park values are only an indirect indicator of the

benefits received from parks. A more direct measure would be to ask individuals to identify the specific benefits received from different parks. Almost all past research on the benefits of recreation relies on the use of the Recreation Opportunity Spectrum (Clark & Stankey, 1979; Driver & Brown, 1978) to define settings. The PPGIS method responds to Pierskalla's (2000) call for a more ecological approach to assess benefits that doesn't assume benefits change at ROS boundaries. The use of PPGIS, described in the methods below, allows people to spatially identify physical activities and other park benefits with specific parks. A further advantage of internet-based PPGIS is the ability to access multiple maps scales and customize the base map to enhance respondent understanding and engagement. In addition, the method reduces data collection costs, increases efficiency of data entry, and increases precision in mapping (Brown & Reed, 2009; Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012).

Much of the early work examining the benefits of park experiences was based on work conducted by Driver and associates (Driver, 1990; Driver & Tocher, 1970) using recreation experience preference scales. Moore and Driver (2005) explain that park studies have focused on five key types of benefits: (1) personal psychological benefits including benefits related to personal development and growth, mental health and maintenance, and personal appreciation or satisfaction; (2) personal psychophysiological benefits including reduced depression, decreased obesity, increased fitness, reduced incidence of disease, and improved perceived quality of life; (3) social/cultural benefits such as community satisfaction, family bonding, and reduced crime; (4) environmental benefits such as development of an environmental ethic, preservation of heritage, and environmental protection; and (5) economic benefits such as reduced health costs, increased productivity, and increased property values.

In this paper, we describe a study conducted in Adelaide, the capital of South Australia, that used PPGIS to examine the spatial distribution of physical activities and other benefits in parks and green spaces as a function of park type. According to the Australian Bureau of Statistics (2000) South Australia has the lowest rate of physical activity participation amongst all Australian states and territories, with 57.1% of South Australians reporting insufficient levels of physical activity (Gill & Taylor, 2005). Additionally, South Australia is the most overweight state in Australia, with 67.2% of South Australian adults reported to be overweight or obese (NHFA, 2012).

The study focused on social, environmental, psychological and physical benefits. The management of many Australian parks is underpinned by the marketing campaign “healthy parks, healthy people”. The campaign is based on the notion that people can contribute to creating healthy environments (environmental benefits) and that healthy environments encourage community identity and social support (social benefits) as well as personal benefits (e.g., physical and psychological benefits to an individual). While not suggesting park-based recreation is a panacea for public health, an increasing body of research has shown that access to even small urban parks can positively impact mental health (Peschardt & Stigsdottir, 2012). Likewise, access to parks has often been correlated with more frequent use of parks and greater levels of physical activity (Cohen et al., 2006; Schipperijn, Stigsdottir, Randrup, & Troelsen, 2010; Toftager et al., 2011) which results in substantial health benefits.

The benefits examined in this study were selected because of their relevance to Australian urban parks (Weber & Anderson, 2010) and the National health priority areas for Australia. The Australian Institute of Health and Welfare (2013) identify nine national health priority areas and previous research (Moore & Driver, 2005) found six of these to be positively impacted as a result of park-based recreation (mental health, cardiovascular disease, diabetes mellitus, asthma, arthritis and musculoskeletal conditions, and obesity).

Our specific research questions included the following:

- (1) What physical activities are associated with different park types and do some types of parks offer more (or less) physical health benefits to the community?
- (2) How are park benefits (environmental, physical, psychological, social) distributed by park type and do some types of parks offer more (or less) of these benefits?
- (3) Does the diversity of physical activities and park benefits differ by park type?
- (4) How are physical activities and park benefits distributed based on park size and distance from domicile, i.e., does park size and the proximity of parks to domicile influence the amount and type of physical activities and benefits received?

The answers to these questions form the basis of our discussion about the contribution of urban parks to community health, the potential role of urban design in contributing to community health, and the strengths and limitations of PPGIS methods for measuring the benefits of urban parks and green spaces.

2. Methods

2.1. Study location

The study was located in City of Campbelltown which encompasses eight suburbs in the inner eastern region of Adelaide, South Australia. The 2436 ha area is predominantly residential, but also contains parklands, reserves, and some commercial areas. Geographically, Campbelltown is bounded in the north by the River Torrens, along which a 50 km linear park greenway was developed. To the east, the council is bounded by the Adelaide Hills, including conservation sites such as Black Hill Conservation Park. In addition to these naturally existing areas of green space, the council area contains many small neighbourhood parks, as well as a variety of reserves, ovals and sports fields.

The study area is characterized by relatively low-density housing and reasonably large residential allotments. Between the 1960s and 1980s, the population of Campbelltown grew dramatically from 15,000 to 43,000 people, and has continued to rise at a much slower rate from the 1980s onwards. Recent population growth in Campbelltown has been attained through urban infill, rather than green field development, and today, the area houses a population of 48,162 people (ABS, 2011).

2.2. Study participants

The data collection portion of study was conducted between 21 August and 15th December 2012. Several methods were used to recruit participants to the internet-based PPGIS system. The City of Campbelltown, a partner in the study, agreed to fund the distribution of a household recruitment brochure to all residences in the Council area (approximately 21,600 households). The bulk distribution was contracted to a local vendor who was to deliver the brochures over a two-day period. Unfortunately, this did not appear to have occurred. After three days of alleged delivery, the response rate was significantly lower than expected. We then sampled 100 houses within the study area and found only one household had received the invitation.

As a result of the failure in the primary recruitment method, additional recruitment methods were employed including posters, a paid newspaper advertisement, and promotion through the Campbelltown e-newsletter. Posters with tear-off tabs containing the PPGIS website URL were placed on notice boards in local shopping centres, at the Campbelltown Public Library, at the University

of South Australia's Magill Campus, and in sheltered locations within various parks. A small paid advertisement was placed in the East Torrens Messenger Newspaper, and an announcement about the study was placed in the Council's monthly e-newsletter, which is emailed to residents of the Council that have subscribed to the e-newsletter. As part of the recruitment effort, an incentive of being entered into a draw for \$500 was offered to participants.

In addition, on the following weekend, on-site convenience sampling intercepts were implemented at four locations within the Council area: Thorndon Park, Torrens Linear Park, Morialta Conservation Park, and Daly Oval. A total of 12 four-hour survey blocks were conducted at the four survey sites from September, 2012 to December, 2012. Eight of these were on weekends and four on weekdays, reflecting the prevailing use patterns of the parks. The individuals contacted were provided with an invitation and encouraged to visit the PPGIS website for study participation. The intercepts served as a reminder for households who should have received an invitation and a means to further assess the effectiveness of the bulk invitation distribution. The intercepts supported our initial evaluation that a very high percentage of the individuals contacted (99%) did not receive the initial household invitation.

2.3. PPGIS methods and process

Prior to PPGIS data collection, a convenience sample of 20 people was used to test the usability of the PPGIS website. A researcher sat nearby as each participant, situated at a computer, was given a copy of the survey invitation that was to be distributed to Campbelltown residents. Participants followed the instructions to complete the survey. The research observed and noted any apparent difficulties in completing the survey, but did not assist the participants. Upon completion, pre-test participants were debriefed and usability issues were corrected prior to the actual launch of the website.

The PPGIS study website consisted of an opening screen for the study participant to request an access code, followed by an informed consent screen for participation,¹ and then a Google® maps interface instructing the participant to drag and drop different digital icons (markers) onto a map of the Campbelltown Council area (See Fig. 1). The icons were located in three panels on the left of the screen (note: the terms "icons" and "markers" refer to the same object. The digital object is an "icon" in the panel and becomes a "marker" once placed on the map). The first panel consisted of 13 physical activities commonly associated with parks and green spaces, the second panel consisted of 12 potential park benefits, and the third panel consisted of 12 potential actions that could be taken to help adapt local parks to climate change. The focus of this paper is on the mapped physical activities and park benefits.

The physical activities were chosen because they were deliberately catered for in the park (e.g., soccer fields) or they had been observed or previously recorded in a study as a common activity in one of the parks. The activities that could be mapped ranged from sedentary activities such as sitting, to running and playing sport (see Table 1). Each activity was aligned to a metabolic equivalent of task (MET) to assess the intensity of each activity. Metabolic equivalents are a unit used to estimate the metabolic cost of physical activity, with the value of 1 MET being approximately equal to a person's resting energy expenditure, or resting metabolic rate (RMR). Activities can be categorized as multiples of resting energy expenditure. For example, fast walking is considered to be 4 METS

¹ The study protocol was approved by the University of South Australia's Human Ethics Committee (#0000030491). An informed consent was provided to prospective participants that identified the risks and benefits associated with participation. The minimum age requirement for participating in the study was 14 years.

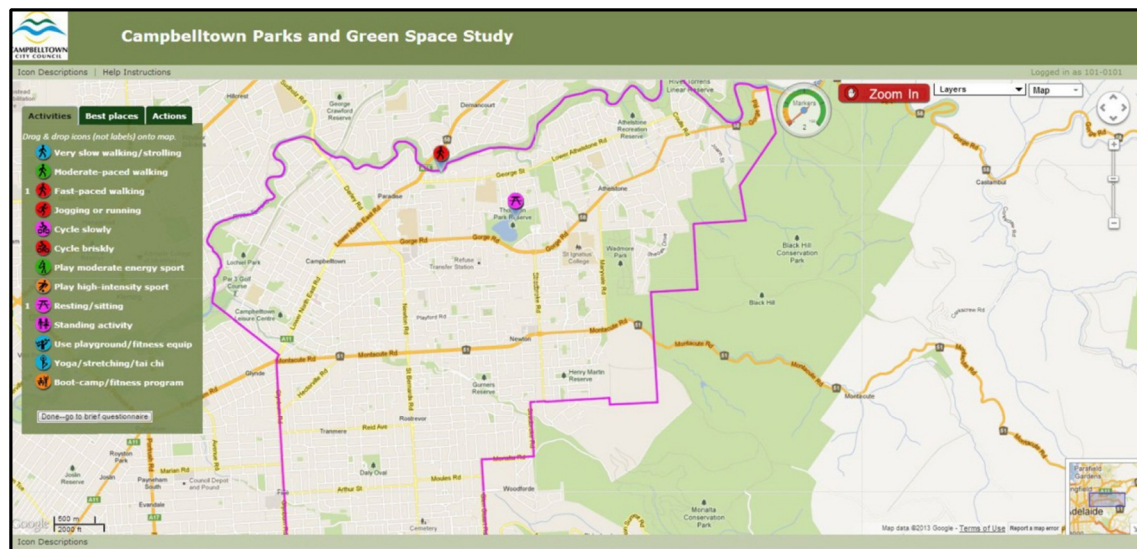


Fig. 1. Internet PPGIS application for collecting information about urban park use and benefits. Campbelltown study boundary appears in purple. Study participants drag and drop different park activity and benefit markers (icons) from left panel onto map location after zooming in.

Table 1

List of PPGIS markers (icons) for physical activities and park benefits used in the PPGIS internet application. Physical activities were classified into one of three intensity categories based on MET scores. Park benefits were classified into one of four benefit types.

Physical activity	Intensity	Benefit	Type
Very slow walking/strolling	Low	Enjoy nature	Environmental
Moderate-paced walking	Moderate	Get exercise/fitness	Physical
Fast-paced walking	Moderate	Escape stress	Psychological
Jogging or running	High	Enjoy tranquillity	Psychological
Cycling slowly	Moderate	Spend time with friends	Social
Cycling briskly	High	Observe nature	Environmental
Moderate intensity sport	Moderate	Be around good people	Social
High intensity sport	High	Do something creative	Psychological
Resting/sitting	Low	Connect with family	Social
Standing activity	Low	Place to think/reflect	Psychological
Using playground/fitness equipment	Moderate	Rest/relax	Psychological
Yoga/stretching/tai chi	Low	Spending time outside	Environmental
Boot-camp or fitness program	High		

because it requires an energy expenditure that is four times RMR (Welks, 2002).

The park benefits that could be mapped (see Table 1) were aligned to the recreation experience preference items developed and validated by Driver and associates (Driver & Bassett, 1977; Driver & Knopf, 1976; Driver & Tocher, 1970; Driver et al., 1991; Manfreda, Driver, & Brown, 1983). While Driver et al. (1991) identified 19 benefit domains, results from Australian park studies led Weber and Anderson (2010) recommended Australian urban park studies focus on a reduced set of benefits. Thus, the potential park benefits we included aligned to those previously identified as most important in Australian urban parks (Weber & Anderson, 2010) and included: enjoy nature, get exercise/improve fitness, escape stress/reduce tension, enjoy tranquillity/avoid crowds, spend time with friends, observe/study nature, be around good people, do something creative, connect with family, think and reflect, rest and relax, and spend time outside. These benefits were categorized into one of four groups based on the classification used by Moore and Driver (2005, p. 29): psychological, physical health (a subset of psychophysiological benefits), environmental, and social benefits.

Study participants were instructed to familiarize themselves with the set of spatial attributes (icons) and their definitions and then click on an icon and drag and drop onto the map location representing where they engaged in the activity or enjoyed the park benefit. To ensure spatial precision in icon placement, the icons

could only be placed when the participant had zoomed to Google® maps zoom level 17 which equates to approximately a 1:4500 map scale. Respondents were able to view the map using the standard Google® maps roadmap display or could choose to switch to a satellite view of the area. Respondents were also able to annotate the icons they mapped to provide more specific information regarding why they had placed an icon in a specific location. Participants were encouraged to place at least 20 icons (activities and benefits). This suggestion was based on previous research and pilot testing that suggested participants wanted some guidance for response expectations. Following the mapping activity, participants were directed to survey questions which asked about their park use, their self-reported personal health characteristics, and selected socio demographic information for comparison with census data.

2.4. Data analysis

At the close of data collection, the spatial data (location of markers) and non-spatial data (marker attributes and responses to survey) questions were downloaded from the web server for analysis in ArcGIS® and SPSS® software. Markers placed outside the study area boundary were dropped from the analyses as the focus was households and park activities/benefits within the Campbelltown Council boundary.

Table 2
Park classifications used in this study adapted from NRPA classifications (Mertes & Hall, 1996).

Classifications used in this study	Description	NRPA classifications	NRPA size & location guidelines	Modification rationale
Neighbourhood park	Neighbourhood—2 to 4 ha optimal, 400 to 800 m distance	Neighbourhood park	Neighbourhood—5 to 10 acres optimal, 1/4 to 1/2 mile distance	Size and distance were converted to metric
School park	School-park—variable size, location determined by school	School park	School-park—variable size, location determined by school	
Community park	Community—usually between 12 and 20 ha, 800 m to 5 km distance	Community park	Community—usually between 30 and 50 acres, 1/2 to 3 mile distance	Size and distance were converted to metric
Sports park	Special use—size variable, location variable Sports complex—usually a minimum of 10 ha with 16–32 ha optimal, strategically located	Special use Sports complex	Special use—size variable, location variable Sports complex—usually a minimum of 25 acres with 40–80 acres optimal, strategically located	The study sites were specifically sports fields
Natural park	Natural resource areas—size variable, location depends on availability and opportunity	Natural resource areas	Natural resource areas—size variable, location depends on availability and opportunity	The new terminology is to clarify that these areas are parks
Linear park	Trails—location variable	Park trails Connector trails	Trails—.5 miles per 1000 (1983 NRPA standard), location variable	More precise terminology has been used because the connector trails in this study were linear parks
		Mini-park	Mini-park—between 2500 sq. ft. and one acre, less than 1/4 mile in residential setting	These parks were classified as Neighbourhood parks
		Large urban park	Large urban park—usually a minimum of 50 acres with 75 or more acres optimal, usually serves entire community	No parks meeting this criterion were contained within the study site

To analyze the level of physical activity and types of benefits occurring in different types of parks, each park within Campbelltown was classified based on an adapted NRPA park typology (Mertes & Hall, 1996). Table 2 shows the NRPA typology definitions and the adaptations of the typology used in this study. A total of 102 different parks and green spaces were identified in the study area that contained one or more activity or benefit markers mapped by study participants. These parks were classified into one of six mutually exclusive categories: (1) Neighbourhood parks ($n=80$) which included small reserves up to 4 ha in size; (2) Community parks ($n=6$) consisting of parks ranging between 4 and 20 ha in size; (3) Sports parks/complexes ($n=7$) designed primarily for group sporting activities such as football/cricket ovals; (4) Natural parks ($n=2$) dominated by native vegetation along the eastern Council boundary and which connect to larger, regional conservation parks in the adjacent Adelaide Hills; (5) Linear parks ($n=2$) consisting of the Torrens linear park that forms the northern boundary of the Council area and a smaller, interior linear park that runs along a small creek; and (6) School grounds ($n=5$) which contain green spaces that are not always accessible to the public.

2.4.1. Associations between physical activities and park type

The 13 physical activities were spatially intersected with the parks located in the Council area. A buffer of 10 m was extended around each park boundary to include markers that were likely intended for inclusion within the park. Physical activities not falling within any park boundary were classified as “outside”. The 13 physical activities were also classified into one of three physical activity intensity categories based on associated MET levels: (1) *low intensity* included activities with less than 3 METS and included sitting, standing, slow walking, and yoga; (2) *medium intensity* activities were those with MET values of 3–7 and included moderate-paced walking, fast walking, slow cycling, moderate-intensity sport, and using park equipment; (3) *high intensity* activities were those with MET values greater or equal to 8 and included jogging, fast cycling, high intensity sport, and fitness/boot camp. Cross-tabulations

between park type and activity intensity categories were generated along with the chi-square statistic and standardized residuals. Chi-square residuals provide a way to assess the strength of association between two categorical variables and is done following a statistically significant chi-square result to determine which pair-wise categorical relationships most contribute to the overall significant association. A residual is the difference in the observed frequency and the expected frequency and a standardized residual is calculated by dividing the residual value by the standard error of the residual. Standardized residuals are a normalized score like a z score without units, and if greater than +2.0, indicate significantly more activities than would be expected, while standardized residuals less than –2.0 indicate fewer activities than expected.

The potential relationships between park size, measured in hectares, and the number of mapped physical activities and other benefits were analyzed using Pearson's product moment correlation for each park with five or more mapped activities or benefits. The results were plotted for each park type.

2.4.2. Associations between park benefits and park type

Similar to the physical activity analysis, the 12 park benefit attributes were spatially intersected with the parks located in the Council area. Prior to spatial intersection, the mapped park benefit attributes were grouped into four types of benefits: (1) *physical* (get exercise/fitness); (2) *environmental* (enjoy nature, observe nature, spend time outside); (3) *psychological* (escape stress, enjoy tranquillity, rest/relax, think/reflect, do something creative); and (4) *social* (spend time with friends, be around good people, connect with family). Cross-tabulations were generated along with the chi-square statistic and standardized residuals to determine significant associations between park type and benefit types. The relationship between park size, measured in hectares, and the number of mapped park benefits was analyzed using Pearson's product moment correlation for each park with five or more mapped benefits. The results were plotted for each park type.

2.4.3. Diversity of physical activities and benefits by park type and relationship to size

Whereas the previous questions examined the *abundance* of physical activities and park benefits by park type, this analysis examined the *diversity* of activities and benefits. For example, one might hypothesize that parks created for a more narrow set of activities such as sports parks would have less diversity of physical activities and benefits while community parks would exhibit a broader range of activities and benefits.

To examine the diversity of activities and benefits by park type, the Shannon diversity index was calculated for each park unit with five or more activities or benefits. The Shannon index (Shannon, 1948) has been widely adopted in the ecology literature as a mathematical measure of species diversity in a community, but it has also been used to quantify and compare the diversity of social values found within bounded landscape areas of interest (Brown & Reed, 2012). The diversity of park activities and benefits was calculated for each park as

$$-\sum p_i \ln p_i$$

where p_i is the proportional abundance of the i th park attribute (activity or benefit) $= (n_i/N)$.

The Shannon diversity index accounts for both the abundance and evenness of attributes located within the different park types. Shannon index values typically fall within the range of 1.5–3.5 with higher index values indicating greater diversity. The Shannon index values are often normalized on a scale from 0 to 1 to provide for easier comprehension of similarities and differences in diversity values. The Shannon index values were computed for both physical activities and benefits and then averaged for each park type category. The diversity of park activities and benefits were then analyzed by park size to test the hypothesis that larger parks offer a greater diversity of physical activities and benefits given that Brown (2008) found larger parks to hold a greater diversity of values for urban residents.

2.4.4. Distribution of activities and benefits as a function of distance from domicile

The willingness to use parks for physical exercise and to receive benefits was operationalized as the distance from domicile to the mapped attribute. Each study participant was asked to indicate the street intersection nearest their home. These locations were geocoded in GIS to provide a proxy for the participants' domicile. For each participant and mapped attribute, the Euclidean distance was calculated in GIS. These distances were averaged for each physical activity and benefit type. A one-way analysis of variance (ANOVA) was performed to determine whether the mean differences in distance for the mapped attributes were statistically significant.

3. Results

3.1. Participant and park use characteristics

There were $n=215$ full (map plus survey questions) and $n=27$ partial (map only) completions for total participation of $n=242$ resulting in 5469 mapped attributes for spatial analysis. Given the mass method of participant recruitment and the apparent failure of the Council contractor to achieve significant household delivery, it is not possible to calculate a traditional study response rate. Our speculative estimate of study response rate based on presumed contacts by the Council contractor and our known contacts would be around 15%. What is known is that other internet-based PPGIS studies of the general public indicate about a 10% response rate (Pocewicz et al., 2012) and that an estimated 24% of households

in the Council area do not have an internet connection of any type (ABS, 2011) and would not have been expected to participate in the study even if they had received a brochure.

We compared study participant demographic variables with census results from the Campbelltown area (ABS, 2011) to assess participant representativeness. About 58% of participants were female (ABS census = 52%) with a median age of 41 (ABS census = 42) and a range of 15–79 years. About 43% of participants were in families with children (ABS census = 45%). Thus, the study participants were close to representative of the general Campbelltown population on these three demographic variables.

From the survey questions, study participants had lived in the Campbelltown area from less than a year to 47 years with a mean residency of 16 years. About 56% of participants rated their knowledge of places in Campbelltown as “excellent” or “good”, 32% rated their knowledge as “average”, 12% rated their knowledge as “below average”, and only 2% rated their knowledge as “poor”. About 65% of participants use Campbelltown parks at least once a week with another 16% using the parks at least once every two weeks or once a month (7%).

In the survey questions following the mapping activity, participants were asked about their non-place specific frequency of engagement in the 13 physical activities as well as the duration of the activity. The most common physical activity was moderate-paced walking followed by sitting and slow walking. The least common physical activity was “boot camp” followed by yoga and high-intensity sport. The total community health benefit for each physical activity was calculated by summing the product of the number of participants by the activity duration. Moderate-paced walking had the greatest aggregate community health benefit followed by fast cycling and jogging while yoga and boot camp had the least aggregate community health benefit.

3.2. Associations between physical activities and park type

The physical activity markers (high, medium, and low MET intensity) were spatially intersected with parks located in the Council area and cross-tabulated. There was a statistically significant association ($X^2 = 440.1$, $df = 12$, $p < 0.001$) between the intensity of physical activities and the urban park type (Table 3). The largest percentage of high intensity physical activity (about 60%) is associated with linear parks while the largest percentages of low intensity

Table 3

Physical activity intensity level by park type showing the percentage of PPGIS markers and standardized chi-square residuals for each category. Overall association is significant ($X^2 = 440.1$, $df = 12$, $p < 0.001$) with standardized residuals greater than +2.0 (green) indicating more markers than expected and standardized residuals less than −2.0 (pink) indicating fewer markers than expected. The number of parks containing one or more activity markers is shown in parentheses.

Park type ($N=91$)	MET intensity level			
	Low	Medium	High	
Outside of park	6.2% −1.2	5.7% −2.5	12.6% 4.9	7.5%
Neighbourhood ($n=71$)	22.7% 3.8	18.4% 1.8	6.7% −6.4	16.5%
Community ($n=6$)	39.6% 10.0	20.2% −.9	7.0% −8.2	21.3%
Sports ($n=6$)	6.3% −2.4	9.7% .6	10.7% 1.3	9.2%
Natural ($n=2$)	7.4% 1.9	6.2% .9	2.8% −3.2	5.7%
Linear ($n=2$)	16.6% −9.0	38.8% −.1	59.9% 8.8	39.0%
School ($n=4$)	1.1% .6	1.0% .4	0.4% −1.2	0.9%
Total markers	631 22.1%	1540 53.8%	690 24.1%	2861 100.0%

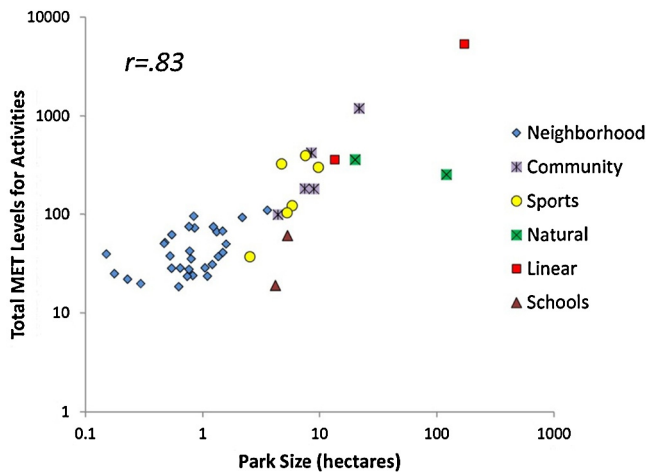


Fig. 2. Relationship between aggregate MET levels for each park based on mapped physical activities by park type and park size (hectares).

physical activity are associated with *community* parks (about 40%) and *neighbourhood* parks (about 23%). From the standardized chi-square residuals, low intensity physical activity is disproportionately associated with *neighbourhood* and *community* parks, while high intensity physical activity is disproportionately associated with *linear* parks and areas outside of park boundaries. As might be expected, low intensity physical activity is underrepresented in *sports* parks.

While park type is significantly associated with the type and intensity of physical activities, park size is also related to the level of physical activity reported. The bivariate correlation between the number of physical activities mapped and park size for parks with five or more mapped activities is 0.83 ($n = 48$, $p < 0.001$). After controlling for park type, the partial correlation between the number of physical activities and park size remains significant at $r = .79$ ($p < 0.001$). Fig. 2 shows the summed MET equivalents for different physical activities mapped within each park, plotted by park size. The park size effect is most apparent for *community* parks and the *linear* parks where increased physical activity increases with park size, but this relationship is less obvious for *neighbourhood* and *natural* parks, although the relationship between physical activities and park size remains significant for *neighbourhood* parks only ($r = .68$, $p < 0.001$). Thus, the number of physical activities mapped is significantly related to park size, but park type is also a significant mediating variable in this relationship.

3.3. Associations between park benefits and park type

The park benefit markers (*environmental*, *physical*, *social*, and *psychological*) were spatially intersected with parks located in the Council area and cross-tabulated. There is a statistically significant association ($X^2 = 96.5$, $df = 18$, $p < 0.001$) between park benefits and park type (Table 4). Community parks have the strongest association with environmental (33%), psychological (34%), and social (49%) benefits while linear parks have the strongest association with physical benefits (36%). From the standardized chi-square residuals, environmental benefits are disproportionately associated with *natural* parks, physical benefits are disproportionately associated with *sports*, *linear*, and *schools*, and social benefits are underrepresented in *natural* and *linear* parks.

Parks benefits appear related to the size of the park with park benefits increasing with park size. The bivariate correlation between mapped park benefits and park size for parks with five or more mapped benefits is $r = .75$ ($n = 38$, $p < 0.001$). Fig. 3 shows the total number of park benefits mapped as a function of park

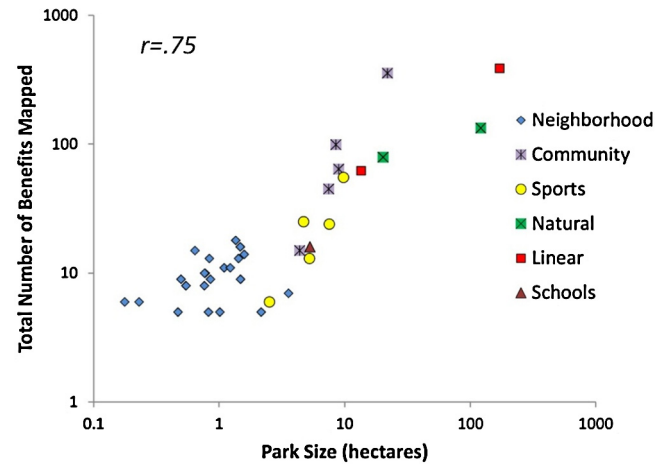


Fig. 3. Relationship between aggregate benefits mapped for parks, park type, and park size (hectares).

type and size. After controlling for park type, the partial correlation between the number of mapped benefits and park size remains statistically significant at $r = .68$ ($p < 0.001$). However, the positive, significant relationship between the number of benefits mapped and park size does not hold for *neighbourhood* parks where the bivariate correlation drops to $r = .11$ ($p > 0.05$). Thus, park type has a stronger mediating influence over the benefits/size relationship when compared to the activities/size relationship.

3.4. Diversity of physical activities and benefits by park type and relationship to size

We examined the diversity of activities and benefits by park type using the Shannon diversity index for each park unit with five or more mapped physical activities and benefits. *Sports* parks ($n = 6$) have the highest diversity of physical activity (normalized Shannon diversity index = .81) while *neighbourhood* parks ($n = 27$) have the least diversity (diversity = .57). For park benefits, *natural* parks ($n = 2$) and *community* parks ($n = 5$) contain the highest diversity (diversity = .82 and .80 respectively) while *neighbourhood* parks ($n = 19$) have the least diversity (diversity = .62).

The diversity of both physical activities and benefits appear modestly related to park size. The bivariate correlation between the Shannon diversity index and park size for parks with five or more mapped physical activities is $r = .57$ ($n = 48$, $p < 0.001$) while the relationship with the diversity of park benefits is somewhat less, but also statistically significant ($r = 0.51$, $n = 38$, $p < 0.01$). Fig. 4 shows the distribution of park benefit diversity as a function of park type and park size.

3.5. Distribution of activities and benefits as a function of distance from domicile

The use of parks and green spaces for physical exercise and to receive other benefits was examined as a function of distance from domicile to the mapped attribute. The mean distance from domicile to where the study participants engaged in different physical activities is plotted in Fig. 5. The shortest mean distance was for jogging (1180 m) while the longest distance was for fast cycling (2264 m). The mean distance from domicile to the fast cycling activity was significantly different from the majority of other physical activities (ANOVA, $p < 0.05$, Tukeys HSD). For other park activities, the mean distances to domicile were not statistically significant.

The spatial distribution of park benefits relative to participant domicile was also examined. The individual park benefit that was

Table 4

Park benefits by park type showing the percentage of PPGIS markers and standardized chi-square residuals for each type of benefit. Overall association is significant ($\chi^2 = 96.5$, $df = 18$, $p < 0.001$) with standardized residuals greater than +2.0 (green) indicating more markers than expected and standardized residuals less than –2.0 (pink) indicating fewer markers than expected. The number of parks containing one or more benefit markers is shown in parentheses.

Park type (N = 65)	Park benefit				
	Environmental	Physical	Psychological	Social	
Outside of park	5.2%	4.4%	3.8%	4.2%	4.5%
Neighbourhood (n = 47)	.9	–.1	–.8	–.2	
Community (n = 6)	15.0%	15.0%	15.8%	18.6%	15.9%
	–.6	–.4	–.1	1.3	
Sports (n = 6)	32.5%	23.1%	33.7%	48.5%	34.6%
	–.9	–3.2	–.3	4.5	
Natural (n = 2)	6.3%	11.4%	5.9%	6.8%	7.0%
	–.8	2.7	–.9	–.2	
Linear (n = 2)	14.8%	8.1%	13.3%	7.3%	11.9%
	2.2	–1.8	.9	–2.5	
School (n = 2)	25.8%	35.9%	26.1%	14.4%	25.2%
	.3	3.5	.4	–4.1	
Total markers	655	273	505	355	1788
	36.6%	15.3%	28.2%	19.9%	100.0%

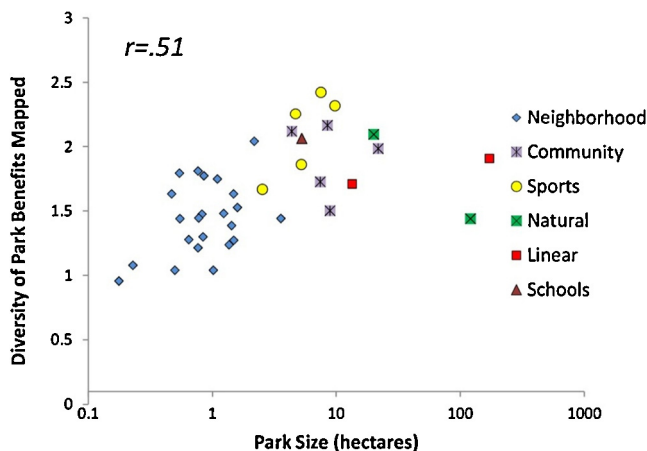


Fig. 4. Relationship between the diversity of mapped benefits for parks by park type and park size (hectares).

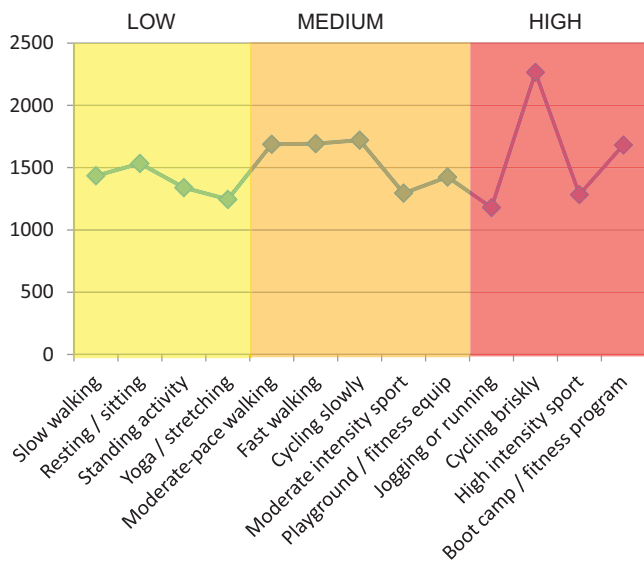


Fig. 5. Mean distance (metres) of 13 mapped physical activities from park location to study participants' domicile. Activities are grouped by MET level.

located most distant from domicile was “spend time with friends” (1918 m) while the shortest mean distance was for “connecting with family” (1315 m). The mean distance for spending time with friends was significantly longer than for other park benefits including “enjoying nature”, “getting exercise”, “connecting with family”, and “spending time outside” (ANOVA, $p < 0.05$, Tukeys HSD). The spatial distribution of park benefits as grouped types (*environmental*, *physical*, *psychological*, *social*) were also examined as function of distance from domicile. The *physical* benefit type was located most proximate to participant domicile while the *social* benefit type was most distant. The mean distance to *physical* benefits was significantly less than the distance to *psychological* and *social* benefits (ANOVA, $p < 0.10$, Tukeys HSD).

4. Discussion

In this study, we used a new research method—PPGIS—to better understand how different types of urban parks are used for physical activity and to determine the range of other benefits provided by different urban parks. Whereas previous research on correlates of physical activity examined park features (see Kaczynski & Havitz, 2009; Kaczynski & Henderson, 2007; Kaczynski et al., 2008), the key independent variable examined herein was the *type of urban park* as potentially mediated by park size and *proximity* (distance) to the park. As such, the implications of our findings relate to urban parks systems—their structure (configuration, type, and size) and relative contribution to community health outcomes.

While the NRPA guidelines for urban parks (1996) provide some standards for local governments to consider in terms of provision of different park types (e.g., size, access distance), the specific type and quantity of urban parks needed to achieve positive community health outcomes is not clearly articulated. The societal value of providing for a diversity of physical activity opportunities and park benefits in urban areas is implicit in the NRPA park classification system but there has been little empirical research to demonstrate the differential benefits from different park types. The simplistic position that more urban parks and green space is better for community health may be a truism, but such a position does not account for the differential community benefits offered by different urban park types and the inherent trade-offs associated with limited physical space for parks within urban areas.

The key findings of this research are that the type of physical activities and the distribution of other park benefits appear strongly influenced by the urban park type as well as park size. Linear parks

attract physical activities with higher MET levels (e.g., fast walking, jogging, cycling) at a time when weight-related human diseases are on the increase globally, but particularly in developed countries (World Health Organisation, 2012). This physical health benefit is exclusive of other potential benefits of linear parks such as urban connectivity and wildlife corridors. Even the smaller, secondary linear park located within the case study area attracted differentially high MET activities compared to other park types. Linear parks are often the result of natural greenways that follow urban waterways, and as such, some cities have more opportunities for natural linear parks. Where current opportunities for building new linear parks appear limited, creative solutions should be found as these types of parks appear most beneficial to human health. One good example of a creative solution is the recent development of the “High Line” park, a 1.6 km New York City linear park built on a 2.3 km section of the former elevated New York Central Railroad.

For the adult participants in this study, neighbourhood parks do not attract high-level MET activities nor do they have particularly high levels of community use compared to the other types of urban parks. Thus, their contribution to physical activity and health is limited, even when larger in size. Community and sports parks provide higher aggregate, community MET benefit, but for different reasons. Community parks attract high use, but the dominant physical activities are low MET activities. Sport parks have less community use because of their specialized purposes, but they have larger, community MET benefit because of the higher-intensity MET activities when the parks are used. The use of school grounds by the community for physical activities is not as common as is some other developed countries such as the U.S. because public access to school grounds is not guaranteed, especially for private schools which are common in Australia and often have larger sports fields and green space compared to their public counterparts. In this study, the two schools that received the highest activity were public schools.

Urban parks provide for a full range of community benefits (i.e., *physical, environmental, psychological, and social*), but some park types appear differentially important in providing certain benefit types. Community parks provide the greatest overall quantity of benefits, but these parks are most important in providing *social* benefits. Linear and sports parks are differentially important in providing *physical* benefits while natural parks provide important *environmental* benefits. The correlation between the diversity of benefits and the park size was moderate indicating that even relatively small parks of any park type can offer a diversity of public benefits. Given the interest in promoting higher levels of physical activity because of the associated health benefits, managers of community and natural parks, may be wise to investigate “non-traditional” ways to increase physical activity, for example through volunteer work, outdoor gyms and mountain biking.

With respect to the relationship between park size and physical activity, Kaczynski et al. (2008) did not find park size to be a significant predictor of physical activity while in our study, park size was significantly related to the number of physical activities mapped. Methodological differences likely account for these different study conclusions. Whereas the Kaczynski study examined 33 parks in Ontario using participant activity logs, our study included over 100 parks/reserves in Adelaide using participatory GIS data collection methods. Further, whereas the Kaczynski study used binary logistic regression to predict correlates of “no” versus “some” physical activity parks, our analysis examined aggregate mapped physical activities by park as a continuous, ratio variable and then measured its relationship to park size using correlation statistics. Both studies may be accurate given the different research methods, but given the importance of park size as a potential contributor to physical activity and its fundamental role in urban design, more research attention to this variable is warranted.

A number of previous studies have examined the association between physical activity and proximity to parks, although relatively few studies provided for the continuous measure of distance as provided by the PPGIS method herein. In reviewing these studies, Kaczynski and Henderson (2007) commented that “drawing conclusions about the importance of proximity was difficult although “substantially more positive or mixed associations were observed than non-significant relationships” (p. 345). Our analysis of distance from domicile to the engagement in particular physical activities only revealed that cycling activity was likely to be more distant from domicile compared to other physical activities, an unremarkable finding given the nature of the activity itself. In our study, there was too much variability in distance to physical activities to show a significant positive or negative association. Thus, our study result is consistent with the Kaczynski et al. (2008) study where distance was not a significant predictor of park use for physical activity. Nonetheless, Shackleton and Blair (2013, p. 105) provide multiple examples of regulatory agencies in different countries that prescribe specific park distances from domicile suggesting that the hypothesized distance/park use relationship continues to have traction despite a lack of conclusive empirical support.

4.1. The strengths and limitations of PPGIS for urban park studies

Although we encountered specific problems related to participant recruitment for this study, sampling methods for PPGIS have similar limitations to any general household survey. Although PPGIS can be implemented using low technology, paper-map methods, our PPGIS study was internet-based and thus introduced an additional constraint associated with the “digital divide” or unequal access to technology. According to census data, about one-fourth of households in the Campbelltown study area do not have convenient internet access. Lower study participation rates are associated with internet PPGIS methods compared to paper-based PPGIS methods (Pocewicz et al., 2012). Our adult study participant profile was not significantly different from what would be expected based on census data, however, our study area is not diverse in socio-economic status or ethnicity which can significantly influence park use and/or behaviour (Dwyer & Gobster, 1992; Gobster, 2002; Shackleton & Blair, 2013). Further, our sampling methods did not specifically target children, a key demographic of concern with respect to community health. Participatory GIS mapping methods can be used to specifically target and identify children’s behaviour (Kytä, Broberg, & Kahila, 2012) which may differ from adult behaviour.

A recurring question for PPGIS as a research method is the spatial accuracy of the data collected. Because many PPGIS variables (e.g., recreation experiences) can apply to a wide range of landscapes, PPGIS methods often lack a direct measure of spatial error. In the absence of specific evidence indicating that a given marker was placed in error, there is a presumption of PPGIS marker placement validity. This presumption is supported by one study that assessed the spatial accuracy of participant-generated data (Brown, 2012). In this study, spatial accuracy was less of a concern given that most markers were intended to be associated with a park and thus, potential spatial error was more easily managed through small buffers around the parks.

A key limitation of PPGIS in this study is the inability to link specific PPGIS marker locations with specific participant use information. This was an intentional design trade-off based on obtaining the best possible community spatial information. The placement of each PPGIS marker is logically associated with specific use characteristics such as frequency and duration of the particular physical activity or benefit received. But the collection of these specific variables with each marker greatly increases participant burden in responding, and thus, we made the decision to collect non-place-specific park use information in the survey questions that followed

the mapping activity. As a consequence, we don't know the frequency or duration of each physical activity associated with specific markers such as "jogging" or how often a study participant visits a particular park to receive the park benefit. A PPGIS study can be designed to collect frequency and duration variables with each marker, but there is a multiplicative effect of the response burden with the placement of each marker. Our pre-testing indicated participants would experience response fatigue during the mapping component of the study and wouldn't map less frequent park uses which were also considered important to this study. Obtaining a more detailed accounting of the physical activities and benefits would require greater participant commitment and thus a different research approach such as a group-administered or personal interview process.

One of the strengths of PPGIS methods for assessing urban park use and benefits, if our results are indicative, is that the relative contribution of various parks to community health can be ascertained relatively quickly at reasonable cost. The web-based technology worked well for most study participants and it is adaptable to new technology such as mobile devices. The research results can be easily presented as maps which assist in communicating results to participants, stakeholders, and local government. Further, the methodology could also interactively engage community members in a monitoring and feedback process that allows planning decisions to be based off "real time" park usage and park characteristic preference data. But like all survey-based research, the quality of the research results is more dependent on participation/response rates and achieving community representation than technology. The novelty of digital mapping in internet-based PPGIS is insufficient to overcome declining survey response rates across all modes of delivery. Incentives will be needed to increase PPGIS participation rates to obtain quality data.

Notwithstanding the limitations of the study, results suggest planners should pay more attention to the types of parks they provide in urban areas. Linear parks have often received attention because of their value to wildlife and their ability to promote sustainable communities (i.e., cycling routes provide an alternative to road transport). This study provides further support for the value of such parks by identifying the contribution they make to increased physical activity, which has positive consequences for many priority health areas. However, the development of linear parks should not be at the expense of other types of parks that may be more capable of facilitating other important benefits, including improved mental health, environmental, and social benefits. This study suggested park size, a critical factor in conservation biology, may also be important in terms of the facilitation of increased physical activity. Interestingly, while many governments have provided recommendations for the provision of green space in terms of the distance from people's home (Shackleton & Blair, 2013), this study suggests that a more prudent focus may be the type and size of green space.

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