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Accessibility to sport facilities in Wales: A GIS-based analysis of socio-economic variations in provision

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ABSTRACT

Previous studies concerned with investigating the relationship between levels of physical activity and aspects of the built environment have often led to inconsistent and mixed findings concerning associations between the availability of recreational or sport facilities and area socio-economic status. Further complications may arise when analysis is conducted separately for access to either publicly available or private facilities or where alternative methodological approaches to measuring accessibility are adopted. This paper provides a review of such research before exploring the potential use of methods for examining variations in accessibility based on enhanced floating catchment area (FCA) models which are increasingly being advocated in medical geography applications. Using bespoke tools developed within a commercial GIS package, which are being made publicly available by the authors, and a national database of sport facilities, variations in accessibility are investigated in relation to a widely used measure of deprivation in the UK. Findings from this analysis suggest that whilst those living in deprived areas of Wales have greater potential access to publicly available sporting opportunities, associations with privately owned facilities are reversed for some distance thresholds and at different spatial scales. The paper concludes by drawing attention to the implications of such findings given current financial pressures on local government and other sport and leisure providers and highlights how spatial analytical techniques can be used to monitor such trends.

1. Introduction

Previous reviews of the factors that might promote or hinder engagement in, or levels of, physical activity have examined the relative importance of the local geographical environment. This includes access to sport facilities and their interaction with individual level characteristics such as age, income, ethnic group and gender, as well as a variety of socio-economic and behavioural variables (see for example Humpel et al., 2002; Davison and Lawson, 2006; Ding et al., 2011; Lee and Moudon, 2004; Norman et al., 2006; van Lenthe et al., 2005). Sterdt et al. (2014; p. 86) after reviewing previous studies of correlates of physical activity levels in children and adolescents (aged 3–18) suggest "a consistent finding is that proximity and access to leisure/training facilities lead to a higher level of activity among young people". Such studies have investigated the relative importance of proximity to sport facilities on rates of engagement in physical activities which may be impacting through a combination of actual travel times/distances to facilities or subjective perceptions regarding the supply of sporting infrastructure (Duncan et al., 2009; McCormack et al., 2004; Panter and Jones, 2008). With regard to the latter, Wicker et al. (2013) critique the use of subjective measures of sporting infrastructure in favour of objective quantitative measures of supply derived from secondary sources for investigating spatial variations in participation rates. Others have drawn attention to the lack of consistency in such objective measures of supply and highlighted methodological concerns related to existing indicators (Hallmann et al., 2011; Sallis, 2009; Wendel-Vos et al., 2007).

There is a relatively large literature base concerned with exploring potential associations between spatial patterns of accessibility to sport facilities and socio-economic characteristics of areas, often with contrasting findings (Kawakami et al., 2011; Macintyre, 2007; Pascual et al., 2009). For example, a national study of the availability of four types of commercial physical activity facilities in the United States found provision was poorer in lower income neighbourhoods and in areas with higher than average numbers of African Americans (Powell et al., 2006) – a trend mirrored for total

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numbers of physical activity resources by Estabrooks et al. (2003) for a Midwestern city in the US. Moore et al. (2008) also found that poor and minority neighbourhoods in three US states (North Carolina, New York and Maryland) were less likely to have sport facilities. In contrast, other national scale investigations show lower income communities to have better access to health promoting opportunities in general and sport facilities in particular (e.g. in a study of New Zealand by Pearce et al., 2007). Others suggest the direction and strength of such relationships are often dependent on the type of sport facility under consideration (Giles-Corti and Donovan, 2002a; Macintyre et al., 2008). This in turn draws attention to the influence of access to different types of sporting infrastructure, and supporting mechanisms such as availability of transportation, on child and adult sport participation rates which to date remains an under-researched theme (O'Reilly et al., in press). The current study shows how models of accessibility that have recently formed the basis of a number of studies in the health geography literature (briefly reviewed in the following section) can been applied to a national database of facilities in order to explore such linkages.

Some studies have alluded to the importance of issues surrounding the measurement of physical activity environments (e.g. Sallis, 2009) and the potential for inconsistencies in findings based on the source of such data and methodological approach adopted. A recent Sports Wales report highlighted that sport participation rates tend to be poorer in more deprived socio-economic groups but acknowledges that more research is needed to examine how the availability of opportunities for physical activity contributes to this trend (Sport Wales, 2013). An earlier report (Sport Wales, 2012) drew attention to the potential significance of "supply-side problems" regarding the provision of sporting facilities which may influence sports participation rates in disadvantaged areas, but also provided information on average travel times to leisure centres across Wales which tended to be lower for the 10% most deprived areas of the country than the national average. Thus it was suggested supply side problems may stem from variations in the quality of facilities on offer, or other facets of provision such as affordability, rather than the physical location of sporting opportunities (Sport Wales, 2012). Recent local government austerity programs in Wales, as elsewhere, are likely to impact on the provision of leisure services as local authorities look to transfer the funding of facilities such as swimming pools and sports halls to leisure trusts, social enterprises, commercial management organisations or local community groups. Because the provision of these services is not a statutory obligation, there is an urgent need to examine the current status regarding variations in access to leisure provision and to monitor the impact of any changes in provision, including the potential closure of facilities, at a time when participation rates in sport in Wales as elsewhere are generally increasing (Sport Wales, 2014).

Whilst Geographical Information Systems (GIS) are now widely used to provide objective measures of neighbourhood facility availability using methodologies such as Euclidean or network buffers centred on residential addresses (e.g. Bailey et al., 2014; Colabiachi et al., 2014; Karusisi et al., 2013; Prins et al., 2011), more research is still required to incorporate the characteristics of facilities in addition to their location so as to provide better assessments of the impact of variations in the quality of provision within available leisure services. The aim of this paper is to investigate spatial patterns in facility provision by providing a detailed picture of access to a range of sport facilities in Wales that go beyond routine catchment area analysis based on defined travel times or distances. Such studies have the potential to investigate the impact of variations in sporting opportunities on people's involvement with sport and ultimately, it is anticipated, associations with variations in physical activity. Furthermore the incorporation of such measures into wider research efforts investigating factors that affect physical activity rates and health outcomes will enable the respective influence of geographical aspects to be examined in relation to individual socioeconomic characteristics collated in, for example, Active Adults Surveys (Sport England, 2010; Sport Wales, 2014). The rest of this paper is structured as follows. In Section 2 a brief review of GIS-based methodologies for examining potential associations between access to sport facilities and socio-economic characteristics is presented. Extensions to early research primarily focused on straight-line distances to services are summarised before the potential advantages of 'floating catchment area' (FCA) techniques are proposed. In Section 3 a brief background to the development of FCA models, and their applications in health geography are provided. In Section 4, the aims and objectives of the present paper are described and Section 5 outlines how enhanced FCA models were executed against a database of sport facilities in Wales using a customised interface recently developed by the authors. The results of an exploratory analysis of accessibility to all facilities (and various subsets) are presented in Section 6, and discussed in relation to previous findings in Section 7. In the concluding section of the paper the policy significance of this research is reinforced.

2. Access to sport facilities and deprivation: review of the literature

Previous studies using GIS to investigate potential consequences of health-promoting or health-damaging influences tend to adopt either *density* or *proximity* type metrics of resource availability. The former are area-based measures that typically count the number of facilities in a given administrative area (or within a spatial buffer around a residential address or area centroid) standardised by a population count (total or sub-group) to calculate a provider-to-population ratio. In contrast, proximity measures calculate access to the nearest facility of a certain type using similar representations of demand points typically using Euclidean (straight-line) or network distances, or a combination of both. As an example of the former, Hillsdon et al. (2007) conducted one of the few national level studies to date of the availability of indoor exercise facilities in relation to socio-economic data. Using a database of private and public services in England their findings suggest a decline in the density of facilities with increasing area deprivation. This relationship held true for both private and public facilities when analysed separately, but when confined to swimming pools those classified as 'private' were more equally distributed by deprivation profile. The density of facilities within administrative areas is a relatively crude if well-established measure of availability. Other studies have sought to calculate accessibility by counting facilities within distance or time based thresholds constructed around the addresses of survey respondents, or more commonly population centroids (Auchincloss et al., 2012). However, problems may still arise where such proximity measures are constrained by arbitrary boundaries used to define potential areas of influence of environmental factors on individual behaviour. This has led others to explore the use of alternative methods such as floating catchment area (FCA) techniques. Whilst such techniques overcome some limitations of the simpler methods described above, they can present other methodological challenges for researchers. For example, there is a lack of a consensus on the appropriate buffer sizes used to measure potential associations between environmental characteristics and different types of physical activity behaviours primarily due to the lack of data on how far individuals are prepared to travel via alternative modes of transport. Likewise, the exact nature of any distance-decay parameters used to account for decreasing likelihood of service utilisation with distance will often depend on facility types and individual characteristics (Prins et al., 2014).

There has been limited assessment of the impact of varying key parameters in spatial modelling activities whilst investigating patterns of physical activity. Studies conducted in Scotland suggest that associations found between income deprivation and number of facilities may be dependent on the context (e.g. urban/rural), the travel-time threshold and the type of facility (private/public). This was highlighted in a study of the distribution of facilities between, and within, the four largest cities in Scotland which showed that density tended to be lowest in the most affluent quintile, but that the situation reversed when only private facilities were considered (Lamb et al., 2010). However the authors cautioned against generalizing these findings to other situations by drawing attention to differences in the direction and strength of the relationship within the four contrasting urban areas, as well as the lack of any linear association between deprivation and estimated number of facilities across the deprivation quintiles (middle income areas recorded greater access than either poor or affluent areas). Ogilvie et al. (2011) varied the walking and cycling travel time thresholds used to investigate this relationship and found generally poorer levels of access in more affluent areas although the significance of this relationship varied spatially across Scotland between, for example, urban areas and small towns. Ferguson et al. (2013) extended this research by investigating whether the trends held when motorised modes of transport were included in the analysis. Their findings suggest that for travel by car, access was highest for the most affluent quintile when compared to the most deprived quintile, particularly in rural areas. However when restricted to urban areas there was no evident trend with deprivation. The reverse was true for travel by bus, with more accessible facilities with increasing deprivation for urban areas and small towns, but not in rural areas. Extending the analysis to include four alternative modes of transport for accessing facilities associated with moderate and vigorous intensity physical activity, Lamb et al. (2012) found significantly higher number of facilities accessible by car in affluent areas within 20 or 30 min travel journey. But this trend reversed when other transport modes were considered (walking, bus and cycling) wherein deprived areas experienced greater access than those living in the most affluent neighbourhoods. Their study thus points to concerns for households without access to cars living in affluent areas who "may be more disadvantaged in terms of access to facilities than if they were living in areas of greater aggregate deprivation" (Lamb et al., 2012; p. 6).

Other studies have focussed on specific recreational or sport facilities. Macintyre (2007) drew attention to the need to consider the context, the type of facility/resource under consideration and the relevant time scale when generalising the findings from such studies. In a follow up study Macintyre et al. (2008) found that some facilities (e.g. publicly owned swimming pools and sport centres) were more prevalent in deprived areas of Glasgow, whereas others (e.g. publicly owned tennis courts and private swimming pools) were more common in affluent areas of the city. Hill and Green (2012) have also highlighted the need to understand the impacts of variations in the quality of facilities on participation rates for different types of sporting activities. Few GIS-based studies to date have considered the relative importance of the type or quality of sport facilities in relation to area socio-economic status. A study conducted for neighbourhoods in Paris by Billaudeau et al. (2011), for example, examined variations in the locations and characteristics of sport facilities within the city in relation to area income levels. As well as finding provision varied with factors such as population size and income, they also drew attention to contrasting trends in the association between spatial accessibility and area income for different types of facilities. The strength of relationship also varied for individual types of sport facilities depending on the buffered distance used to represent the 'immediate' neighbourhood. This led the authors to hypothesise that differences in the findings between studies could be due in part to the spatial scale of analysis used to investigate associations between accessibility to different types of sport facilities and area socio-economic status.

Whilst some have questioned the importance of geographical factors within such frameworks, others suggest that the lack of facilities can impinge on people's perceptions, if not their use, of recreational choices (Jackson, 1994). Previous reviews have drawn attention to the different approaches used to define the physical environment in general, and elements of the sporting infrastructure in particular, that tend to be adopted in such studies (Davison and Lawson, 2006). So whilst acknowledging that access to sporting facilities is multi-faceted and encompasses financial and educational aspects in addition to geographical availability, research aimed at providing a more nuanced understanding of spatial variations at detailed spatial scales remains a priority (Karusisi et al., 2013). Furthermore, although spatial and temporal patterns in service provision in relation to socio-demographic characteristics have been explored, few studies have incorporated supply-side attributes of the sporting opportunities. To date there has been no national-level study of variations in spatial access to sport facilities across Wales, although Evans et al. (2013) considered financial barriers via an investigation of mean entry prices to publicly and privately run gyms and fitness centres in relation to neighbourhood levels of deprivation. Drawing on the inconsistencies in trends in spatial accessibility with deprivation levels evidenced in previous studies, they highlight the need to address financial affordability as an explanatory factor for lower levels of physical activity in deprived neighbourhoods. Their analysis suggests that this relationship varied such that access costs were higher in more affluent neighbourhoods (for privately run facilities) while those associated with public facilities have no significant difference between affluent and deprived areas. Service quality and other supply-side characteristics (such as the range of sporting facilities) were not considered and the deprivation score was assigned to gyms located within the census tract thus ruling out the possibility of attending a centre from a neighbouring tract.

3. Floating catchment area (FCA) models

Previous studies have reviewed conceptual and methodological issues related to alternative approaches to measuring spatial accessibility using GIS (e.g. Apparicio et al., 2008; Higgs, 2004; Koppen et al., 2014a; Neutens, 2015; Wang, 2012; Yang et al., 2006). Yang et al. (2006) amongst others have compared the use of different approaches to measuring accessibility in the context of measuring social inequities in health care provision. Neutens (2015) highlights the shortcomings associated with a range of accessibility measures in understanding access to health care from the perspective of transport geography before making recommendations for spatially disaggregate measures that incorporate temporal and individualised components. FCA models redress the limitations of studies alluded to previously that use either a 'container' approach to estimate the density of facilities in an administrative area, or 'shortest distance' (*proximity*) methods which assume people use their nearest facility and do not exercise choice in their behaviour whilst at the same time ignoring population size or supply-side characteristics.

In contrast the two-step 'floating' catchment area (2SFCA) approach considers all the options that are potentially available for (recreation) opportunities within a specified time (or distance) threshold (Luo, 2004; Wang and Luo, 2005). By examining the interactions between demand and supply within time/distance thresholds the restrictions of density and proximity approaches are relaxed to provide a more realistic impression of accessibility. In the first stage, centred on the location of each sport facility a *facility-to-population* ratio (R_j) is calculated by aggregating the population within threshold distances of each facility using population weighted centroids (or other demand points) as the source of the population denominator. In the second stage, the facilities falling within the catchment of each population demand point are determined and service accessibility measured by summing all Rj values obtained in step 1. The final accessibility measure reflects both service quality (facility-to-population ratio) and quantity (the sum of all supply points within reach of a demand point), returning higher values as accessibility increases.

The advantages of FCA approaches are that they allow an assumed potential demand for the facility to be taken into account and also permit supply side capacity constraints (e.g. limits on numbers who can use swimming pools or badminton courts at any one time) and competition between providers to be incorporated into the analysis thus including an element of freedom of choice. A drawback, as noted by Neutens (2015), is that similar scores can arise where individuals live in areas of high demand and high supply as those living in areas with low demand and low supply (a problem also inherent in the calculation of most density measures). However, potential demand can be tailored to a particular population subgroup who may be more inclined to use a particular service (Ngui and Apparicio, 2011). Thus in the context of the present study, FCA has the potential to draw on the findings of, for example, population health surveys (Belanger et al., 2011) to identify those population groups with a preference for certain types of physical activity. Since the earliest studies demonstrating the utility of the FCA approach, a number of enhancements have been proposed to the ways in which access scores are calculated. Luo and Qi (2009) for example drew attention to two limitations of the original 2SFCA approach relating, firstly, to the assumption of equal access for all people within the same catchment area and, secondly, to the assumption that locations outside a catchment have no access at all. They proposed an enhanced two-step floating catchment area (E2SFCA) technique by adding a discrete (stepped) distance-decay parameter into the model. Both the magnitude of weightings and position of break points could be varied according to the nature of the service being considered. But deciding how these parameters should be set introduces new dilemmas and, as the researchers suggest, "...to properly address these issues, detailed surveys of actual utilization of health services would be necessary" (Luo and Qi, 2009; p. 1105). McGrail and Humphreys (2009) also proposed the addition of a distance-decay function to account for within catchment impedance as well as dynamic catchment sizes to reflect 'expected' service and population catchments. Once again however detailed empirical data on service utilisation is needed to justify the setting of such parameters and, as this is rarely available, the "decision points" used to improve the method remain based on local or anecdotal evidence (McGrail and Humphreys, 2009).

Most studies to date using FCA models have been in relation to investigating spatial variations in access to health services (e.g. Dai, 2010; Dewulf et al., 2013; Guagliardo, 2004; McGrail and Humphreys, 2009; Ngui and Apparicio, 2011). Few have investigated variations in access to sport facilities, with the exception of Cutumisu and Spence (2012), who applied an E2SFCA model to examine the potential contribution of accessibility to sports fields on levels of physical activity in Edmonton, Canada, whilst comparing such scores to individual socio-demographic factors and their survey respondents' perceptions of provision. Their analysis used a 1500 m threshold distance, with differential weights applied in three travel zones at 500 m increments. Calculated FCA scores were then assigned to respondents address (based on proximity to population centroids) to establish the contribution that objective measures of accessibility made to overall levels of physical activity. In this paper the impacts of varying thresholds on subsequent FCA scores are also investigated using an ArcGIS Desktop Add-In, developed using Visual Studio and the Microsoft. NET platform. The purpose of this tool is to facilitate easy computation of Enhanced Two-Step Floating Catchment Area (E2SFCA) accessibility scores, together with other commonly used geographical accessibility metrics.[1]

4. Aims and objectives

This study aims to provide a descriptive analysis of trends in the provision of sporting facilities in relation to a well-established measure of disadvantage in the UK (the Townsend Index). Using a national database of facility locations and small area socio-economic data drawn from the UK Census of Population the paper describes the potential for E2SFCA models to investigate spatial patterns in service provision in relation to socio-economic characteristics in Wales. It presents several enhancements over previous studies concerned with investigating spatial variation in access to sport opportunities. Firstly, as well as adopting FCA approaches to investigate access to all sport facilities in Wales, further separate analyses are conducted for different types of facilities and for those with different ownership status (private membership/public use). This overcomes problems of assuming that all facilities are *potentially* available to all population groups and takes into account the likelihood that facilities based on higher education establishments or Ministry of Defence sites, for example, are not typically available to the general public. Secondly, various network distance thresholds are used in the FCA models in order to describe potential associations with deprivation. The review by Brownson et al. (2009) on GIS-based analyses of associations between measures of the built or social environment and physical activity found that a wide range of buffer thresholds have been used to represent local 'neighbourhoods'. Meanwhile the impacts of varying buffer size and shape on reported relationships have been the focus of several recent studies (James et al., 2014) and have led to calls for sensitivity analyses to be routinely conducted in such studies.

Several studies have alluded to the importance of neighbourhood definition and the problem of boundary delineation when investigating potential effects of environmental and social processes on health outcomes (Haynes et al., 2007; Kwan, 2012). Others have drawn attention to the importance of geographic scale and zoning effects in such studies (Houston, 2014). This so-called modifiable areal unit problem (Openshaw, 1984) has long been recognised as having a potentially significant impact on the results of such associational studies. To date, despite calls for further research on the most appropriate spatial scale of analysis, few studies have varied the base units of analysis (Brownson et al., 2009). Thus a third contribution of this paper concerns an examination of the potential influence of scale on the findings from FCA modelling. Specifically differences are sought between accessibility and deprivation at two spatial scales based upon UK Census dissemination units. Firstly, the study uses Output Areas (OAs) which have a mean population size of 300 and are the lowest geographical level at which UK census estimates are provided (and in

[1] The authors have developed an interface to ArcGIS™ which automate the implementation of the enhanced FCA models and which is now freely available for others to download. https://www.researchgate.net/publication/261398233_USWFCA__An_ArcGIS_(10.110.2)_Add-In_tool_to_compute_Enhanced_Two-Step_Floating_Catchment_Area_accessibility_scores. Installation Instructions at: https://www.researchgate.net/publication/261437885_USWFCA_Installation_and_Usage_Instructions.

this respect are roughly equivalent to the US Census Block). Secondly, the study incorporates Lower Super Output Areas (LSOAs) which are aggregates of adjacent OAs with a mean population of around 1500 residents (Cockings et al., 2011) and so roughly approximate the US Census Block Group. Official population weighted centroids for both OA and LSOA units are used to represent demand points in the FCA models. Variables drawn from the 2011 UK Census have been used to calculate Townsend deprivation scores for both spatial units to support our investigation of potential associations. This allows the study to contribute to wider debates about the importance of neighbourhood area definitions and the impacts of spatial dimensions on the strengths of association between access to recreational/sporting opportunities and levels of physical activity and health outcomes (Boone-Heinonen et al., 2010; Spielman and Yoo, 2009).

5. Data and methods

5.1. Database of sport facilities

A database of all privately and publicly-owned sport facilities in Wales as of January 2014 was provided by Sport Wales (Fig. 1). It included information on owner type (e.g. commercial, local authority, higher education establishment), usage status (e.g. registered membership use, pay and play, private use), physical availability (disabled access and parking) and facility type descriptions (e.g. health and fitness, sports hall, swimming pools, tennis courts). In total this covered 2276 facilities at over 800 sites in Wales. Of these, just over 20% are available from commercial owners and 11% are sports clubs, but the largest percentage are currently owned or managed by local authorities (just under 50%). In terms of ownership and access by the public, just over 68% are available as 'Pay and Play' facilities, just under 12% are for private or registered membership use, and 18% are categorised as Sports Clubs or Community Association facilities. Sports halls (17%) comprise the commonest facility type, followed by 'Health and Fitness' (16%), swimming pools (12.7%) and outdoor tennis courts (12%). Detailed information on supply-side characteristics (e.g. length and lane count of swimming pools, number of badminton or volleyball courts within sports halls, etc.) is available for each facility and will be used in our future research concerned with including quality measures in FCA calculations (Section 7). The classification used by Evans et al. (2013), was used to compare findings with regard to access to those facilities under private and public ownership. *Private* facilities were composed of all locations where facilities were run commercially as well as venues for sports clubs. *Public* facilities were composed of those provided by public sector organisations including local authorities and health authorities. Facilities managed by the Ministry of Defence and higher education establishments which are not typically available to all members of the public were omitted from the analysis but together only account for 3.7% of total provision in Wales.

5.2. Running E2SFCA models

Demand and supply-side information is incorporated into a FCA analysis in order to examine variations in access scores associated with a widely used measure of socio-economic deprivation (Townsend Index). Using functions contained within the ArcGIS extension we compute the closest service supply point facility for each demand point and generate an origin-destination matrix of network travel costs between the designated service supply and demand points subject to a threshold distance/time parameter, from which the ES2FCA scores and other metrics are then computed. This requires an appropriately configured network dataset and the Ordnance Survey Integrated Transport Network (ITN) layer is used to calculate road network travel distance and time. The extension tool offers several alternative models for defining a continuous distance-decay factor operating within the user specified catchment threshold; a *Linear* option simply tapers off uniformly to zero at the threshold point, while the *Gaussian* and *Butterworth* options offer a slower initial decline followed by a faster rate thereafter. The latter options require parameters to specify the detailed shape of the function; increasing the power function steepens the declining section, while increasing the passband value extends the flat shoulder so it extends further towards the limit of the threshold. In the absence of empirical data on the actual use of such services in Wales, the linear option was chosen in the first instance to represent the decay in utilisation with distance.

E2SFCA models were applied for the complete and two sub-sets of the database; in the first instance FCA models are run for all facilities for two network distance thresholds and using the population weighted centroids of both OAs and then LSOAs as the demand points. Secondly, to compare our findings with those of Ferguson et al. (2013) in Scotland, E2SFCA models were run separately for subdivisions of ownership where facilities were categorised as publicly or privately run. Finally, to compare our findings with those of Macintyre et al. (2008) in Glasgow, FCA scores were computed separately for swimming pools and sports halls (Fig. 2) so as to examine variations in accessibility to the two types of facilities that have the highest use in Wales.

5.3. Choice of distance thresholds and implementation of FCA models

A variety of thresholds have been used in previous studies seeking associations between accessibility and levels of physical activity or health outcomes. For example, Billaudeau et al. (2011) used 500 m as the threshold walkable distance to facilities, while Prins et al. (2012) calculated sports facilities and parks within 1600 m cycling distance from the home addresses of respondents in a Dutch study. This in turn was based on the research of Colabianchi et al. (2007) who surveyed just over 900 12th grade adolescent girls regarding "easy" walking and driving distances. Their findings highlighted differences by age, weight and urban status but pointed to 0.75mile or approximately 1200 m (assuming a walking speed of 3 miles per hour) as a <u>walking</u> based threshold definition of 'neighbourhood' and 16.4 km as a <u>driving</u> based threshold (approximately 10 miles). In summary, despite an increasing literature base in the area of accessibility research, there is little empirical analysis on the actual distances people are prepared to travel to access sport and recreation facilities, or the nature of decay gradients with distance or time. In one of the few studies conducted to date, Spinney and Millward (2013) used time diary data and GPS to empirically measure travel-distance thresholds in Nova Scotia, Canada. They suggest travel times are in the order of 15–30 min with distance based thresholds of 4–20 km for different sports and recreation activities. Variations in the time individuals are prepared to travel to different types of sporting facilities has also been investigated by authors such as Pawlowski et al. (2009). Drawing on a review of previous research, two thresholds were chosen in our study, namely 1000 m (to represent those walking to facilities) and 5 km (for modelled driving distances) which are considered to be a fair representation of the likely distances people are prepared to travel (Millward et al., 2013); these distances can easily be varied if better empirical evidence became available on the modal split and actual time taken by individuals to access sport facilities in Wales. Neighbourhoods are constructed around two separate population weighted demand points (i.e. OA and LSOA centroids) and associations sought through a comparison of FCA scores with deprivation scores at

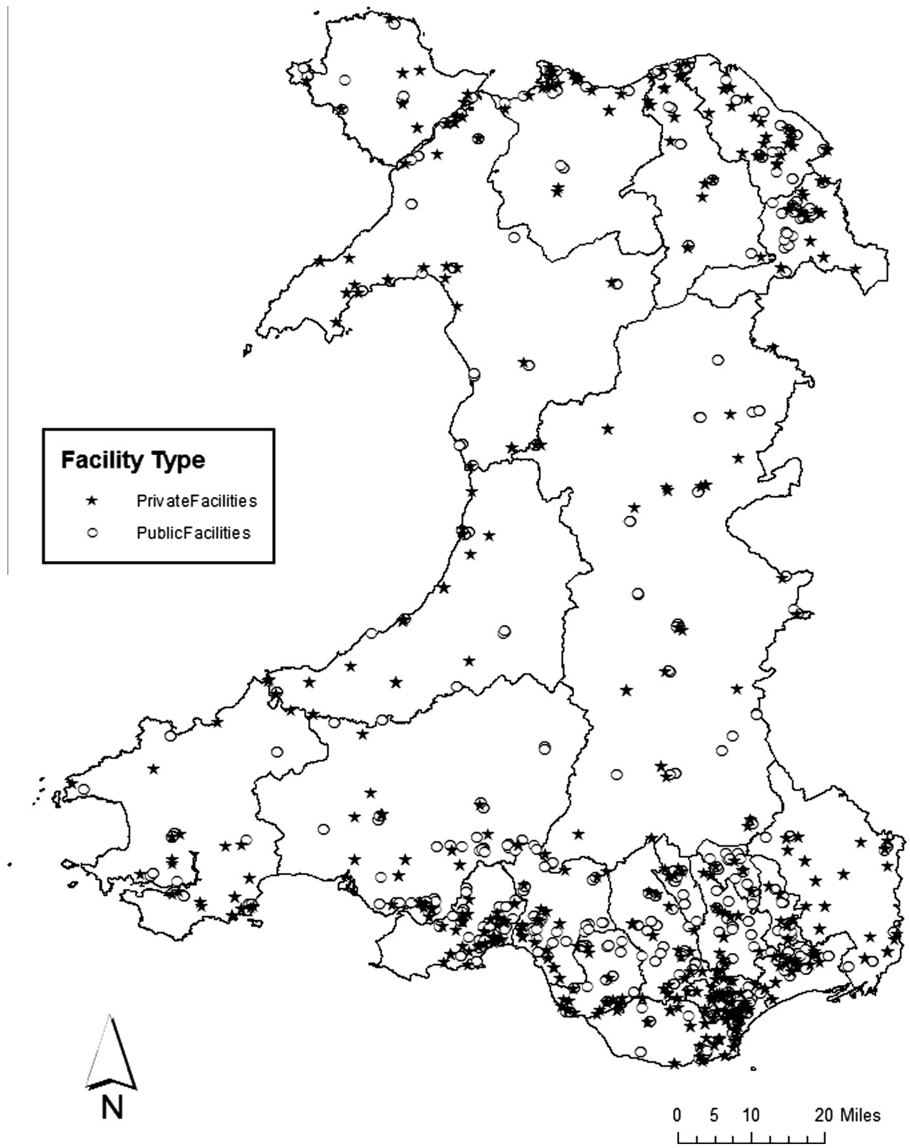

Fig. 1. Privately and publicly-owned recreational facilities in Wales (January 2014). *Source:* Sport Wales.

these two levels of spatial aggregation using a descriptive analysis of deprivation quintile averaged FCA scores.

5.4. Townsend deprivation scores

Deprivation is defined as disadvantage relative to the local community, wider society or the nation to which an individual, family or group belongs (Townsend, 1987). The Townsend Index (Townsend, 1987) is an area based measure calculated from four input variables drawn from the census on percentages of unemployment, lack of access to a car, non-home ownership and household overcrowding. After transformation to near normal distributions where appropriate, the variables are standardised (to z-scores) and summed, equally weighted, to form an index in which more positive scores represent more deprived locations and more negative scores represent less deprivation locations. Here Townsend Scores have been calculated for 2011 at both OA and LSOA levels with the deprivation scores categorised into population weighted quintiles (20% of the population in each quintile). Fig. 3 shows the variations in Townsend scores in Wales (classified by quintiles). To consider whether accessibility scores varied between areas with differing socio-economic profiles within Wales, descriptive data analysis techniques are used to compare mean FCA scores within areas divided into quintiles of deprivation, based on the Townsend Index at the two spatial scales. As an illustration the distribution of FCA scores (for all facilities using a 1000 m threshold) and Townsend scores for the Cardiff unitary authority at the LSOA level are displayed in Fig. 4. Figs. 5–7 provide a visual comparison of graphs of the means and 95% confidence intervals by deprivation quintile for different combinations of FCA calculations including distance thresholds and are discussed in more detail in the next section.

6. Results

6.1. All facilities and private/public split and variations in threshold distance

Firstly when all facilities are considered there is a general pattern of FCA scores being low for those areas in Townsend quintile 1 (least deprived) and high in the most deprived quintiles (quintile 3–5). However for at least the ‘all facilities’ and ‘public facilities’

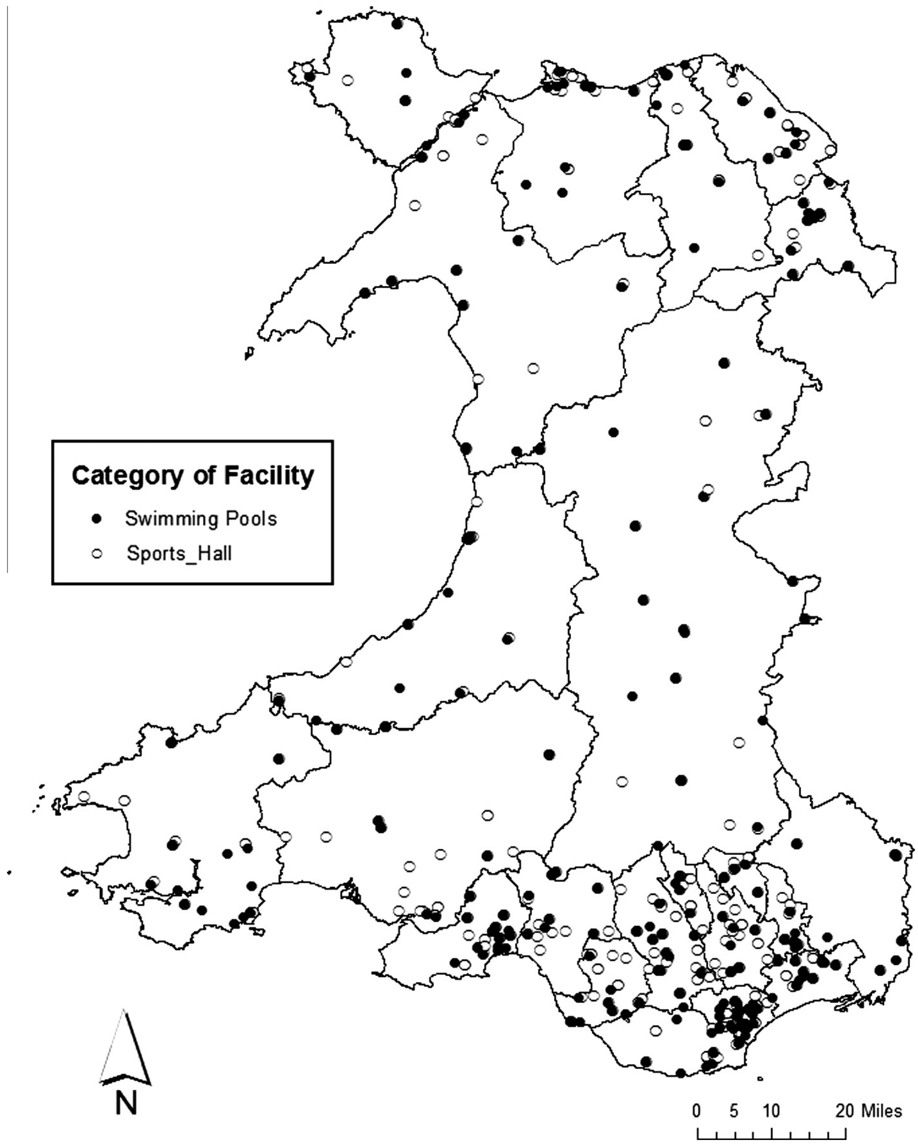

Fig. 2. Swimming pools and sports halls in Wales (January 2014). *Source:* Sport Wales.

categories, the highest mean scores are in quintile 3 (Fig. 5). At the 1000 m threshold level, patterns for all three categorisations are consistent. However, as expected given that larger threshold distances capture spatial units with a wider range of deprivation scores, average FCA scores are less discriminatory at the 5000 m threshold value. There is also some evidence, at least at this spatial scale, that associations with deprivation for access to private facilities are reversed (i.e. that more deprived LSOAs have lower accessibility) although patterns are not linear with respect to deprivation. This mirrors the findings of previous studies that have investigated variations in access between publicly and privately managed facilities reviewed previously.

6.2. Variations with spatial scale

Variations at the Output Area level tend to mirror those at the more aggregate level (compare Fig. 6 with Fig. 5) in that access to 'all facilities' and those publicly managed or owned tends to be highest in more deprived OAs in Wales. This is the case for both the 1000 m and 5000 m thresholds. However differences in mean FCA scores are less pronounced at the 5000 m threshold level when the distance threshold encompasses a wider range of OAs with scores that are 'averaged out'. The most interesting association is with accessibility to privately run or managed facilities when modelled at this spatial scale. Differences are more pronounced than those seen at the LSOA level in that the weak reversal of the relationship between deprivation and access at that scale (at least at the 5000 m threshold) is more pronounced for the smaller spatial unit. At 1000 m there is barely any difference in the mean FCA score with deprivation across the five quintiles but at the 5000 m threshold there is evidence that those in the most deprived quintiles of OAs have poorer access to private facilities than those in quintiles 1–3.

6.3. Variations in access to sports halls and swimming pools

Finally the FCA models have been run for both thresholds (1000 m and 5000 m) at the OA and LSOA levels for two specific sporting facilities (namely sports halls and swimming pools) in order to compare our findings with those of previous studies (Fig. 7). In this instance no attempt has been made to categorise these facilities by owner type. In all cases a pattern emerges of

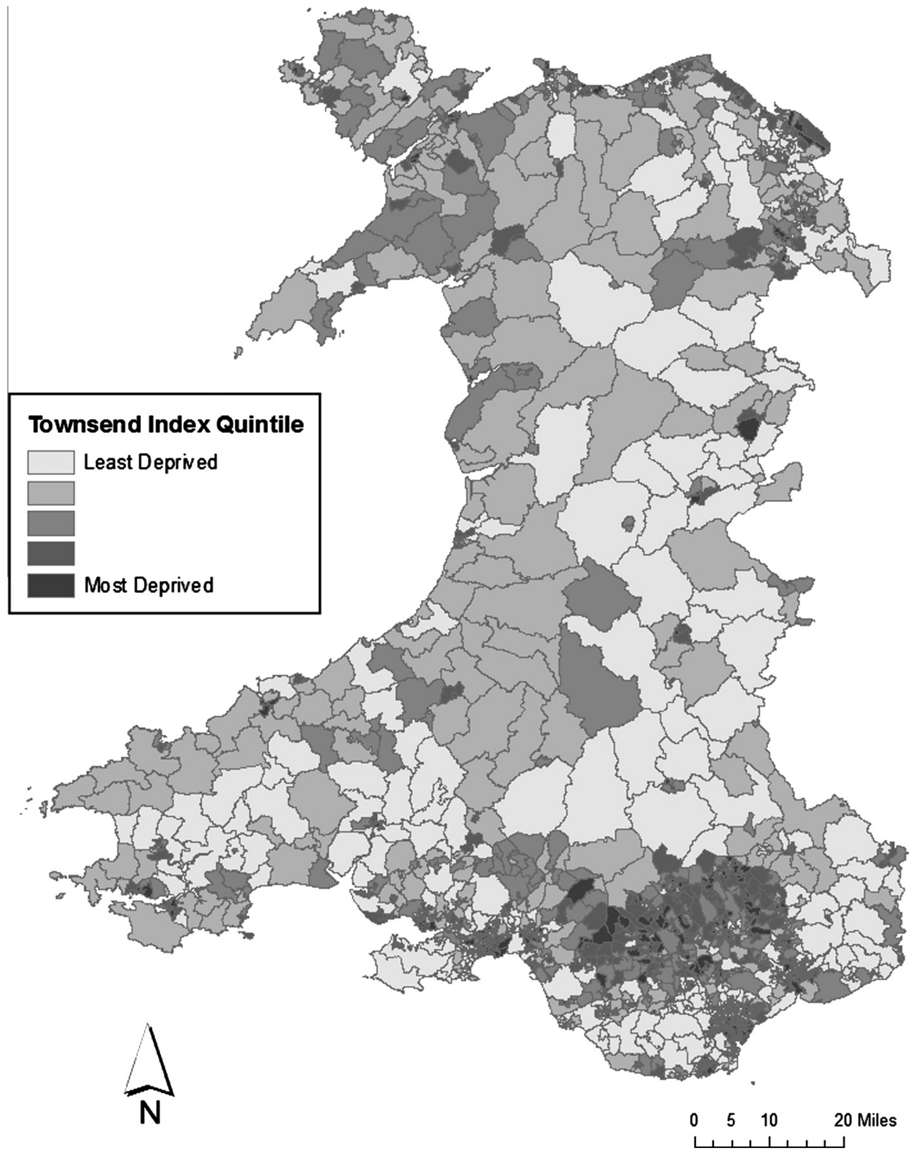

Fig. 3. Distribution of townsend quintiles in Wales, Lower Super Output Area. *Source:* 2011 Census of Population.

increasing access with greater deprivation although differences are less pronounced for swimming pools than sports halls.

7. Discussion

Previous studies of the relationship between levels of physical activity and different aspects of the built environment have often led to inconsistent and mixed findings concerning trends in the availability of sport facilities and variations in socio-economic geography. The main strength of the present study is that it outlines the first attempt to use floating catchment area (FCA) techniques to provide a measure of potential accessibility to sport facilities using a high quality nation-wide database which provides not only locational information but also permits separate analysis for different classes of facility. Furthermore, enhanced FCA models based on network distances enable a consideration of cross-boundary availability of services as well as competition from other facilities whilst permitting distance-decay parameters to be included and thus overcome the limitations of 'container approaches' where opportunities are assumed to stop at administrative boundaries (e.g. Hillsdon et al., 2007; Lamb et al., 2010). Given the appropriate measure of capacity restrictions associated with sport facilities, such an approach also permits supply-side parameters to be included in the accessibility calculations. Based on an implementation of enhanced FCA models within a proprietary GIS, this paper presents a preliminary descriptive analysis of the relative distribution of different types of facilities, as evidenced by area measures of accessibility, with spatial trends in material deprivation (as revealed by the Townsend Index). This approach has involved an analysis at two spatial scales (OA and LSOA) which accommodates potential cross-boundary use of facilities in adjoining areas and incorporates different distance (or time) thresholds. In common with several other studies (e.g. Lamb et al., 2010; Witten et al., 2011), the patterns revealed from this analysis suggests that accessibility to the whole range of sport facilities tends to be highest in the most socially deprived areas of Wales and lowest in the more affluent areas. However, as also observed in other studies the distribution of accessibility scores does not vary consistently with variations in deprivation. These findings concur with those of Lamb et al. (2010) who found that middle income areas appear to have greater access than either the poorest or most affluent areas to some types of facilities, suggesting there is not a smooth

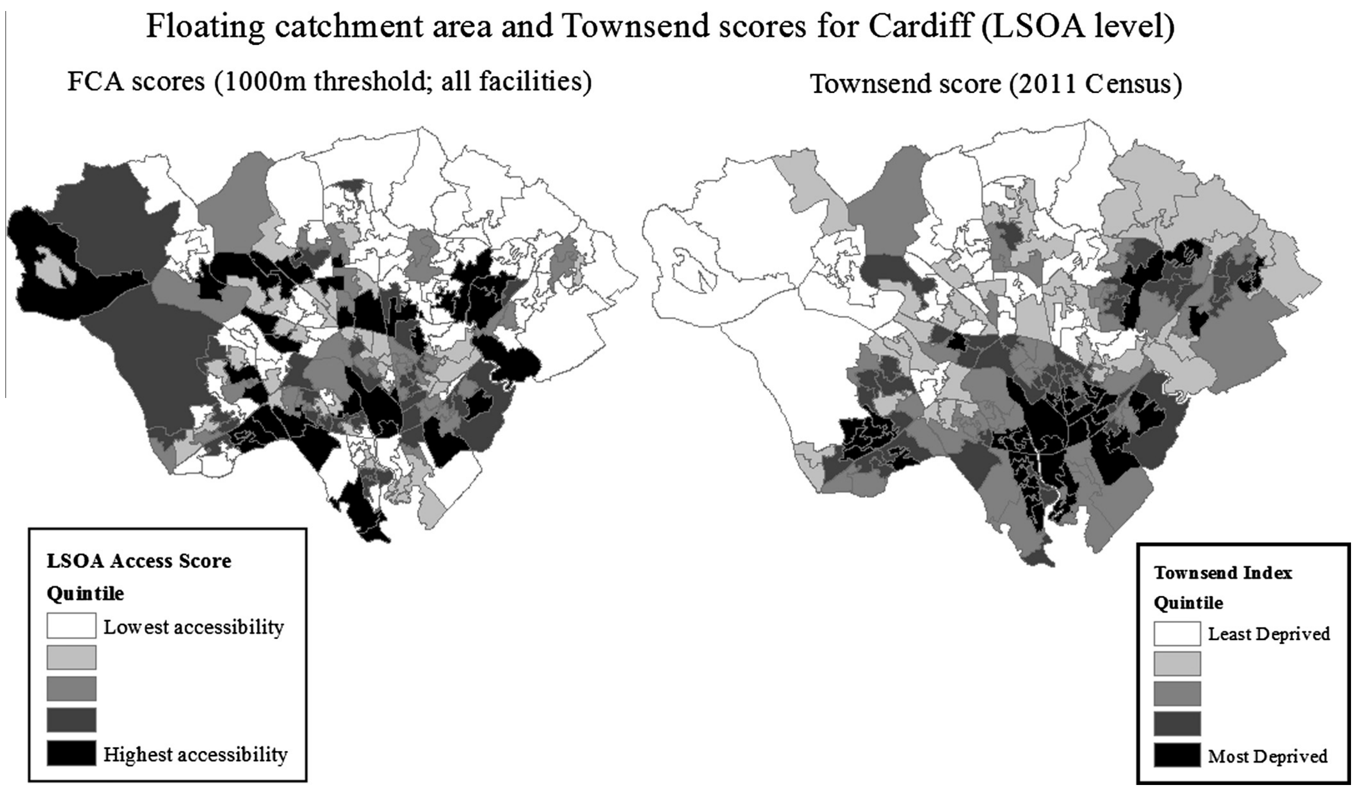

Fig. 4. Associations between accessibility scores and deprivation for Cardiff.

social gradient in the FCA scores between quintiles of deprivation. More research is needed to understand these trends in the Welsh context and to ascertain whether this trend is consistent across studies which use different methodological approaches to measuring accessibility and which also consider aspects other than the quantitative measure of the presence of facilities such as their quality and affordability (Lamb et al., 2010). Alternatively, as Billaudeau et al. (2011; p. 120) suggest, such trends could be reflective of different policies towards the provision of sports facilities in different countries with different planning/policy contexts ("a true heterogeneity between territories"). When analysis is confined to modelling access to private sports facilities evidence emerges of a reversal in trends, mirroring findings reported in previous studies such as Estabrooks et al. (2003), Macintyre et al. (2008) and Billaudeau et al. (2011) and suggesting that more research is needed to study the distributional impacts of pay-for-use and free-to-use facilities in the light of recent policy developments.

O'Reilly et al. (in press) has suggested that understanding the relationship between the existence of different types of sporting infrastructure and sport participation is complex and may require a wider consideration of tools that go beyond accessibility measures to encompass geographical notions of distance decay, range and thresholds. FCA models have the potential to include such parameters within accessibility calculations but, to date, have been less frequently adopted in sports geography research. Part of the reason maybe that the outputs from FCA calculations are less intuitive than those based on 'traditional' measures of geographical accessibility such as the nearest distance to a facility or measures of cumulative opportunity within threshold distances which can be represented in absolute units easily understood by researchers and operationalised by policy makers. In contrast, outputs from FCA methods are relative values which are more challenging to interpret. In addition, although FCA approaches have advantages in investigating spatial patterns in accessibility that simultaneously account for variations in demand and supply-side parameters, they also have some limitations which must be acknowledged in the context of the approach taken in this study. Firstly, in common with other approaches, they represent potential indicators of access based on modelled locations of population demand and so do not necessarily reflect the actual usage rates of particular facilities. At this stage we have not incorporated any analysis of spatial patterns in the actual use of such facilities in Wales or investigated the means through which people access such services (although this will form the basis of our on-going research study). The distinction between potential to use a sports facility and its actual use by local population groups has been explored in previous studies. For example, Giles-Corti and Donovan (2002a) in a cross sectional analysis of just over 1800 Australian adults found that residents living in areas of lower socio-economic status in Perth had better access to sports centres, gyms and swimming pools. Despite this the likelihood of using some of these facilities by those living in lower SES areas was generally less than those living in more affluent areas (with the exception of the use of swimming pools).

Secondly, our research to date has not involved any attempts to examine the relationship between objective measures of accessibility derived from FCA-based analysis and peoples' perceptions of access to, or the quality of, sport facilities, which may impact upon their use. A number of studies concerned with potential associations between environmental factors and physical activity have compared 'traditional measures' based on census tracts/administrative boundaries with measures derived from GIS-based analysis (e.g. buffers) and with more self-defined assessments of neighbourhood boundaries based on the experiences of those population groups using different types of services (Colabiachi et al., 2014). Findings from such studies conducted to date suggest the level of agreement between the sets of measures used to approximate neighbourhood environments varies by the type of amenity under

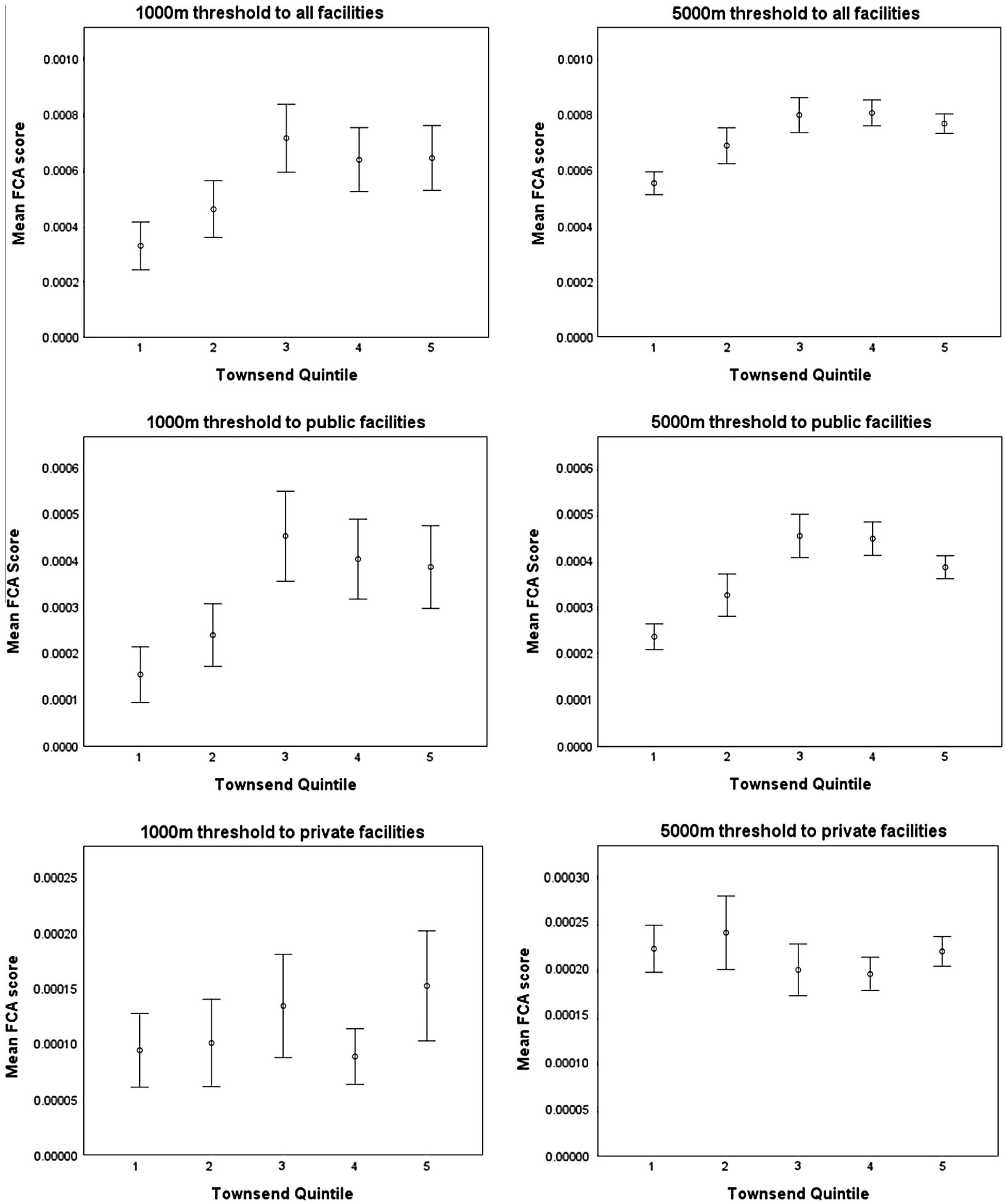

Fig. 5. Mean FCA Scores by Townsend Deprivation Quintile (LSOA level; 1000 and 5000 m thresholds); all facilities, public and private.

consideration, the threshold size and the characteristics of the individuals and neighbourhoods (e.g. urban/rural) surveyed (Bailey et al., 2014; MacDonald et al., 2013). More research is needed to investigate the extent to which people's perception of the availability of facilities in their neighbourhoods, or of the distances involved in accessing sport facilities, is influencing their use and potentially impacting on their physical activity levels (Ball et al., 2008; McGinn et al., 2007; Ries et al., 2011). Sallis et al. (2011) for example have compared perceptions regarding access to recreation facilities amongst residents in differing neighbourhoods of Seattle and Baltimore and found lower income communities had poorer levels of perceived access and were thus less likely to actually use the facilities.

Thirdly, no attempt has been made in the present study to vary the differences in potential demand for facilities by incorporating, for example, the age, ethnic grouping, socioeconomic circumstances, sporting preferences or gender of the local population and their interaction with the type of sporting facility being used. Increasingly such data is being collected via surveys conducted by organisations such as Sport Wales, and this has real potential to further refine the analysis to include for example the time people are prepared to travel to access different sports facilities by

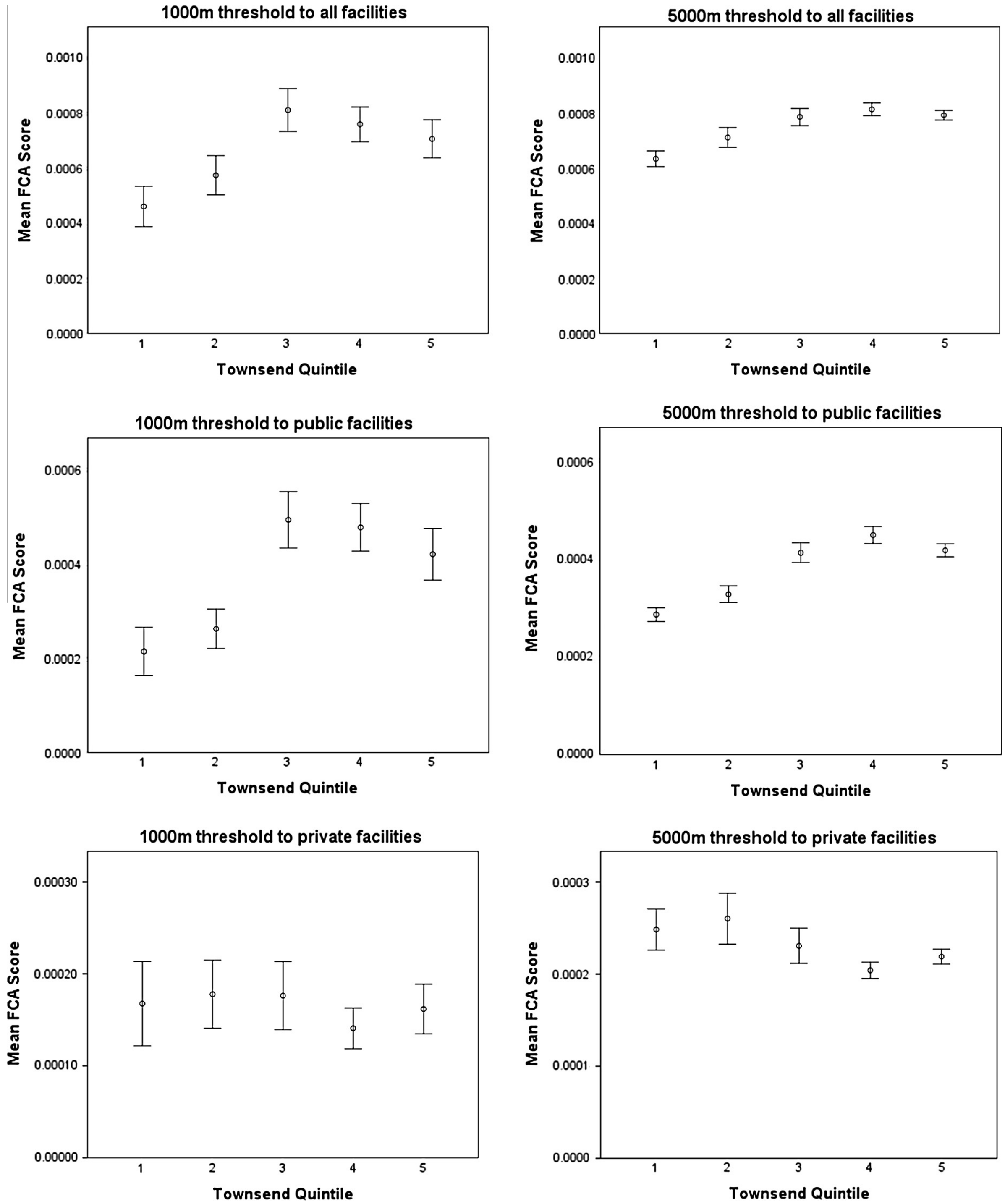

Fig. 6. Mean FCA Scores by Townsend Deprivation Quintile (OA level; 1000 and 5000 m thresholds); All facilities, public and private.

different modes of transport. If available such empirical findings could be adopted as the thresholds included in different stages of the FCA analysis. Some survey work was carried out in Australia on the distances people were willing to travel to access different types of sport facilities (McCormack et al., 2006). The average network distance travelled to all destinations for physical activity amongst a sample of just over a 1000 adults was approximately 5.5 km. However it varied by the socio-economic circumstances of these individuals as well as their demographic profiles, destination type and the physical activity conducted at the facility, such that those participating in moderate activity sports/leisure seemed to be prepared to travel further. There was also evidence that respondents were using facilities at varying distances from their homes despite having others within a local 'neighbourhood' (as represented by a 1600 m buffered distance) and thus assumptions regarding the use of the closest facility typically incorporated into study designs can be questioned illustrating the need for more data on personal preferences, the actual facilities used and the origins of trips (e.g. from home or a workplace) to be incorporated.

Fourthly, as with previous studies that have used enhanced FCA models to date in North American contexts (e.g. Bell et al., 2012; Luo and Wang, 2003; Mao and Nekorchuk, 2013; Wan et al.,

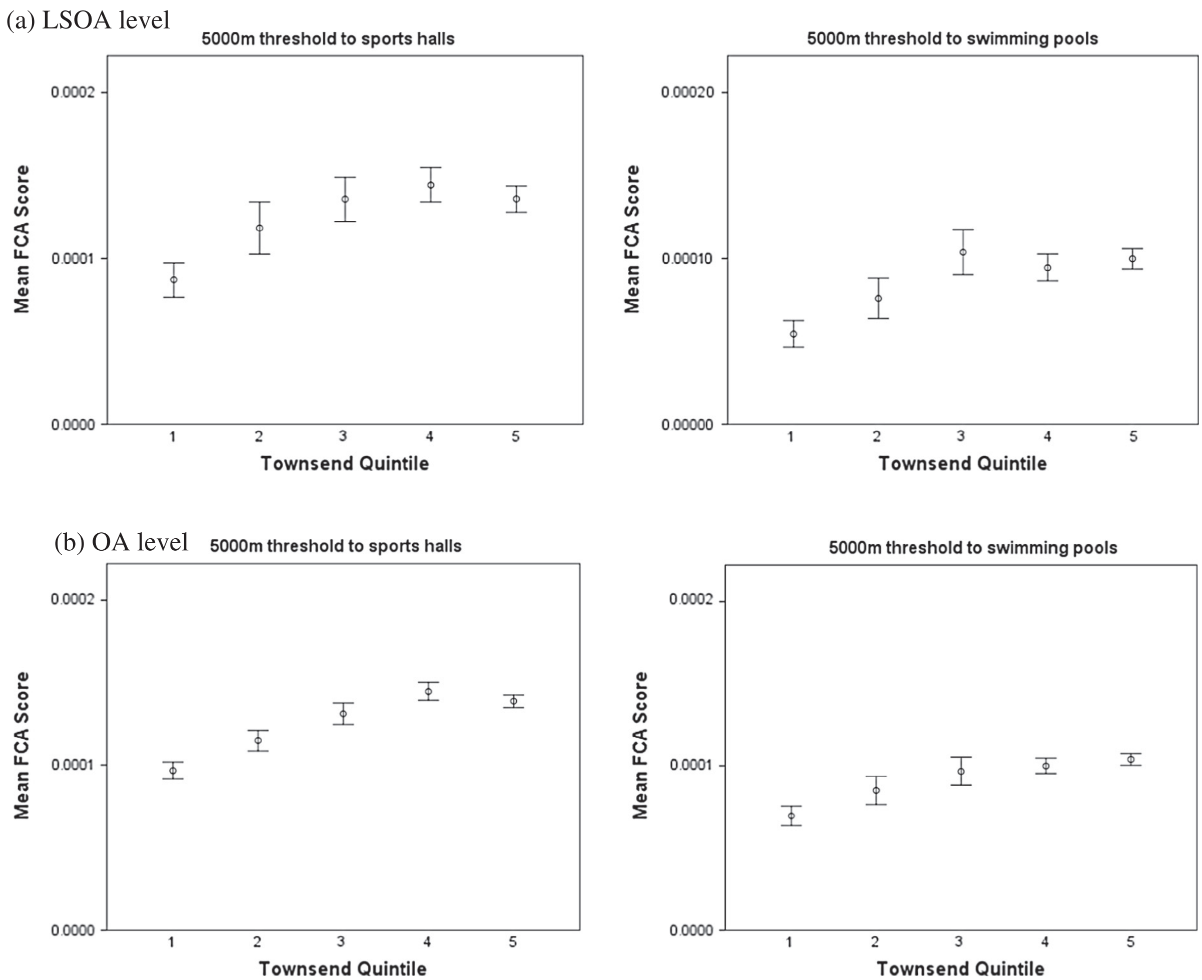

Fig. 7. Mean FCA Scores by Townsend Deprivation Quintile (for sports halls and swimming pools at the 5000 m threshold).

2012), potential demand from night-time populations is assumed to originate from census tract population-weighted centroids. In this study, such single representative points proxied for population demand for Output Areas (average population size: 300 residents) and Lower Super Output Areas (average size of 1500 residents) respectively. In the case of the latter in particular these are variable in size, and in rural areas will be much larger than in urban areas of Wales. In such cases, the use of population weighted centroids will represent a more sensitive reflection of population distribution than geometric centroids which could be located at significant distances from the main communities within large rural units. A number of studies have considered further enhancements to the FCA models to account for representing population within such models (e.g. Langford and Higgs, 2006) but nevertheless it is acknowledged that the use of population weighted centroids in network-based models may not accurately reflect the time taken to reach such facilities from all residential locations and that this may be compounded for larger units and for small thresholds within FCA models. In our future research, the use of postcode headcounts which have recently been made available for 2011 Census of Population data will be investigated to provide a finer scale of analysis and the nature of the area under consideration (e.g. urban versus rural) will be controlled for in order to examine the sensitivity of the FCA scores to the context. Unaggregated address level data would be the perfect solution, but are unavailable under current legislative frameworks. UK postcodes derived directly from individual addresses and each with a typical count of 50 persons are the closest to this ideal. In addition, previous studies have shown that journeys often originate from workplace or school locations; Millward et al. (2013) for example drew on travel diaries and questionnaire data for the city of Halifax, Canada to suggest the majority of walking trips in their study did not originate from home locations and that the use of residential 'demand' points is inappropriate in such scenarios. Nevertheless there are opportunities to include such refinements to our models should detailed information on demand points based on workplace or school locations with appropriate levels of potential demand become available.

An important enhancement in this study has been the incorporation of different distance thresholds that are used to estimate how far people are prepared to travel to access services. Previous studies have found that the choice of buffer threshold used in GIS-based studies of this type, either based on residential address or area centroids, varies according to the aspect of the built environment under consideration, the characteristics of the population and the setting under investigation (e.g. age, gender and socio-economic status; urban, suburban, rural), and also the mode of transport used to access such facilities. Some have called for sensitivity analyses of the potential impacts of variable buffer size on findings to be conducted; calls that are being taken up by researchers investigating environment/physical activity relationships which acknowledge the potential importance of neighbourhood scale (e.g. Billaudeau et al., 2011; van Loon et al., 2014). Diez-Roux et al. (2007) for example demonstrated that the levels of association between a measure of recreational facility density and levels of physical activity were dependent on the buffer size used to define the immediate neighbourhood around residential addresses. Whilst it is reasonably straightforward to vary the thresholds used in the FCA analysis using the type of bespoke tools developed in the course of our study in order to incorporate a range of threshold distances, more research is still needed to provide empirical evidence for the optimal thresholds to use when examining such relationships.

Other improvements to the models that could be investigated following on from this study could include examining the impacts of spatial scale on findings in relation to the type of facility under consideration, the characteristics of neighbourhoods or the population under investigation, further investigation of the implications for varying the form of the distance decay parameter used in the FCA calculations (potentially aided by empirical evidence of the use of different types of sports facilities) and the incorporation of public transport timetables. With regard to the latter there is a widespread recognition that studies which involve an analysis of accessibility to private and public services should include a measure of public transport availability and frequency (Farber et al., 2014). More research is needed on how such variations can be incorporated into 'static' accessibility measures such as the E2SFCA method so as to investigate temporal variability in access to sport facilities resulting from variations in daily activities, travel time and facility opening times. Such analysis could benefit from the inclusion of detailed data on public transport provision, cycle and walking paths as well as knowledge of commuting patterns and enhancements have been made to floating catchment areas models that permit different types of complex travel behaviour to be incorporated into calculations (Fransen et al., 2015; Langford et al., 2012; Mao and Nekorchuk, 2013).

More research is also needed to analyse the impact of quality of the built-form facilities included in the FCA analysis. Despite an increased interest in examining spatial variations in access to open spaces and outdoor recreation activities in recent academic studies (Koppen et al., 2014b), few studies to date have incorporated an analysis of the potential implications of quality of provision into measures of either objective or perceived availability (O'Reilly et al., in press; Ries et al., 2011; Wicker et al., 2013). To date, attempts to create such facility 'attractiveness' measures based on factors such as numbers of parking spaces, changing rooms, shower facilities and distance to transit stops have been relatively crude (O'Reilly et al., in press). Our future research will explore the use of some of the supply–side parameters available in the national database of facilities to move beyond the consideration of location of facilities alone to investigate variations in accessibility (and potentially sport participation) in relation to the quality of provision. Billaudeau et al. (2011; p. 116) show how "technical or comfort characteristics of specific facilities" (including for example facilities for disabled groups, the presence of heated changing rooms/shower facilities, the availability of indoor sporting opportunities or suitable lighting in the closest facilities), can be included in a GIS-based analysis of the quality of provision for Paris. Our future research will explore how such supply-side parameters can be included in a FCA analysis using the national database of sport facilities for Wales.

The findings from these types of studies have a number of health related policy implications which could form the basis of follow-up work. Firstly, it would be interesting to examine the association between variations in access to all facilities (or those broken down by type) and participation rates in these sports as well as overall measures of physical activity using the FCA approaches adopted in this research. Previous approaches to measuring the potential influence of the supply of sporting infrastructure on levels of participation have been relatively crude (e.g. counts within an individual's residential district) or have been based on simplistic assumptions regarding utilisation of facilities solely within existing administrative boundaries (Hallmann et al., 2011; Wicker et al., 2009). For example, Wicker et al. (2013) using geocoded data for individual participants and aggregate measures of sporting infrastructure, applied multi-level models for sub-regions within the city of Munich in order to demonstrate how the location of swimming pools and sports fields can significantly impact on levels of sports participation within specific areas of the city. In contrast, FCA approaches have the potential to be used to examine how the overall pattern of sports provision varies across wider areas which takes into account cross boundary interactions between supply and demand.

Clearly there are other factors besides the immediate physical environment that influence levels of physical activity within communities including individual level characteristics such as age, gender, ethnicity, socio-economic status and personal circumstances (Giles-Corti and Donovan, 2002b) as well as a variety of environment factors aside from accessibility to facilities (see Limstrand, 2008 for a wider review). Evidence from France suggests that variations in accessibility to physical activity facilities in urban areas may influence levels of obesity amongst some children in particular socio-economic groups (Casey et al., 2012). However other studies have found no association between the availability of sport facilities and sports participation or physical activity levels (Diez-Roux et al., 2007; Pascual et al., 2009; Prins et al., 2009), have highlighted the importance of confounding variables such as levels of neighbourhood social capital (Prins et al., 2012) or have found relationships for the use of some types of facilities and associated physical activity (e.g. spatial accessibility to swimming pools and swimming activities) but not for others (Karusisi et al., 2013). The latter study for example used both the street distance to the closest facility and the count of facilities within street network buffers at a range of threshold distances as measures of accessibility to sports facilities and found, after accounting for potential confounding variables, that in the Paris metropolitan area at least "disparities in the spatial accessibility to sport facilities do not have a major impact on utilization, except perhaps for swimming pools" (Karusisi et al., 2013; p, 9). Further research is needed to examine the potential implications of variable access to, and preferences for, different types of sport facilities for participation rates in the Welsh context using the types of accessibility measures developed during the course of this study.

8. Conclusion

The research reported here shows how GIS-based analysis can be used to identify variations in accessibility to the network of sporting facilities as part of wider studies concerned with exploring variations in sport participation rates and levels of physical activity. The study has shown how floating catchment area (FCA) approaches, widely used to examine variations in accessibility to a range of predominantly health services to date, can be used in conjunction with a nation-wide database of sports facilities to provide a descriptive analysis of potential accessibility in relation to socio-economic patterns. This has enabled variations in the location (and characteristics) of sports facilities, both publicly and privately provided, to be examined in relation to an area-level measure of social deprivation. Although more statistically based research is needed to analyse detailed patterns of accessibility in relation to different area types (e.g. urban versus rural; inner-city versus suburban areas) findings to date point to those living in deprived areas of Wales having greater potential access to publicly-owned or managed sporting opportunities. However associations with privately owned facilities are reversed at some distance thresholds and at alternative spatial scales. Similar findings of a positive relationship between increasing neighbourhood deprivation and access to some sporting facilities, with a reversal of trends for some privately run facilities, have been found in cities in Scotland and France. However this is the first study that has taken advantage of a spatially consistent database of sports facilities made available at a national level in order to explore the use of FCA techniques in analysing trends in provision with socio-economic geography.

We posit that such analysis has the potential to identify communities that could benefit from improved supply of sports facilities in relation to policies geared to improving participation rates and levels of physical activity. Furthermore this study has demonstrated how spatial analytical approaches can be used to monitor the implications of, for example, government austerity programmes that may have serious implications for the level and types of sporting provision made available in the future. With local authorities in Wales, as elsewhere, facing increasing pressures on their budgets, sports and leisure services are increasingly at threat as alternative management plans are sought. It is important therefore that trends in provision of such facilities are monitored using the type of tools described in this paper to investigate the consequences of any service cuts for local communities. This could include for example combining the findings from school-based and adult sport participation surveys with spatial patterns in provision to examine the potential influence of geographical barriers on the use of such facilities. Our research to date does not encompass other types of physical activity opportunities such as access to open spaces, walking trails or cycle paths which may not be spatially constrained. However Sport Wales collect data on outdoor recreation facilities which could be used to investigate accessibility to a wider range of such opportunities using the types of tools developed here and reported in other studies (Koppen et al., 2014a). Further research is also needed to examine whether variations in access to facilities as evidenced by spatial patterns in FCA scores is reflected in variations in individual level participation rates and physical activity levels in different areas of Wales and this, together with further refinement of the models presented in this paper, to include for example inclusion of public transport availability and frequency as well as additional data on the quality/costs of particular types of sports facilities, will form the basis of our future work programme in this area. This will include for example the potential for incorporating public transport scheduling information into the calculation of such measures in relation to the daily activity spaces of individuals using such services (Farber et al., 2014).

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