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# How do type and size of natural environments relate to physical activity behavior?

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ABSTRACT

Natural environments (NE) are promoted as places that support physical activity (PA), but evidence on PA distribution across various types and sizes of NE is lacking. Accelerometers and GPS-devices measured PA of Dutch general population adults aged 45–65 years (N=279). Five NE types were distinguished: ‘parks’, ‘recreational area’, ‘agricultural green’, ‘forest & moorland’, and ‘blue space’, and four categories of size: 0–3, 3–7, 7–27, and ≥27 ha. Modality (i.e. spatially concentrated PA, walking, jogging, and cycling) and intensity (i.e. sedentary behavior, LPA, and MVPA) of PA varied significantly between NE types. Compared to parks, less sedentary behavior and walking but more spatially concentrated PA was observed in recreational areas and green space. Cycling levels were found to be significantly lower in recreational areas and forest & moorland, but higher in blue space as compared to parks. Larger sized NE (≥7 ha) were associated with higher levels of MVPA, walking, jogging and cycling. Insight in which environments (according to type and size) facilitate PA, contributes to the development of tailored PA promoting interventions with ensuing implications for public health.

## 1. Introduction

Physical inactivity is seen as a major global public health problem (Kohl et al., 2012) and policy makers, health professionals and urban planners seek for opportunities to increase levels of physical activity (PA). A growing body of evidence indicates that PA levels can be related to environmental factors such as street design, land use mix, street connectivity, access to facilities (e.g. shops) and population density (Lee et al., 2015; McCormack and Shiell, 2011; Van Holle et al., 2012). In particular natural environments (NE) such as city parks, beaches, or grasslands, have been found to be frequently used for a variety of PA behaviors (Lee et al., 2015). Due to the opportunities such environments provide for PA, and their potential to promote also other aspects of health and well-being, NE have become of increasing interest in land-use planning aimed at promoting PA, and the relationship between NE and PA is increasingly studied (Lee et al., 2015). However, previous studies suffer from various shortcomings.

Where most studies have examined whether associations exist between (access to) NE and PA (e.g. Cohen et al., 2007; Evenson et al., 2013; Veitch et al., 2013; White et al., 2014; Witten et al., 2008), only limited research has examined what different types and intensities of PA are actually performed in such natural spaces (Elliott et al., 2015). As different environments facilitate different behaviors, researchers suggest that type of NE (e.g. forest, parks, moorland) may be an important moderator in the relationship between NE and PA (Thompson Coon et al., 2011). Since NE fulfil a wide range of roles (Elliott et al., 2015; Koohsari et al., 2015; Lee et al., 2015), i.e. they provide opportunities for social interactions, relaxation, recreation, cultural activities and they facilitate PA behaviors such as walking, cycling, running, and sports (e.g. soccer)Lee et al., 2015) , it is likely that different types of NE are used for different types and intensities of PA. To assess these hypotheses, a detailed examination of specific PA behaviors across various types of NE is necessary. However, the majority of previous studies has focused on green spaces in general, or isolated only one type of NE: mostly parks, or less frequently, coastal areas (e.g. Bancroft et al., 2015; Cohen et al., 2007; Evenson et al. 2013; Han et al., 2013; McCormack et al., 2010; Schipperijn et al., 2013; Shores and West, 2010; Stewart et al., 2016; Veitch et al., 2013; White et al., 2014).

Besides typology, it is assumed that the size of NE may also be related to how these environments are used for PA (Lee et al., 2015; Peschardt, Schipperijn en Stigsdotter 2012). For example, small inner-

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city public green spaces seem to be used for social activities and relaxation more often than for PA (Peschardt et al., 2012), whereas larger NE may be settings in which people engage in PA more often. However, evidence is largely missing and it is a first step is to describe how NE of various sizes are used for different PA behaviors. Insight in this is necessary to allow urban planners to make informed decisions about the PA behavior they wish to facilitate when designing the environment (Elliott et al., 2015).

A methodological limitation of previous studies on PA and NE, is the use of self-report measures to determine levels of PA and concurrent locations. The availability of newer technologies and measurement methods (i.e. accelerometer and GPS) provides more options to accurately assess context specific PA behavior (Bancroft et al., 2015; Koohsari et al. 2015) and improves the quality of such studies (Bancroft et al. 2015; Schipperijn et al., 2013). Some studies that used accelerometers and GPS-devices compared PA locations and included various types of NE, such as overall green space, parks, green verges, gardens and beaches Coombes et al., 2013; Lachowycz et al., 2012). These studies were however conducted among children, whereas there is a lack of evidence for adults (Stewart et al., 2016).

This study adds to current literature by using accelerometers and GPS-devices to investigate different PA intensities and modalities in various NE with different sizes, among an adult population (45–65 years). This study aims to provide insight in the different PA behaviors according to modality (i.e. spatially concentrated PA, walking & jogging, and cycling) and intensity (i.e. sedentary behavior, light PA and moderate-to-vigorous PA) that occur in different NE (i.e. according to typology and size), and to examine the associations of size and type of NE, with PA intensity and PA modality.

## 2. Methods

### 2.1. Study design, setting, participants

This cross-sectional study was part of the PHASE (Physical Activity in public Space Environments) project (Jansen et al., 2016). Adults aged 45–65 years were recruited from four neighborhoods in Rotterdam (623 652 inhabitants) and Maastricht (122 397 inhabitants), the Netherlands. These four neighborhoods, two in Rotterdam (Oude Noorden and Kralingen-West) and two in Maastricht (West and Zuid-Oost), differed in presence of green space, distance to the city center, and population density, to increase variations in exposure to (natural) environments. Adults' home addresses (N =14889) were randomly selected from the municipal population registers of Rotterdam and Maastricht. An information letter, in which one was asked to participate in the study, was sent to each adult of the selected sample. Those who were willing to participate could register through a website or by telephone (N =516 adults registered). After registration, researchers contacted the participants by phone or e-mail to plan the accelerometer and GPS-logger distribution. Trained staff members distributed the devices and explained monitor wear to participants (N =406) in community centers on weekday evenings. One community center per neighborhood was selected, to ensure short travel distances for participants. Sheets with a summary of monitor wear instructions were provided. Data collection occurred from April 2014 to December 2014. Participants signed informed consent. Analyses included data of 279 participants (175 Maastricht, 104 Rotterdam) after applying criteria for valid data (see below). The study was conducted with approval of the institutional review board of the faculty of Social and Behavioural Sciences of the Utrecht University.

### 2.2. Measures

The outcome measure was 'PA behavior during NE visits'. To measure PA behavior as well as the locations in which the behaviors occurred, participants were asked to wear an Actigraph GT3X+ accelerometer (Actigraph, Pensacola, Florida) and a BT-Q1000XT GPS-device (QStarz International Co) for seven consecutive days during waking hours. Both devices were attached to an elastic, adjustable belt which participants were asked to wear on the right hip. GPS-devices and accelerometers provided data for every 5 s.

#### 2.2.1. Accelerometer data

Accelerometer data were downloaded using Actilife v6.11.2 (Firmware 2.2.1, Actigraph), and triaxial counts were summed as counts per minute (cpm). Consecutive zero strings of ≥90 min were defined as non-wear episodes, which is similar to other Actigraph accelerometer studies with samples of approximately similar age range (e.g. Berkemeyer et al., 2016; Jefferis et al., 2014). Short interruptions of up to 2 consecutive minutes of 1–100 counts per minute (cpm) were allowed as non-wear time to account for the possibility of accidental monitor movements (e.g. a monitor being disturbed while left on a table) (Jefferis et al., 2014). Vector magnitude cut-points, that were developed for similar age groups, were used to define 4 intensities of PA: sedentary behavior ( < 150 cpm), light PA (150–3208 cpm), moderate PA (3208–8564 cpm) and vigorous PA (≥8565 cpm) (Carr and Mahar, 2012; Santos-Lozano et al., 2013). Moderate PA and vigorous PA were summed to moderate-vigorous PA (MVPA). We used the 70/80 rule to define a valid day (Catellier et al., 2005). Therefore, we calculated the time during which ≥70% of participants wore the accelerometer device: 611 min in this study. A day was considered valid if ≥80% of this episode had non-missing counts (488.8 min). If participants had ≥4 of such valid days, their data were included in analyses (Bento et al., 2012).

#### 2.2.2. GPS data

GPS data were downloaded using QStarz QTravel software (v1.45, QStarz International Co). All GPS data-points that were measured on valid days were uploaded in ArcMap 10.2.2 (Esri, Redlands, California). Since only data on land use of the Netherlands was available (available from Dutch Statistics, 2012), data-points lying in other countries were excluded (about 4% of the data). For each data-point it was determined in which type of land use it was located. Only data-points that lay in NE were selected for this study. Based on the land use data we labelled each data-point with the NE type and NE size in which it occurred. Five different types of NE were distinguished: 'parks' (e.g. city parks, children's farm), 'recreational area' (e.g. zoo, playground, picnic places), 'agricultural green' (e.g. grassland, orchard), 'forest & moorland' (e.g. forest, moorland, dunes), and 'blue space' (e.g. lakes, rivers, water in parks, seas). ArcMap was used to calculate the size (i.e. surface) of each NE. SPSS 23.0 was used to calculate quartiles of NE size (i.e. so that each size category had an approximately equal number of visits). The cut points were rounded to: 3 ha, 7 ha, and 27 ha.

Besides, GPS-data were also used to classify PA behavior during NE visits into three categories of modality: 'spatially concentrated PA' (i.e. PA in one place, e.g. gardening), 'walking & jogging', and 'cycling'. A spatially concentrated activity was defined as a cluster of successive data-points that occurred within a range of 150 m or less, a maximum speed of 3 km/h, and a duration of ≥2 min. Spatially concentrated activities may thus include sedentary behavior (e.g. sitting on a bench in a park), but also include (sporting) activities (e.g. volleyball, soccer). Non-spatially concentrated activities were defined as clusters of successive data-points with a minimum length of 100 m, an average speed of ≥3 km/h, and a duration of ≥1 min. If the speed of GPS data-points was < 12 km/h, modality was set to 'walking & jogging', and if the speed of the GPS data-points was ≥12 and < 25 km/h, modality was set to 'cycling'. For each day of each participant, consecutive GPS data-points linked to a NE area of similar size and type were clustered and considered as one NE visit. However, if the time difference between GPS data-points of similar size and type of NE was 5 min or more, these data-points were assigned to separate visits. Then, the duration of visits was calculated. Visits in NE of less than 5 min were considered too short to have meaningful relations with PA (e.g. cycling through a small inner-city park for 30 s), and were therefore excluded from the analyses.

#### 2.2.3. Linking GPS and accelerometer data

To link GPS-data with accelerometer data, a procedure was written in Python 2.7.2. Based on the time stamps of both types of data, this procedure added the accelerometer counts in each direction (x-, y-, z-axis) to the GPS-data point that was closest in time, where the GPS-data point could be timed before or after the accelerometer data point. A maximum time difference of 10 s was allowed to link GPS- to accelerometer data.

#### 2.2.4. Questionnaire data

Participants received a questionnaire that queried gender, age, ethnicity, highest level of education, employment, health status, height and weight (to calculate body mass index), household structure (i.e. having children, a partner), car ownership, and having a garden. Participants were asked to fill out their highest level of completed education, and three levels of education were distinguished: 1) no education, primary education, lower professional or intermediate general education (i.e. lower education); 2) intermediate and higher general education (i.e. middle education); and 3) higher professional education and university (i.e. higher education). Employment was dichotomized into yes and no, where 'yes' applied to adults with a job and entrepreneurs, and 'no' applied to retired adults, adults with social security payments, adults who were unable to work, job-seekers, and housewife/houseman. Health status was measured using the question 'In general, would you say your health is', with excellent, very good, good, fair, and poor as the response categories.

### 2.3. Statistical analyses

Descriptive statistics were used to describe the study population and the levels of PA intensity and modality during NE visits according to type and size of NE. Multiple regression analyses were performed to assess the association between size and type of NE (independent variables), and PA behavior during NE visits (dependent variable). Outcome variables were not normally distributed and neither log-transformations nor taking the square root led to normal distributions. Due to this non-normality of outcome variables, regression analyses were bootstrapped with the sample size set to 5000. Multilevel analyses (linear mixed models) were used to correct for clustering of visits to NE within respondents, as visits within respondents are likely more similar to each other than to visits of other respondents. Herewith, we systematically addressed within and between person variations. Parks were selected as the reference category in analyses as this type of NE has been studied most in literature and comparisons of other types of NE with parks would be of great interest. The regression analyses were controlled for the following confounders: gender, age, health status, BMI, education, employment, ethnicity, car ownership, having children, having a dog, having a garden, and city (Rotterdam vs. Maastricht). Garden was controlled for as it is plausible to assume that adults who have a garden may have different PA behavior than adults who live in a flat without a garden. For example: adults who have a garden are able to have diner or lunch within their garden and may therefore use parks or other NE more for LPA and MVPA activities, whereas adults living in a flat may be more likely to go to parks for a picnic (e.g. with friends) – which is sedentary behavior. This theory is based on findings of a previous study which showed that adults who have a garden had higher levels of MVPA in green spaces such as city parks, than adults without a garden (Jansen et al., 2016). SPSS 23.0 for windows was used to perform all statistical analyses.

## 3. Results

### 3.1. Population characteristics

Participants' mean age was 57.1 years, and a little more than half of the sample was female. Most participants were native Dutch. Almost half of participants were overweight or obese, and most had a middle or higher education. This study sample reflects the national Dutch adult population (45–65 years) as regards gender and BMI, as figures for being female, and being overweight or obese are approximately similar. Western immigrants and non-western immigrants are slightly under-represented in this study sample (i.e. national figures according to Dutch Statistics are 9.5% and 12.3%, respectively) (Dutch Statistics, 2016). Also, adults with a lower education are underrepresented in this study (i.e. according to Dutch Statistics Public Health 1/3 of adults aged 45–65 years has a lower education).

Accelerometers and GPS-devices were on average worn for approximately 14 h per day. Most visits to NE were park visits and many adults visited multiple NE (i.e. the sum of percentages of adults who visited NE types adds up to over 100%).

### 3.2. Visits to NE according to type and size of NE

Of total visits to NE, most were park visits and least were forest & moorland visits (Table 1). Most NE visits occurred in places with a size of 3–7 ha (Table 2). Of the visits to parks, most took place in such

**Table 1**
Sample characteristics.

| | *Total study sample (N=279)* |
|---|---|
| **Age** in years | |
| *Median (IQR)* | 57.1 (10.9) |
| **Female** (%) | 54.1 |
| | |
| **BMI** (%) | |
| Healthy weight *(18.5 < BMI ≤ 25)* | 54.1 |
| Overweight *(25 < BMI ≤ 30)* | 36.6 |
| Obese *(BMI > 30)* | 9.3 |
| | |
| **Ethnicity** (%) | |
| Autochthonous | 85.7 |
| Western immigrants | 5.7 |
| Non-Western immigrants | 7.2 |
| Missing | 1.5 |
| | |
| **Education** (%) | |
| Lower | 4.7 |
| Middle | 52.3 |
| Higher | 41.6 |
| Missing | 1.4 |
| | |
| **Wear time** in minutes per day | |
| *Mean (SD)* | 843.1 (155.4) |
| **Total visits to NE** (N) | 3948 |
| Park (%) | 41.0 |
| Recreational area (%) | 5.6 |
| Agricultural green (%) | 31.9 |
| Forest & moorland (%) | 5.1 |
| Blue space (%) | 16.4 |
| | |
| **Participants who visited NE**[a] | |
| Park (%) | 66.3 |
| Recreational area (%) | 16.1 |
| Agricultural green (%) | 62.0 |
| Forest & moorland (%) | 19.4 |
| Blue space (%) | 44.1 |
| | |
| **Visits per person** | |
| *Median (IQR)* | 9 (16) |

[a] Percentages represent the share of the total study sample that visited the NE at least one time.

**Table 2**
Amount of visits in different types of green.

| | *Total visits* | *Size 0 – 3 ha* | | *Size 3 – 7 ha* | | *Size 7 – 27 ha* | | *Size ≥ 27 ha* | |
|---|---|---|---|---|---|---|---|---|---|
| | N | N | % | N | % | N | % | N | % |
| Parks | 1620 | 479 | 58.0 | 738 | 65.0 | 278 | 27.4 | 125 | 12.8 |
| Recreational areas | 220 | 25 | 3.0 | 13 | 1.1 | 128 | 12.6 | 54 | 5.5 |
| Agricultural green | 1260 | 157 | 19.0 | 219 | 19.3 | 386 | 38.1 | 498 | 51.1 |
| Forest & moorland | 202 | 21 | 2.5 | 36 | 3.2 | 40 | 3.9 | 105 | 10.8 |
| Blue space | 646 | 144 | 17.4 | 129 | 11.4 | 181 | 17.9 | 192 | 19.7 |
| **Total** | **3948** | **826** | **20.9** | **1135** | **28.7** | **1013** | **25.7** | **974** | **24.7** |

Note: Visits had a minimum duration of 5 min. Percentages in columns add up to 100%.

environments with a size of 3–7 ha. Visits to recreational areas occurred mostly in such environments that had a size of 7–27 ha. Of the visits to agricultural green, forest & moorland and blue space, most occurred in such environments with a size of ≥27 ha.

### *3.3. Intensity and modality of PA according to type and size of NE*

An average visit to a NE lasted 12.3 min. Of the visits to the different types of NE, forests & moorland visits had the longest duration (Table 3). As regards the size of NE, visits with the longest duration were observed for 0–3 ha sized NE. Of an average visit, 60.3% was spent sedentary, 24.9% was light PA, and 3.4% was moderate-vigorous PA (Table 3). An average visit consisted mostly of spatially concentrated activities, and partly of walking & jogging, whereas observed cycling levels were very low (Table 4).

Highest percentages of sedentary behavior were observed in blue space. Parks, recreational areas, and agricultural green were found to have the highest (and approximately similar) proportions of time spent in LPA. Highest levels of MVPA were observed in agricultural green. Generally, percentages of sedentary behavior were found to be lowest in NE of the largest size categories, whereas MVPA levels were found to be highest in these largest size categories (this pattern is even more clear when looking at the mean MVPA percentages). An exception was found for forest & moorland, where the percentage of sedentary behavior was lowest for forest & moorland with a size of 0–3 ha (although the percentages in the 7–27 ha and ≥27 ha categories were also lower than in the 3–7 ha category).

In general, spatially concentrated PA levels were high in all NE types, but lowest in forest & moorland. Highest levels of walking were observed in forest & moorland. Cycling levels were low in all NE types. Furthermore, percentages of spatially concentrated PA were generally lowest in the largest size categories of NE. Highest walking levels were observed in the largest size category. Cycling levels were low in all size categories. When looking at mean percentages, higher cycling percentages were observed in the largest size categories.

**Table 3**
PA intensity per visit, according to type and size of NE.

| | **Time** (minutes) | | | | **Sedentary behavior** (%) | | **LPA** (%) | | **MVPA** (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *(SD)* | *Median* | *(IQR)* | *Mean* | *Median* | *Mean* | *Median* | *Mean* | *Median* |
| **Total** | 30.5 | (54.3) | 12.3 | (21.2) | 55.8 | 60.3 | 30.2 | 24.9 | 13.9 | 3.4 |
| *0 – 3 ha* | 39.4 | (15.1) | 64.4 | (35.7) | 62.4 | 67.8 | 30.7 | 26.6 | 7.0 | 3.1 |
| *3 – 7 ha* | 29.6 | (55.5) | 12.0 | (19.0) | 62.6 | 68.8 | 30.3 | 25.0 | 7.1 | 1.8 |
| *7 – 27 ha* | 30.0 | (50.7) | 12.3 | (36.0) | 54.6 | 58.6 | 30.2 | 23.5 | 15.2 | 4.2 |
| *≥ 27 ha* | 24.5 | (45.6) | 11.2 | (14.3) | 43.6 | 41.3 | 29.9 | 24.6 | 26.5 | 5.9 |
| **Parks** | 29.8 | (46.9) | 12.4 | (22.8) | 61.4 | 66.1 | 29.6 | 25.6 | 9.0 | 2.7 |
| *0 – 3 ha* | 40.9 | (60.6) | 16.3 | (43.4) | 62.2 | 66.2 | 31.0 | 27.8 | 6.8 | 3.3 |
| *3 – 7 ha* | 25.8 | (42.5) | 11.0 | (16.2) | 63.7 | 69.2 | 29.4 | 25.0 | 6.9 | 1.8 |
| *7 – 27 ha* | 27.8 | (34.9) | 14.6 | (26.4) | 56.7 | 58.9 | 28.3 | 23.2 | 15.0 | 4.1 |
| *≥ 27 ha* | 15.3 | (17.4) | 8.5 | (8.6) | 55.6 | 60.0 | 28.6 | 25.3 | 15.8 | 3.0 |
| **Recreational areas** | 35.7 | (73.0) | 13.1 | (26.1) | 56.1 | 62.2 | 31.5 | 25.4 | 12.4 | 3.8 |
| *0 – 3 ha* | 45.2 | (37.7) | 41.0 | (67.0) | 72.0 | 71.4 | 22.2 | 24.3 | 5.8 | 4.4 |
| *3 – 7 ha* | 59.1 | (120.1) | 15.7 | (44.0) | 56.7 | 67.3 | 34.0 | 23.3 | 9.3 | 4.6 |
| *7 – 27 ha* | 25.3 | (45.5) | 10.7 | (12.5) | 53.0 | 50.5 | 31.9 | 23.7 | 15.1 | 4.3 |
| *≥ 27 ha* | 50.5 | (111.8) | 15.9 | (30.0) | 56.0 | 62.1 | 34.3 | 26.7 | 9.7 | 2.1 |
| **Agricultural green** | 33.3 | (61.8) | 12.6 | (22.5) | 47.1 | 48.4 | 31.1 | 25.6 | 21.8 | 4.5 |
| *0 – 3 ha* | 58.0 | (96.5) | 18.6 | (46.1) | 59.5 | 62.5 | 33.3 | 29.4 | 7.2 | 2.8 |
| *3 – 7 ha* | 34.1 | (65.5) | 14.1 | (26.7) | 58.3 | 64.2 | 32.9 | 25.8 | 8.8 | 1.6 |
| *7 – 27 ha* | 35.3 | (62.4) | 12.1 | (26.2) | 53.8 | 59.7 | 30.4 | 24.6 | 15.8 | 4.2 |
| *≥ 27 ha* | 23.5 | (39.6) | 11.6 | (13.3) | 33.1 | 23.4 | 30.1 | 23.2 | 36.8 | 14.2 |
| **Forest & Moorland** | 27.6 | (49.6) | 13.3 | (20.3) | 52.9 | 57.7 | 29.4 | 23.7 | 17.7 | 4.0 |
| *0 – 3 ha* | 27.2 | (33.1) | 14.9 | (21.7) | 47.8 | 31.1 | 42.5 | 38.5 | 9.6 | 6.1 |
| *3 – 7 ha* | 52.2 | (102.3) | 17.7 | (50.8) | 61.3 | 61.4 | 32.0 | 33.3 | 6.7 | 2.0 |
| *7 – 27 ha* | 16.1 | (14.3) | 9.8 | (8.9) | 55.5 | 60.8 | 24.2 | 15.2 | 20.3 | 7.2 |
| *≥ 27 ha* | 23.7 | (25.9) | 13.5 | (19.2) | 50.0 | 50.0 | 27.9 | 23.4 | 22.2 | 5.4 |
| **Blue space** | 26.0 | (49.5) | 11.1 | (16.2) | 59.6 | 67.7 | 30.0 | 22.8 | 10.4 | 2.2 |
| *0 – 3 ha* | 15.1 | (11.4) | 10.8 | (13.6) | 66.4 | 75.7 | 26.5 | 20.6 | 7.1 | 1.5 |
| *3 – 7 ha* | 34.7 | (70.8) | 12.8 | (23.0) | 64.7 | 73.0 | 30.3 | 21.9 | 5.0 | 1.8 |
| *7 – 27 ha* | 28.2 | (51.1) | 11.3 | (17.6) | 54.1 | 61.3 | 32.6 | 22.7 | 13.3 | 3.8 |
| *≥ 27 ha* | 26.3 | (47.1) | 10.2 | (13.7) | 56.2 | 63.7 | 30.1 | 24.7 | 13.7 | 2.2 |

Note: LPA= light PA, MVPA= moderate-vigorous PA. SD = standard deviation. IQR= interquartile range.Ha = hectare. Percentages of sedentary behavior, LPA and MVPA do not necessarily add up to 100% because medians are reported.

**Table 4**
PA modality per visit, according to type and size of NE.

| | **Time** (minutes) | | | | **Spatially concentrated PA** (%) | | **Walking & jogging** (%) | | **Cycling** (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *(SD)* | *Median* | *(IQR)* | *Mean* | *Median* | *Mean* | *Median* | *Mean* | *Median* |
| **Total** | 30.5 | 54.3 | 12.3 | 21.2 | 70.3 | 99.1 | 27.1 | 0.5 | 2.6 | 0.0 |
| *0 – 3 ha* | 39.4 | (15.1) | 64.4 | (35.7) | 84.7 | 100.0 | 14.3 | 0.0 | 1.0 | 0.0 |
| *3 – 7 ha* | 29.6 | (55.5) | 12.0 | (19.0) | 81.0 | 100.0 | 17.7 | 0.0 | 1.3 | 0.0 |
| *7 – 27 ha* | 30.0 | (50.7) | 12.3 | (36.0) | 71.8 | 98.9 | 26.0 | 0.2 | 2.2 | 0.0 |
| *≥ 27 ha* | 24.5 | (45.6) | 11.2 | (14.3) | 44.2 | 23.3 | 50.1 | 45.5 | 5.7 | 0.0 |
| **Parks** | 29.8 | (46.9) | 12.4 | (22.8) | 74.3 | 100.0 | 23.7 | 0.0 | 2.0 | 0.0 |
| *0 – 3 ha* | 40.9 | (60.6) | 16.3 | (43.4) | 83.7 | 100.0 | 15.3 | 0.0 | 1.0 | 0.0 |
| *3 – 7 ha* | 25.8 | (42.5) | 11.0 | (16.2) | 79.1 | 100.0 | 19.6 | 0.0 | 1.4 | 0.0 |
| *7 – 27 ha* | 27.8 | (34.9) | 14.6 | (26.4) | 66.6 | 95.8 | 31.2 | 2.8 | 2.2 | 0.0 |
| *≥ 27 ha* | 15.3 | (17.4) | 8.5 | (8.6) | 27.5 | 0.0 | 63.2 | 93.6 | 9.4 | 0.0 |
| **Recreational areas** | 35.7 | (73.0) | 13.1 | (26.1) | 82.3 | 100.0 | 16.9 | 0.0 | 0.7 | 0.0 |
| *0 – 3 ha* | 45.2 | (37.7) | 41.0 | (67.0) | 94.6 | 100.0 | 5.4 | 0.0 | 0.0 | 0.0 |
| *3 – 7 ha* | 59.1 | (120.1) | 15.7 | (44.0) | 84.6 | 95.7 | 14.9 | 4.3 | 0.5 | 0.0 |
| *7 – 27 ha* | 25.3 | (45.5) | 10.7 | (12.5) | 78.0 | 100.0 | 21.0 | 0.0 | 0.9 | 0.0 |
| *≥ 27 ha* | 50.5 | (111.8) | 15.9 | (30.0) | 86.3 | 100.0 | 13.0 | 0.0 | 0.7 | 0.0 |
| **Agricultural terrain** | 33.3 | (61.8) | 12.6 | (22.5) | 65.7 | 95.3 | 31.4 | 3.1 | 2.9 | 0.0 |
| *0 – 3 ha* | 58.0 | (96.5) | 18.6 | (46.1) | 84.5 | 99.0 | 14.1 | 0.6 | 1.4 | 0.0 |
| *3 – 7 ha* | 34.1 | (65.5) | 14.1 | (26.7) | 88.4 | 100.0 | 10.8 | 0.0 | 0.8 | 0.0 |
| *7 – 27 ha* | 35.3 | (62.4) | 12.1 | (26.2) | 75.8 | 99.3 | 22.9 | 0.3 | 1.3 | 0.0 |
| *≥ 27 ha* | 23.5 | (39.6) | 11.6 | (13.3) | 41.9 | 11.5 | 52.6 | 57.9 | 5.5 | 0.0 |
| **Forest & Moorland** | 27.6 | (49.6) | 13.3 | (20.3) | 55.8 | 75.4 | 42.8 | 23.6 | 1.4 | 0.0 |
| *0 – 3 ha* | 27.2 | (33.1) | 14.9 | (21.7) | 86.2 | 100.0 | 13.7 | 0.0 | 0.2 | 0.0 |
| *3 – 7 ha* | 52.2 | (102.3) | 17.7 | (50.8) | 74.6 | 100.0 | 24.8 | 0.0 | 0.6 | 0.0 |
| *7 – 27 ha* | 16.1 | (14.3) | 9.8 | (8.9) | 47.4 | 52.2 | 51.1 | 47.0 | 1.5 | 0.0 |
| *≥ 27 ha* | 23.7 | (25.9) | 13.5 | (19.2) | 46.4 | 42.6 | 51.6 | 52.9 | 2.0 | 0.0 |
| **Blue space** | 26.0 | (49.5) | 11.1 | (16.2) | 69.9 | 100.0 | 25.8 | 0.0 | 4.3 | 0.0 |
| *0 – 3 ha* | 15.1 | (11.4) | 10.8 | (13.6) | 86.6 | 100.0 | 12.8 | 0.0 | 0.6 | 0.0 |
| *3 – 7 ha* | 34.7 | (70.8) | 12.8 | (23.0) | 80.9 | 100.0 | 16.7 | 0.0 | 2.4 | 0.0 |
| *7 – 27 ha* | 28.2 | (51.1) | 11.3 | (17.6) | 72.2 | 100.0 | 22.6 | 0.0 | 5.2 | 0.0 |
| *≥ 27 ha* | 26.3 | (47.1) | 10.2 | (13.7) | 47.9 | 38.8 | 44.7 | 28.2 | 7.4 | 0.0 |

Note: SD = standard deviation. IQR= interquartile range. Ha = hectare. Percentages of spatially concentrated PA, walking & jogging, and cycling do not necessarily add up to 100% because medians are reported.

### 3.4. The association of typology and size of NE with PA behavior

Table 5 shows the raw and adjusted associations of typology and size of NE with PA modality and intensity during NE visits. Adjusted analyses showed the following significant results.

Significant differences between types of NE were found for all intensities and modalities of PA, except for MVPA. Recreational areas and agricultural green were associated with significantly less sedentary behavior than parks, whereas LPA levels were observed to be higher in these types of environments. Recreational areas and agricultural green were furthermore associated with significantly more spatially concentrated activities than parks, but walking & jogging levels were significantly lower. For recreational green, cycling levels were also found to be significantly lower than cycling levels in parks. Forest & moorland was associated with higher LPA levels and lower cycling levels. Blue space was associated with higher LPA levels and higher cycling levels.

The largest NE size category (≥27 ha) was associated with significantly less sedentary behavior than the smallest size category ( < 3 ha, reference category). Larger sized NE (≥7 ha) were also associated with significantly lower LPA levels. MVPA levels in the two largest size categories were significantly higher than in the smallest size category. Furthermore, larger sized NE (≥7 ha) were associated with less spatially concentrated activities, but more walking & jogging, and more cycling.

## 4. Discussion

### 4.1. Main findings

In contrast to previous studies, which often investigated only one type of NE, this study examined adults' PA behavior (modality and intensity) in different types and sizes of NE. Results showed that walking & jogging, cycling, and especially LPA and MVPA were not typically observed in one type of NE, but across various types of NE. Nevertheless, significant differences in PA behaviors were found between different types of NE. Besides, the study showed higher levels of MVPA, walking & jogging and cycling in larger sized NE (≥7 ha). These new insights provide answers to questions raised in the literature (Elliott et al., 2015; Lee et al. 2015; Schipperijn et al., 2013) and inform public health policymakers who are interested in environmental supports for PA, on the types and sizes of NE that facilitate certain PA behaviors [Elliott et al., 2015].

### 4.2. Interpretation

This study emphasizes that PA behavior was distributed across a variety of places, which is illustrated by the percentages in Table 1. These percentages, representing the amount of adults who visited the different types of NE, add up to over 100%. Hence, it is clear that there is an overlap: many adults do not just visit one, but multiple types of NE. The findings of the current study are consistent with previous findings of our study on MVPA behavior (Jansen et al., 2016). The results of that study showed that MVPA was not observed in one particular place such as sports locations, as one may expect, but in various places. Based on those findings and on findings of the current study, it thus seems that PA is not bounded to one specific type of environment, but that people tend to use various environments for PA.

The significant differences in PA modality and intensity between various types of NE, indicate that NE typology may indeed be important to consider in research on the relationship between the environment and PA. However, as our results cannot be used to predict behavior change, it remains unclear whether the presence of all these different NE types is necessary to maintain PA levels. More evidence is

**Table 5**
Bootstrapped multilevel regression results on the relationship between size and type of NE and PA.

| | Model 1 – raw analyses | | | Model 2 – adjusted analyses[a] | | |
|---|---|---|---|---|---|---|
| **Sedentary behavior (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | −4.62 | (−10.65; 1.04) | 0.112 | **−6.67** | **(−13.11; −1.05)** | **0.027** |
| Agricultural green | **−7.98** | **(−11.21; −4.23)** | **0.000** | **−6.76** | **(−10.19; −2.84)** | **0.000** |
| Forest & moorland | −2.10 | (−7.70; 3.76) | 0.451 | −2.63 | (−8.07; 3.22) | 0.359 |
| Blue space | −1.34 | (−5.39; 2.09) | 0.488 | −2.69 | (−6.65; 1.18) | 0.178 |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | −0.48 | (−4.57; 3.12) | 0.808 | 0.87 | (−3.07; 4.66) | 0.655 |
| 7 – 27 ha | −2.04 | (−5.92; 1.70) | 0.284 | −1.33 | (−5.04; 2.70) | 0.483 |
| ≥ 27 ha | **−9.89** | **(−13.65; −6.00)** | **0.000** | **−10.73** | **(−14.32; −6.28)** | **0.000** |
| **LPA (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | 3.15 | (−1.03; 7.34) | 0.139 | **5.32** | **(0.53; 9.86)** | **0.023** |
| Agricultural green | **3.87** | **(1.32; 6.36)** | **0.002** | **3.98** | **(1.25; 6.62)** | **0.004** |
| Forest & moorland | **4.34** | **(0.59; 8.42)** | **0.028** | **4.99** | **(1.11; 8.99)** | **0.013** |
| Blue space | **3.30** | **(0.59; 6.29)** | **0.021** | **3.51** | **(0.59; 6.59)** | **0.020** |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | −0.31 | (−3.22; 2.84) | 0.841 | −1.22 | (−4.38; 1.82) | 0.433 |
| 7 – 27 ha | **−4.53** | **(−7.19; −1.65)** | **0.001** | **−5.09** | **(−8.17; −2.19)** | **0.001** |
| ≥ 27 ha | **−3.92** | **(−6.73; −0.68)** | **0.009** | **−3.90** | **(−7.06; −0.82)** | **0.014** |
| **MVPA (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | 1.88 | (−2.14; 6.25) | 0.359 | 1.99 | (−2.23; 6.57) | 0.381 |
| Agricultural green | **3.25** | **(0.24; 5.88)** | **0.024** | 2.43 | (−0.68; 5.18) | 0.105 |
| Forest & moorland | −2.92 | (−7.37; 1.53) | 0.213 | −3.10 | (−7.55; 1.35) | 0.178 |
| Blue space | −1.69 | (−4.24; 0.97) | 0.201 | −0.87 | (−3.53; 1.74) | 0.525 |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | 1.05 | (−1.62; 3.82) | 0.447 | 0.39 | (−2.25; 3.15) | 0.792 |
| 7 – 27 ha | **6.53** | **(3.80; 9.40)** | **0.000** | **6.11** | **(3.35; 8.91)** | **0.000** |
| ≥ 27 ha | **13.34** | **(10.33; 16.35)** | **0.000** | **13.72** | **(10.37; 16.72)** | **0.000** |
| **Spatially concentrated PA (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | **13.10** | **(5.54; 20.07)** | **0.001** | **11.78** | **(3.42; 18.99)** | **0.003** |
| Agricultural green | **7.91** | **(3.01; 12.44)** | **0.001** | **7.86** | **(2.45; 12.24)** | **0.002** |
| Forest & moorland | 3.91 | (−3.66; 10.90) | 0.293 | 2.46 | (−5.05; 9.66) | 0.504 |
| Blue space | 2.59 | (−2.76; 7.46) | 0.321 | 1.44 | (−4.08; 6.56) | 0.589 |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | −1.03 | (−5.86; 4.18) | 0.692 | 0.19 | (−4.81; 5.46) | 0.948 |
| 7 – 27 ha | **−11.19** | **(−15.74; −6.41)** | **0.000** | **−9.14** | **(−13.51; −4.02)** | **0.000** |
| ≥ 27 ha | **−31.81** | **(−36.39; −26.22)** | **0.000** | **−30.60** | **(−35.36; −24.74)** | **0.000** |
| **Walking & jogging (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | **−11.45** | **(−18.12; −4.19)** | **0.001** | **−9.62** | **(−16.40; −1.80)** | **0.011** |
| Agricultural green | **−7.68** | **(−12.13; −2.96)** | **0.001** | **−7.42** | **(−11.92; −2.44)** | **0.003** |
| Forest & moorland | −2.02 | (−8.93; 5.16) | 0.569 | −0.34 | (−7.34; 6.89) | 0.924 |
| Blue space | **−5.19** | **(−9.77; −0.48)** | **0.029** | −3.99 | (−8.95; 1.04) | 0.113 |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | −0.06 | (−4.97; 4.79) | 0.982 | −1.04 | (−6.12; 3.81) | 0.697 |
| 7 – 27 ha | **8.63** | **(3.98; 12.94)** | **0.000** | **6.77** | **(1.88; 11.00)** | **0.004** |
| ≥ 27 ha | **25.29** | **(19.87; 29.67)** | **0.000** | **24.33** | **(18.81; 28.71)** | **0.000** |
| **Cycling (%)** | *B₁* | *CI* | *P-value* | *B₁* | *CI* | *P-value* |
| *(Ref: Park)* | | | | | | |
| Recreational areas | −1.67 | (−3.04; 0.19) | 0.052 | **−2.05** | **(−3.67; −0.09)** | **0.028** |
| Agricultural green | −0.33 | (−1.53; 1.27) | 0.642 | −0.46 | (−1.72; 1.14) | 0.541 |
| Forest & moorland | **−2.03** | **(−3.85; 0.02)** | **0.043** | **−2.27** | **(−4.11; −0.06)** | **0.030** |
| Blue space | **2.48** | **(0.89; 4.75)** | **0.014** | **2.42** | **(0.73; 4.85)** | **0.025** |
| *(Ref: < 3 ha)* | | | | | | |
| 3 – 7 ha | 0.96 | (−0.09; 2.21) | 0.098 | 0.74 | (−0.38; 1.89) | 0.205 |
| 7 – 27 ha | **2.34** | **(1.23; 3.73)** | **0.001** | **2.13** | **(0.93; 3.51)** | **0.002** |
| ≥ 27 ha | **6.15** | **(4.71; 7.79)** | **0.000** | **5.83** | **(4.27; 7.57)** | **0.000** |

$B_1$ = regression coefficient. CI = confidence interval (lower; upper). LPA = light PA. MVPA = moderate – vigorous PA. Bold text indicates statistical significance (P-value < 0.05).
[a]Adjusted for the following confounders: gender, age, health status, BMI, education, employment, ethnicity, car ownership, having a garden (at home), having children, having a dog, and city (Rotterdam vs. Maastricht).

needed to understand whether PA levels would decrease when less different types of NE would be available, or whether this would lead to less variation in PA. For example, if agricultural green would no longer be available, it is unclear if PA levels would decrease because adults would be unable to be active in or near agricultural green, or if adults would compensate those activities by using other types of NE for their PA.

Parks were the most frequently visited type of NE compared to other NE. This may indicate that parks are important places for urban residents, but it is also likely that park density is higher than the density of other NE. In both ways, the high amount of visits to parks confirm that research into the association between parks (and their characteristics) and PA (Kaczynski and Henderson, 2008; Kaczynski et al., 2014; Lackey and Kaczynski, 2009; Veitch et al., 2013; Veitch et al., 2012; Van Cauwenberg, et al. 2015) is indeed relevant. There is however still much insight to be gained regarding the association between parks and PA (levels). For example, the role of the quality of parks, but also of other NE types (e.g. maintenance, aesthetics, and facilities) in PA behavior is still relatively unknown.

Results showed that agricultural green and recreational areas were associated with significantly lower sedentary behaviors, and significantly higher spatially concentrated PA. Besides, in these types of NE, LPA levels were higher where walking levels (and for recreational areas also cycling levels) were lower. In other words, agricultural green and recreational areas appear to be well suited for light activities, with such activities being spatially concentrated PA (i.e. within a certain distance range) rather than walking and cycling. More in depth research (e.g. using PA diaries or interviews) on PA behaviors in and around agricultural green is needed to better understand these findings. Recreational areas such as picnic places may indeed offer more facilities for light PA behaviors (e.g. playing Frisbee) than for walking or cycling. On the contrary, blue spaces are NE types that were associated with significantly higher cycling levels. In the Netherlands there are many cycling lanes alongside rivers, canals, and lakes, and it is likely that adults often use (parts of) such cycling lanes when cycling.

Our findings on differences in PA intensities (i.e. sedentary behavior, LPA, MVPA) between different types of NE and parks, are in line with previous findings of Elliot et al. (2015). They showed that different types of NE support different PA intensities and (thus) different energy expenditures [Elliott et al., 2015]. The authors link differences in type of NE to differences in size of NE as they argue that more expansive types of NE (e.g. coasts) contribute to higher energy expenditure. Although this is a plausible assumption, evidence was lacking. Our study provides evidence on this matter and emphasizes the role that size of NE has in PA behavior. With increasing size, lower levels of sedentary behavior and higher levels of MVPA were observed. Also, in larger sized NE (≥7 ha), walking, jogging, and cycling levels were higher.

Findings that higher walking levels were observed in larger sized NE are in congruence with findings by Giles-Corti et al. (2005), who found that good access to large public open spaces was associated with higher levels of walking. This may be because larger sized NE have more facilities such as walking trails, which contribute to an increase in PA levels (Giles-Corti et al., 2005). It may further be that smaller sized NE are mostly used for social and relaxation activities (mostly sedentary behaviors) (Peschardt et al., 2012). However, most of the NE types may facilitate social activities and it is not unlikely that the relatively high percentages of sedentary behavior in each type of NE are an indication of such social activities (e.g. picnics).

As we found both higher levels of MVPA and higher levels of walking, jogging and cycling in larger NE, one might argue that this is because more walking, jogging and cycling induces more MVPA. Although this seems plausible, additional correlation analyses showed only small or medium correlations (as the highest Pearson's correlation - found for the correlation between percentage of walking & jogging and the percentage of MVPA - was only 0.462). It would be of great interest to further investigate what types of PA contribute to these higher intensity levels in larger sized NE.

The finding that LPA levels were significantly lower in larger sized NE than in smaller sized NE may seem somewhat contradictive to the findings that levels of MVPA, walking & jogging, and cycling were significantly higher in larger sized NE. However, an explanation for this may be that light physical activities may occur as spatially concentrated activities – of which significantly lower levels were found in larger sized NE. Such spatially concentrated activities require less space, but can still be of light intensity (e.g. playing Frisbee, or toss a ball around).

As explained by Chaix et al. (2013), cross-sectional studies with a so called contemporaneous momentary design (i.e. data on the location, the related context and the outcome (PA) were measured at the same moment (Chaix et al., 2013), such as the current study, are unable to assess the causal effects of the environment on PA behaviors. From the results of this cross-sectional study, it remains unclear whether adults who want to be physically active anyway, simply select certain types and sizes of NE that fit with their choice for a specific modality or intensity of PA, or that certain types and sizes of NE stimulate specific types and intensities of PA. In other words: it may be that adults who are highly motived to walk, will seek for a large-sized green area with good walking trails. However, studies have shown that the presence of a PA facilitating environment may be especially important to increase PA levels among those who are not highly motivated (e.g. those with a negative attitude towards PA) (Beenackers et al. 2014).

### 4.3. *Policy implications*

This study showed that adults walk, jog and cycle in a variety of NE types. Such a variety in environments allows people to visit types of environments that are highly conducive for walking, as well as other environments that are ideally suited for cycling. Moreover, this study emphasizes the importance of large sized NE (especially ≥7 ha), since these places were associated with higher levels of MVPA, walking, jogging, and cycling. Note that the presence of various types and large-sized NE not only positively affects health via PA behavior, but also via stress reduction, increased social interaction, noise mitigation, heat and humidity regulation and air pollution filtration (James et al., 2015). The finding that PA occurs to the same extent but in different forms in different types of NE, suggests that it is beneficial to provide different types of NE in urban regions, to accommodate taste differences with respect to using green facilities.

### 4.4. *Strengths and limitations*

The use of objective methods (i.e. accelerometers and GPS-devices) improves accuracy and comprehensiveness of research on time spent in various PA modalities and intensities in NE, compared to the common used questionnaires and diaries. Adults are likely to forget the exact duration of activities or they forget to report certain activities (e.g. the walk to the bus stop) in questionnaires and diaries; information that is registered into detail by the accelerometers and GPS-devices. Moreover, GPS-data provides the opportunity to match PA behavior to objective data on typology and size of NE. However, data loss due to e.g. insufficient wear time, or canyoning could not be avoided. Furthermore, misclassification of intensities, walking, jogging, and cycling may have occurred since cut-off values may not be applicable to each participant (e.g. due to age, health status). Diaries with additional information on activities in NE may reduce misclassification.

Cut-off values for the different size categories were based on the calculation of quartiles. Sensitivity analyses showed that the use of different cut-off values yielded similar results with regard to effect sizes, direction of the effect, and significant associations. Sensitivity analyses were also run regarding the cut-off value (i.e. 12 km/h) for walking/jogging and different cut-off values yielded similar results.

Inherent to the methodology (i.e. use of accelerometer and GPS can be more burdensome to participants than the use of questionnaires), study samples are often smaller than samples of studies using questionnaires. Of 14889 adults who received an invitation letter, only 516 registered to participate in this study. Although this is a low response rate ( ± 3.5% agreed to participate), the final sample size is comparable to other studies (Bento et al., 2012). It is however likely that adults who registered to participate have an interest in PA and/or healthy living, and it may thus be that adults in this study sample are more active than the average Dutch adult population aged 45–65 years. This may have led to an overestimation of PA.

Although the current study did not assess week- and weekend day differences, it is important to be able to include both sufficient weekdays and weekend days in analyses. For example, it may be that specific types of NE are more often visited on weekend days than on week days. An overrepresentation of weekend days may then lead to an overrepresentation of visits to these specific types of NE. Therefore, additional analyses were performed to assess the ratio of week- and weekend days that were included in the current study. These analyses showed that 65.5% of the days on which NE visits took place were weekdays, and 34.5% were weekend days. It is therefore unlikely that visits to specific NE were over- or underrepresented in this study.

### *4.5. Future research*

For this study, four categories of NE size were distinguished. It may however be necessary for some NE types to further distinct the size categories. This may particularly apply to parks, since the sizes of this type of NE vary widely within and between cities. Future studies may therefore aim to make a further distinction in size to gain more thorough insight in the importance of size for PA behavior in (urban) green and blue spaces.

Moreover, to improve our understanding of the relationship between typology and size of NE and PA, future (longitudinal) research is needed to investigate what specific characteristics and facilities of these environments explain the effects found in the current study. Other research methods, such as observations of NE and (walk along) interviews could be used to provide additional information that, together with accelerometer- and GPS-data, provides a more comprehensive insight in the effect of specific features of NE (e.g. quality aspects) on PA behavior of adults. It would for example be of great interest to compare similar types of NE (e.g. parks) that have different facilities (e.g. sports facilities).

Furthermore, it is known that distance to green spaces may be related to PA behavior in those spaces (Toftager et al., 2011). It would be of great interest to investigate what distances adults are willing to travel to be physically active in NE, depending on type and size of the NE and the type of PA that adults engage in. For policy makers and urban planners to make well-informed environmental changes, insights in the role of distance to specific types and sizes of NE is necessary. Also, it is plausible to assume that PA which takes place on the journey to NE may be related to availability of and distance to NE. As the purpose of this study was not to assess whether, but how NE are used for PA (i.e. when people are actually within the NE and not on their way to the NE), active travel towards NE was not included in analyses. Future research may focus on active travel to NE, to further expand the knowledge on PA behavior and NE.

As non-native adults and adults with a lower education were underrepresented in this study, findings on PA may be biased due to preferences or motivations for certain PA behaviors or specific NE that may differ between subpopulations. We did not find existing research that provides a basis for speculating about the direction of such bias. For instance, although various studies found lower PA levels for lower educated groups, this gives no indication for the intensity of PA once being in a NE. The current study provided a first step in investigating the role of type and size of NE in objectively measured PA behaviors and future research may expand the field by examining how the role of type and size of NE differ between various subpopulations (e.g. based on education or ethnicity).

The current study did not assess week- and weekend day differences, whereas it may be that PA behavior during weekday visits to NE differ from PA behavior during NE visits on weekend days. For example, on weekend days adults may have more time to make long walking or cycling trips within NE than on weekdays. Future research may therefore aim to assess week- and weekend day differences, taking size and typology of NE into account.

## 5. Conclusion

This study showed a new use of GPS- and accelerometer data to provide insight in how NE of different types and sizes are used for PA behavior. Walking & jogging, cycling, LPA and MVPA were not typically observed in one type of NE, but across various types of NE. Larger sized NE were associated with less sedentary behavior and higher levels of MVPA, walking, jogging and cycling. Insight in which environments afford health-enhancing PA, contributes to the development of tailored PA promoting activities with ensuing implications for public health. Future research is needed to gain more insight in the relationship between more specific characteristics (e.g. benches, lightning, or aesthetics) of NE and PA to provide policy makers and urban planners with more specific knowledge on the design of NE.

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## References

Bancroft, C., Joshi, S., Rundle, A., Hutson, M., Chong, C., Weiss, C.C., Lovasi, G., 2015. Association of proximity and density of parks and objectively measured physical activity in the United States: a systematic review. Social. Sci. Med. 8, 22–30. http://dx.doi.org/10.1016/j.socscimed.2015.05.034.

Beenackers, M.A., Kamphuis, C.B.M., Prins, R.G., Mackenbach, J.P., Burdorf, A., Van Lenthe, F.J., 2014. Urban form and psychosocial factors: do they interact for leisure-time walking? Med. Sci. Sports Exerc. 46, 293–301. http://dx.doi.org/10.1249/MSS.0000000000000017.

Bento, T., Cortinhas, A., Leitao, J.C., Mota, M.P., 2012. Use of accelerometry to measure physical activity in adults and the elderly. Rev. Saude Publica 46, 561–570. http://dx.doi.org/10.1590/S0034-89102012005000022.

Berkemeyer, K., Wijndaele, K., White, T., Cooper, A.J.M., Luben, R., Brage, S., 2016. The descriptive epidemiology of accelerometer-measured physical activity in older adults. Int. J. Behav. Nutr. Phys. Act., 13. http://dx.doi.org/10.1186/s12966-015-0316-z.

Carr, L.J., Mahar, M.T., 2012. Accuracy of intensity and inclinometer output of three activity monitors for identification of sedentary behavior and light-intensity activity. J. Obes., 2012. http://dx.doi.org/10.1155/2012/460271.

Catellier, D.J., Hannan, P.J., Murray, D.M., Addy, C.L., Conway, T.L., Yang, S., Rice, J.C., 2005. Imputation of missing data when measuring physical activity by accelerometry. Med. Sci. Sports Exerc. 37, s555–s562. http://dx.doi.org/10.1249/01.mss.0000185651.59486.4e.

Chaix, B., Méline, J., Duncan, S., Merrien, C., Karusisi, N., Kestens, Y., 2013. GPS tracking in neighborhood and health studies: a step forward for environmental exposure assessment, a step backward for causal inference? Health Place 21, 46–51. http://dx.doi.org/10.1016/j.healthplace.2013.01.003.

Cohen, D.A., McKenzie, T.L., Sehgal, A., Williamson, S., Golinelli, D., Lurie, N., 2007. Contribution of public parks to physical activity. Am. J. Public Health 97, 509–514. http://dx.doi.org/10.2105/AJPH.2005.072447.

Coombes, E., Van Sluijs, E., Jones, A. 2013. Is environmental setting associated with the intensity and duration of children's physical activity? Findings from the SPEEDY GPS study. Health and Place 20, 62-65. http://dx.doi.org/10.1016/j.healthplace.2012.11.008.

Elliot, L.R., White, M.P., Taylor, A.H., Herbert, S., 2015. Energy expenditure on recreational visits to different natural environments. Social. Sci. Med. 139, 53–60. http://dx.doi.org/10.1016/j.socscimed.2015.06.038.

Evenson, K.R., Wen, F., Hillier, A., Cohen, D.A., 2013. Assessing the contribution of parks to physical activity using global positioning system and accelerometry. Med. Sci. Sports Exerc. 45, 1981–1987. http://dx.doi.org/10.1249/MSS.0b013e318293330e.

Giles-Corti, B., Broomhall, M.H., Knuiman, M., Collins, C., Douglas, K., Ng, K., Donovan, R.J., 2005. Increasing walking: how important is distance to, attractiveness, and size of public open space? Am. J. Prev. Med. 28, 169–176. http://dx.doi.org/10.1016/j.amepre.2004.10.018.

Han, B., Cohen, D., McKenzie, T.L., 2013. Quantifying the contribution of neighborhood parks to physical activity. Prev. Med. 57, 483–487. http://dx.doi.org/10.1016/j.ypmed.2013.06.021.

James, P., Banay, R.F., Hart, J.E., Laden, F., 2015. A review of the health benefits of greenness. Curr. Epidemiol. Rep. 2, 131–142. http://dx.doi.org/10.1007/s40471-015-0043-7.

Jansen, F.M., Ettema, D.F., Pierik, F.H., Dijst, M.J., 2016. Sports facilities, shopping centers or homes: what locations are important for adults' physical activity? A cross-sectional study. Int. J. Environ. Res. Public Health 13 (3), 287.

Jefferis, B.J., Sartini, C., Lee, I., Choi, M., Amuzu, A., Gutierrez, C., Whincup, P.H., 2014. Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. BMC Public Health, 14. http://dx.doi.org/10.1186/1471-2458-14-382.

Kaczynski, A., Henderson, K., 2008. Parks and recreation settings and active living: a review of associations with physical activity function and intensity. J. Phys. Act. Health 5, 619–632.

Kaczynski, A.T., Besenyi, G.M., Stanis, S.A.W., Koohsari, M.J., Oestman, K.B., Bergstrom, R., Reis, R.S., 2014. Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. Int. J. Behav. Nutr. Phys. Act., 11. http://dx.doi.org/10.1186/s12966-014-0146-4.

Kohl, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G., Kahlmeier, S., 2012. The pandemic of physical inactivity: global action for public health. Lancet 380, 294–305. http://dx.doi.org/10.1016/S0140-6736(12)60898-8.

Koohsari, M.J., Mavoa, S., Villianueva, K., Sugiyama, T., Badland, H., Kaczynski, A.T., Giles-Corti, B., 2015. Public open space, physical activity, urban design and public health: concepts, methods and research agenda. Health Place 33, 75–82. http://dx.doi.org/10.1016/j.healthplace.2015.02.009.

Lachowycz, K., Jones, A.P., Page, A.S., Wheeler, B.W., Cooper, A.R., 2012. What can global positioning systems tell us about the contribution of different types of urban greenspace to children's physical activity? Health Place 18, 586–594. http://dx.doi.org/10.1016/j.healthplace.2012.01.006.

Lackey, J.L., Kaczynski, A.T., 2009. Correspondence of perceived vs. objective proximity to parks and their relationship to park-based physical activity. Int. J. Behav. Nutr. Phys. Act., 6. http://dx.doi.org/10.1186/1479-5868-6-53.

Lee, A.C.K., Jordan, H.C., Horsley, J., 2015. Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning. Risk Manag. Health Policy 8, 131–137. http://dx.doi.org/10.2147/RMHP.S61654.

McCormack, G.R., Rock, M., Toohey, A.M., Hignell, D., 2010. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. Health Place 16, 712–726. http://dx.doi.org/10.1016/j.healthplace.2010.03.003.

McCormack, G.R., Shiell, A., 2011. In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Int. J. Behav. Nutr. Phys. Act., 8. http://dx.doi.org/10.1186/1479-5868-8-125.

Peschardt, K.K., Schipperijn, J., Stigsdotter, U.K., 2012. Use of Small Public Urban Green Spaces (SPUGS). Urban Urban Green. 11, 235–244. http://dx.doi.org/10.1016/j.ufug.2012.04.002.

Santos-Lozano, A., Santin-Medeiros, F., Cardon, G., Torres-Luque, G., Bailon, R., Bergmeir, C., Garatachea, N., 2013. Actigraph GT3X: validation and determination of physical activity intensity cut points. Int. J. Sports Med. 34, 975–982. http://dx.doi.org/10.1055/s-0033-1337945.

Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M., Stigsdotter, U.K., 2013. Associations between physical activity and characteristics of urban green space. Urban For. Urban Green. 12, 109–116. http://dx.doi.org/10.1016/j.ufug.2012.12.002.

Shores, K.A., West, S.T., 2010. Rural and urban park visits and park-based physical activity. Prev. Med. 50, s13–s17. http://dx.doi.org/10.1016/j.ypmed.2009.07.023.

Stewart, O.T., Moudon, A.V., Fesinmeyer, M.D., Zhou, C., Saelens, B.E., 2016. The association between park visitation and physical activity measured with accelerometer, GPS, and travel diary. Health Place 38, 82–88. http://dx.doi.org/10.1016/j.healthplace.2016.01.004.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., Depledge, M.H., 2011. Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. Environ. Sci. Technol. 45, 1761–1772. http://dx.doi.org/10.1021/es102947t.

Toftager, M., Ekholm, O., Schipperijn, J., Stigsdotter, U., Bentsen, P., Grønbæk, M., Kamper-Jørgensen, F., 2011. Distance to green space and physical activity: a Danish national representative survey. J. Phys. Act. Health 8, 741–749, (**ISSN:** 15433080).

Van Cauwenberg, J., Cerin, E., Timperio, A., Salmon, J., Deforche, B., Veitch, J., 2015. Park proximity, quality and recreational physical activity among mid-older aged adults: moderating effects of individual factors and area of residence. Int. J. Behav. Nutr. Phys. Act., 12. http://dx.doi.org/10.1186/s12966-015-0205-5.

Van Holle, V., Deforche, B., Van Cauwenberg, J., Goubert, L., Maes, L., Van de Weghe, N., De Bourdeaudhuij, I., 2012. Relationship between the physical environment and different domains of physical activity in European adults: a systematic review. BMC Public Health 12, 807, (**ISSN:** 14712458).

Veitch, J., Ball, K., Crawford, D., Abbott, G., Salmon, J., 2013. Is park visitation associated with leisure-time and transportation physical activity? Prev. Med. 57, 732–734. http://dx.doi.org/10.1016/j.ypmed.2013.08.001.

Veitch, J., Ball, K., Crawford, D., Abbott, G., Salmon, J., 2012. Park improvements and park activity: a natural experiment. Am. J. Prev. Med., 42. http://dx.doi.org/10.1016/j.amepre.2012.02.015.

White, M.P., Wheeler, B.W., Herbert, S., Alcock, I., Depledge, M.H., 2014. Coastal proximity and physical activity: is the coast an under-appreciated public health resource? Prev. Med. 69, 135–140. http://dx.doi.org/10.1016/j.ypmed.2014.09.016.

Witten, K., Hiscock, R., Pearce, J., Blakely, T., 2008. Neighbourhood access to open spaces and the physical activity of residents: a national study. Prev. Med. 47, 299–303. http://dx.doi.org/10.1016/j.ypmed.2008.04.010.

Other consulted sources: Dutch Statistics, 2016Nederland regionaal. Retrieved on November 10, 2016 from URL: ⟨http://statline.cbs.nl/Statweb/selection/?DM=SLNL&PA=82931NED&VW=T⟩.