# The impact of renewal of an urban park in Belgium on park use, park-based physical activity, and social interaction: a natural experiment

Poppe L., Van Dyck D., De Keyser E., Van Puyvelde A., Veitch J., & Deforche B.

## Abstract

Studies investigating the impact of park renewal on park use, park-based physical activity (PA), and social interaction are scarce and mainly conducted in Australia and North-America. This study investigates the impact of renewal of an urban public park in Belgium, Europe, on park use, park-based PA, and social interaction using a natural experiment. Baseline observational data of park visitors and their levels of PA were collected in two public parks with similar features and amenities. After the renewal of one park (i.e., installation of (1) paved walking and cycling paths, (2) benches and picnic tables, (3) outdoor fitness equipment, and (4) playgrounds for different age categories), observations were repeated in both parks. At posttest, park users' social interaction was assessed. Generalized linear (mixed) models were fitted to investigate the impact of the renewal on the number of park visitors, their levels of PA, and their level of social interaction. We found that urban park renewal can strongly increase the number of park visitors across age categories. However, no evidence for an effect of park renewal on visitors' mean PA level was detected. Similarly, the level of social interaction observed among park visitors at posttest did not differ between both parks.

## Keywords

Public park; natural experiment; physical activity; natural environment; green spaces; public open spaces

# 1. Introduction

By 2050, nearly 70% of the world's population is estimated to live in high-density urban areas (World Health Organization, 2021). This advancing urbanization poses many challenges, including increased obesity rates (Kirchengast & Hagmann, 2021), social isolation (Lai, Kumari, Webster, Gallacher, & Sarkar, 2021), mental health problems (van der Wal et al., 2021), and air pollution (Di Sabatino, Buccolieri, & Kumar, 2018). The provision of urban greenspace, such as public parks and gardens, is considered an important avenue to mitigate these health risks and create healthier cities (Nieuwenhuijsen, Khreis, Triguero-Mas, Gascon, & Dadvand, 2017).

According to the theoretical framework of Markevych et al., there are three pathways via which green spaces can enhance urban health (Markevych et al., 2017). The first pathway is harm mitigation by, for example, reducing exposure to air pollution. The second pathway is psychological restoration. This pathway refers to research highlighting, for example, the stress reducing effects of park visitation. Finally, green spaces are expected to contribute to citizens' health by building capacities, such as increasing levels of physical activity (PA) and social interaction. In this study we focus on this pathway.

Public urban parks are green spaces allowing visitors to be physically active (e.g., via trails, cycling paths and open space) and create opportunities for social interaction (e.g., via benches and playgrounds). Furthermore, they are usually free of charge. Consequently, public parks are considered a relevant setting to promote PA and social interaction across people from different age categories and socio-economic backgrounds. For example, the World Health organization states that increasing equitable and age-friendly access to good-quality public and green open spaces is a key action point to promote PA (World Health Organization, 2018).

However, to date, cross-sectional studies show mixed evidence for the relation between park access and levels of PA among (older) adults (Bancroft et al., 2015; Carlson et al., 2012; Moran, Rodríguez, Cotinez-O'Ryan, & Miranda, 2020; Schipperijn et al., 2017) and children (Ding, Sallis, Kerr, Lee, & Rosenberg, 2011). Access to public parks may therefore be insufficient to raise people's activity levels.  Furthermore, research examining the relation between park access and social interaction is limited (Markevych et al., 2017). To optimize the potential health effects of public parks, a better understanding of how public parks can promote park-based PA and social interaction is of upmost importance (Veitch et al., 2014).

To gain more insight in the effect of park characteristics on park use and park-based PA and social interaction, studies implementing an experimental design are needed. Considering the extensive costs of park renewal, natural experiments, rather than randomized controlled trials, provide a feasible methodology to assess this impact. Natural experiments allow researchers to (1) investigate the impact of park renewal on park use and park-based PA and social interaction, and (2) examine which park characteristics promote these behaviors. Because natural experiments are opportunistic endeavors, the number of natural experiments conducted to assess the impact of park renewal on park use and park-based PA and social interaction is limited.

Natural experiments assessing the effect of park renewal have mainly been performed in Australia and North-America. Veitch et al. (2012) conducted a natural experiment in Victoria (Australia) and found that park improvement including the installation of an all-abilities playground, a fenced leash-free area for dogs and a walking track, resulted in elevated park use across sex and age groups and a higher number of visitors being physically active compared to a control park (i.e., a similar park in which no changes took place) (Veitch, Ball, Crawford, Abbott, & Salmon, 2012). A natural experiment performed to assess the effect of installing a play-scape in a park in Melbourne (Australia) showed that, in contrast with the control park, the intervention park showed a larger increase in the number of visitors and park users performing PA at a moderate-to-vigorous intensity, especially among adults and children (Veitch et al., 2018). A significant increase in the share of older park visitors engaged in moderate-to-vigorous PA was detected in the natural experiment of Cranney et al. (2016) examining the effect of installing an outdoor gym in a park in Sydney (Australia) (Cranney et al., 2016). Cohen and colleagues (2012) investigated the effect of installing outdoor exercise equipment in parks in Los Angeles (USA) and found no significant increase in park use or total park-based energy expenditure in comparison to the control parks (i.e., parks without outdoor exercise equipment) (Cohen, Marsh, Williamson, Golinelli, & McKenzie, 2012). A natural experiment assessing the effect of park improvement (including the installation of new play equipment and landscaping) of two parks in San Francisco (USA) showed an increase in adult and child visitors and higher levels of total energy expenditure in the interventions parks in comparison with the control parks (Cohen et al., 2015). A natural experiment conducted in Melbourne (Australia) showed that the renewal of parks in low socio-economic areas resulted in an increase in park use and park-based PA (Dobbinson et al., 2020). To the best of our knowledge, only one study has examined the impact of park renewal on levels of PA in Europe. Andersen et al. (2017) performed a natural experiment to assess the impact of an extensive urban renewal project (including the creation of four new urban green spaces and playgrounds, the renewal of a public park as well as the establishment of a new public open space) on adolescents' PA levels in Copenhagen (Denmark)(Andersen et al., 2017). The urban renewal project was found to increase adolescents' time spent and PA performed in the district.

There are salient environmental differences between European cities and North-American or Australian cities. Whereas North-American and Australian cities are characterized by car-oriented, low-density neighborhoods, European cities tend to have a more compact urban design (Beatley, 2012; Willing & Pojani, 2017). Consequently, average trip distances are often shorter in Europe compared to the USA (Forsyth & Krizek, 2010) and European cities tend to have better cycling infrastructure (Pucher & Buehler, 2016). Due to the historical emphasis on urban compactness, European cities are considered guideposts for efficient urban planning (Beatley, 2012). Furthermore, the importance of access to urban green is well recognized in Europe. The European Environment Agency states that green space should be available within 15 minutes walking distance (Stanners & Bourdeau, 1995). Consequently, findings from natural experiments focusing on parks in North-American or Australian cities might not be applicable to parks in Europe. More research is needed to investigate the generalizability of findings across different continents.

A limitation with existing natural experiment evidence focusing on the impact of park renewal on park-based PA is related to the definition of park-based PA used in these studies. Several studies focus on the change in the absolute number of users performing PA at a moderate-to-vigorous intensity (Veitch et al., 2012; Veitch et al., 2018), instead of focusing on the relative number of active park users compared to visitors displaying lower levels of PA (i.e., lying, sitting or standing). An increase in the absolute number of active park users might not reflect an increase in the mean PA intensity of the park visitors, but might be the result of an increase in the total number of park visitors (including both active and less active park users). Other studies have focused on total energy expenditure by all park visitors (e.g., by assigning a metabolic equivalent (MET) to the observed activity categories) (Cohen et al., 2015; Cohen et al., 2012). However, the total energy expenditure will always increase when there is an increase in the total number of park visitors, irrespective of how physically active the visitors are. We therefore recommend that natural experiments report both the number of visitors observed in each activity category as well as the mean PA intensity level among park users.

The potential of public parks to enhance social health is often described in the literature (Markevych et al., 2017). However, natural experiments examining the impact of park renewal rarely provide attention to visitors' level of social interaction. Using a natural experiment, Dobbinson et al. (2020) examined the impact of park renewal (including the installation of playground equipment and quality walking paths) on park users' social interaction. A larger increase in social interaction among park visitors was found from pretest to follow-up in the intervention parks in comparison to the control parks (Dobbinson et al., 2020). However, social interaction was assessed via surveys, which are susceptible to social desirability and recall biases.

The aim of this study was to examine the effect of the renewal of an urban park in Ghent (Flanders, Belgium) on park use and park-based PA and social interaction. We examined the total number of park visitors, the number of visitors observed in different activity categories, the mean PA intensity level, and social interaction among park users. Considering the extensive renovations performed in the park targeting activities performed at varying intensities, we hypothesized to detect an increase in the number of people visiting the park and in the mean PA intensity level of the park users. Furthermore, considering the installation of features enhancing social interaction (e.g., picnic tables and playgrounds), higher levels of social interaction were expected to be observed in the renewed park in comparison with the control park.

# 2. Methods

## 2.1 Study setting

The study was performed in Ghent, Belgium. Belgium has a population density of 382 inhabitants per km², which makes it third most densely populated country in the European Union (The World Bank). Belgium has a temperate climate with cool and humid summers and mild and rainy winters. Ghent is a provincial town with a surface area of 156.2 km² and 263 406 inhabitants (population density = 1668 inhabitants per km²).

Park “De Vijvers”, comprising an area of 51 313 m² and located in the neighborhood “Ledeberg”, was initially planned to be refurbished in 2015. Hence, in 2014 park “Vaarnewijkpark”, located in the neighborhood “Mariakerke”, was selected to act as a control park for the natural experiment (see Figure 1). The control park comprised an area of 31 502 m² and was selected because of different reasons. First, this park was not planned to be refurbished in the near future. Second, similar to the intervention park, the control park is located in a residential area and offers a grassy area including a playground, trails, pond and wooded area. Finally, the park is located on the other side of Ghent (see Figure 2), minimizing the chances that people visiting the control park would also visit the intervention park. Relevant differences between the two neighborhoods in which the parks are located are listed in Table 1. The neighborhood of the intervention park has a higher population density and building density than the neighborhood of the control park. Consequently, the percentage of inhabitants having access to private outdoor space (i.e., (shared) garden, balcony, terrace, or patio) is lower for the neighborhood of the intervention park. Furthermore, the percentage of older adults and the mean income level is lower for the neighborhood of the intervention park compared to the neighborhood of the control park (Stad Gent, 2022). The features and amenities of both parks as well as the number, the characteristics and the PA levels of the park visitors were assessed in the summer and at the beginning of autumn (i.e., July – October) of 2014 (Van Hecke et al., 2017). The features and amenities of both parks at baseline have been reported elsewhere (Van Hecke et al., 2017).

[Figure 1]

[Figure 2]

[Table 1]

The renewal of park ‘De Vijvers’ was postponed and was eventually finished in spring 2020, leading to an enlarged and extensively renovated park. First, an area that originally belonged to the adjacent elderly care facility was added to the park to enable residents of the elderly care facility and its visitors to have easier access to the park. This resulted in an increase in the park’s surface area by 12 000 $m^2$. In addition, low vegetation was removed and the following features were added: landscaping beds, paved walking and cycling paths accessible to people in wheelchairs or mobility scooters, floating paths along the pond, wheelchair-accessible picnic tables, seat walls and benches, outdoor fitness equipment, a football/basketball cage, and playgrounds for individuals of different age categories (i.e., toddlers, children, and teenagers) (see Figure 3). No alterations were performed in the control park. Pictures taken before and after the renewal and maps of park ‘De Vijvers’ can be found here (https://osf.io/2z7sg/). The features and amenities of both parks as well as the number, the characteristics and the PA levels of the park visitors were assessed again in the summer and at the start of autumn (i.e., July - October) of 2020. Furthermore, park users’ social interaction was observed at this timepoint. An overview of the amenities and features present in the parks at baseline and the intervention park at posttest is provided in Supplementary file 1. At both timepoints access to the parks was free. The study protocol was approved by the Ethics Committee of the Ghent University Hospital (Belgian registration numbers: B670201524813 and B6702020000249).

During the posttest, several governmental measures were in force to reduce the spread of the COVID-19 pandemic. People were advised to limit their close contacts to a maximum of five persons and to keep a physical distance of at least 1.5 meters from all other persons (Federal Public Service Health Food Chain Safety and Environment, 2020). During the entire period public parks were freely accessible in Belgium.

[Figure 3]

## 2.2 Measurements

### 2.2.1 Characteristics of the parks

The features and amenities of the parks were assessed using the Environmental Assessment of Public Recreation Spaces (EAPRS) instrument. This observational instrument allows researchers to make a detailed assessment of the physical environment of public parks (Saelens et al., 2006).

### 2.2.2 Park visitors' socio-demographic characteristics, PA level, and social interaction

#### *2.2.2.1 Protocol for the observations*

The number, the characteristics and the PA levels of the park users were assessed using the System for Observing Play and Recreation in Communities (SOPARC). SOPARC is a reliable and feasible observation instrument for assessing socio-demographic characteristics and PA levels of park users (McKenzie, Cohen, Sehgal, Williamson, & Golinelli, 2006). At posttest, the number of park users displaying social interaction was assessed based on the recently developed Method for Observing pHysical Activity and Wellbeing (MOHAWk), which has been validated in Europe (Benton et al., 2022).

As recommended by SOPARC, both parks were divided into target areas before the start of the observations. At the pretest, the intervention park was divided into six target areas and the control park was divided into eight target areas. The renewal included the installation of different paths and new features (e.g., fitness zone) as well as an enlargement of park 'De Vijvers'. Therefore, the original target areas did not cover the whole park and contained too many amenities to effectively observe the visitors. Hence, at posttest park 'De Vijvers' was divided into target areas based on its new design which resulted in fifteen target areas. In the control park the same eight target areas were maintained at posttest. The altered size of the intervention park was taken into account in the analyses. Supplementary file 2 provides an overview of the target areas for each park at baseline and at posttest. In both parks, visitors are not allowed to use the pond therefore the target areas encompassing the pond were not included in the analyses. At the posttest, one target area of the intervention park (i.e., the area connecting the elderly care facility with the park) was closed to the public on each of the observation moments due to the COVID-19 pandemic. Hence, people observed in this target area were not included in the analysis.

We aimed to collect data on a minimum of five weekdays and four weekend days and all observations were planned on non-rain days. The observations at baseline were performed by three researchers (LVH, LVE, and SVH). At posttest, the observations were performed by four observers (LP, EDK, IS, and JH). All observations were simultaneously performed in both parks to ensure similar weather conditions. The observations were carried out in the morning (7.30 AM), during lunch time (12.30 PM), in the afternoon (3.30 PM) and in the evening (6.30 PM). On each of the observation days there was only one observer in each park. The researchers visually scanned all target areas and counted each park user within that area during each of the observation rounds. The following characteristics were recorded for each person observed: estimated age category (i.e., child: 0-12 years, teen: 13-20 years, adult: 21-59 years, or senior: ≥60 years), sex (i.e., male or female), and activity level (i.e., sedentary (lying down, sitting, or standing in place), walking (walking at a casual pace), or vigorous PA (activity more vigorous than an ordinary walk)) (McKenzie et al., 2006). At posttest, the number of park users displaying social interaction was counted. Users who were (1) conversing with other users, (2) physically linked with someone (e.g., parent carrying a child), (3) smiling or made eye contact when passing other park users, or (4) in a group activity were considered displaying social interaction (Benton et al., 2022). Each observation round took approximately 15-30 minutes. Afterwards, the observations were summed per target area using the SOPARC observation form.

#### 2.2.2.2 Weather conditions

At baseline, the mean temperature over the observation days was 20 degrees Celsius. On one of the weekdays, the observations were only performed in the morning and during lunch time due to rain in the afternoon and in the evening. The remaining observations (afternoon and evening) were performed on another weekday (Van Hecke et al., 2017). All the other observations were performed on non-rainy days. Consequently, over a period of six weekdays and four weekend days, 72 observation rounds (i.e. 8 full days (32 observation rounds) and two half days (four observation rounds) for each park) were performed in dry weather.

At posttest, the mean temperature over days was 15 degrees Celsius. Because the number of non-rainy days in this period was limited, it was decided to perform all four observation moments on each day irrespective of the presence of unexpected rain. An additional observation day was added due to rain during three of the four observation periods on one of the weekdays. Consequently, at posttest, 80 observation rounds (40 in each park) were conducted over six weekdays and four weekend days. Of these 80 observation rounds, twelve (six in each park) were performed in rainy weather.

#### 2.2.2.3 Training of the observers

The SOPARC protocol and training videos were used to train the seven observers. To assess the interrater reliability, observers performed ten test audits in both parks (20 in total). During these test observations, the observers (three at baseline and four at the posttest) simultaneously and independently coded the characteristics and activity levels of present park visitors. The interrater reliability had to be good to excellent before the start of the observations (Hallgren, 2012). The interrater reliability was assessed by calculating the intraclass correlation coefficient (ICC). The interrater reliability was good to excellent at baseline (ICC = 0.74 – 1.00) and at the posttest (ICC = 0.71-1.00) (Hallgren, 2012; Van Hecke et al., 2017).

## 2.3 Statistical analysis

The data were analyzed using R version 4.2.3 (R Core Team, 2023). First, the data were summarized per observation period per day. For each observation timepoint, the total number of visitors, the number of visitors in each age category, males and females, the number of visitors within each activity category (i.e., sedentary/standing, walking and vigorous PA), and the number of visitors displaying social interaction were calculated. Considering the difference in size between the intervention park and the control park and between the intervention park at baseline versus at posttest, these variables were divided by the size of the park (in hectares) at the time of the observation period. The size of the target area that was closed due to COVID-19 (i.e., 3000 $m^2$) was subtracted from the size of the park at the posttest (i.e., 63 313 $m^2$). The mean PA intensity level was calculated by giving a weighted metabolic equivalent (MET) to each activity category (i.e., 1 MET for sedentary, 3 METs for walking, and 6 METs for vigorous activity) and by multiplying the weighted MET scores by the number of people observed in each activity category. To create a mean PA intensity score independent of the number of visitors, this number was divided by the total number of visitors observed during that observation period (Van Dyck et al., 2013). Finally, to obtain a measure of the level of social interaction independent of the number of park visitors, the percentage of people displaying social interaction was calculated.

Considering the clustering of moments within days, the need for a multilevel model was examined for each of the outcome variables. To do so, an empty model allowing the intercept to vary by observation day and an empty model with a fixed intercept were compared using analysis of variance. Only for the number of adult visitors per hectare the model allowing the intercept to vary by observation day outperformed the model with the fixed intercept ($p<.05$). Hence, a generalized linear mixed model was used for this dependent variable, whereas generalized linear models were used for the other outcomes. To investigate whether the intervention effect differed over the observation moments, a three-way interaction including the variables ‘Park’ (two categories: Intervention and Control), ‘Time’ (two categories: Baseline and Posttest) and Observation Moment (four categories: Morning, Noon, Afternoon and Evening) was added. In case the three-way interaction was not significant, the variable Observation Moment was removed from the model. Considering that visitors’ social interaction was only observed at the posttest, the model examining the effect for this dependent variable did not contain the variable Time. The Akaike Information Criterion (AIC) value of models with different variance and link functions (i.e., Gaussian with identity, Gamma with identity, and Gamma with log) were compared and the model providing the lowest AIC value was selected. To facilitate interpretation, the betas of models with a Gamma distribution and log link were exponentiated. The homoscedasticity assumption was visually checked by plotting the deviance residuals against the fitted values.

Several dependent variables (e.g., observed number of children per hectare) showed a high percentage of zeros, indicating that during multiple observation moments no visitors belonging to this specific category were observed. To account for the elevated number of zeros in the data, a sensitivity analysis using hurdle models was carried out for dependent variables with ≥10% zero observations. A hurdle model consists of two parts. In the first part, a logistic regression is carried out to calculate the probability of attaining value zero (in this case: the probability of observing no visitor from the specific category). In the second part, the regression is carried out with the non-zero observations. For this part, the AIC values of models with different variance and link functions (i.e., Gaussian with identity, Gamma with identity, and Gamma with log) were again compared and the model providing the lowest AIC value was selected. Considering that high numbers of zero observations were mostly seen during the morning observations, the variable ‘Observation Moment’ was not added to the hurdle model. The homoscedasticity assumption was also visually checked by plotting the deviance residuals against the fitted values. The results of the sensitivity analysis are provided in Supplementary File 3.

# 3. Results

## 3.1 Descriptive statistics

At baseline, the total number of visitors counted over the 72 observation periods was 425 for the intervention park and 412 for the control park. Over the 80 observation periods at the posttest, 1318 people were counted in the renewed park and 350 in the control park. The descriptive statistics of the observed park visitors at baseline and at the posttest are provided in Table 2.

At baseline, the intervention park was mostly visited by adults, whereas the control park was mostly visited by teens. At posttest, both parks were mainly visited by adults. Across both timepoints, park visitors were mostly male and performing PA at a vigorous intensity. The percentage of visitors displaying social interaction were the same for both parks at posttest (i.e., 40%).

[Table 2]

## 3.2 Effect of park renewal on park use

Table 3 provides the median, mean and standard deviation (SD) for the number of visitors per hectare per observation moment and the results of the time by park (by observation moment) interactions. The significant interaction effects indicate that, compared with the control park, the intervention park showed a stronger increase in visitors across all age categories and across both sexes from baseline to the posttest. Figure 4 displays the intervention effect for the total number of visitors. Similar results were obtained by the sensitivity analysis (see Supplementary File 3).

[Table 3]

[Figure 4]

### 3.3 Effect of park renewal on park-based PA

Table 4 provides the median, mean and SD for the number of people sitting/standing, walking and being vigorously active per hectare per observation moment. An intervention effect was observed for each of these outcome variables. However, no significant time-by-park interaction was detected for the mean PA intensity level (beta (95% CI) = -0.22 (-0.98; 0.53)). In comparison with the control park (baseline: mean(SD) = 4.00 (1.37); posttest: mean (SD) = 4.14 (1.21)), no significant change in the mean PA intensity level in the intervention park from baseline (mean(SD) = 3.95 (1.19)) to posttest (mean(SD) = 3.86 (0.80)) was detected. This finding indicates that, although the number of people in each activity category increased, the mean PA intensity level of park visitors remained unchanged. The sensitivity analysis provided the same results (see Supplementary File 3).

[Table 4]

### 3.4 Difference between the renewed park and the control park regarding social interaction

At posttest, the mean number of park visitors displaying social interaction per hectare was 2.18 (SD: 2.62) for the renewed park and 1.12 (SD: 2.56) for the control park. A larger number of people displaying social interaction per hectare in the renewed park in comparison with the control park was found for observations conducted at noon (beta (95% CI) = 0.72 (0.25; 1.62) and in the evening (beta (95% CI) = 2.96 (1.39; 6.19)). Similarly, the sensitivity analysis showed that the odds of observing social interaction was 5.67 times higher for the renewed park than for the control park (95%CI = 2.01;14.28) (see Supplementary File 3).

However, the percentage of people displaying social interaction did not differ between the renewed park (mean(SD) = 0.29(0.22)) and the control park (mean(SD) = 0.22(0.30)).

## 4. Discussion

The overall objective of this study was to examine the impact of an extensive renewal of an urban park in Belgium via a natural experiment. The first aim was to assess the impact on the number of park visitors (i.e., park use). The second aim was to investigate the effect of the renewal on park-based PA. Finally, we aimed to examine whether there was a higher level of social interaction in the renewed park in comparison with the control park.

In line with previous studies (Cohen et al., 2015; Cohen et al., 2012; Kelly, Clennin, & Hughey, 2021; Veitch et al., 2012; Veitch et al., 2018), we found that the renewal of an urban public park that included the installation of (1) paved walking and cycling paths accessible to people with mobility impairments, (2) wheelchair-accessible picnic tables and benches, (3) outdoor fitness equipment, and (4) playgrounds for different age categories resulted in higher levels of park use. From baseline to posttest, the number of people visiting the intervention park increased by 210% which is in line with the change in visitors reported in previous studies (ranging between 50% and 319%) (Cohen et al., 2015; Kelly et al., 2021; Veitch et al., 2012; Veitch et al., 2018). Interestingly, the increase of certain subgroups of visitors differed according to the observation moment. For example, the positive intervention effect for the number of child visitors was stronger for observations conducted during noon and in the evening compared to observations conducted in the morning. This may be attributed to the fact that the number of children observed in the morning was often zero for both parks (data not shown). Furthermore, the lack of intervention effect for the number of children observed in the afternoon may be explained by the fact that the control park was used by a youth group during some of the observation periods conducted in the afternoon, resulting in a high number of children in the control park. In contrast, in the intervention park, there is a separate section (i.e., the island within the pond) reserved for the local youth group. As this section is closed for other visitors (and hence not accessible for the observers), this part of the park was not covered by our observations.

In the current study an increase was detected among all subgroups of park users. In the natural experiment by Veitch et al. (2018) that assessed the effect of a play-scape installation on park use an intervention effect was detected for the number of children and adults, but not for the number of teenagers and older adults (Veitch et al., 2018). Several factors may have contributed to the positive intervention effects found across sexes and age groups. First, the park was extensively renovated and the needs of different target groups (i.e., different age groups and people with limited mobility) were taken into account. Second, posttest took place during the COVID-19 pandemic, which affected the lives of people from all age groups. In Belgium, people reported more visits to green spaces during the COVID-19 restrictions (Da Schio et al., 2021). In contrast with the control park, the renewed park is located in a neighborhood with higher residential density and offers new facilities, including picnic tables and play structures for different age groups. Hence, this park may have been appealing as a place to meet friends and family during the COVID-19 pandemic. As a result, the COVID-19 pandemic in combination with the higher residential density of the neighborhood of the intervention park may have enlarged the effect of the park renewal on the number of visitors.

The second aim of the current study was to examine the effect of renewing the park on park visitors' levels of PA. Interestingly, at both timepoints, the most frequently observed PA category was vigorous PA. According to the review of Evenson et al., the distribution of observed PA levels shows strong variation across parks, with the proportion of people displaying vigorous PA ranging between 6 – 72 % (Evenson, Jones, Holliday, Cohen, & McKenzie, 2016). Our finding could be explained by the fact that both parks have a road connecting the park with residential streets. Hence, many people were observed cycling. As indicated above, park-based PA can be operationalized in different ways. An intervention effect for the number of visitors observed sitting/standing, walking and performing vigorous PA was detected. The fact that the adaptations performed in the park were not only focused on vigorous PA (e.g., installation of a football/basketball cage), but also on walking (e.g., paved walking paths) and sedentary activities (e.g., installation of wheelchair-accessible picnic tables and benches) is a potential explanation for this finding. Similarly, Veitch et al. (2018) observed an intervention effect for the number of people performing moderate-to-vigorous PA in a natural experiment assessing the effect of a play-scape installation (Veitch et al., 2018). In the current study no intervention effect was, however, found for the mean PA intensity level. Similarly, McCormack et al. (2016), who examined the impact of dog supportive modifications to public parks, reported comparable levels of mean PA intensity at baseline (i.e. MET levels ranging between 3.5 and 4.7) and found no significant change in adult visitors' mean PA intensity level (McCormack, Graham, Swanson, Massolo, & Rock, 2016). In the current study, the lack of effect on park visitors' mean PA intensity levels might be attributed to (1) the fact that the alterations did not solely focus on providing amenities to support vigorous PA, (2) the efforts made to make the park more accessible to people with limited mobility, and (3) the fact that vigorous PA was the most frequently observed PA category in both parks at baseline. One could argue that park renewal projects should give higher priority to park attributes aiming to increase visitors' activity levels (e.g., by installing outdoor fitness equipment) than to attributes associated with lower PA levels (e.g., installation of benches). Nevertheless, attributes associated with low-intensity physical activities might be highly relevant to attract vulnerable groups to the park (e.g., people with limited mobility). Furthermore, it should be highlighted that public parks serve multiple health benefits, including relaxation by the natural environment (Holy-Hasted & Burchell, 2022; Mouratidis,

2021) and social interaction with other park visitors which are beneficial for mental and social health (Jennings & Bamkole, 2019).

Considering these other health benefits, our final aim was to investigate whether the level of social interaction differed between the renewed park and the control park. We found that the number of people displaying social interaction was higher in the renewed park than the control park at noon and in the evening. However, no difference in the percentage of visitors displaying social interaction was found between both parks. This indicates that the increase in social interaction was mainly caused by an increase in the number of visitors, rather than specific alterations in the park encouraging social interaction among park visitors. A potential explanation for this finding could be that the renewed park does not only offer features that encourage social interaction (e.g., playgrounds targeting different age categories), but also features that visitors can enjoy by themselves (e.g., benches with view on the pond, wheelchair-accessible walking routes).

This study has several strengths. It is the first natural experiment specifically focusing on the effect of renewing a public urban park on park use and park-based PA in Europe. Second, to our knowledge, this is the first natural experiment examining the impact of renewal on social interaction among visitors via observation. Previous natural experiments in which social interaction was observed focused on small public amenity spaces (0.04-0.14 hectares) adjacent to residential streets (Benton, Cotterill, Anderson, Macintyre, Gittins, Dennis, Lindley, et al., 2021) and improvements along an urban canal (Benton, Cotterill, Anderson, Macintyre, Gittins, Dennis, & French, 2021). Third, observations were carried out four times a day on a high number of days simultaneously in the intervention park and the control park. Third, the change in the number of people observed in each activity category as well as the change in the mean PA intensity level were calculated as indicators for park-based PA. A first limitation of this natural experiment is the extended period between baseline and the posttest.

The intervention park was planned to be renewed in 2015, but the renewal was postponed and was not complete until spring 2020. These delays are often seen in natural experiments and contribute to the complexity of conducting this type of experiment (Cohen et al., 2015; Veitch et al., 2017). In our case, this delay resulted in having different observers for the baseline and follow-up measurements. Nevertheless, all observers were trained using the same materials and the interrater reliability was assessed before the actual observations commenced at both timepoints. A second limitation is the context in which the posttest took place. During the posttest the weather was colder and COVID-19 related restrictions were in place. However, it should be highlighted that these conditions were the same for the intervention and the control park. Nevertheless, as indicated above, it is possible that the COVID-19 pandemic amplified the effect of the renewal of the park. A final limitation is that there was only one control site. Although the characteristics of the two parks were similar at baseline, the neighborhoods in which the parks are located differed regarding population and building density as well as income level. Having multiple matched control sites improves the internal validity of a study and is therefore recommended in future natural experiments assessing the impact of park renewal (Benton, Cotterill, Anderson, Macintyre, Gittins, Dennis, & French, 2021).

The results of this study illustrate that park renewal including new features that address the needs of varying age groups and people with limited mobility can have a positive impact on the number of park visitors. Hence, urban planners are encouraged to consider the preferences of different target groups when renewing urban parks. An overview of specific guidance to adapt green spaces such as public parks to specific cohorts has been provided by Douglas and colleagues (2017) (Douglas, Lennon, & Scott, 2017). Furthermore, participatory action research, an approach in which the subjects of the study collaborate with the researcher in each step of the research process (Whyte, Greenwood, & Lazes, 1989), would allow the development of plans for park renewal in collaboration with specific target groups (e.g., people with mobility impairments). Furthermore, urban planners are encouraged to explore opportunities for collaboration with organizations located near the park. For example, in this case, the collaboration between the parks and maintenance department of the City of Ghent and the elderly care facility located adjacent to the park resulted in benefits for both parties (i.e., an enlargement of the park and higher accessibility of the park for people with limited mobility).

Other natural experiments, preferably using several matched control sites, in Europe should be conducted to assess the robustness of our findings. Furthermore, we recommend to examine park-based PA as the number of visitors observed in each activity category as well as the mean PA intensity level observed among visitors and to include the assessment of social interaction among park visitors. Finally, further research is necessary to better understand which specific attributes should be prioritized in future renewal projects. Experimental research assessing the role of specific park attributes for promoting park visitation and park-based PA and social interaction among different target groups is therefore warranted. Virtual reality methodologies have already been shown feasible to investigate the association between physical environmental attributes and cycling among older adults (Mertens et al., 2020). A similar approach could be used to test the relevance of different park attributes for park use and park-based PA and social interaction among different target groups.

## 5. Conclusions

Renewal of an urban park in Europe that included facilities and amenities targeting the needs of different target groups resulted in a strong increase in park visitors. The COVID-19 pandemic may have amplified the positive effect of the park renewal on the number of observed visitors. The renewal increased the number of park visitors being sedentary, walking and performing PA at a vigorous intensity, but had no impact on the mean intensity of PA performed in the park. The detected increase in the number of active visitors demonstrates the relevance of park renewal for promoting PA. Because public parks also provide opportunities for mental and social health, the increased number of less-active park visitors in the intervention should not be considered problematic.

## References


Andersen, H. B., Christiansen, L. B., Klinker, C. D., Ersbøll, A. K., Troelsen, J., Kerr, J., & Schipperijn, J. (2017). Increases in use and activity due to urban renewal: Effect of a natural experiment. *American Journal of Preventive Medicine, 53*(3), e81-e87.

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 science & medicine, 138*, 22-30.

Beatley, T. (2012). *Green urbanism: Learning from European cities*: Island press.

Benton, J. S., Anderson, J., Pulis, M., Cotterill, S., Hunter, R. F., & French, D. P. (2022). Method for observing pHysical activity and wellbeing (MOHAWk): validation of an observation tool to assess physical activity and other wellbeing behaviours in urban spaces. *Cities & health, 6*(4), 818-832.

Benton, J. S., Cotterill, S., Anderson, J., Macintyre, V. G., Gittins, M., Dennis, M., & French, D. P. (2021). A natural experimental study of improvements along an urban canal: impact on canal usage, physical activity and other wellbeing behaviours. *International Journal of Behavioral Nutrition and Physical Activity, 18*(1), 1-16.

Benton, J. S., Cotterill, S., Anderson, J., Macintyre, V. G., Gittins, M., Dennis, M., . . . French, D. P. (2021). Impact of a low-cost urban green space intervention on wellbeing behaviours in older adults: a natural experimental study. *Wellbeing, Space and Society, 2*, 100029.

Carlson, J. A., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Kerr, J., . . . King, A. C. (2012). Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Preventive Medicine, 54*(1), 68-73. doi:https://doi.org/10.1016/j.ypmed.2011.10.004

Cohen, D. A., Han, B., Isacoff, J., Shulaker, B., Williamson, S., Marsh, T., . . . Bhatia, R. (2015). Impact of park renovations on park use and park-based physical activity. *Journal of physical activity and health, 12*(2), 289-295.

Cohen, D. A., Marsh, T., Williamson, S., Golinelli, D., & McKenzie, T. L. (2012). Impact and cost-effectiveness of family fitness zones: a natural experiment in urban public parks. *Health & place, 18*(1), 39-45.

Cranney, L., Phongsavan, P., Kariuki, M., Stride, V., Scott, A., Hua, M., & Bauman, A. (2016). Impact of an outdoor gym on park users' physical activity: A natural experiment. *Health & place, 37*, 26-34.

Da Schio, N., Phillips, A., Fransen, K., Wolff, M., Haase, D., Ostoić, S. K., . . . Davies, C. (2021). The impact of the COVID-19 pandemic on the use of and attitudes towards urban forests and green spaces: Exploring the instigators of change in Belgium. *Urban forestry & urban greening, 65*, 127305.

Di Sabatino, S., Buccolieri, R., & Kumar, P. (2018). Spatial distribution of air pollutants in cities. *Clinical handbook of air pollution-related diseases*, 75-95.

Ding, D., Sallis, J. F., Kerr, J., Lee, S., & Rosenberg, D. E. (2011). Neighborhood environment and physical activity among youth: a review. *American Journal of Preventive Medicine, 41*(4), 442-455.

Dobbinson, S. J., Simmons, J., Chamberlain, J. A., MacInnis, R. J., Salmon, J., Staiger, P. K., . . . Veitch, J. (2020). Examining health-related effects of refurbishment to parks in a lower socioeconomic area: The ShadePlus natural experiment. *International journal of environmental research and public health, 17*(17), 6102.

Douglas, O., Lennon, M., & Scott, M. (2017). Green space benefits for health and well-being: A life-course approach for urban planning, design and management. *Cities, 66*, 53-62.
Evenson, K. R., Jones, S. A., Holliday, K. M., Cohen, D. A., & McKenzie, T. L. (2016). Park characteristics, use, and physical activity: A review of studies using SOPARC (System for Observing Play and Recreation in Communities). *Preventive Medicine, 86*, 153-166.
Federal Public Service Health Food Chain Safety and Environment. (2020). Coronavirus COVID-19 news. Retrieved from https://www.info-coronavirus.be/en/news/archive/nsc-21-08/
Forsyth, A., & Krizek, K. J. (2010). Promoting walking and bicycling: assessing the evidence to assist planners. *Built environment, 36*(4), 429-446.
Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: an overview and tutorial. *Tutorials in quantitative methods for psychology, 8*(1), 23.
Holy-Hasted, W., & Burchell, B. (2022). Does public space have to be green to improve well-being? An analysis of public space across Greater London and its association to subjective well-being. *Cities, 125*, 103569.
Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. *International journal of environmental research and public health, 16*(3), 452.
Kelly, C., Clennin, M., & Hughey, M. (2021). A Natural Experiment: Results of Community-Designed Park Improvements on Park Use and Physical Activity. *Health Promotion Practice*, 15248399211026265.
Kirchengast, S., & Hagmann, D. (2021). " Obesity in the City"–urbanization, health risks and rising obesity rates from the viewpoint of human biology and public health. *Human Biology and Public Health, 2*.
Lai, K. Y., Kumari, S., Webster, C., Gallacher, J., & Sarkar, C. (2021). Associations of neighbourhood housing density with loneliness and social isolation: a cross-sectional study using UK Biobank data. *The Lancet, 398*, S60.
Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., . . . Nieuwenhuijsen, M. J. (2017). Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environmental research, 158*, 301-317.
McCormack, G. R., Graham, T. M., Swanson, K., Massolo, A., & Rock, M. J. (2016). Changes in visitor profiles and activity patterns following dog supportive modifications to parks: a natural experiment on the health impact of an urban policy. *SSM-Population Health, 2*, 237-243.
McKenzie, T. L., Cohen, D. A., Sehgal, A., Williamson, S., & Golinelli, D. (2006). System for Observing Play and Recreation in Communities (SOPARC): reliability and feasibility measures. *Journal of physical activity and health, 3*(s1), S208-S222.
Mertens, L., Van Cauwenberg, J., Deforche, B., Van de Weghe, N., Matthys, M., & Van Dyck, D. (2020). Using virtual reality to investigate physical environmental factors related to cycling in older adults: A comparison between two methodologies. *Journal of Transport & Health, 19*, 100921. doi:https://doi.org/10.1016/j.jth.2020.100921
Moran, M. R., Rodríguez, D. A., Cotinez-O'Ryan, A., & Miranda, J. J. (2020). Park use, perceived park proximity, and neighborhood characteristics: Evidence from 11 cities in Latin America. *Cities, 105*, 102817.
Mouratidis, K. (2021). Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being. *Cities, 115*, 103229.
Nieuwenhuijsen, M. J., Khreis, H., Triguero-Mas, M., Gascon, M., & Dadvand, P. (2017). Fifty shades of green. *Epidemiology, 28*(1), 63-71.

Pucher, J., & Buehler, R. (2016). Safer cycling through improved infrastructure. In (Vol. 106, pp. 2089-2091): American Public Health Association.
R Core Team. (2023). R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/
Saelens, B. E., Frank, L. D., Auffrey, C., Whitaker, R. C., Burdette, H. L., & Colabianchi, N. (2006). Measuring physical environments of parks and playgrounds: EAPRS instrument development and inter-rater reliability. *Journal of physical activity and health, 3*(s1), S190-S207.
Schipperijn, J., Cerin, E., Adams, M. A., Reis, R., Smith, G., Cain, K., . . . Frank, L. D. (2017). Access to parks and physical activity: An eight country comparison. *Urban forestry & urban greening, 27*, 253-263.
Stad Gent. (2022). Gent Buurtmonitor. Retrieved from https://gent.buurtmonitor.be/dashboard/dashboard/
Stanners, D., & Bourdeau, P. (1995). The urban environment. *Europe's Environment: The Dobříš Assessment*.
The World Bank. Population density (people per sq. km of land area) - European Union. Retrieved from https://data.worldbank.org/indicator/EN.POP.DNST?locations=EU&most_recent_value_desc=true
van der Wal, J. M., van Borkulo, C. D., Deserno, M. K., Breedvelt, J. J., Lees, M., Lokman, J. C., . . . Smidt, M. P. (2021). Advancing urban mental health research: From complexity science to actionable targets for intervention. *The Lancet Psychiatry, 8*(11), 991-1000.
Van Dyck, D., Sallis, J. F., Cardon, G., Deforche, B., Adams, M. A., Geremia, C., & De Bourdeaudhuij, I. (2013). Associations of neighborhood characteristics with active park use: an observational study in two cities in the USA and Belgium. *International journal of health geographics, 12*(1), 1-9.
Van Hecke, L., Van Cauwenberg, J., Clarys, P., Van Dyck, D., Veitch, J., & Deforche, B. (2017). Active use of parks in Flanders (Belgium): an exploratory observational study. *International journal of environmental research and public health, 14*(1), 35.
Veitch, J., Ball, K., Crawford, D., Abbott, G. R., & Salmon, J. (2012). Park improvements and park activity: a natural experiment. *American Journal of Preventive Medicine, 42*(6), 616-619.
Veitch, J., Salmon, J., Carver, A., Timperio, A., Crawford, D., Fletcher, E., & Giles-Corti, B. (2014). A natural experiment to examine the impact of park renewal on park-use and park-based physical activity in a disadvantaged neighbourhood: the REVAMP study methods. *BMC Public health, 14*(1), 1-9.
Veitch, J., Salmon, J., Crawford, D., Abbott, G., Giles-Corti, B., Carver, A., & Timperio, A. (2018). The REVAMP natural experiment study: the impact of a play-scape installation on park visitation and park-based physical activity. *International Journal of Behavioral Nutrition and Physical Activity, 15*(1), 1-14.
Veitch, J., Salmon, J., Giles-Corti, B., Crawford, D., Dullaghan, K., Carver, A., & Timperio, A. (2017). Challenges in conducting natural experiments in parks—lessons from the REVAMP study. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 1-6.
Whyte, W. F., Greenwood, D. J., & Lazes, P. (1989). Participatory action research: Through practice to science in social research. *American Behavioral Scientist, 32*(5), 513-551.
Willing, R., & Pojani, D. (2017). Is the suburban dream still alive in Australia? Evidence from Brisbane. *Australian planner, 54*(2), 67-79.

World Health Organization. (2018). Global action plan on physical activity 2018–2030: more active people for a healthier world.
World Health Organization. (2021). Urban Health. Retrieved from https://www.who.int/health-topics/urban-health

## Data availability

The data and the R-script are available on OSF (https://osf.io/2z7sg/).

## List of tables

## Individual tables

Table 1. Comparison between neighborhoods of the intervention park and the control park

| | **Intervention park neighborhood** | | **Control park neighborhood** | |
|---|---|---|---|---|
| | **2014** | **2020** | **2014** | **2020** |
| Population density (inhabitants per $km^2$) | 6158 | 6365 | 1608 | 1706 |
| Population (%) | | | | |
| Children (0 – 19 years) | 23 | 22 | 21 | 22 |
| Adults (20 – 64 years) | 62 | 64 | 57 | 55 |
| Older adults (≥65 years) | 15 | 14 | 22 | 23 |
| Building density (%) | 27 | 28 | 12 | 13 |
| Access to private outdoor space[1] (%) | 85 | 85 | 95 | 95 |
| Mean net income per inhabitant (in euro) | 15476 | 17177* | 21312 | 22679* |

[1]Private outdoor space is defined as (shared) garden, balcony, terrace, or patio. *Numbers for 2019

Source: (Stad Gent, 2022)

Table 2. Descriptive statistics of the observed park visitors at baseline and at posttest.

| | **Intervention Park** | | | | **Control Park** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Baseline** | | **Posttest** | | **Baseline** | | **Posttest** | |
| | **Total N (%)** | **Mean (SD) per observation moment** | **Total N (%)** | **Mean (SD) per observation moment** | **Total N (%)** | **Mean (SD) per observation moment** | **Total N (%)** | **Mean (SD) per observation moment** |
| Total park visitors | 425 | 11.81 (10.67) | 1318 | 32.95 (24.88) | 412 | 11.44 (11.34) | 350 | 8.75 (11.12) |
| Park-use by age groups | | | | | | | | |
| Children | 73 (17) | 2.03 (5.89) | 328 (25) | 8.20 (9.80) | 100 (24) | 2.78 (6.61) | 106 (30) | 2.65 (7.19) |
| Teens | 80 (19) | 2.22 (2.73) | 169 (13) | 4.23 (4.23) | 136 (33) | 3.78 (5.50) | 67 (19) | 1.68 (2.48) |
| Adults | 242 (57) | 6.72 (4.12) | 701 (53) | 17.53 (13.04) | 125 (30) | 3.47 (2.56) | 145 (41) | 3.63 (3.51) |
| Older adults | 30 (7) | 0.83 (1.30) | 120 (9) | 3.00 (3.36) | 51 (12) | 1.42 (1.68) | 32 (9) | 0.80 (1.29) |
| Park-use by sex | | | | | | | | |
| Women | 187 (44) | 5.19 (5.44) | 572 (43) | 14.30 (11.44) | 159 (39) | 4.42 (4.73) | 104 (30) | 2.60 (3.09) |
| Men | 238 (56) | 6.61 (5.52) | 746 (57) | 18.65 (14.23) | 253 (61) | 7.03 (9.29) | 246 (70) | 6.15 (9.32) |
| Activities | | | | | | | | |
| Sedentary/standing | 123 (29) | 3.42 (3.67) | 417 (32) | 10.43 (12.98) | 104 (25) | 2.89 (3.69) | 95 (27) | 2.38 (3.83) |
| Walking | 119 (28) | 3.31 (5.90) | 355 (27) | 8.88 (7.56) | 88 (21) | 2.44 (3.45) | 70 (20) | 1.75 (2.30) |
| Vigorous PA | 183 (43) | 5.08 (3.91) | 546 (41) | 13.65 (9.67) | 220 (53) | 6.11 (6.66) | 185 (53) | 4.63 (6.15) |
| Park visitors displaying social interaction | *NA* | *NA* | 526 (40) | 13.15 (15.78) | *NA* | *NA* | 141 (40) | 3.53 (8.05) |

Table 3. Intervention effects for number of park visitors per hectare.

| **Dependent variable** | **Intervention Park** | | **Control Park** | | **Time x Park (exp)beta (95% CI)** | **Time x Park x Noon (exp)beta (95% CI)** | **Time x Park x Afternoon (exp)beta (95% CI)** | **Time x Park x Evening (exp)beta (95% CI)** |
|---|---|---|---|---|---|---|---|---|
| | **Baseline Median; Mean (SD)** | **Posttest Median; Mean (SD)** | **Baseline Median; Mean (SD)** | **Posttest Median; Mean (SD)** | | | | |
| Total | 1.85; 2.30 (2.08) | 4.56; 5.46 (4.13) | 2.38; 3.63 (3.60) | 1.59; 2.78 (3.53) | 0.97 (-0.14; 2.27) | **3.20 (0.74; 6.28)** | 3.72 (-2.55; 10.78) | **5.25 (1.46; 10.45)** |
| Men | 0.97; 1.29 (1.15) | 2.49; 3.09 (2.36) | 1.27; 2.23 (2.95) | 1.27; 1.95 (2.96) | 0.60 (-0.06; 1.41) | 1.28 (-0.23; 3.16) | 1.36 (-3.27; 6.21) | **3.28 (0.69; 6.98)** |
| Women | 0.78; 1.01 (1.06) | 1.91; 2.37 (1.90) | 0.95; 1.40 (1.50) | 0.48; 0.83 (0.98) | 0.37 (-0.30; 1.16) | **1.92 (0.54; 3.79)** | 2.36 (-0.48; 6.10) | 1.97 (0.13; 4.61) |
| Children | 0.00; 0.40 (1.15) | 0.75; 1.36 (1.62) | 0.00; 0.88 (2.10) | 0.00; 0.84 (2.28) | -0.12 (-0.55; 0.04) | **1.12 (0.62; 2.62)** | 0.78 (-5.80; 7.10) | **2.61 (1.06; 7.53)** |
| Teens | 0.19; 0.43 (0.53) | 0.50; 0.70 (0.70) | 0.32; 1.20 (1.75) | 0.00; 0.53 (0.79) | **0.93 (0.35; 1.71)** | *NA* | *NA* | *NA* |
| Adults* | 1.27; 1.31 (0.80) | 2.57; 2.91 (2.16) | 0.95; 1.10 (0.81) | 0.95; 1.15 (1.11) | **2.08 (1.17; 3.69)** | *NA* | *NA* | *NA* |
| Older adults | 0.19; 0.16 (0.25) | 0.33; 0.50 (0.56) | 0.32; 0.45 (0.53) | 0.00; 0.25 (0.41) | 0.08 (-0.15; 0.37) | **0.61 (0.11; 1.46)** | 0.76 (-0.27; 2.30) | 0.42 (-0.09; 1.14) |

Notes. Time by park interaction with park = control, time = baseline and observation moment = morning as reference categories. Statistically significant effects are indicated in bold. *Gamma model with log link.

Table 4. Intervention effects for park-based PA.

| Dependent variable | Intervention Park | | Control Park | | Time x Park beta (95% CI) | Time x Park x Noon beta (95% CI) | Time x Park x Afternoon beta (95% CI) | Time x Park x Evening beta (95% CI) |
|---|---|---|---|---|---|---|---|---|
| | **Baseline Median Mean (SD)** | **Posttest Median Mean (SD)** | **Baseline Median Mean (SD)** | **Posttest Median Mean (SD)** | | | | |
| Sitting/standing | 0.39; 0.67 (0.71) | 0.99; 1.73 (2.15) | 0.63; 0.92 (1.17) | 0.32; 0.75 (1.22) | 0.20 (-0.03; 0.49) | 0.66 (-0.12; 1.82) | 0.87 (-2.04; 4.36) | **2.59 (0.67; 6.02)** |
| Walking | 0.39; 0.64 (1.15) | 1.08; 1.47(1.25) | 0.32; 0.78 (1.10) | 0.32; 0.56 (0.73) | **1.05 (0.31; 2.01)** | *NA* | *NA* | *NA* |
| Vigorous PA | 0.78; 0.99 (0.76) | 1.99; 2.26 (1.60) | 1.27; 1.94 (2.11) | 0.95; 1.47 (1.95) | 0.46 (-0.49; 1.47) | **1.99 (0.40; 4.01)** | 1.65 (-1.83; 5.39) | 1.51 (-0.47; 3.97) |

Notes. Time by park interaction with park = control, time = baseline and observation moment = morning as reference categories. Statistically significant effects are indicated in bold.

## List of figures


Figure 1. The intervention park and the control park at baseline (Photographs taken by Linde Van Hecke) (Panel A: Pictures of the control park. Panel B: Pictures of the intervention park)

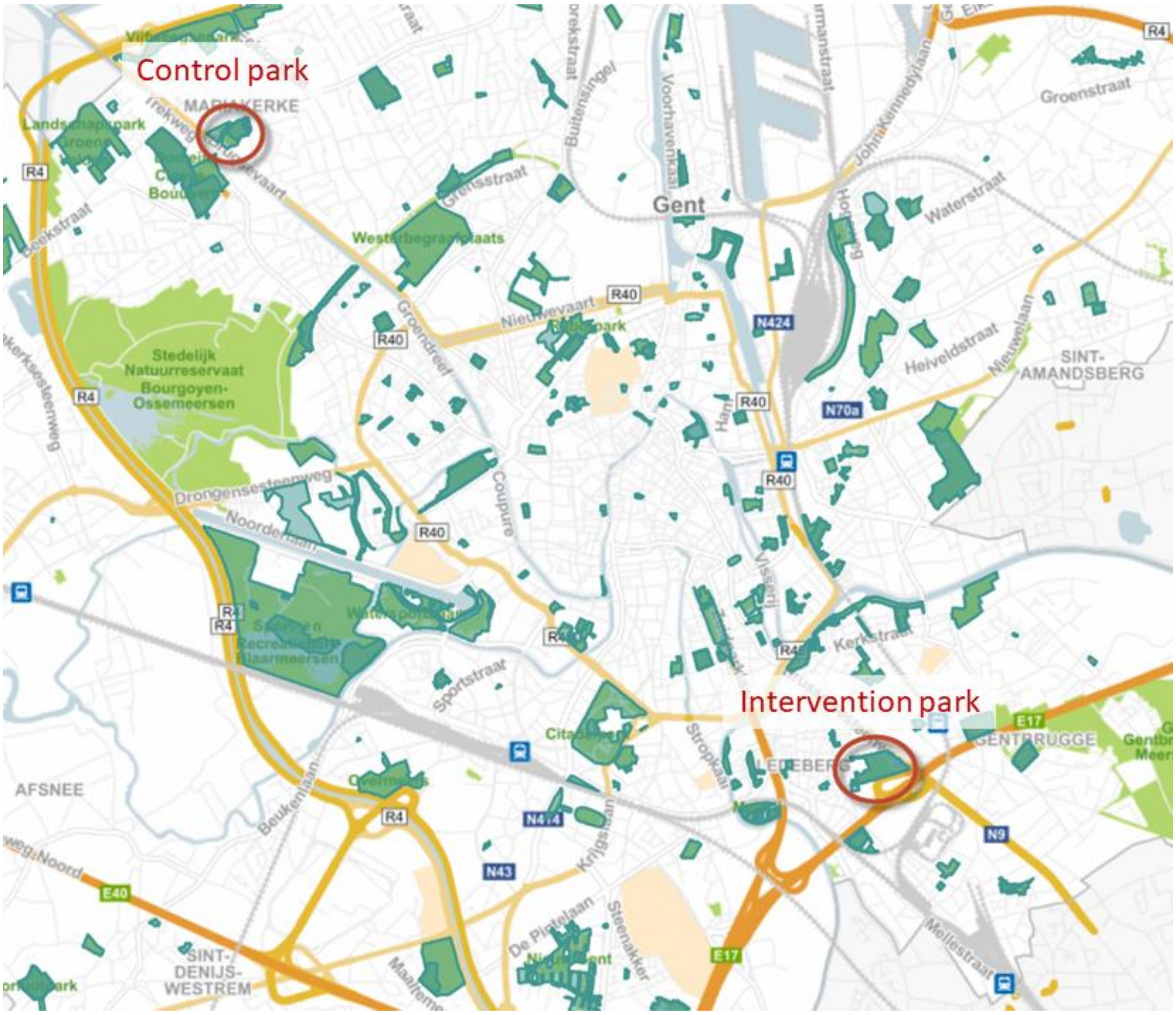


Figure 2. Map of Ghent with location of the intervention park and the control park


Figure 3. Intervention park after the renewal (Photographs taken by Louise Poppe)

a. Paved walking and cycling paths. b. Benches and picnic tables. c. Outdoor fitness equipment. d. Playgrounds for different age categories

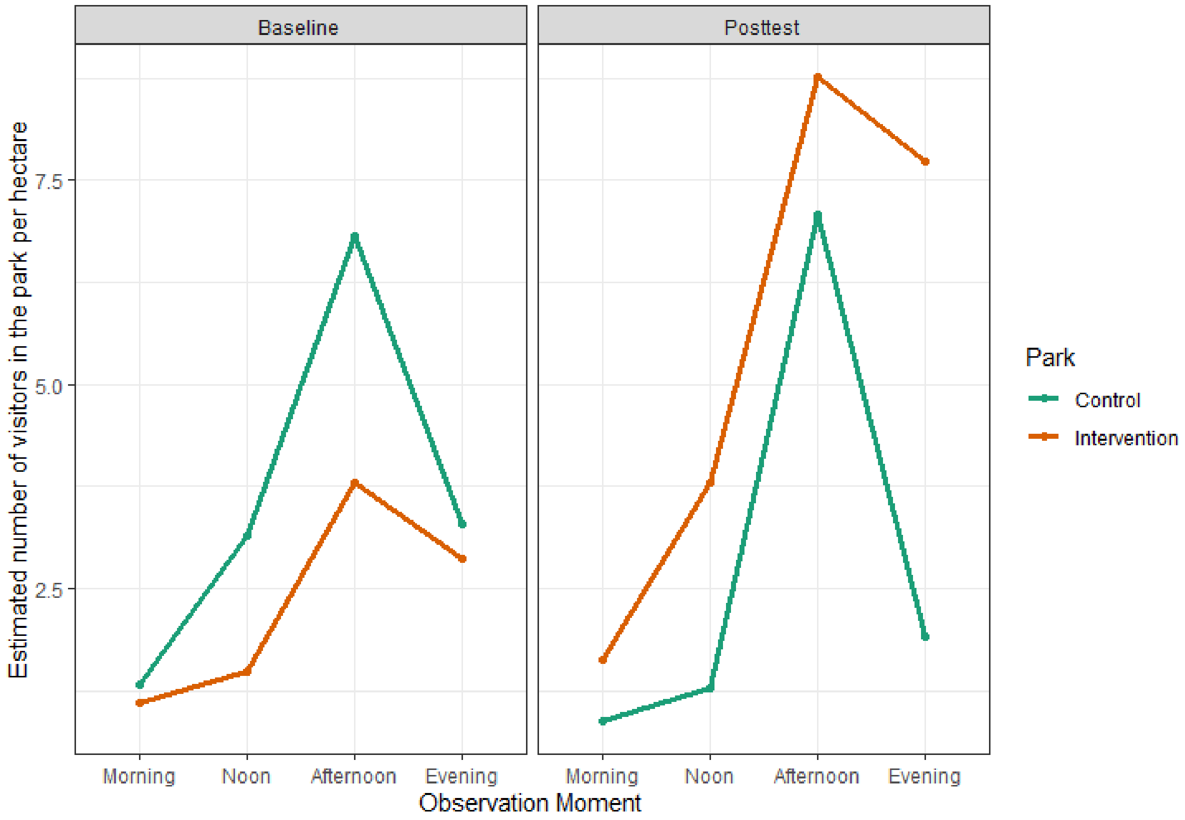


Figure 4. Intervention effect for the total number of visitors

## List of Supplementary Files

Supplementary file 1. Overview of the features and amenities at baseline and in the intervention park at posttest.

Supplementary file 2. Target areas of the intervention park and control park at baseline and posttest.

Supplementary file 3. Sensitivity analysis with hurdle models.