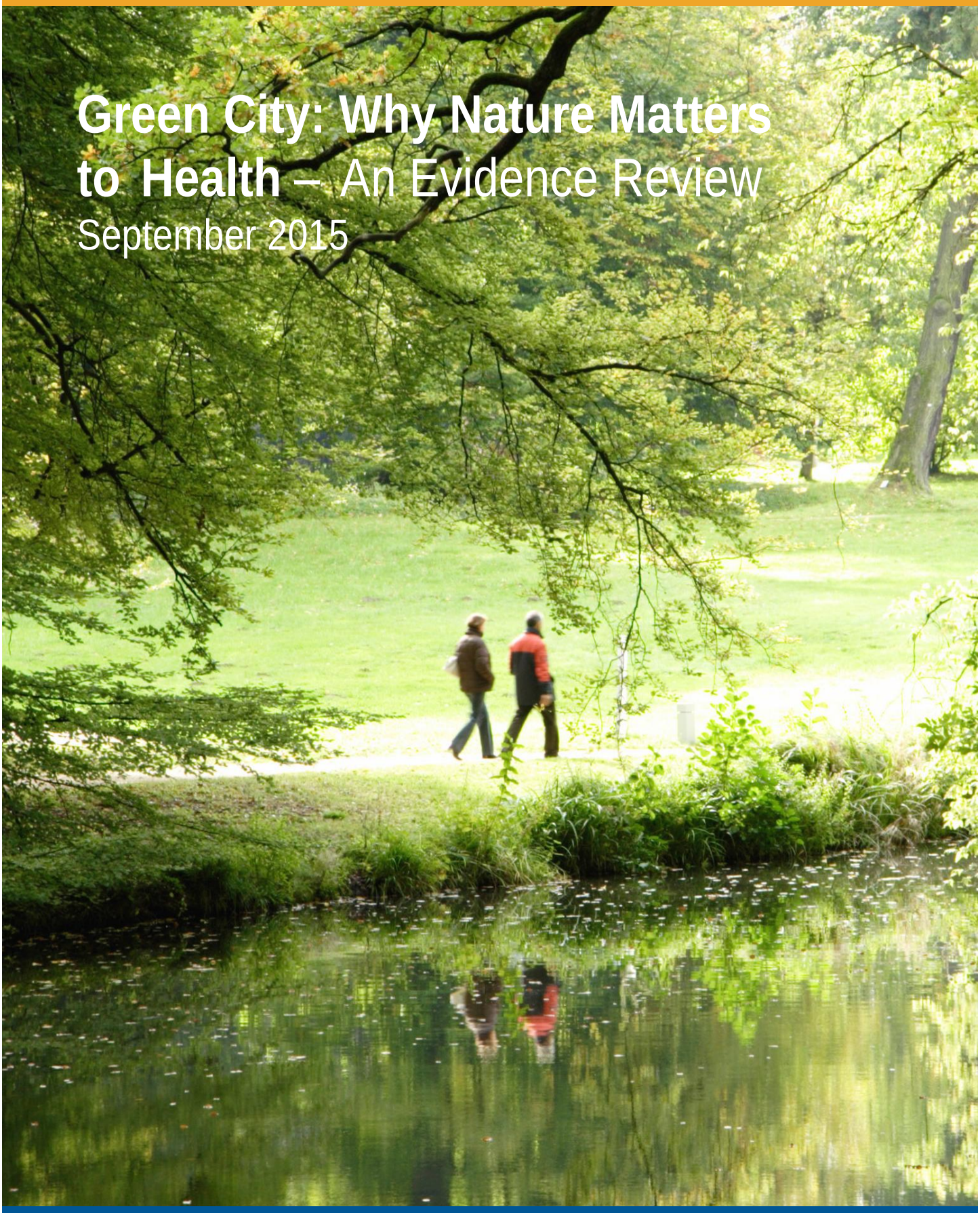

Green City: Why Nature Matters to Health – An Evidence Review

September 2015

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About the Healthy Toronto By Design Series

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- **Active City, Designing for Health** (2014) - focuses on the city's physical built environment to create healthy places that encourage active living for all Torontonians. The report outlines design principles to guide changes to neighbourhoods, streets and buildings that allow people of all ages and abilities to incorporate physical activity into their daily routines without extra costs for physical exercise.

About this report

In 2012 the GTA Conservation Authorities were looking for a way to engage with the public health sector. This led to the formation of the EcoHealth Ontario, in which Toronto Public Health participates. The group found that there was a lack of synthesized evidence regarding green space and human health.

Two meta-narrative systematic reviews were conducted as partner reports. The first report was released by the David Suzuki Foundation in March 2015, entitled: *The impact of green space on heat and air pollution in urban communities: A meta-narrative systematic review* (Zupancic et al., 2015). It looks at the impact urban green space has on heat island mitigation and reducing air pollution. Zupancic et al. (2015) analyzed 102 peer reviewed studies published over the past five years and found that all scales of green space from single green walls to urban forests have been associated with relief from heat stress, reduced urban heat islands and air pollution. The findings for pollution mitigation were particularly strong, 92% of studies reported that green space mitigates air pollution.

Green City: Why Nature Matters to Health – A Literature Review focuses on the impact green space has on physical health, mental health and wellbeing, along with green space features which can benefit health.

This second report excluded studies that looked solely at the impact green space has on physical activity due to the existence of two very good reviews on the subject (by Lachowycz & Jones 2011, Koohsari et al., 2015).

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Executive Summary

This report focuses on the impact green space has on health outcomes and the characteristics that may modify the impacts. The meta-narrative systematic review includes literature that examines urban green space and physical health, mental health and wellbeing.

The 106 studies included in the review cover a wide range of health outcomes and green space types. The methodological quality of each study was assessed. The number of studies published by year show a increasing interest in the topic - almost 75% were published since 2008, with 24% published in 2013 alone.

Overall, 78% of the associations investigated were found to be statistically significant for a positive relationship between green space and at least one aspect of health. The relationship between mental health and green space was most consistent; 92% of the studies found a statistically significant relationship. The overall strength of these studies was assessed as fair. A majority (67%) of studies that looked at aspects of physical health found statistically significant relationships as well. The overall strength of these studies was good, higher than the mental health studies. A large majority (79%) of studies that investigated wellbeing and green space also found significant, positive relationships. The overall strength of these studies was fair.

In all of the health outcomes, the studies that did not find a statistically significant relationship between green space and health had a lower quality than the ones that found a significant relationship.

The main conclusions of this review are:

- Green space improves physical health, mental health and wellbeing of urban residents.
- Frequent access to nearby green space is important, especially for children.
- Nearby green space may provide added benefit in low-income neighbourhoods.
- Green space that is perceived as unsafe and poorly maintained does not provide health benefits.

Introduction

Humans have long recognized the importance of green space in cities. There are records of Egyptian aesthetic gardens dating back 3600 years ago. In ancient Rome, Vitruvius wrote the oldest surviving design manual in 27 BC, where the importance of basic design elements of green spaces was described. The first public parks were built by the Spanish Crown in the 16th century in Europe and the Americas. At the turn of the 20th century, the garden city movement became widespread in the Canada, UK and U.S. Humanity clearly values green space in urban areas and have been attempting to quantify the reasons for over 30 years.

A landmark study by Ulrich (1984) examined the relationship between green space and patient recovery in a Pennsylvania hospital. Surgical in-patients with a view of a natural setting were compared with patients who had a view of a brick wall. Patients who had a view of the natural setting healed faster, had shorter hospital stays and took less pain medication.

Since 2000, many studies have looked at the potential impacts of green space on health. Reviews and synthesis of the green space and health studies (Table 1) have been increasing over the last 10 years and the overwhelming evidence shows statistically significant relationships between health outcomes and green space.

These reviews suggest that the presence of green space in an urban environment is important for people's health for a number of different reasons. For instance, access to safe, natural settings has been found to have a positive influence on overall physical health and wellbeing, increasing rates of physical activity, fostering social connections and reducing stress.

Green space is thought to influence health through many pathways, summarized in Figure 1. The presence of green space can promote physical activity, stress reduction, cognitive restoration and increased social interaction and cohesion. Green spaces help cool down areas in hot weather and improve air quality. These factors then lead to health and wellbeing improvements provided by green space, such as reduced obesity, reduced psychiatric morbidity, reduced cardiovascular diseases and improved birth outcomes.

Green space can have health benefits through a range of exposures, from experiencing green space while not being physically present (i.e. viewing nature through a window), engaging in another activity (e.g. biking through a park) or intentionally engaging in the green space (e.g gardening, hiking, camping, etc.) (James et al., 2015).

The presence of green space provides opportunity for physical activity. It is well established that physical activity is important for good health. Exercise done in a green space seems to provide additional health benefits than exercise done indoors, including greater feelings of enjoyment, energy, vitality, restoration and self-esteem (Nielsen & Hansen, 2007; Coon et al. 2011). Other studies have also found that greener environments were associated with better cardiovascular and mental health greater than what physical activity alone contributed to these outcomes.

Table 1: Summary of published reviews for green space and health outcomes, from 2004 to 2015

	Author(s)	Year	Mental Health	Physical Activity	Wellbeing	Physical Health	Social Connectivity	Cardiovascular Disease	All Cause Mortality	Weight status	Birth Outcomes
1	Health Council of Netherlands	2004	+								
2	Croucher et al.	2007	+	+	+	+					
3	Maller et al.	2009	+	+	+		+				
4	Brodhead	2009	+	+							
5	Kuo	2010	+	+	+	+	+				
6	Bowler et al.	2010	+	+/ns	+			+			
7	Lee & Maheswaran	2010	+		+	+					
8	Barton & Pretty	2010	+								
9	Lachowycz & Jones	2011								+/ns	
10	Blaschke	2013	+		+	+			ns		
11	Cheng & Berry	2013	+	+			+	+			
12	Russell et al.	2013	+		+	+					
13	Keniger et al.	2013	+		+	+					
14	Hartig et al.	2014	+	+/ns			+				
15	James et al.	2015	+	+				+	+	+/ns	+
16	Sandifer et al.	2015	+	+	+	+		+	+		+
17	Shanahan et al.	2015	+	+	+		+				
18	Sallis et al.	2015	+	+			+				
19	Rugel	2015	+				+/ns				

Legend

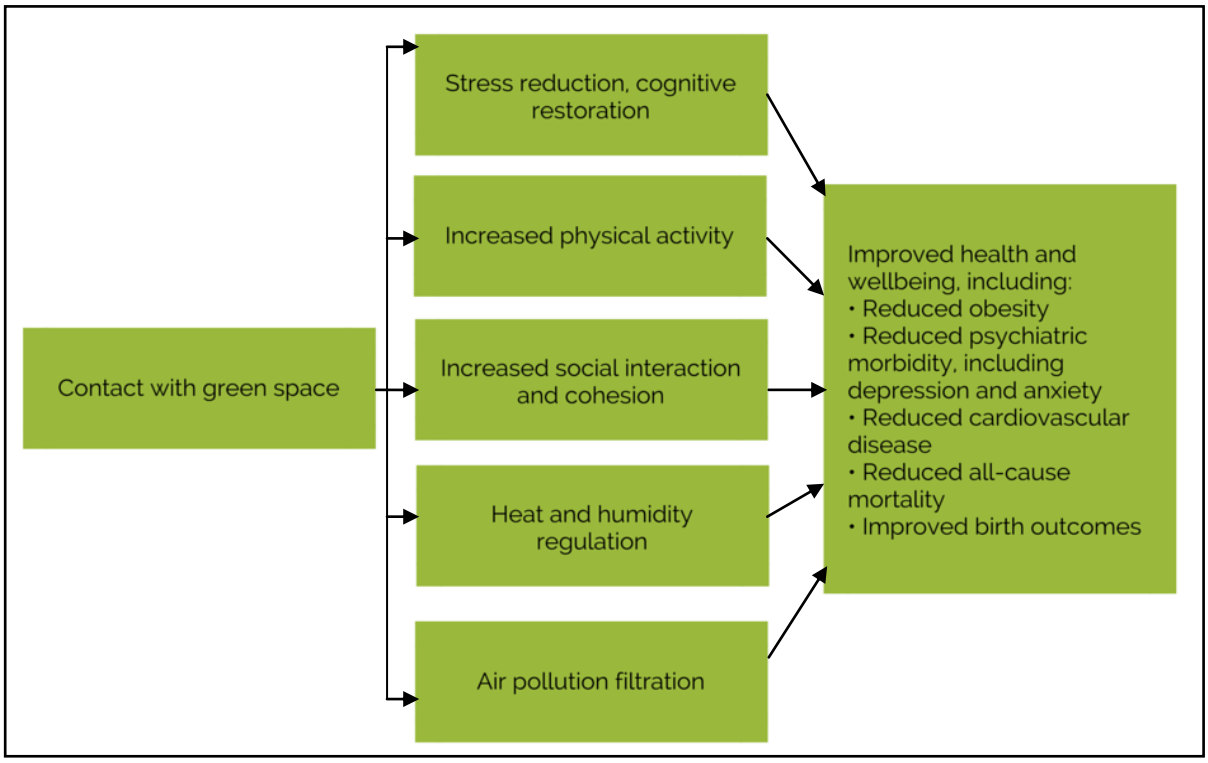
+ indicates the authors found that contact with green space significantly improves a health outcome or behaviour.

ns indicates the authors did not find a significant impact of green space on a health outcome or behaviour.

- indicates the authors found a significant negative impact of green space on a health outcome or behaviour.

Note: a blank cell indicates that the authors did not examine or describe the health outcome

Figure 1: Associations and pathways through which green space benefits health (adapted from James et al., (2015)



Green space has been found to provide restoration from stress and attention fatigue, an improved ability to cope with stress and reported reduction in stress (Grahn & Stigsdotter, 2003; Hartig et al., 2003; Kuo, 2010; Lottrup, Grahn, & Stigsdotter, 2013) which leads to improved health. Good health is also associated with social engagement and cohesion, which green space has been found to increase (de Vries et al., 2013).
To better understand how different types of green space promote good health for residents, Toronto Public Health conducted a critical analysis of existing literature. It is intended to provide planners and policy makers with additional information to guide the provision and design of green spaces in the city.

In this report, green space is defined as any vegetated land within an urban area; it includes parks, gardens, playing fields, children's play areas and school yards, woods and other natural areas, grassed areas and green corridors.

This report provides findings of a systematic meta-narrative review of the evidence, focused on answering the following questions about the relationship between green space and health:

- Does green space impact health outcomes?
- If so, which ones and to what degree?
- Are there green space types and characteristics found to modify the impact of green space on health?
- What are the potential adverse impacts of green space that need to be taken into consideration?

Findings

Profile of studies

The data demonstrates a recent surge of research on the topic of green space and health. Of the 106 studies included in this review, almost 75 percent (74.5%) were published since 2008, with 23.5 percent published in 2013 alone. Most of the studies included in this review are set in an American urban context (44 studies, which accounts for 47.9% of total studies), followed by Europe (32), Canada (7), New Zealand (7) and Australia (3).

Studies that looked solely at physical activity and green space were excluded because of the existing reviews on this subject. However, 17 studies in this report looked at other health impacts of green space also included physical activity as one of the study parameters. Given this, the evidence on physical activity from these studies was included in this review.

Studies included in this review were varied in design and included national-scale epidemiological studies, community and neighbourhood case studies and experimental studies. While the vast majority of studies are cross sectional (78), other approaches include community-based studies (8), case control studies (6), longitudinal studies (5), reviews (7) and mixed methods (2) and control trials (1). Sample size varied considerably from small case studies to a sample size of 40,813,236 (adult population of England below 65 years of age).

Table 2 shows the range of topics explored in the articles reviewed: the type of engagement with green space, the health measure of interest and sub-populations of focus, if any. The type of green space most commonly studied was green space near people's homes. The main type of green space engagement most often studied was general exposure or proximity.

Table 3 shows the results of the strength of evidence assessment. Overall, 78% of the associations investigated were found to be statistically significant for a positive relationship between green space and at least one aspect of health. When broken down into physical health, mental health and wellbeing, the strongest evidence is for physical health, with a mean study quality score of 2.5, which rates as good (Table A3). All the studies that did not find a significant relationship between green space and a health outcome were of lower quality.

There were several common limitations found in the studies, which included:

- A lack of a clear definition of green space and a lack of agreement between studies regarding the definition;
- Lack of the use of accurate measures; for example, some studies relied on perception of green space only, rather than using defined indices such as the Normalized Difference Vegetation Index (NDVI); and
- A reliance on self reported data.

Table 2: Summary of articles reviewed

Aspect	Subject	Number of studies
Types of green space	mixed amount of green space near home	53
	parks	18
	community gardens	7
	play grounds	5
	naturalized woodlands	4
	tree canopy	3
	coastal open space	2
	green streetscape	1
	brownfields	1
Types of engagement with green space	general exposure/proximity (non-specific)	47
	physical activity*	17
	therapeutic rest	11
	social engagement	8
	gardening	7
Subpopulation of focus (if any)	low-socio-economic groups	33
	children and youth	30
	African Americans	9
	low income Hispanics	6
	seniors	5
	women	3
	Aboriginals	1
	refugees seeking asylum	1

*This review excluded studies that looked solely at physical activity and green space. However, some studies also included physical activity as one of the study parameters and are included here.

Table 3: Assessed strength of evidence for health outcomes

Health Outcome	Direction of association[1]	# of Studies[2]	Mean Quality Score (range: -5 to 5)
Physical Health	↑	**31**	**2.5**
	-	13	1.3
	↓	3	0.3
	Total:	47	
Mental Health	↑	**34**	**1.9**
	-	3	-0.7
	↓	0	n/a
	Total	37	
Wellbeing	↑	**42**	**1.8**
	-	11	-0.1
	↓	0	n/a
	Total	53	

1. ↑ indicates a statistically significant positive relationship, which is defined as green space access or exposure leading to an improvement in a health outcome.
   ↓ indicates a significant negative relationship, which is defined as green space access or exposure leading to a worsening of a health outcome.
   - indicates no significant relationship was found in either direction.
2. Where a study investigated more than one health outcome, each is separately included under each different outcome.

Health outcomes

Physical Health

In this report, physical health is defined as the health outcomes and attributes associated with the human body, ranging from birth outcomes to all-cause mortality. The majority of studies (67%) found that exposure to green space was beneficial to physical health. These studies were of good quality (mean quality score = 2.5) compared to the studies that either found no relationship or in the case of three studies, a negative relationship (Table 4).

Table 4: Assessed strength of evidence for physical health outcomes

Health Outcome	Direction of association[1]	# of Studies[2]	Mean Quality Score (range: -5 to 5)
Physical Health	↑	**32**	**2.5**
	-	13	1.3
	↓	3	0.3
	Total:	48	
Health outcomes included in Physical Health Total			
Healthy weights	↑	11	2.1
	-	11	1.2
	↓	0	n/a
Birth outcome	↑	8	2.6
	-	0	n/a
	↓	0	n/a
Cardiovascular disease	↑	5	2.7
	-	1	2
	↓	0	n/a
All-cause mortality	↑	4	3.3
	-	0	n/a
	↓	1	0
Respiratory disease	↑	2	3
	-	1	2
	↓	1	-1
Cardiometabolic risk factors	↑	1	1
	-	0	n/a
	↓	0	n/a
Morbidity	↑	1	3
	-	0	n/a
	↓	0	n/a
Skin cancer	↑	0	n/a
	-	0	n/a
	↓	1	2

Simply being near green space can improve health and wellbeing (De Vries et al., 2003; Evans et al., 2003; Grahn & Stigsdotter, 2003; Maas et al., 2006; Nielsen & Hansen, 2007; Mitchell & Popham, 2008Van den Berg et al., 2010; Korpela et al., 2011; Lottrup et al., 2013; Richardson et al., 2013). This may be due to the findings that green space exposure can reduce stress and restore cognitive function. Physiological data measured by Ulrich (1984) suggests that natural settings elicit a response that includes a component of the parasympathetic nervous system associated with the restoration of physical energy.

The highest quality score a study received in this review was a four (very good). In the Physical Health category, four studies that examined healthy weights and green space achieved a quality score of four:

- Ohri-Vachaspati et al., 2013
- West et al., 2012
- Villeneuve et al., 2012
- Bell et al., 2008

Ohri-Vachaspati et al. (2013) assessed 702 children, ages 3-18, living in four low-income cities in New Jersey. They found significant associations between children's weight status and the presence of a large park within 800m (1/2 mile) radius. Bell et al. (2008) also looked at children's weight status associated with neighbourhood greenness in areas with high population density. Higher greenness was associated with lower odds of children and youth increasing their BMI z-scores (a measure of relative weight adjusted for child age and sex) over a 2 year period.

A study of large US cities looked at the association of available parkland, physical activity and body weight (West et al., 2012). It found significant positive correlations between park density and both physical activity and healthy weights.

Villeneuve et al., (2012), along with three other studies looked at all cause mortality at the neighbourhood level all found a significant inverse relationship with mortality and green space – mortality rates decrease with increasing neighbourhood greenness (Mitchell & Popham, 2008; Villeneuve et al., 2012; Harlan et al., 2013; Xu et al., 2013) .

Three studies found a negative relationship between green space and health (Richardson et al., 2012; Astell-Burt et al., 2013; Lovasi et al., 2013a). An Australian study (Astell-Burt et al., 2013) found a strong correlation between green space use and skin cancer ($p<0.001$). People who lived in greener areas spent more time outdoors which leads to an increase in the risk of skin cancer; people who resided in areas with >80% green space had a 9% (adjusted odds) higher chance of having skin cancer than those with 0–20% green space.

Another study found that high tree canopy cover near a child's prenatal address was associated with higher prevalence of allergic sensitization to tree pollen at age 7 (Lovasi et al., 2013a). However, information was not available on the effect of specific tree species had on sensitization.

Richardson et al. (2012) looked at green space coverage at the city level in the U.S. and selected mortality rates. While there was no association found between greenness and mortality from individual causes, such as heart disease or automobile accidents, mortality from all causes combined was significantly higher in greener cities. The authors propose that this could be due to

the nature of American cities - greener cities tend to have more sprawl and higher levels of car dependency.

At the neighbourhood level, healthy weights, body mass index (BMI) and obesity has been the focus of several studies (Table 4). Half of the studies (11) have found statistically significant evidence that access and use of green space positively impacts weight status (Lachowycz & Jones, 2011, Koohsari et al., 2015), while the other half did not have statistically significant findings. These studies had a much lower mean quality score (1.2) than the studies that had statistically significant findings (mean quality score 2.1).

The findings for physical activity and green space have a similar pattern. Lachowycz and Jones (2011) reviewed 60 studies and found that the majority of studies (68%) found some evidence of a positive association between the presence of green space and increased physical activity, while 40% of those found a strong, unambiguous link. Koohsari et al. (2015) suggests that the mixed findings may be due to conceptual and methodological issues with the studies.

Park playgrounds are found to be important for supporting healthy weights. One study found that of 13 public park characteristics examined (e.g., open space, path, wooded area), children with a park playground located within one kilometre of their home were almost five times more likely to be classified as being of a healthy weight than those without nearby playgrounds (Potwarka, Kaczynski & Flack, 2008).

Mental Health

Mental health is a state of being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community (WHO, 2015). An overwhelming majority of studies (92%) that looked at mental health found statistically significant associations between green space and positive mental health (Table 5). These studies had an average quality score of 1.9 (fair). Studies that found no relationship were of poor quality (mean quality score = -0.7). No studies found a negative relationship.

Most of the studies (22 out of 37) investigated the impact green space has on stress, anxiety or depression. Anxiety disorders, which can be severe and debilitating, are one of the most common mental illnesses.

Four studies that examined the association between green space and mental health had a quality score of 4 (very good):

- Jiang et al. (2014)
- White et al. (2013)
- Maas et al. (2008)
- Kuo & Sullivan (2001)

Table 5: Assessed strength of evidence for mental health outcomes

Health Outcome	Direction of association[1]	# of Studies[2]	Mean Quality Score (range: -5 to 5)
Mental Health	↑	**34**	**1.9**
	-	3	-0.7
	↓	0	n/a
	Total	37	
Health outcomes included in Mental Health Total			
Stress, anxiety, depression	↑	21	1.9
	-	1	-2
	↓	0	n/a
Self reported mental health	↑	10	1.6
	-	2	0
	↓	0	n/a
ADD/ADHD symptoms	↑	3	2.3
	-	0	n/a
	↓	0	n/a

Jiang et al. (2014) looked at the dose–response relationship between the impact of tree cover density on stress reduction. They showed participants a 6-minute, 3-D video of community street scenes with varying level of tree canopy and measured skin conductance and salivary cortisol levels as measures of participants' stress. For men, there was a significant dose–response inverted-U shape curve, while no significant relationship between tree cover density and stress reduction was found for women.

Both White et al. (2013) and Maas et al. (2008) used very large data sets and both found statistically significant relationships between green space and mental health. White et al. (2013) used data from the British Household Panel Survey, a nationally representative longitudinal survey of households in the UK that ran annually from 1991-2008, containing information from over 10,000 individual adults. They found that people reported lower mental distress and higher wellbeing when living in urban areas with more green space.

These findings are consistent with another large (n=10,089), high quality study conducted in the Netherlands by Maas et al. (2008). They looked at social contacts and health in relation to the percentage of green space within a one or three kilometre radius around an individual's residence. After adjustment for socio-economic and demographic characteristics, less green space in people's living environment was significantly associated with feelings of loneliness and with perceived shortage of social support.

Kuo & Sullivan (2001) compared levels of aggression for 145 urban public housing residents randomly assigned to buildings with varying levels of nearby nature (trees and grass). Residents living in the greener areas reported less aggression, violence and mental fatigue than did residents living in the relatively barren buildings.

While only three studies looked at children with ADD/ADHD and green space, all were good quality (mean score 2.3). The findings were consistent and all found that attention deficit symptoms significantly decrease when children play in an environment with big trees and grass (in comparison to other settings without green space). It was also found that the greener a child's play area, the less severe his or her attention deficit symptoms (Taylor, Kuo & Sullivan, 2001). Another study found that a 20-minute walk in an urban park improved concentration performance of children with ADHD (Kuo, 2010).

Wellbeing

There are many aspects that contribute to a feeling of wellbeing, including social connectivity, feeling healthy and the ability to cope with life stresses. General wellbeing means that people experience (Cacioppo & Patrick, 2008):

- Sense of belonging and purpose
- Happiness
- Better recovery from illness
- Longer life expectancy

This area of study can be difficult to study empirically because the results are usually based on self-assessment of participants. The mean quality score for the 53 studies that looked at associations between green space and wellbeing was 1.8 (fair). Of these studies, 79% found statistically significant associations between green space and wellbeing (Table 6). As with the other health outcomes, the studies that found no relationship were of poorer quality (mean quality score = -0.1). No studies found a negative relationship.

Table 6: Assessed strength of evidence for wellbeing

Health Outcome	Direction of association[1]	# of Studies[2]	Mean Quality Score (range: -5 to 5)
Wellbeing	↑	**42**	**1.8**
	-	11	-0.1
	↓	0	n/a
	Total	53	
Health outcomes included in Wellbeing Total			
Self reported wellbeing	↑	23	1.6
	-	6	-0.7
	↓	0	n/a
Self reported health	↑	13	2.9
	-	5	0.6
	↓	0	n/a
Inequity	↑	5	3.2
	-	0	n/a
	↓	0	n/a
Cognitive functioning	↑	1	0
	-	0	n/a
	↓	0	n/a

Four studies that examined the association between green space and wellbeing, one of which looked specifically at reducing health inequities through green space (Mitchell & Popham, 2008), had a quality score of 4:

- White et al. (2013)
- Maas et al. (2009)
- Mitchell & Popham (2008)
- Maas et al. (2006)

As with the other high quality studies, these four studies had well defined measures, well defined green space measurements and large sample sizes. Two of the studies used data from 10,000 individuals (White et al., 2013; Maas et al., 2009), while Maas et al. (2006) used the data of 250,782 people. The largest sample size included in this review was in Mitchell & Popham (2008) which looked at the data from 40,813,236 individuals. All four of these studies found statistically significant positive associations between green space and some aspect(s) of wellbeing.

Maas et al. (2006) found that the percentage of green space inside a one kilometre and a three kilometre radius of residences had a significant relation to perceived general good health and the relationship was more pronounced for lower socioeconomic groups. Maas et al. (2009) tried to clarify these findings with more specific measures and found that people with more green space in their living environment reported less loneliness, which can have negative health impacts. White et al. (2013) had similar findings - people who live in areas with less green space report significantly lower mental distress and significantly higher wellbeing (as indexed by life-satisfaction ratings).

Equity

There were five studies that looked at low-income neighbourhoods and/or vulnerable populations and all found a significant positive association between green space and health for these groups (Mitchell & Popham, 2008; Mundel et al., 2010; Dadvand et al., 2012; Dadvand et al., 2014; Xu et al., 2013). For instance, Mitchell & Popham (2008) classified the population of England at or below retirement age into area-based income deprivation and green space exposure groups. They found that income deprivation related health inequalities in all-cause mortality and mortality from circulatory diseases were significantly lower among populations resident in the greenest areas.

Types of green space and health

The majority of research on green space and health consists of epidemiological studies that relate health outcomes to the presence of green space within a certain distance to place of residence. A few studies compare specific characteristics of green space such as parks, playgrounds and community gardens, which are described below.

Parks and playgrounds

Among the research on parks and children, playgrounds are found to be associated with healthy weights. One study found that children with a park playground located within one kilometre of their home were almost five times more likely to be classified as having a healthy weight than those without nearby playgrounds (Potwarka, Kaczynski & Flack, 2008). Another study found that children were more active on playgrounds that included a diversity of elements, such as shade

structures, banners, gardens, public art and student art as opposed to playgrounds with few amenities (Anthamatten et al., 2011).

Community gardens

Several case studies look at the relationship between community gardens, including urban agriculture and health. One of these studies was conducted in South-East Toronto, which includes the Regent Park neighbourhood (Wakefield et al., 2007).

These studies have found that people who use community gardens report:

- improved access to food
- better nutrition
- increased physical activity
- improved mental health
- enhanced social health and community cohesion (Wakefield et al., 2007; Comstock et al., 2010; Castro, Samuels, & Harman, 2013; Zick et al. 2013)

One case study looked at formerly homeless, HIV-positive men participating in a community garden program. The men that gardened reported fewer distress symptoms, improved overall general health and reduced frequency of illegal drug use than those who did not participate in the program (Shacham et al., 2012).

Features of green space that promote health

Several studies have found that the most beneficial green spaces are those that promote inclusivity and respond to the needs of various ages, ethno-cultural interests and levels of mobility (Tinsley et al., 2002; Kytta et al., 2010; Gidlow & Ellis, 2011). For example, an inclusive park is one with a playground for children, wheelchair accessible paths, places to sit and a place for a group to gather.

Attributes of green space, such as safety, good maintenance, interesting features (e.g. art tiles, banners, variety of plant species) and inclusiveness are associated with feelings of better health and wellbeing. In terms of psycho-social stress, several studies found that perceptions of green space quality was even more important than green space quantity (Francis, Wood, & Giles-Corti, 2012; De Vries et al., 2013). In fact, perceived safety and upkeep of green space may have the greatest influence over whether or not it is used (Maas et al. 2008; Habarth, Graham-Bermann & Bermann, 2009). A perceived lack of care is associated with poorer self-reported health, neighbourhood dissatisfaction, stress, exclusion and poorer mental health (Guite, Clark, & Ackrill, 2006; Gidlow & Ellis, 2011; Masuda et al., 2012). One of the benefits of green spaces is the impact it has on healthy weights in children (Veugelers et al., 2008; Bell, Wilson & Liu, 2008; Christian et al., 2011), particularly in low-income settings (Burdette & Whitaker, 2004; Lovasi et al., 2013b) but this relationship is only significant if the park is perceived as safe.

The specific features that modify the impact of green space on health outcomes are difficult to determine and are likely to vary from context to context (Kyttä, Kahila & Broberg, 2010). However, based on the research available, the characteristics found to be most beneficial to health are summarized in Table 7.

Distance to green space and health

Many studies exploring distance to green space focus on its relationship to body mass index and healthy weights in children. Some studies show that the presence of a park in close proximity to home (e.g., within a one kilometre radius) is associated with lower odds of a child being overweight or obese (Wolch, Wilson & Fehrenbach, 2005; Ohri-Vachaspati et al., 2013). Other studies found no associations between distance to parks and weight status among children (Liu et al., 2002; Burdette & Whitaker, 2004).

These mixed results may indicate confounding variables, such as safety and other social factors (Potwarka et al., 2008; Lachowycz & Jones, 2011; Christian et al., 2011). Other objective and subjective measures of park accessibility may provide an improved understanding of green space distance and its relationship with the weight status of children.

Distance to green space may also influence healthy births (Kihal-Talantikite et al., 2013). A recent, large U.S. study used hospital perinatal database (n=80,000) to study the relationships between green space and birth weight (in term born infants), preterm deliveries and preeclampsia. They found a significant increase in birth weight and decrease in preterm deliveries in relation to the amount of green space within a 50 metre radius of home (Laurent et al., 2013).

Green space close to home has been found to be significant for other health outcomes. Grahn and Stigsdotter (2003) found that adults do not compensate for lack of green space in their own residential area by visiting public parks or other green spaces farther away. Closer proximity to green space is associated with reduced morbidity (Maas et al., 2009a), reduced stress and a lower likelihood of obesity (Neilsen & Hansen, 2007). These findings are supported by another study that found living more than one kilometre away from the nearest green space is associated with poorer health and decreased quality of life (Stigsdotter et al., 2010).

Density of green space and health

Similarly to distance, high neighbourhood density of green space (proportion of an area that is classified as green space) is associated with several positive health outcomes, ranging from healthy births to reduced morbidity (Table 8), particularly for older adults, children and youth and low socio-economic groups (Maas et al., 2006; Maas et al., 2009a).

One study conducted in the Netherlands investigated whether physician-assessed morbidity is related to the relative amount of green space in living environments (Maas et al., 2009a).The study found that the prevalence of 15 out of 24 disease clusters was significantly lower in home environments with greater relative green space within a one kilometre radius. The relationship was strongest for anxiety disorder and depression and for children and people of lower socio-economic status.

Table 7: Green space features that have been shown to positively impact health

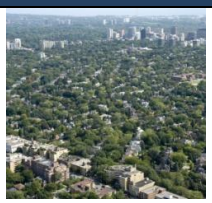
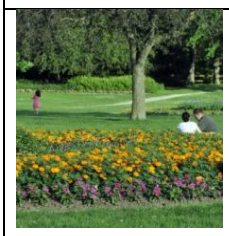
Feature		Feature	
	High neighbourhood green space density		Green space in close proximity to residences
	Diversity of plants		Perceived cleanliness
	Perceived safety		Play structures
	Grass and large trees		Water features
	Community garden		Accessible to a range of ages and mobility levels

Table 8: Density of green space has been found to be significantly associated with several health outcomes

Health Benefit	Related Study
• lower stress levels and a greater resilience to stressful life events	Van den Berg, et al., 2010; Nielsen & Hansen, 2007
• healthy weights	Lachowycz & Jones, 2011; Norman et al., 2010; West, Shores & Mudd, 2012; Bell et al., 2008
• reduced morbidity	Maas et al., 2009a
• reduced risk of cardiovascular disease	Mitchell & Popham, 2008; Maas et al., 2009a
• lower risk of heat-related stress and morbidity	Harlan, Declet-Barreto, Stefanov & Petitti, 2013
• healthy blood pressure	Hartig et al., 2003
• improved cardio-metabolic health (reduced risk of diabetes, heart disease or stroke)	Paquet et al., 2013
• healthy pregnancy and births	Kihal-Talantikite et al., 2013; Donovan et al., 2011; Laurent et al., 2013; Dadvand et al., 2012

Conclusions

Green space benefits the physical health, mental health and wellbeing of urban residents.
There is good evidence that green space is associated with better health. Increased green space density is associated with several positive health outcomes, including healthier births, reduced all-cause mortality and decreased stress**.**

The numerous benefits of green space far outweigh potential negative impacts. These negative aspects include increased risk of skin cancer, contact with insects carrying vector borne-diseases and poisonous plants. Increasing the tree canopy near residences may also slightly increase the chance of pollen sensitization in children. The adoption of protective measures can reduce these risks.

Frequent access to nearby green space is important, especially for children.
Children who live near parks and playgrounds are more likely to have healthy weights, improved cognitive function, reduced stress and reduced ADD/ADHD symptoms.

Nearby green space may provide added benefit in low-income neighbourhoods.
While all segments of the population benefit from exposure to green space, children and low-income groups appear to benefit the most. Increasing access to nearby green space, particularly in low income neighbourhoods, may offer considerable opportunities for reducing health inequalities.

Green space that is perceived as unsafe and neglected does not provide health benefits.
Several studies indicate that perceptions of safety and good maintenance are more important than the specific characteristics of the green space. Green space that is poorly maintained or perceived as unsafe or unsatisfactory has been shown to increase stress and negatively impact the health and wellbeing of residents.

Many of the studies have methodological limitations, such as reliance on self reported health data and perceptions of green space. There are many confounding variables involved, such as selection effects where more active or health conscious people choose to live in greener environments. Another challenge encountered with this area of research is the confounding variable of socioeconomic factors. While several studies adjust for this, there are many others the inadequately take these into account.

Further research is needed to understand confounding factors in the relationship between green space and health. Large, epidemiological studies based on objective health data is needed to address the methodological limitations of previous studies. Also, community-driven initiatives and Toronto based studies can add to the evidence base and provide much needed context specific research.

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Appendix A: Methods

Meta-narrative review

To consolidate the evidence on green space and health, we applied a meta-narrative systematic review. This method of systematic review was developed out of the need to support complex policy-making questions, where the evidence-base includes many different theories, disciplines and study designs (Barnett-Page & Thomas, 2009). This approach is ideal when there is a need to: examine a range of methods to studying an issue (as opposed to a single intervention); interpret and create an account of different streams of evidence; create an overarching meta-summary of the findings (see Gough, Thomas & Oliver, 2012). The approach is well-suited to evidence reviews on human health and the environment, where there is typically a complex, diverse and interdisciplinary evidence base (see Masuda, Zupancic, Poland & Cole, 2008; Greenhalgh et al., 2005). To identify and understand the current evidence on green space and health in an urban setting, we followed six standard review stages (see Wong, Greenhalgh, Westhorp et al., 2013):

- Scoping
- Systematic searching
- Article appraisal and quality assessment
- Data extraction
- Data analysis and synthesis
- Integration and results reporting

Landmark papers and reviews on green space and health were explored to develop the search protocol (See Table A1). The search protocol and quality criteria are shown in Table A2. Studies were included if they looked at one or more human health outcome, set in urban areas in North American, Europe, Australia or New Zealand and published after 2000.

After systematic searching, two reviewers independently appraised the resulting 795 articles, by title and abstract and rejected articles that failed to meet either the inclusion or quality criteria (Figure 2). Disputed articles were accepted for full review (see Appendix B for article exclusion tool). Due to the large scope of the review, we excluded studies that focussed on the indirect benefits of green space (e.g. heat mitigation, air quality mitigation and other climate change related benefits).

A number of studies explored the relationship between green space and physical activity. Because this review is focused on direct health outcomes, only studies that explored physical activity and green space in relationship to a direct health outcome were accepted. For a review of the evidence on green space and physical activity in general, see page 185 of Lachowycz and Jones (2011).

The reference lists of the accepted 104 articles were searched to identify additional relevant studies. A total 106 studies were selected for full review. Two reviewers then independently applied a standard data extraction form and provided a brief narrative of each article's contribution, if any, to the seven review questions (see Appendix C for data extraction form). Simple variables, such as date, author, city, study method, green space type and health impact,

were also recorded. Raw inter-rater concordance (the degree of agreement between reviewers) averaged 94 percent, with a range from 87.3 percent to 100 percent across variables.

Strength of evidence assessment

Once the articles were extracted for the meta-narrative review, they were assessed and given a total quality score ranging from -5 (lowest quality, weakest evidence) to 5 (high quality, strong, reliable evidence) (Table A3). A primary reviewer conducted the quality analysis on all eligible articles and a secondary reviewer conducted a quality analysis on a 20% random sample to assess the degree of inter-rater reliability.

The studies were scored on -1 to 1 on each of the following criteria:

1. Study design (using the Oxford Centre for Evidence-based Medicine Level of Evidence)
2. Sampling strategy
3. Measures and data collection
4. Statistical analysis
5. Clarity of findings

To simplify interpretation, we termed 'positive relationship' as one that denotes green space improving a health outcome. For example, nearby parks were associated with a decrease in anxiety symptoms and an increase in reported wellbeing. Both of these associations are described as positive associations in this report. Where a study investigated more than one health outcome, each is separately included under each different health outcome.

Figure 2: Article selection process and results

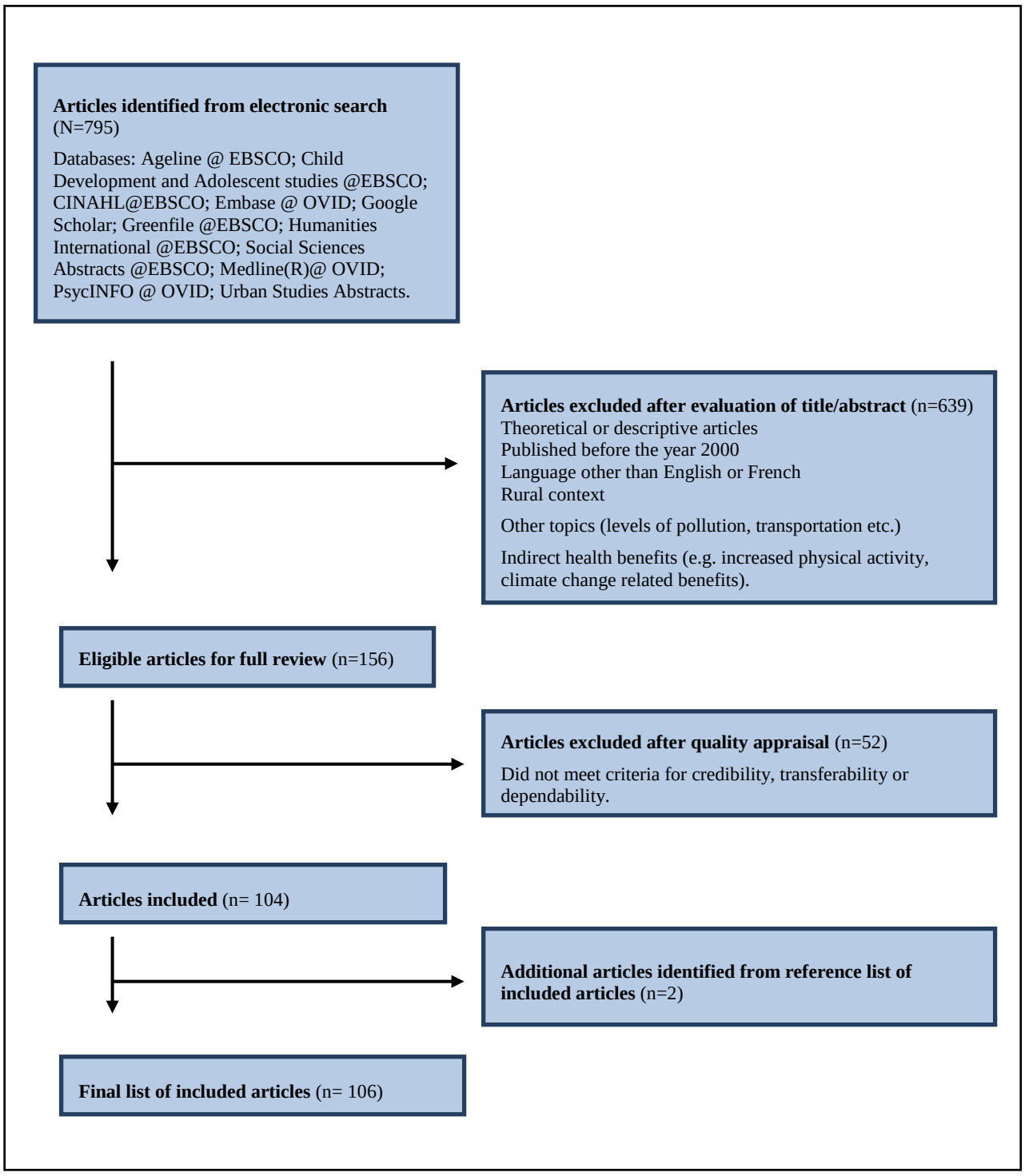

Table A1: Scoping: selected landmark studies and reviews on green space and health

Landmark papers Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of environmental psychology*, *15*(3), 169-182. Kaplan, R., Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge: Cambridge University Press. Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15,169–182. Ulrich, R. (1984). View through a window may influence recovery. *Science*, *224*(4647), 224-225.
Reviews Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*(1), 456. Kaczynski, A. T., Henderson, K. A. (2007). Environmental correlates of physical activity: a review of evidence about parks and recreation. *Leisure Sciences*, *29*(4), 315-354. Lachowycz, K., & Jones, A. P. (2011). Green space and obesity: a systematic review of the evidence. *Obesity reviews*, *12*(5), e183-e189. Lee, A. C. K., & Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health*, *33*(2), 212-222.

Table A2: Search protocol and quality criteria

Inclusion criteria	Empirical studies from peer reviewed, grey and white literature on the relationship between green space and human health that: • Explicitly explore one or more human health impact • Are focused on the health of residents in urban and peri-urban settings in North America, Europe, Australia or New Zealand • Were published between the year 2000 and 2014 Literature search was conducted November to December 2013 and repeated in November 2014.
Exclusion criteria	• Theoretical or descriptive articles that do not include original empirical findings • Papers published before the year 2000 • Articles written in languages other than English or French • Studies focusing on green space in a rural context • Studies on the impact of green space on other topics, such as levels of pollution or transportation planning • Studies that focus on the indirect benefits of green space (e.g. increased physical activity, heat mitigation, air quality mitigation and other climate change related benefits)

Terms and key words	*Health*: our review defines health broadly and includes both objective and subjective measures of physical, mental and social wellbeing (see Ottawa Charter for Health Promotion. WHO, Geneva, 1986). *Green space*: noncommercial, public open space intended for human rest, exercise, play, recreation or plant growing. *Urban:* city settings that include urban, suburban and peri-urban contexts in North America, Europe, Australia and New Zealand. Keywords: (Health): well being OR health OR physical health OR mental health OR social health OR psychosocial health OR diabetes OR cancer OR asthma OR chronic disease OR obesity OR equity OR equality OR inclusion AND (Green Space): green space OR playground OR public park OR garden* OR community garden* OR landscap* OR field* OR green path OR trail OR brownfield OR wildlife OR habitat OR natural* OR living wall OR green roof* OR open space OR green corridor AND (Urban): urban OR peri urban OR suburban OR high rise OR vertical community OR towers OR inner city OR high density OR low-income AND (Setting): Canad* OR United States Or America* OR Europe* OR Australia OR New Zealand OR Mexico
Electronic Databases (n= 11)	Ageline @ EBSCO; Child Development and Adolescent studies @EBSCO; CINAHL@EBSCO; Embase @ OVID; Google Scholar; Greenfile @EBSCO; Humanities International @EBSCO; Social Sciences Abstracts @EBSCO; Medline(R)@ OVID; PsycINFO @ OVID; Urban Studies Abstracts.
Quality Criteria	This review draws on a diversity of studies, methods and disciplines. As a result, no single set of quality criteria could be applied, since each study would have to be assessed in its particular research tradition. Articles were appraised and accepted if they met the three following quality criteria (see Hannes, 2011, Cochrane Collaboration Qualitative Methods Group): • *Credibility:* evidence of outside auditors or participants validating findings, such as peer debriefing, expert advisor, or independent analysis of data by more than one researcher • *Transferability:* providing details of the study participants and context, to enable reviewers to evaluate which target groups or context the study applies; • *Dependability:* clear documentation of methods, with third party validation or peer review. See Appendix A for article exclusion and quality assessment tool

Table A3: Strength of evidence quality descriptions

Quality score range	Description
-5 to -3.1	Very poor
-3 to -0.1	Poor
0 to 1.9	Fair
2 to 3.9	Good
4 to 5	Very good

Appendix B: Article Exclusion Tool

Articles were accepted into the review based on meeting the inclusion criteria and quality criteria. Contested articles were accepted for full article review. Since this review draws on a diversity of studies, using various mixed methods, study sizes, etc., no single set of quality criteria was applied, since each study would have to be assessed in its particular research tradition. Articles were appraised for quality based on the following criteria:

> *Credibility:* evidence of outside auditors or participants validating findings, such as peer debriefing or independent analysis of data by more than one researcher.
> *Transferability:* providing details of the study participants and context, to enable reviewers to evaluate which target groups or context the study covers.
> *Dependability:* clear documentation of methods with third party validation or peer review. (see: Hannes, 2011, Chapter 4 in *Supplementary Guidance for Inclusion of Qualitative Research in Cochrane Systematic Reviews of Interventions*).

Based on the above criteria, accepted articles were empirical studies with a clear description of a) methods and underlying methodology, b) the context and settings and c) evidence of third party advisors (i.e. peer review, expert advisory board etc.). Descriptive papers, editorials or opinion papers were excluded.

1. **Article number**	2. **Article citation**
3. **Acceptance**	4**. Reason for rejection***

*Reasons for rejection

- Non-empirical (theoretical, narrative or opinion articles – no original empirical findings)
- Published before the year 2000
- Written in languages other than English and French
- Focus is on green space in a rural context
- Focus is on impact of green space on other topics, such as levels of pollution, transportation planning
- Focus is on the indirect benefits of green space (e.g. increased physical activity, heat mitigation, air quality mitigation and other climate change related benefits).
- Credibility*:* The article ***does not*** show evidence of outside auditors or participants validating findings (examples: no reference to peer debriefing, advisory board or independent analysis of data by more than one researcher)
- Transferability*:* The article ***does not*** provide details of the study participants and context, to enable reviewers to evaluate which target groups or context the study covers
- Dependability*:* The article ***does not*** provide clear documentation of methods and underlying methodology.

Appendix C: Data extraction form

1. Each reviewer independently reviewed each article, using the data extraction form developed in correspondence to the seven research questions. Reviewers recorded simple variables, such as article year, publisher, author, city, neighbourhood type and green space type etc. After reading the full text of each article, the reviewers provided a brief narrative of the article's contribution and relevance, referring to specific data as they relate to each other.

2.1 Short answer

2.1.1 ☐ Reviewer 1 ☐ Reviewer 2

2.1.2 Title 2.1.3 Year 2.1.4 Authors

2.1.5 Publisher 2.1.6 City

2.1.7 Setting (if specified)

☐ urban ☐ periurban ☐ other _____

☐ vertical (high rise) ☐ suburban

3. Green space type (if specified)

☐ public parks ☐ green path/ trail ☐ open public space

☐ garden ☐ brownfield ☐ green corridor

☐ community gardens ☐ living wall ☐ other _____

☐ naturalized area ☐ green roof

4. Engagement with green space (if specified)

☐ physical activity ☐ therapeutic (rest, relaxation) ☐ social engagement (inclusion)

☐ close proximity to residence ☐ gardening ☐ other _____

5. Health concern of focus (if specified)

☐ chronic disease ☐ diabetes ☐ cancer

☐ asthma ☐ cardiovascular disease ☐ psychosocial health

☐ addiction and mental health ☐ depression ☐ Alzheimer's/ dementia

☐ anxiety ☐ other _____

6. Population (if specified)

☐ lifespan ☐ children ☐ youth

☐ older adults ☐ socio-economic status ☐ low income

☐ occupational ☐ minority group ☐ mental health status

☐ other priority population ☐ physical health status ☐ other _____

7. Type of study

☐ cross sectional	☐ case control	☐ cohort
☐ ethnography	☐ grounded theory	☐ mixed method
☐ phenomenology	☐ review	☐ other

8. Narrative account of article: limit to one paragraph (4-5 sentences plus relevant statistics)

8.1 Study purpose and method.

8.2. Key findings. Be sure to document important statistics to support study findings.

8.3. Study implications.

8.4. Study limitations.

8.5. Unique features of the green space in the study, if any

8.6. Health tradeoffs described in relation to green space use or planning. Be sure to document important statistics to support critique.

8.7. Risks described in relation to green space use or planning. Be sure to document important statistics to support critique.