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Does the built environment moderate the relationship between having a disability and lower levels of physical activity? A systematic review

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ABSTRACT

The relationship between the built environment and physical activity has been well documented. However, little is known about how the built environment affects physical activity among people with disabilities, who have disproportionately higher rates of physical inactivity and obesity. This study is the first systematic review to examine the role of the built environment as a moderator of the relationship between having a disability (physical, sensory or cognitive) and lower levels of physical activity. After conducting an extensive search of the literature published between 1990 and 2015, 2039 articles were screened, 126 were evaluated by abstract and 66 by full text for eligibility in the review. Data were abstracted using a predefined coding guide and synthesized from both qualitative and quantitative studies to examine evidence of moderation. Nine quantitative and six qualitative articles met the inclusion criteria. Results showed that most research to date has been on older adults with physical disabilities. People with disabilities described how aspects of the built environment affect neighborhood walking, suggesting a positive moderating role of features related to safety and aesthetic qualities, such as benches, lighting and stop light timing. There were mixed results among studies that examined the relationship quantitatively. Most of the studies were not designed to appropriately examine moderation. Future research should utilize valid and reliable built environment measures that are more specific to disability and should include people with and without disabilities to allow for testing of moderation of the built environment.

1. Introduction

Based on the World Health Survey of 59 countries, the average prevalence of disability is around 18% among adults age 18 and older (World Health Organization, 2011). People with disabilities comprise 22% of the U.S. adult population, or 53.3 million people (Courtney-Long et al., 2015) and is a population made up of individuals who experience limitations in physical mobility (difficulty walking or unable to walk), sensory function (vision and hearing difficulties), and/or cognition (intellectual disabilities). Individuals with physical disabilities are the largest subgroup (13.0%) (Courtney-Long et al., 2015).

People with disabilities have been described as an unrecognized health disparate population (Krahn et al., 2015). For example, when compared to people without disabilities, people with disabilities were more likely to report no physical activity (47.1% vs. 26.1% respectively) (Carroll et al., 2014) or be obese (41.6% vs. 29.1% respectively) (Froehlich-Grobe et al., 2013).

Physical inactivity can contribute to obesity (Liou et al., 2005), increased healthcare costs and utilization (Arterburn et al., 2005), depression (Liou et al., 2005) and secondary health conditions (Rasch et al., 2008) among people with disabilities. Whereas participation in physical activity has been shown to positively benefit people with disabilities (Rimmer, 2005; Van der Ploeg et al., 2004) in terms of weight loss (Rimmer et al., 2000), psychosocial improvements (Rimmer et al., 2000), self-efficacy (Zemper et al., 2003), and a higher quality of life (Buffart et al., 2009).

While the benefits of engaging in regular physical activity are well-known, people with disabilities experience many barriers that make physical activity opportunities more challenging to access. There have been numerous studies examining perceived barriers and facilitators to physical activity among people with disabilities (Bloemen et al., 2015). Major access barriers to physical activity have include lack of accessible physical activity sites and transportation to these sites (Rimmer et al., 2004). The accessibility of the design of pedestrian infrastructure as well as the maintenance of the infrastructure have been described as barriers to outdoor walking among people with disabilities (Kirchner et al., 2008; Rosenberg et al., 2013).

Abbreviations: PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; GIS, Geographic Information Systems; LTPA, Leisure Time Physical Activity.

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Searching for new ways to address the lack of physical activity among people with disabilities has become an international focus. Both the United Nations Conventions on the Rights of Persons with Disabilities and the United Nations Educational, Scientific and Cultural Organization aim to address inequities that individuals with disabilities experience by addressing individual rights, inclusion, and access to physical activity and sports(UNESCO, 2015; United Nations, 2006). In the United States, one of the Healthy People 2020 objectives is to, "Reduce the proportion of people with disabilities who report physical or program barriers to local health and wellness programs" (Healthy People 2020, 2015).

1.1. The built environment and physical activity

The built environment has been described as having 3 dimensions: density, destinations and design (Cervero and Kockelman, 1997). *D*ensity represents the population density of a neighborhood and areas of higher residential density have been associated with increased walking (Frank et al., 2005). The number and variety of *D*estinations in a local area that one has access to is associated with increased physical activity (Brownson et al., 2009; Fan and Jin, 2014; Khan et al., 2009; Papas et al., 2007). Lastly, the *D*esign of the built environment includes the aesthetics, the sidewalk infrastructure, pedestrian safety and crime (Sallis et al., 2012). Street connectivity (Grasser et al., 2013) and land use mix (McCormack and Shiell, 2011) have been associated with physical activity individually and as part of neighborhood walkability indices (Frank et al., 2010).

It is unclear whether the built environment measures used for the general population are specific enough to capture elements of the built environment that impact an individual with a disability. People with disabilities experience additional barriers based on the quality of the pedestrian infrastructure, and the accessibility of destinations as defined by the American's with Disabilities Act Accessibility Guidelines (ADAAG)(U.S. Access Board, 2014). It is important to understand how these barriers affect physical activity among people with disabilities.

1.2. The built environment as a moderator for low physical activity levels among persons with disabilities

Reducing barriers in the built environment aids individuals with disabilities in independently moving throughout communities and using community fitness and recreation facilities (Rimmer et al., 2004). Fig. 1 shows a conceptual model of the interaction between the built environment, disability and physical activity. It illustrates the hypothesized role of the built environment as a moderator for the relationship between having a disability and lower levels of physical activity. A moderator is a 'third variable' that influences the strength of the relationship between the independent and dependent variables (Baron and Kenny, 1986). In this case, we hypothesize that a supportive built environment may decrease the strength of the relationship between having a disability and lower physical activity. In the same way, poorly designed built environments may increase the strength of this relationship. Having disability as an independent variable is a way to model disability as a characteristic instead of as an outcome. Disability does vary with different life circumstances and with age. Work among those who have studied older adults with physical disabilities suggests that the built environment may further the disablement process (Clarke et al., 2008). To show this complexity, the model also shows a line from the built environment to disability with a negative sign, indicating that environments with more barriers may lead to reduced mobility.

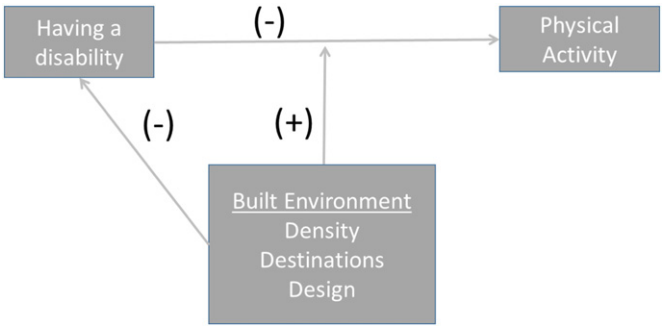

Fig. 1. Model of built environment moderation A model that hypothesizes the built environment (comprised of density, destinations and design) as a positive moderator of the relationship between having a disability and lower levels of physical activity. A negative relationship is also shown between the built environment and disability, based on previous literature.

A search of the academic literature found no previous systematic reviews that have examined the role of built environment factors in moderating the association of having a disability with lower levels of physical activity. There have been several reviews identifying factors associated with physical activity in people with disabilities but not focused on the built environment (Bloemen et al., 2015; Bult et al., 2011; Jaarsma et al., 2014). A few have focused on the environment's effect on participation for people with disabilities but not physical activity (Anaby et al., 2013; Bodde and Seo, 2009). None have examined whether there is evidence that the built environment is a moderator. Therefore, this systematic review seeks to explore:

(1) Whether built environment factors moderate the association between having a disability and lower levels of physical activity?
(2) How the built environment, physical activity and disability have been operationalized?
(3) Which disability types have been most studied?
(4) Where are there gaps in the research?

2. Methods

A predefined review protocol was developed that outlined search strategy, data extraction and assessment of the quality of studies. The existing literature was searched using advanced search terms and Boolean operators (see Appendix A). Databases searched included PubMed, Web of Science, NARIC (National Rehabilitation Information Center), CINAHL, Embase, and ProQuest Dissertations & Theses Database. The search included studies published between 1990 and 2015 because in 1990 the Americans with Disabilities Act (ADA) was passed. Contact was made with 5 authors who have published on aspects of the association of built environment factors and physical activity for people with disabilities to ask about unpublished work and suggestions for seminal publications in this area. An ancestry approach was employed to identify articles from the bibliographies of the publications that met the review criteria but weren't found in the databases based on the original search criteria (Cooper, 2010).

Following PRISMA guidelines for reporting, (Moher et al., 2009) the following steps were used for identifying, screening, evaluating eligibility and deciding on inclusion. After removing duplicates from the combined results of the 6 databases, the first author screened all studies by title. Then, two authors (YE and KV) independently examined the remaining potential articles by abstract and subsequently by full text, discarding studies based on the inclusion/exclusion criteria. The percent agreement for articles to include was measured between the 2 authors. A consensus based approach was used to reach a final set of articles to include in the study.

The inclusion criteria were as follows: The target population had to be persons with disabilities, or for studies that included both individuals with and without disabilities, the authors had to report independent findings for those with disabilities. Descriptions of the sample had to fit into one of the six measures of disability used by the US Census Bureau that includes, hearing, vision, cognitive, ambulatory, self-care, and independent living difficulties (full definition in Appendix B)

(Brault et al., 2007). The articles needed to be original research (not reviews, concept papers, policy briefs), full-text, in English, and >50% of the sample population included participants who were 18 years old or older. The review includes studies outside of the U.S. where similar patterns of built environments exist. Qualitative study designs as well as predictive analysis were included. The unit of analysis could be at either the individual or community level. Individual level studies examined associations within a sample from a particular geographic area. Community level studies compared aggregate physical activity measures between communities of different built environment types.

Studies were excluded if they 1) did not specify at least one form of physical activity (walking, exercise, or sports) as part of the topic area or outcomes, 2) defined disability as the outcome of interest instead of as a characteristic of the population, or 3) did not specifically set out to examine built environment factors. Articles that examined barriers and facilitators to physical activity in general would not meet these criteria. The built environment would not include social aspects including friends and social networks or policy aspects not related to the built environment, such as changes in the price of gas.

2.1. Data abstraction

The articles were coded using a predefined coding guide developed by the authors (available upon request). To test the reliability of the coding guide, 25% of the articles were coded by 2 authors (YE and VV) and the level of agreement was measured for each study. Codes with disagreements were edited/clarified. Afterwards, a single coder reviewed each study one at a time and additional codes were generated iteratively. If a new code was generated, the coder would recode already completed studies. The types of information extracted for coding included general study characteristics, demographics of the sample, the types of disabilities studied, objectives, research design, procedures, measures used to define disability, the built environment and physical activity, findings and study quality.

Descriptive statistics (frequency, M, range) were obtained across the studies to provide an overall summary of the research articles used.

The quality of the studies was examined using validated evaluation tools, which included the CASP checklist (Critical Appraisal Skills Programme CASP, 2013) for qualitative studies and the Community Guide to Preventative Services Data Abstraction Form on Study Quality (Part III) (Zaza et al., 2000) for quantitative, predictive analysis studies. For each type, a study was ranked high if >75% of the study quality factors were positive, as moderate if between 50 and 75% of the factors were positive and low if <50% of the factors were positive.

Evidence of the built environment acting as a moderator on the relationship between disability and physical activity was examined based on 3 kinds of studies. Study type (1) was descriptive studies, which examined built environment barriers and facilitators to physical activity among people with disabilities. We examined how the built environment was discussed as affecting physical activity or modifying the effect that one's disability had on physical activity to better understand its role as a moderator. Study type (2) includes studies using quantitative analysis of the association between measures of the built environment and physical activity among people with disabilities only. Study type (3) is quantitative analysis of the differential association of the built environment and physical activity among people with and without disabilities. Evidence of moderation was summarized for study types 2 & 3 by categorizing associations as positive, negative or insignificant. Effect sizes (Cohen's D) were calculated when possible using a well-known effect size calculation website (Lenhard and Lenhard, 2015).

Data were also extracted from the discussion sections of all studies and synthesized through constant comparison analysis. After the data from the studies were grouped by the codes, the authors systematically reviewed all information in the group and developed descriptive labels. Each of these labels or codes were then used across the studies so that previously developed codes were used where similarities were found. Once all data from the studies were labelled, similar codes were clustered and the themes that emerge were elaborated upon (Onwuegbuzie et al., 2012).

3. Results

3.1. Study characteristics

Fifteen manuscripts met the study criteria with 14 of them being unique studies. One study had two manuscripts: one that was qualitative analysis of barriers and one that was a quantitative analysis of the built environment & physical activity relationship. Fig. 2 is a flow chart adapted from the PRISMA statement (Moher et al., 2009) describing how many articles were found from the different sources and how many were removed in each stage of selection.

The agreement between authors on which studies met the inclusion criteria was initially 91%. Initial disagreements had to do with whether disability was defined as an outcome, whether physical activity was assessed and whether the paper focused on the built environment. Final consensus was reached on the 15 articles used in the studies.

The range of inter-rater agreement of the coding guide across a quarter of the studies was 90–94%. Disagreements were related to needing more definitions of terms such as urban/suburban/rural, research design definitions, classifications of different physical activity types, and definitions of density, destinations, and design.

Table 1 illustrates the general characteristics of the studies included in the review. All of the 15 manuscripts were peer-reviewed and were published between 2002 and 2015. All studies were conducted in urban settings with some including suburban settings and 2 including people from rural communities.

Ten of the studies were conducted in the U.S., 1 was conducted in Turkey, 2 in Canada, 1 in Sweden and 1 in both the U.S. and Canada.

Eleven of the studies used the individual as the unit of analysis and 4 used the community as the unit of analysis. Six of the studies were descriptive studies, employing a qualitative approach (study type 1). Two of these included a quantitative analysis, which did not meet the inclusion criteria so only the qualitative sections were used in the review (Shumway-Cook et al., 2002; Wennberg et al., 2010). Nine studies were cross-sectional and of these, 4 studied only people with disabilities (study type 2) and 5 examined people with and without disabilities (study type 3).

3.2. Study quality

Four of the quantitative manuscripts had high study quality, four had moderate and one had low quality. Some of the reasons for lower quality were because of not using valid/reliable measures of the built environment and physical activity, study design and selection bias issues, failure to control for confounding factors or the multi-level nature of the data in the statistical analyses and/or not discussing potential confounders or bias.

Two of the qualitative studies had a high study quality, three had moderate, and one had low study quality. The reasons for lower quality among the qualitative manuscripts had to do with recruitment strategies being poorly described and/or justified, lack of reporting on ethical considerations, insufficient data analyses and unclear or very limited statement of findings.

3.3. Disability defined

All studies included people with ambulatory difficulties, 4 included people with visual difficulties, 3 included people with cognitive difficulties, and 2 included people with hearing difficulties. How studies measured ambulatory difficulty differed across studies. The majority of the studies (n = 7) used questions about whether participants needed to use an assistive device such as a wheelchair, walker, scooter, or cane

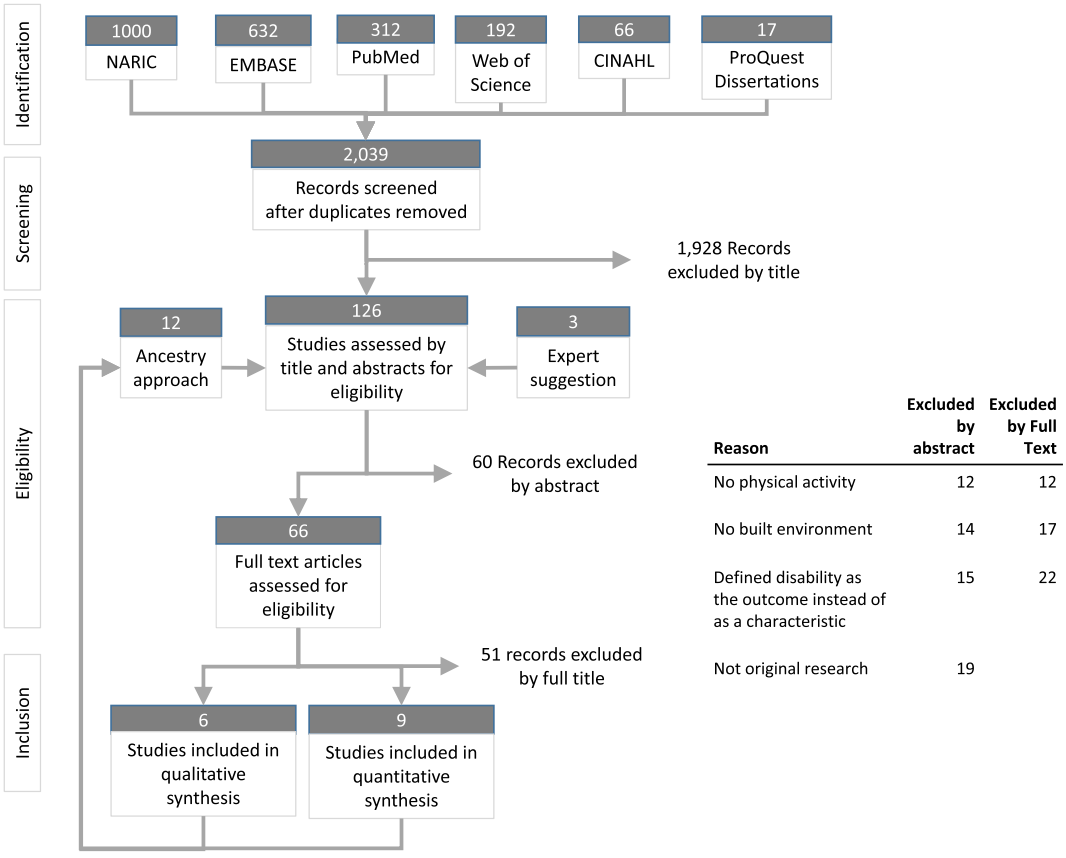

Fig. 2. Flow chart of studies screened, evaluated for eligibility and included in the review Adapted from the PRISMA-Statement flowchart, this diagram shows the results of the database searches and each of the steps used by the authors to arrive at the final number of articles to review.

as a proxy for disability (Arbour-Nicitopoulos et al., 2010; Baris and Uslu, 2009; Gell et al., 2014; Harris et al., 2015; Kirchner et al., 2008; Liang et al., 2008; Rosenberg et al., 2013). Four studies used functional ability questions that included items such as walking up and down stairs, walking a certain distance, or ability to carry heavy objects (King et al., 2011; Morris et al., 2008; Shumway-Cook et al., 2002; Spivock et al., 2008). Finally, four studies used a combination of both functional ability and use of assistive devices to determine disability (Christensen et al., 2010; Gallagher et al., 2012; Hallgrimsdottir et al., 2015; Wennberg et al., 2010).

3.4. Physical activities assessed

Walking for exercise was assessed in nearly all of the studies (n = 11). Some of the studies (n = 3) asked participants about multiple types of physical activity (leisure time, sport, stretching, household etc.) or about physical activity in general (n = 2). All the studies used self-report methods for assessing physical activity, one also included observation and 2 included accelerometers in addition to the self-report.

The studies varied in how physical activity was operationalized. Several used validated measures of physical activity for the populations under study including, Neighborhood Physical Activity Questionnaire (NPAQ), Community Healthy Activities Model Program for Seniors (CHAMPS) Physical Activity Questionnaire, Physical Activity Recall for People with SCI (Spinal Cord Injuries), the Physical Activity and Disability scale, Physical Activity Scale for the Elderly and accelerometers. Five of the studies did not report on the validity or reliability of their physical activity measures.

3.5. Measurement of the built environment

The built environment was operationalized in different ways. Ten of the studies inquired about the perceptions of the built environment in one's neighborhood with only some using validated measures such as the Neighborhood Environment Walkability Scale (NEWS) (Saelens et al., 2003) or other measures developed by the authors (Harris et al., 2015; Spivock et al., 2008). Three of the studies did not report on the validity or reliability of the built environment perception measures they used.

Several studies used more objective approaches to measuring the built environment. Three of the studies utilized GIS based measures that had been previously validated for the general population including residential density, street connectivity, retail floor-area ratio, and land use mix. Liang et al. introduced new GIS measures of the built environment but did not report on their reliability or validity (Liang et al., 2008). One study used a previously validated systematic social observation approach to assess the built environment in the census tracts where people lived, recording the presence or absence of particular features that support pedestrian mobility among people with disabilities (Spivock et al., 2008). For three studies (Gallagher et al., 2012; King et al., 2011; Morris et al., 2008), the measures of the built environment were grouped, making it impossible to identify which built environment dimension was perhaps more responsible for the significant associations.

3.6. Evidence of moderation

Participants in the qualitative studies (study type 1) listed many barriers to physical activity. Most of the built environment barriers people

Table 1
General study characteristics of manuscripts included in the systematic review.

Author	Year	Setting	Sample size	% disability (n) in sample	Age M (SD)	Unit of analysis	Location	Study Design	Study Quality
Arbour-Nicitopoulos	2010	urban	574	100% ambulatory	46.9 (13.2)	Individuals	Canada	2	High
Baris	2009	urban	238	64% ambulatory, 32% visual, 4% multiple	NR	Individuals	Turkey	1	Moderate
Christensen	2010	urban, suburban, rural	4947	17% of total (ambulatory, cognitive & independent living)	42 (NR)	Individuals	U.S.	3	Moderate
Gallagher	2012	NR	326	50% ambulatory	76.1 (8.3)	Individuals	U.S.	3	High
Gell	2015	urban and suburban	28	100% ambulatory	67 (9.4)	Communities	U.S.	2	Moderate
Hallgrimsdottir	2015	urban	646	33% ambulatory, 9% cognitive, 21% both	76.5 (NR)	Communities	Sweden	3	Low
Harris	2015	urban, suburban, rural	385	100% ambulatory	44.4 (10.8) for those <60 and 66.2 (5.7) for ≥60	Individuals	U.S.	1	Moderate
King	2011	urban and suburban	719	100% ambulatory for those with limitation, but % of total not reported	74.4 (6.3)	Communities	U.S.	3	High
Kirchner	2008	urban	134	46% ambulatory, 54% vision	NR	Individuals	U.S.	1	Moderate
Liang	2008	urban	131	100% ambulatory	39 (10.6)	Communities	U.S.	2	Moderate
Morris	2008	NR	137	85% ambulatory	69.6 (NR)	Individuals	U.S.	3	Moderate
Rosenberg	2012	urban and suburban	35	100% ambulatory	67 (9.4)	Individuals	U.S.	1	High
Shumway-Cook	2002	urban and suburban	26	47% ambulatory	77.7 (±4.7) w/disability 83.2 (±5.7) wo/disability	Individuals	U.S. and Canada	1	High
Spivock	2008	urban	205	95% ambulatory, 2.9% vision, & 1.8% hearing	39% < 45 & 61% ≥45	Individuals	Canada	2	High
Wennberg	2010	Urban	244	38.5% ambulatory, 11.1% cognition/vision, 25.8% both	77 (NR)	Individuals	Sweden	1	Low

Notes
Study Types:
Type 1: Qualitative
Type 2: Cross-sectional, with disability only
Type 3: Cross-sectional, with and without disability
NR = Not reported

Notes. Study types: Type 1: Qualitative; Type 2: Cross-sectional, with disability only; Type 3: Cross-sectional, with and without disability. NR= Not reported.

with disabilities experience to neighborhood walking fall into the 'design' category. They had to do with physical, temporal and the behaviors of other people. Physical barriers included factors such as uneven sidewalks, inadequate lighting, and barriers on the paths. Studies conducted in the U.S. described sidewalk barriers, such as construction and icy sidewalks. Whereas, the study from Turkey mentioned cars parked on the sidewalk as a barrier to walking. Wheelchair users viewed the accessibility of physical features as barriers and not just whether they are

Table 2
Associations of the Built Environment and Physical Activity.

BUILT ENVIRONMENT ATTRIBUTE	NEIGHBORHOOD WALKING	LTPA	ANY PA
DESIGN			
Active living facilitatorsfor people with disabilities	Ø[9]	+ (d=0.80)[9]	
Activity friendly features for general population	Ø[9]	Ø[9]	
Aesthetics		Ø[1],Ø[2]	
Block length	Ø[4]		
Crime (property)	Ø[4]		
Crime (violent)	Ø[4]		
Crime (total)			− (d = -1.08)[7]
Lighting		− (d = -0.59)[2]	
Neighborhood design scale (NEWS)	Ø[3]		
Neighborhood satisfaction	+[8]		
P resence of sidewalk		Ø[1], Ø[2]	+ (d = 0.26)[2]
Perceived neighborhood barriers	Ø[5]	Ø[9]	
Safety	Ø[9]	Ø[2], Ø[9]	
Slope (meters)	Ø[4]		
Vacant housing			Ø[7]
DENSITY			
Mean Block area			Ø[7]
Population density per km	+ (d = 0.9)[4], Ø[3]		Ø[7]
Street density	+ (d = 1.2)[4]		
DESTINATIONS			
Distance to transit			–[7]
Number of transit stops			Ø[7]
Recreation facilities		Ø[2]	
Retail and service destinations	+[3], Ø[9]	Ø[9]	
Walk score	+ (d = 1.0)[4]		
COMPOSITE INDEX			
Walkability index	+[6]Ø[6]		Ø[6]

Notes
(+) = positive, (−)= negative, (Ø)=insignificant, d= Cohen'sd

Effect size: <0 = adverse, 0-0.1 = none, 0.2-0.4 = small, 0.5-0.7 = intermediate, ≥0.8 large

Authors:
1-(Arbour-Nicitopoulos et al., 2010), 2-(Christensen et al., 2010),3-(Gallagher et al., 2012), 4-(Gell et al., 2014), 5-(Hallgrimsdottir et al., 2015), 6-(King et al., 2011), 7-(Liang et al., 2008), 8-(Morris et al., 2008), 9-(Spivock et al., 2008)

Table 3
Summary of research findings and policy/practice implications of the systematic review on the built environment, disability and physical activity.

RESEARCH FINDINGS	POLICY/PRACTICE IMPLICATIONS
Built environment barriers	*Reduce barriers to improve physical activity*
Common barriers across qualitative studies had to do with the design of the built environment and had a strong influence on intentions to engage in neighborhood walking and leisure time physical activity.	Instead of focusing on preventing disability, practitioners conducting HIAs should also focus on how a proposed built environment change could reduce barriers for people with existing disabilities, which could lead to increased physical activity.
Density and destinations	*Consider the neighborhood*
In the quantitative studies included in this review, neighborhood walking was most affected by density (of people and streets), and nearby destinations. Design had more mixed results.	In order to address health disparities, density and nearby destinations should be considered when planning accessible and/or subsidized housing for people with disabilities.
Built environment quality	*Measure accessibility*
Studies should examine not just whether a built environment facilitator (sidewalk) is present, but the quality of that built environment feature (e.g.,sidewalk condition vs. sidewalk presence).	As part of a community planning process, practitioners should conduct walkability audits that measure conditions affecting accessibility, such as broken or incomplete sidewalks.
Inclusion in research	*Inclusion in community planning*
There is a lack of research on people with sensory and cognitive disabilities. Additional training to encourage researchers to include people with sensory and cognitive disabilities in studies would help to further our understanding of the role of the built environment.	Including people with disabilities (mobility, sensory, and cognitive)in the community design process could help plannersand policy makers identify built environment accessibility elements to consider adding/modifying.

present (e.g. the slope of the curb cuts and not just their presence)(Harris et al., 2015). Temporal barriers had to do with stop light timing, maintenance from snow and rain puddles, and difficulties at night compared to the day. Behaviors of others included feeling pressure to keep up with pace of others, crowded sidewalks, and fear of motorists.

The built environment can increase the effect of having a disability on physical activity. When participants talked about barriers, they reported avoiding environments with barriers because it made them feel unsafe (Baris and Uslu, 2009; Rosenberg et al., 2013). Due to the low sense of safety and security, participants explained that they walk less or not at all at night when poor lighting was perceived as an insurmountable barrier (Rosenberg et al., 2013; Wennberg et al., 2010). On the other hand, supportive built environments can reduce the effect of having a disability on physical activity. In several studies, participants explained that they would walk more if certain facilitators were present, such as benches, good lighting and attractive aesthetics. Facilitators can make walking around one's neighborhood more enjoyable and makes people more confident in their walking (Hallgrimsdottir et al., 2015; Rosenberg et al., 2013).

Table 2 summarizes the quantitative results for study types 2 and 3 based on built environment attributes and type of physical activity assessed. Only associations for people with disabilities were included. The two study types were combined because most of the studies in type 3 reported statistics separately for people with disabilities. King et al., 2011 was the only study that examined the built environment as a moderator in the statistical analysis and had a significant interaction term of mobility limitation X built environment on neighborhood walking. Through further analysis, they found that the effect was only seen among people with a lower level of impairment, but not for moderate or high impairments. Unfortunately, they did not include a test statistic of the interaction term in their reporting to allow for calculation of Cohen's D.

There was a mix of positive/negative relationships and significant/non-significant results. Most of the studies tested attributes that were part of the design category of the built environment, but there were mostly insignificant results in this category. Cohen's D was not able to be calculated for several studies that just reported beta coefficients or just significance levels. When possible to calculate, the largest effect sizes were seen in the density category (0.9 and 1.2), for crime (−1.08) and for the walk score of a neighborhood (1.2).

Although most studies tested direct relationships of the built environment on physical activity, two tested indirect relationships through other constructs, such as perceptions, attitudes and beliefs via structural equation modeling (Arbour-Nicitopoulos et al., 2010; Morris et al., 2008).

3.7. Themes across studies

Looking across the 15 studies through the constant comparison analysis, several themes emerged. Numerous articles (n = 9) discussed whether measures of the built environment that were developed for the general population are generalizable to people with disabilities. Three articles in this review used measures that came from the general population and argued that these measures were applicable (Gallagher et al., 2012; Gell et al., 2014; King et al., 2011). Four argued that more disability specific built environment measures are needed to detect the influences on physical activity in an appropriate manner (Arbour-Nicitopoulos et al., 2010; Harris et al., 2015; Liang et al., 2008; Wennberg et al., 2010). Two articles concluded that both disability specific measures as well as general population measures are necessary to detect the different levels of influences of the built environment (Christensen et al., 2010; Spivock et al., 2008).

A theme emerged that people with disabilities are resilient and walk/roll in the built environment for certain types of trips despite experiencing barriers (Baris and Uslu, 2009; Christensen et al., 2010; Kirchner et al., 2008). In fact, those that report more barriers, may do so because they are out and about more than those who spend more time at home (Hallgrimsdottir et al., 2015). There may be different purposes for the walk such as, walking for exercise vs. walking for transport (Gallagher et al., 2012). For necessary commuting trips people may have developed methods for overcoming these design barriers by route planning (Kirchner et al., 2008) and using paths that they have more confidence walking on (Rosenberg et al., 2013), while leisure trips may not be considered as vital. Overcoming barriers adds an additional burden onto their daily activity (Kirchner et al., 2008) and the long-term impact

of this may be avoidance of non-critical walking around the neighborhood (Christensen et al., 2010). Whereas, the presence of facilitators helps to relieve this burden (Rosenberg et al., 2013).

4. Discussion

This paper is the first systematic review to specifically examine the built environment as a moderator of the relationship between disability and physical activity. A mixed-methods approach helped to examine evidence of moderation from studies with different methodologies, facilitating a triangulation of evidence.

The public health field faces a monumental challenge in tackling the health disparities that exist for people with disabilities (Krahn et al., 2015). Policies, systems and environmental changes are needed to have a lasting impact on the overall health of this growing subgroup (Fox et al., 2013). This review synthesized how the built environment and the policies that shape it, have the potential to shift physical activity inequities for people with disabilities.

Urban planning and public health practitioners use Health Impact Assessments (HIAs) to examine how new built environment improvements will impact health and as a step towards planning new active friendly environments (Mueller et al., 2015). A key to the success of HIAs are having evidence of association that can be used to estimate potential impacts and develop plans for the built environment. HIAs often focus on preventing disability (Grosse et al., 2009). In order to shift the prevailing perspective on disability, evidence of moderation by the built environment is necessary. Instead of focusing on how the built environment might prevent disability, practitioners conducting HIAs should also focus on how a proposed built environment change could reduce barriers for people with existing disabilities, which could lead to increased physical activity.

The qualitative studies used in this review showed that built environment barriers were mostly in the design category and had a strong influence on intentions to engage in neighborhood walking and LTPA. Aspects of design have similarly been cited as a barrier in general among people with physical disabilities (Bloemen et al., 2015; Rimmer et al., 2004). The built environment acts as a moderator by being viewed as a barrier or a facilitator to physical activity based on one's disability. The articles cited behaviors of other people as a barrier to walking. Design of the built environment can influence behaviors of other people as a narrower sidewalk gives more of a crowded feeling or that people are moving fast because there isn't space for different travel speeds and poor traffic safety features can make walking a fearful activity.

Conversely, the empirical testing of built environment attributes in the design category had mostly insignificant results, as seen in Table 2. Part of the reason for the mixed results could be that many studies tested a multitude of variables within each category of the built environment. Neighborhood walking seemed to be most affected by density (of people and streets) and then by destinations. Being in more urban environments with smaller blocks and more connectivity seems to be an important consideration. In order to address health disparities, housing planners and policy makers should consider these factors when planning for the placement and distribution of accessible and/or subsidized housing for people with disabilities.

Evidence of moderation was more difficult to detect among studies that used a quantitative analysis. Most looked at direct relationships between the built environment and physical activity. The direct associations examined had mixed results across the three categories of the built environment and the three physical activity variables used across studies. Mixed results are common in built environment systematic reviews for the general population (McCormack and Shiell, 2011), research on older adults (Van Cauwenberg et al., 2011) as well as research examining the built environment's impact on social participation of people with disabilities (Botticello et al., 2014). In this case, mixed results may have occurred because testing for direct relationships does not take into account how disability interacts with the built environment. Some studies compared results of the built environment, physical activity association for people with and without disabilities but did not use an interaction term. This is an inappropriate comparison because any difference found may not be attributed to a differential impact of the built environment.

This review helped to identify details of the measurement of the built environment for people with disabilities. Similar to other systematic reviews, there is a need for the use of valid and reliable measures of the built environment (Ding and Gebel, 2012; Van Cauwenberg et al., 2011). Additionally, valid and reliable built environment measures specific to people with disabilities are needed that take into account the quality of the built environment. In other words, studies would examine not just whether a built environment facilitator (sidewalk) is present, but the quality of that built environment feature – sidewalk condition vs. just sidewalk presence (Harris et al., 2015), intensity of lighting vs. lighting presence (Rosenberg et al., 2013), and availability of accessible facilities and not just availability of facilities (Christensen et al., 2010). As part of the community planning process, urban planners and public health practitioners seeking to understand the quality of the built environment, should conduct walkability audits that measure conditions affecting accessibility, such as broken or incomplete sidewalks. Although many assessment tools exist (Gray et al., 2012) and such detailed assessments are required by law in some countries, such as the U.S. (U.S. Department of Justice, 2008), it is not clear how often such audits are implemented. Policies, such as Complete Streets, should include details on accessibility to ensure future built environments are accessible to all ages and abilities.

A majority of the studies focused on older adults. Although universally designed communities can help facilitate walking in both people with disabilities and older adults (Steinfeld and Maisel, 2012), additional research is needed that focuses on adults under 65 because younger adults with disabilities have different experiences with the built environment than older adults. Consequently, we cannot infer findings of older adults to younger adults with disabilities.

The lack of studies on people who have disabilities that are not ambulatory shows an important gap in the research. Decision makers (researchers and Institutional Review Boards) may often exclude people with disabilities from studies that could potentially benefit by including this population because of misperceptions of risks and benefits (McDonald and Keys, 2008). Additional training to encourage researchers to include people with sensory and cognitive disabilities in studies would help to further our understanding of the built environment's role as a moderator and ensure that samples are truly representative of the population as a whole. Because of this lack of research, including people with disabilities (mobility, sensory, and cognitive) in the community design process could help planners and policy makers identify built environment accessibility elements to consider adding/modifying.

A summary of the takeaways for policy/practice and research (described in this section) are presented in Table 3.

4.1. Limitations

There could have been other sources of literature that were not identified including, other grey literature, such as conference findings and magazine articles. Although attempts were made to calculate effect sizes, several studies did not report the statistics in a way that could be transformed into a common metric (Cohen's D). Quantitative and qualitative studies of low quality were included in review. Lastly, the studies included mostly focused on physical disabilities, so extending these results to other disabilities may not yet be appropriate.

5. Conclusion

While there is clear evidence that the built environment acts as a moderator based on qualitative studies, empirical evidence of built

environment moderation is lacking. Additional research is needed to further differentiate which aspects of the built environment are truly moderators that can impact neighborhood walking among people with disabilities. In particular, studies should examine not just whether a built environment facilitator is present, but the accessibility of that built environment feature. Future research should also consider how the built environment affects local, neighborhood walking for different purposes for people with disabilities. This review found that most of the research focused on older adults with physical disabilities; however, more built environment research is needed for adults who are younger than 65 with physical disabilities and people with cognitive and sensory disabilities. Lastly, future study designs that incorporate people with and without disabilities will allow for comparison of the differential impact of the built environment on physical activity based on disability.

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

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