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Effects of enriched physical activity environments on balance and fall prevention in older adults: A scoping review

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Running head [enriched environment in older adults]

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Abstract

The incidence of falling, due to ageing, is related to both personal and environmental factors. There is a clear need to understand the nature of the major risk factors and design features of a safe and navigable living environment for potential fallers. The aim of this scoping review was to identify studies that have examined the effectiveness of environments which promote physical activity and have an impact on falls prevention. Selected studies were identified and categorised into four main topics: built environment; environment modifications; enriched environments, and task constraints. The results of this analysis showed that there are a limited number of studies aiming to enhance dynamic postural stability and fall prevention through designing more functional environments. This scoping review study suggests that the design of interventions and the evaluation of an environment to support fall prevention is a topic for future research.

Keywords: falling, enriched environments, constraints, postural stability

Introduction

Ageing is complex in nature and is accompanied by physical, sensory-perceptual and cognitive changes in the body that could affect balance and gait in predictable and unpredictable situations (Melzer, Kurz & Oddsson, 2010). A fall after losing balance and control of upright posture is a common problem in older adults that has increased the cost of hospitalisation and falls-related injuries and disabilities (Scuffham, Chaplin, & Legood, 2003). It is estimated that one in three people aged 65 years and over experience a fall at least once a year in the UK. In the USA, 28.7% of community-dwelling adults aged 65 years and older reported falling, and there were an estimated 33000 fall-related deaths in 2015 (Bergen, Stevens, & Burns, 2016). Approximately 5 per cent of older people in community-dwelling settings who fall in a given year experience a fracture or require hospitalisation (Perrell et al. 2001).

In the older adults, falls have a multidimensional aetiology and the ability to compensate in response to falling is a key determinant for physical rehabilitation (Nyberg & Gustafson, 1995; Rensink, Schuurmans, Lindeman, & Hafsteinsdottir, 2009). Factors such as diminished sensory-motor functions (Dhital, Pey, & Stanford, 2010), neuro-musculoskeletal impairments (Daly, Rosengren, Alwis, Ahlborg, Sernbo, & Karlsson, 2013), deconditioning related to inactivity (Kabeshova, et al., 2014), severe pain, sarcopenia, chronic diseases, frailty and depression (Gale, Cooper, & Sayer, 2016) have been recognised as significant predictors of fall incident in older adults.

In recent years, special attention from health care organisations has been paid to effective interventions that prevent the risk of falling or reduce the fall incident rate in older adults (Public Health England, 2017). There have been a promising number of studies that have examined effects of different interventions on reductions of fall incident rate. Two systematic reviews that included 40 randomised clinical trials between 1992 and 2002 (Change, et al.,

2004) and 62 randomised clinical trials between 2016 and 2018 (Guirguis-Blake et al., 2018) have demonstrated that a multifactorial programme as well as exercise and vitamin D supplementation, were effective interventions to reduce the rate of falls incidents in community-dwelling older adults. The multifactorial programme included comprehensive geriatric assessments (balance, gait, vision, blood pressure, understanding of environment hazards, cognition and psychological health), a treatment intervention (supervised/unsupervised exercise, cognitive behavioural therapy, nutrition therapy, medication management, education tutorials and environment modifications) and a referral to a specialist support team. The most common types of exercise interventions targeted improvements in gait, balance and provided functional training as a form of individual or group exercise. Occupational therapy practice aims to maintain or create a balance between these elements (Law et al., 1996). A Cochrane review (Gillespie, et al., 2009) found that environmental assessment and modification was an effective approach to reduce incidence of falls and a further review (Clemson, et al., 2019) is currently being undertaken because different environmental intervention types, different delivery approaches, may have different effects on falls and fall-related injuries. For example, a large trial (Clemson, et al., 2019) suggests that environmental interventions can prevent falls in older people at high risk of falls, but they have little or no benefit in people at low risk (Pighills, et al., 2019).

Environmental assessment and modification encompass a comprehensive, validated functional assessment of the individual in their home environment, a joint problem-solving approach, and follow-up as required.

The physical and cognitive dysfunctions could be conceptualised by relational models of disability that emphasise on the inclusive and exclusive roles of space/environment to enable or disable the person in his/her daily activities (Hall & Wilton, 2017). In other words, the way that a person perceives the environment could enable him/her to participate in daily activities

as it is shown in children with disability in educational environments (Stephens, Ruddick, & McKeever, 2015). The relational perspective on physical (dis)ability and the environment could establish a principle in the provision of physical activity and fall prevention programmes so that designing more enabling physical activity environments that could mitigate the performance declines due to ageing process is emphasised. Another theory that supports a cyclic interaction between the person and the surrounding environment for action planning is ecological dynamic approach (Fajen & Matthis, 2011). According to this approach, the environment and activities could facilitate the movement organisation despite the physical limitations that are experienced due to ageing or motor disabilities. The role of perception to the environment in fall prevention could also explain the major limitation in previous interventions that mainly focused on the physical and motor fitness factors (e.g. strength, balance, coordination) instead of the perception of environmental challenges (contextual enabling/limiting factors). These types of intervention lack representativeness due to a mismatch between the types of task activities included in the interventions and the necessary adaptive responses that are required to interact with the dynamic physical environments such as negotiating gaps, inclines, steps, obstacles and surfaces in an everyday living environment (Qiu, et al., 2012).

The ability to cope with key environmental constraints such as surfaces, barriers and external objects (size, shape, colour, etc.) is an important cognitive-perceptual factor that could affect movement planning (Caballero Sanchez, Barbado Murillo, Davids, & Moreno Hernandez, 2016). In addition, the postural adaptations needed in a dynamic environment, due to the presence of physical hazards, demands a continuous perceptual-motor calibration and re-calibration (Brand & de Oliveira, 2017). Perceptual-motor (re)calibration is an ability to scale an action (pace, amplitude, intensity, force etc.) to available perceptual information following external and internal perturbations (Withagen & Michaels, 2004). For example, walking in

dynamic and unpredictable environments, which requires negotiating static obstacles and barriers, involves continuous movement adaptations in path direction, speed and stride length. These adaptive behaviours emerge from a direct link between perception and action (Gibson, 1979) and their dissociation during task performance can hinder functional coordination in activities of daily living (ADL). Previous studies have shown that visual perception constrains walking because it provides essential information for upright stability and postural regulation, as well as for body positioning relative to objects (Logan, et al., 2010; Paquette & Vallis, 2010; Pinheiro Menuchi & Bucken Gobbi, 2012). Paquette and Vallis (2010) showed that, for instance, older adults display a cautious strategy during obstacle crossing due to spending more time looking at the obstacle to pick up relevant perceptual information to guide the actions.

The ecological dynamic approach and the environmental assessment and modification are two approaches that differ in practice. For example, environmental assessment and modification led by an occupational therapist include the option of introducing a mobility aid or additional assistance with any activities of daily living. In some cases, environmental elements such as trip hazards are eliminated and medicines optimisation may be advised such as the reduction in psychoactive medications. It has been shown that accident/environment-related factors such as objects on floors, external forces and wet, uneven and icy surfaces are key risk factors for falls in older adults (Talbot, et al., 2005).

In contrast, the ecological dynamic approach views the environment as a rich and dynamic contextual backdrop for the older adult, that provides valuable information for action planning and movement adaptations. This study advocates the ecological dynamic approach in the design of exercise interventions for falls prevention, because there are opportunities for maintaining mobility and reducing falls risk based on ‘perception of affordances’ (information extracted from surrounding objects and space). There are several reasons for

taking this approach. First, natural indoor or outdoor environments in everyday life situations include events and objects that require the integration of the individual's cognitive and perceptual skills along with appropriate physical actions to mobilise safely in these environments. By creating enriched physical activity environments with different levels of social and cognitive interactions (from home to public places) that people can gradually adapt to the level of challenges by exploring their dynamic environments. Secondly that the likelihood of losing balance in older adults during walking is higher than when standing (Aranda-Gallardo, et al., 2018), which indicates a higher degree of complexity in dynamic postural control during walking and more needs to create an environment to enable a person to practise more challenging skills such as walking. Thirdly, the need for perceptual (picking up information to regulate action) and cognitive skills (e.g. navigation, object recognition and negotiation, anticipation, reaction responses and postural control) to support mobility in everyday life are paramount (Rosenbaum, 2010). This integration of perception, cognition and action could emerge through creating an enriched environment where participation in everyday physical activities and independent problem-solving is encouraged without a significant intervention by practitioners to facilitate the transfer of learning and self-regulatory mechanisms. Lastly, the association between fear of fall, low self-efficacy and the higher perceived risk of environments (Chippendale & Boltz, 2015) that could support our view that the more exposure to challenging and enriched environments is beneficial for dynamic balance and fall prevention.

An enriched environment is defined as "an intervention to facilitate physical, cognitive and social activity by the provision of equipment and organisation of structured, stimulating environment" (Nithianantharajah & Hannan, 2006). We conceptualised an enriched environment to be assessed in an exercise context: a) with familiar environmental and task constraints; b) with less explicit information provided by a support practitioner and more

opportunities for guided-discovery and exploration; c) is representative of everyday life situations, and d), requiring integrated physical movements and perceptual-cognitive activity. In other words, a physical activity environment that encourages participants to stand from sitting, walk, manoeuvre their bodies through gaps and up and down steps, turn, reach and bend, similar to daily living activities, also providing opportunities to use anticipation, pace changes, path direction changes, composes an enriched environment that can improve dynamic stability skills.

Whether exposure to a dynamic and an enriched environment could facilitate postural adaptations in older adults is unknown, and the aim of this scoping review was to identify previous studies that have examined effects on movement behaviours of environmental designs to promote physical activity generally and to enhance dynamic postural balance and falls prevention in older adults.

Methods

The design of this study was to undertake a scoping review (Rumrill, Fitzgerald, & Merchant, 2010) to enable the mapping of the current literature and to identify the size of the topic, as well as identify gaps in the literature (Arksey & O'Malley, 2005).

The review followed the methodological frameworks of previous scoping reviews (Arksey & O'Malley, 2005; Levac, Colquhoun, & O'Brien, 2010). The framework involved five steps: 1) defining a research question, 2) comprehensive and systematic identification of relevant studies, 3) independent and objective screening and selection of studies, 4) extraction and charting of the data, and 5), summary of the findings for recommendations for future research.

Scope of review/research question

The scope of review and the research question was defined using population, intervention, comparison and outcome (PICO) format. The operational definitions, outcomes of interest

and the key search strategy were decided and finalised through a consensus in the panel that was formed from experts in rehabilitation/physiotherapy, physical activity/exercise and movement science. The research question was: *are there enough studies on the effectiveness of various environments on postural stability in older adults?* Specifically, an enriched environment was defined as any exercise setting that stimulates the physical, sensory-perceptual and cognitive skills of an individual through the provision of equipment and facilities (Nithianantharajah & Hannan, 2006) to facilitate the transfer of motor learning to everyday life contexts (Araújo, Davids, & Passos, 2007). Postural stability was defined as the ability to maintain balance and postural sway during performance of everyday tasks (Mesbah, Perry, Hill, Kaur, Hale, 2017).

Literature search strategy

The following electronic databases were searched between 1990 and July 2019: MEDLINE, EMBASE, PsycINFO, CINAHL, Scopus, ERIC, SportDiscus, Cochran Library and AMED. The key terms that were used in a combination with “Older adults” were “enriched environment”; “environmental enrichment”; “environmental assessment and modification”; “meaningful activity/task”; “task-oriented activity”; “recreational activity”; “functional tasks”; “stimulating environment”; “enriched rehabilitation”; “task constraints”; “environment constraints”; “built environment”. Those key terms were always used with specific terms like “Older adults” in separate searches: “environmental enrichment” AND “older adults”, “stimulating environment” AND “older adults” and so on. In addition, relevant studies in the systematic review and meta-analysis studies were also included after reading the full-text of the published article. Key terms were adapted from studies that aimed to increase participation in physical activity and rehabilitation exercises through changing the environment (McDonald, Hayward, Rosbergen, Jeffers, & Corbett, 2018).

Study selection

Studies were included if they met the following criteria: 1) included participants with a mean age of 65 years and older, 2) the type of study was correlational, cross-sectional or experimental, 3) the article was published in a peer-reviewed journal, 4) published in English, 5) the dependent variable was neuromotor fitness (e.g. strength, balance, etc.) or quality of life (QoL), 6) the population included able-bodied individuals or people with a long-term condition, and 7), human participants. The studies were excluded if: 1) the type of study was descriptive, 2) it was a review study (literature review, systematic review and meta-analysis), and 3), it was documented in conference proceedings or a dissertation/thesis. Two reviewers (M.S. & S.P.) independently applied the inclusion criteria to select the relevant articles and resolved all disagreements by consensus. The selection process was carried out at title, abstract and full-text levels. First, the reviewers read the selected titles and identified the relevant studies, then they read the abstract and full-text of selected studies to finalise the list. The final selection was conducted by both reviewers.

Data extraction and charting of data

Two independent reviewers participated in the charting of the data that were extracted from the full-text of selected studies. The information that was extracted by the first reviewer (M.S.) was verified by the second reviewer (J.M.). All discrepancies were discussed between the reviewers until a consensus was reached. Unlike most systematic reviews, scoping reviews do not reject studies based on a risk of bias assessment (Arksey & O'Malley, 2005); therefore, we did not carry out any quality assessment on the selected studies. The important information that was extracted from the studies was organised by study domain, the participants' demographic measures, the type of study, the nature of the intervention and the outcome measures as presented in Table 1.

-----Insert Table 1 here-----

Results

Of the 197 articles initially identified, 40 studies met the inclusion criteria. The flowchart detailing the selection process is presented in Figure 1. Descriptive data including topics, participants, research design, nature of the intervention, outcome measures and main findings are presented in Table 1. The majority of studies were published between 2011 and 2019 (28 studies, 70%). Some of them were published between 2001 and 2010 (11 studies, 27%) and only 1 study was published between 1990 and 2000 (3%) that indicates that the topic is still a contemporary issue for studies in older adults population. The origin of the study was in North America (12 studies), Australia (9 studies), South-East Asia (8 studies), Europe (7 studies), South America (2 studies) and Africa (2 studies).

-----Insert Figure 1 here-----

Areas of study

The subject of the published studies was classified into 4 main areas: a) built environment and physical activity (19 studies; 48%), b) environmental modifications, neuromotor fitness and QoL (12 studies; 30%), c) task constraints, neuromotor fitness and QoL (6 studies; 15%) and d) enriched environment in clinical settings (3 studies; 7%).

Research design

The majority of studies were randomised control trials (20; 50%) that investigated the effect of environment hazards in falls prevention or a specific task intervention on neuromotor fitness components. The correlational study (12; 30%) was the second-highest common research design that mainly was used to explore the association between the built environment and physical activity. The other type of research was cross-sectional (8; 20%).

Participants

The participants of this scoping review were only selected from the older adult group (mean age ≥ 65 yrs). Due to the nature of the research design, the highest sample size was reported in studies in the built environment (n=24096), then environmental modifications (n=4919). The

studies in task interventions (n=183) and enriched environment (n=179) had the lowest number of participants.

Nature of intervention

In the selected studies, 22 studies (55%) used a specific intervention, whereas 18 studies (45%) did not implement any interventions. Depending on the nature of the intervention, the study duration was different and ranged from 10 days to 2 years. The task intervention emphasised included functional training, dual-tasking, strength training, coordination and balance exercises and their duration were between 6 and 12 weeks. The hazard assessment and environment modifications had the longest follow-up period (1-2 years) and mainly included home visits to reduce the number of potential hazards and one-on-one education. The special care units were the main context for enriched environments that was facilitated by the staff to provide more tasks and activities for physical, cognitive and social involvements.

Main findings

The outcome measures that were reported in the selected studies included a combination of physical activity level (Colom et al., 2019; Forte et al., 2019; Gell, Rosenberg, Carlson, Kerr, & Belza, 2015; Giehl, Hallal, Corseuil, Schneider, & d'Orsi, 2016; Hanibuchi, Kawachi, Nakaya, Hirai, & Kondo, 2011; Huang, Kung, & Hu, 2018; Janssen et al., 2014; Kolbe-Alexander, Pacheco, Tomaz, Karpul, & Lambert, 2015; Li, Fisher, Brownson, & Bosworth, 2005; Y. Lu, Chen, Yang, & Gou, 2018; Mazzei, Gillan, & Cloutier, 2014; Nagel, Carlson, Bosworth, & Michael, 2008; Parra, Gomez, Fleischer, & Pinzon, 2010; Rosbergen, Grimley, Hayward, & Brauer, 2019; Rosbergen et al., 2017; Sato, Inoue, Du, & Funk, 2019; Timmermans et al., 2016; Winters et al., 2015), falling rates (Campbell et al., 2005; Cumming et al., 1999; Day et al., 2002; Lannin et al., 2007; Nikolaus & Bach, 2003; Pardessus et al., 2002; Stevens, Holman, Bennett, & De Klerk, 2001), QoL (De Vriendt,

Cornelis, Vanbosseghem, Desmet, & Van de Velde, 2019; Engel et al., 2016; Lannin et al., 2007; Lin, Wolf, Hwang, Gong, & Chen, 2007; Nicholson, McKean, & Burkett, 2014; Pighills, Torgerson, Sheldon, Drummond, & Bland, 2011; Rosbergen et al., 2017), ADL (Lannin et al., 2007; Law, Barnett, Yau, & Gray, 2013; Law, Fong, & Yau, 2018; Liu, Jones, Formyduval, & Clark, 2016; Pighills et al., 2011; Rosbergen et al., 2017), neuromotor fitness (Leach, Maring, & Costello, 2019; Lin et al., 2007; Y. Y. F. Lu et al., 2016; Nicholson et al., 2014; Pedroso et al., 2018; Soma et al., 2017) and cognitive functioning (Janssen et al., 2014; Law et al., 2013; Law et al., 2018; Pedroso et al., 2018).

In the studies that aimed to find a relationship between built environments and physical activity, there was a positive association between the level of physical activity and access to green parks and recreational facilities; however, the link to wellbeing and QoL was not conclusive. The environmental modifications reported a mixed effect on fall rate and QoL. In other words, 3 studies (42%) have shown a positive effect of environment modifications on fall rate (Campbell et al., 2005; Cumming et al., 1999; Nikolaus & Bach, 2003). Of the 7 studies that measured QoL, 6 studies did not report any changes (De Vriendt et al., 2019; Engel et al., 2016; Lannin et al., 2007; Nicholson et al., 2014; Pighills et al., 2011; Rosbergen et al., 2017). The task constraint interventions resulted in significant improvements in neuromotor fitness components such as balance, strength and ADL, but their effects on cognitive functions and fear of falling were inconsistent. The studies that examined the effects of enriched environments on physical, cognitive and social functions showed that the effects of increased levels of physical activity led to an increase in the amount of socialisation time in stroke survivors. Other domains (e.g. QoL and ADL) were not affected significantly.

Discussion

The aim of this scoping review was to identify previous studies that have examined the effects of environments on the level of physical activity generally, and dynamic postural

balance and fall prevention specifically, in older adults. The findings of the current analysis showed that there were 19 studies that reported a positive relationship between built environments and the level of physical activity in older adults. In addition, there were 12 studies that related to the positive effects of environmental modifications on falls prevention and the effectiveness of task constraints on neuromotor improvements in this population group. An enriched environment tended to be specifically used only for stroke survivors in acute units and included any task that could facilitate the physical activity, cognitive functioning and socialisation of participants (Janssen, et al., 2014; Rosbergen, et al., 2017; Rosbergen, Grimley, Hayward, & Brauer, 2019). Altogether, these findings suggest that an enriched environment can facilitate the activity of participants, and that manipulating the task constraints in the targeted context can enhance neuromotor fitness in older adults.

A central question concerns how physical environments change mobility and the risks of falling. There were different views expressed on the implications of the findings for falls prevention that are reviewed in the current study: environment assessment and modification approach and ecological dynamic approach. However, both approaches emphasise on the interactions between a person and environments, they are different on the applications. For example, in the environmental assessment and modification approach that tends to be used by occupational therapists, the environmental elements are viewed as hazards that increase the risk of falling, whereas in the ecological dynamic approach, the perception of environments (affordances) plays an important role in anticipation, judgement and spatiotemporal awareness that are important for fall prevention in more dynamic and challenging environments (Fajen & Matthis, 2011). In fact, in a truly preventative approach, the combination of challenges presented by an enriched environment could engage patients to in more representative everyday life situations where the environment is used as a way to provide older adults with an opportunity for risk management and fall prevention. The focus

on indoor falls prevention in the healthcare centres has so far concentrated on mitigating risks in the home environment but this approach also allows the older adult to consider the navigation and use of outdoor spaces as a potential place to exercise and maintain mobility and function.

As a method for rehabilitation in acute stroke units, the enriched environment also emphasises on stimulating experiences to enhance exploration and engagement in social, cognitive and sensorimotor activities to promote recovery (Rosbergen, et al., 2019). This type of environment might be appropriate to increase physical activity and upper-limbs functioning after brain injuries, but its applications in older adults without any neurological disabilities might require different task/environmental designs that have yet to be studied. Furthermore, the other interventions that mainly aimed to improve neuromotor fitness components of participants through manipulating task constraints (Leach, Maring, & Costelo, 2019; Liu, Jones, Formyduval, & Clark, 2016; Nicholson, McKean, & Burkett, 2014) currently lack credibility because the interventions do not emphasise guided-discovery and exploration, were less representative of the everyday life situations and lacked integration between physical movements and perceptual-cognitive activity. Only a few studies (Law, Barnett, Yau & Gray, 2013; Law, Fong, & Yau, 2018; Pedroso, Ayán, Fraga, da Silva, Cancela, Santos-Galduròz, 2018) have used some kind of functional training procedures to enhance cognitive functions, ADL and balance. However, they either displayed contradictory findings or only recruited participants with cognitive impairments that might limit the generalisation of the outcomes to other groups of older adults (e.g. those with greater risks of falling and those who were generally fit and healthy).

By identifying abovementioned limitations in the previous studies, there are two versions of an enriched environment for enhancing dynamic postural stability that are recommended for future study interventions. The proposed interventions could borrow principles from the

ecological dynamic approach (Fajen & Matthis, 2011) that mainly emphasise functionality of perception, cognitions and actions and the representative design of tasks.

1. Environmental constrained physical activity (ECPA)

Dynamic postural stability during locomotion significantly relies on the strategy, cognitive planning and perception of surrounding environments (Rosenbaum, 2010). According to the theory of direct perception (Gibson, 1979), an organism could directly utilise environmental information for action planning without added explicit instructions from a therapist. Hence, exercise sessions with the aims to improve dynamic postural stability and falls prevention need to stimulate continuous perception-action coupling in training designs (representativeness) to educate the attention of participants (picking up or ignoring information from the surrounds, such as objects, equipment, space and people). In fact, the environment should be designed to encourage activities and it should be stimulating to encourage motor learning (Nithianantharajah & Hannan, 2006), and to cause older adults to initiate and maintain movement.

The emergence of body adaptations through constraining the environments and tasks, as a training method, has been used extensively in investigations of sport performance where the roles of cognitive activity, perception, decision-making and tactical behaviours are paramount (Davids, Araújo, Correia, & Vilar, 2013). In this approach to practice designs in sport, the emphasis is on exposing the participant to a dynamic environment (game-like situations) instead of constant repetition of techniques (e.g. running, passing, tackling, shooting, etc.). Traditionally, practice of these techniques occur in isolation from the targeted performance context, and motor behaviours emerge that are somewhat artificial and dissimilar to perceptual-motor experiences of competitive sports environments. In contrast, ecological dynamics proposes that practice environments should simulate performance environments to

improve creativity, problem-solving and self-organisation without a need for explicit augmented instructions of coaches and practitioners (Davids, et al., 2013). So older adults at risk of falling can be engaged in a 'training' that includes a range of functional tasks that promote the maintenance of active engagement in the environment through movement. New form of complex intervention (ECPA) could be used for *falls prevention* in healthy older adults and *falls rehabilitation* in people with falls experiences. Instead of designing an exercise setting to repeat the same movement pattern in long period of time (e.g. biking, treadmill walking and running, pulling /pushing the weight machines, etc.) or performing specific exercise routines in closed environments (e.g. yoga, tai chi, Pilates, etc.), a falls prevention programme could emphasise the adaptation of movements in dynamic and challenging environments to help individuals (re)calibrate postural adaptations needed for satisfying contextual demands. The ECPA could be designed by integrations of health-related fitness components (muscular strength, muscular endurance and aerobic capacity), motor fitness components (agility, speed, reaction, coordination and balance) and perceptual and cognitive functions (decision-making, dual-tasking, problem-solving and perception of visual and haptic information) to simulate the ADLs. The ECPA model could be investigated as a preventive or rehabilitation strategy for fall incident and postural balance in older adults in future studies.

2. Senior playgrounds in parks

The implications of affordance perception in promoting physical activity also were supported by the tenets of an ecological dynamic approach. From this point of view, practitioners are physical activity designers that create or re-shape the designs of urban areas, parks, green spaces, residential complexes and travel venues based on the relevant affordances to encourage physical activity (Davids, Araújo, & Brymer, 2016). Studies on the relationship between built environments and physical activity in older adults have also suggested that

access to parks, open areas and recreational facilities has a positive association with increased physical activity (Winters, et al., 2015; Timmermans, et al., 2016). Urban and public places should encourage physical activity and enable older adults to participate in more outdoor exercises (Cinderby, et al., 2018). The findings of Inclusive Design for Getting Outdoor (I'DGO, 2006) project showed that if older people live in an environment that makes it easy and enjoyable for them to go outdoors, they are more likely to be physically active and satisfied with life. This finding along with other similar studies demonstrated that the quality and accessibility of the urban spaces have a facilitator role in the physical activity and wellbeing of older adults (Levasseur et al., 2015; Keskinen, Rantakokko, Suomi, Rantanen, & Portegijs, 2018).

However, there is no evidence to show that access to green park areas has positive effects on the regulation of dynamic postural balance and falls prevention. This specific topic requires further study in future. One idea is to utilise the affordances that are embedded in nature (e.g. slopes, uneven surfaces, trails, muddy tracks etc.) or to design special activity spaces for older adults, similar to children's playgrounds, which encourage them to continuously challenge their postural control and balancing skills in a safe environment. Activities in modified forms such as walking on river stepping stones, rope climbing, tire swinging and ladder walking could provide opportunities to increase balance and postural skills.

This is the first study that reviewed the different roles of environments on physical activity and balance functions in older adults. This review is a unique attempt to recognise the differences between the existing frames of reference used in rehabilitation for falls prevention (home-based environmental risk assessment) and the ecological dynamic approach that promotes a holistic approach to movement and considers the normalisation of exercise and activity indoors and outdoors. However, this study has some limitations in its methodology. There are qualitative studies on the role of environments in the ageing population that were

not included in the our scoping review. Also, due to the nature of our review, the quality of included studies was not assessed, and that might slightly affect the implications of our findings.

Conclusion

The results of this scoping review showed that there is insufficient work utilising the physical activity environment as a vehicle for improving dynamic postural balance and falls prevention in older adults. It is necessary to formulate the research questions on the randomised control trials that are related to the physical and cognitive functions and fall prevention in everyday scenarios and in the context of enriched environments. Here it was proposed that a comprehensive theoretical framework to explain human movement behaviours, such as ecological dynamic approach, might provide a useful underpinning for further research and practical work on effects of enriching physical activity environments.

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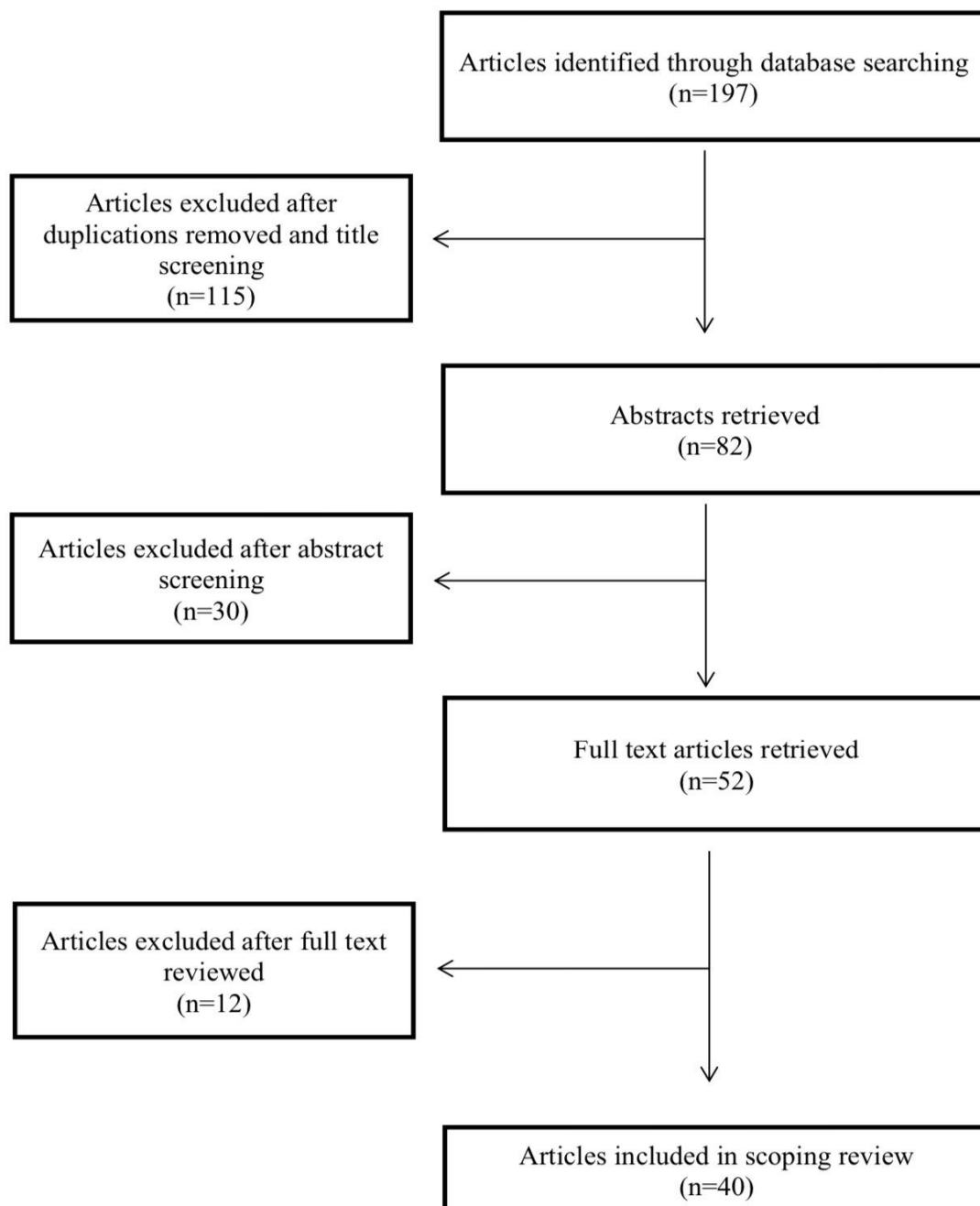


Figure 1. Flow diagram of selection of studies focusing on environments, physical activity and balance.

Table 1: The main characteristics of participants, intervention, research design and findings

No	Study	Topic	Participants	Type of study	Intervention	Measures	Findings
1	Alves et al (2006)	Built Environments	15 Hispanic and 15 White older adults in USA	Cross-sectional	N/A	Views on the photographs from different environments (natural, authentic)	The perspectives of older adults to different environments for participating in physical activity depends on the ethnicity
2	Campbell et al (2005)	Environment modifications	391 older adults in New Zealand divided into 3 groups: assessment and modification, exercise and both	Randomised control trials	The assessment and modification of hazards at home, exercise programme for strength and balance, social visits	Fall incident rate in 12 months	Fewer falls were reported in the assessment and modification group not other groups
3	Cerin et al (2013)	Built Environments	96 older adults in HongKong	Correlational	N/A	Accelerometry and Physical Environment Audit	Walking for recreation was positively associated with access to services, street connectivity, indoor places for walking, and bridge/overpass connecting to services

4	Clarke et al (2013)	Built Environments	1188 older adults in USA	Cross-sectional	N/A	Perception to environment in different activity groups	Individuals living in more accessible environments had a 18 % higher odds of being more active
5	Colom et al (2019)	Built Environments	218 middle-aged and older adults in Spain	Correlational	N/A	Accelerometry and Physical Environment Audit	Access to walk-friendly routes had an influence on accelerometer-measured physical activity in older adults
6	Cumming et al (1999)	Environment modifications	530 older adults in Australia divided into 2 groups: assessment and modification and control	Randomised control trials	The intervention was 12-month assessment and modifications of home environment	Fall incident rate in 12 months	The intervention was effective to reduce the risk of fall in people who reported the fall in the last year.
7	Day et al (2002)	Environment modifications	1090 older adults from Australia divided into 3 groups: assessment and modification, exercise and vision intervention	Randomised control trials	15 weeks intervention that emphasised on the hazard and risk assessments at home or exercise programme for balance and strength gains or were referred to eye care clinic	Fall incidents, balance and strength	The environment hazard assessment was not effective for improving balance, strength and fall incident reductions, whereas the exercise group improved strength and balance but not fall rate.

8	De Vriendt et al (2019)	Environment modifications	36 older adults from home cares in Belgium	Quasi-experimental	A client-centred meaningful activity to daily living for 2 years	Pre-post tests on QoL, MMSE and EMS	The residents experienced a higher satisfaction with their social environment and participation, and they were significantly more satisfied with the offered leisure. QoL remained unchanged, as well as self-perceived performance
9	Engel et al (2016)	Built Environments	160 community-dwelling older adults in Canada	Cross-sectional	N/A	Perceived built environment measure, QoL and wellbeing	Older adults' capability wellbeing was associated with street connectivity and social cohesion, while no statistically significant associations were found between environmental factors and HRQoL.
10	Forte et al (2019)	Environment modifications	135 older adults in Italy	Cross-sectional	Dual-task under environmental constraints (flat versus obstructed walking)	Gait performance and physical activity level	Environmental constraints affected the gait variability and executive function performance. A small contribution of PA in gait variability was reported.

11	Gell et al (2015)	Built Environments	28 middle-aged and older adults with mobility disabilities in USA	Correlational	N/A	GPS walking trip, environment walkability score	More walkable environments promote active mobility among mid-life and older adults with mobility disabilities.
12	Hanibuchi et al (2011)	Built Environments	9414 older adults in Japan	Correlational	N/A	Frequency of leisure time activity and total walking time	Presence of parks or green spaces had positive associations with the active leisure but not walking time.
13	Huang et al (2018)	Built Environments	2214 older adults in Taiwan	Correlational	N/A	Physical activity level and access to the parks and sport centres	Parks and green spaces were associated with achieving the recommended level of physical activity
14	Janssen et al (2014)	Enriched environment	29 older adults with stroke in Australia	Quasi-experimental	One group exposed to the enriched environment and another group in non-enriched environment for 10 days	Quantity and type of physical activity through behavioral mapping method	Enriched environment increased the amount of physical activity by 1.2 times, the amount of cognitive activity by 1.7 times and the amount of social activity by 0.7 times
15	Kolbe-Alexander et al (2015)	Built Environments	44 older adults in South Africa	Correlational	N/A	Self-report physical activity, accelerometer and subjective assessment of neighborhood walkability	The perceived built environment was associated with the amount of physical activity and leisure time activity

16	Lannin et al (2007)	Environment modifications	10 older adults in Australia divided into pre-charge hazard assessment and control	Randomised control trials	Intervention was assessment of the functions and environment and education for 12 weeks	Fall rate, ADLs and QoL	No changes were reported for any outcome
17	Law et al (2013)	Task constraints	11 older adults at risk of Alzheimer's disease in Hong Kong	Single-group repeated measure study	10-week (3 session/week; 1h per session) home-based functional task exercise that includes serial skills, bimanual coordination tasks, switching and memory tasks, body-orientation tasks and dual-tasking	Activity of daily living and cognitive functioning tasks	The intervention significantly improved the cognitive functions and ADLs
18	Law et al (2018)	Task constraints	43 older adults with mild cognitive impairment in Hong Kong	Single-group repeated measure study	13 sessions (10 week) participation in functional task exercise same as Law et al (2013)	Chair stand balance test, ADLs and cognitive function assessments	The intervention significantly improved the cognitive functions, balance and ADLs
19	Leach et al (2019)	Task constraints	30 community-dwelling older adults in USA	Randomised-control study	The experimental group participated in attention and stepping accuracy task whereas the control group took part in	Walking measures, balance, leg strength, aerobic endurance	Stepping group outperformed bike&strength group in balance and maximal step length. The bike&strength group was better in

					bike&strength programme for 6 week		leg strength
20	Li et al (2005)	Built Environments	577 older adults in USA	Cross- sectional	N/A	Self-report walking activity and perceived neighbourhood environment	Access to green and open spaces for recreation was associated with walking activity
21	Lin et al (2007)	Environment modifications	150 older adults with fall experience in Taiwan	Single-group Randomised- control trial	The intervention lasted for 4 months and participants received enither education (1), hazard assessment and environment modifications (2) or exercise (3)	Balance, Gait, ADLs, QoL, Fear of fall,	The QoL score was improved in education group, home safety and environment modification group also improved the QoL and functional assessments, the exercise group imrpved functional assessments
22	Liu et al (2016)	Task constraints	14 older adults in USA	Single-group repeated measure study (feasibility study)	10-week (3-4 sessions per week) of 3-step workput for life (strenght training, functional training and ADL training)	30s chair stand test, ADLs and function and disability assessment	Significant improvements in balance score, disability score and ADLs activity score

23	Lu et al (2016)	Environment modifications	40 older adults with mild cognitive impairment in USA	Randomised pre-post intervention design	One group took part in DEMA intervention and another group in information support and attention intervention. The length of study was 3 months.	Functional ability assessment, self-efficacy, meaningful activity score and life satisfaction score	The DEMA group showed higher scores on functional ability awareness, life satisfaction and more meaningful activities such as increased the amount of recreational activity and socialisation
24	Lu et al (2018)	Built Environments	720 older adults in HongKong	Correlational	N/A	Perceived environment and International Physical Activity Questionnaire	Recreational moderate-to-vigorous physical activity positively was associated with the number of recreational facilities
25	Mazzei et al (2014)	Built Environments	6 older adults in acute care Dementia unit in Canada	Cross-sectional	Pre-test in a traditional geriatric psychiatry unit; post-test in purpose-built acute care (person-centred modifications)	Behaviour mapping during daytime for 6 months	The pattern of activity was changed in the post-test observations and more time spent in the nursing station than in the private rooms. The number of pacing events were decreased
26	Nagel et al (2008)	Built Environments	546 older adults in USA	Correlational	N/A	Perceived environment and Yale Physical Activity Scale	No association between built environment and the likelihood of walking or not walking was observed in this cohort of older adults,

							but, among those who do walk, it was associated with increased levels of activity
27	Nikolaus et al (2003)	Environment modifications	360 older adults with risk of fall in Germany	Randomised pre-post intervention design	Home hazard assessment and environment modifications versus usual care at home	Fall rate	The intervention group had 31% fewer fall rate than the control group
28	Nicholson et al (2014)	Task constraints	28 older adults in Australia	Randomised pre-post intervention design	15 participants took part in BodyBalance intervention for 12 weeks that was combinations of yoga, tai chi and pilates, the control had normal activity	Timed Up and Go, 30sec Chair stand, stability score (COP), fear of fall and QoL	Significant improvements in balance scores but not fear of fall and QoL in the intervention group
29	Padressus et al (2002)	Environment modifications	60 older adults with fall in France	Randomised-control study	Home visit for hazard assessment and environment modifications	Fall rate, autonomy and hospitalisation due to fall	The intervention group was not different from the control group on the fall rate, hospitalisation and autonomy

30	Parra et al (2010)	Built Environments	1966 older adults in Bogota	Cross-sectional	N/A	Perceived environment and active park use	Residents from areas with higher park density and highland-use mix were more likely to report active park use while those from areas with high connectivity were less likely
31	Pedroso et al (2018)	Task constraints	57 older adults with Alzheimer's disease were divided into 3 groups in Brazil	Randomised pre-post intervention design	Functional-task group took part in 12 week intervention that was combinations of aerobic endurance, flexibility, muscular strength and balance. The social group took part in group dynamic activities such as singing, dancing, painting and playing games. The control group just carried on their usual activities	Cognitive function, functional fitness (strength, sit and reach, 6-min walk test) and balance test	Functional task training had no significant effect on cognitive functions, ADL and functional fitness.

32	Pighills et al (2011)	Environment modifications	238 older adults with fall experience in England divided into intervention and control groups	Randomised control trials	The intervention was 12-month assessment and modifications of home environment	Fear of fall, QoL and ADLs	The intervention had no effect on the fear of fall, QoL and ADLs, but the fall rate was reduced in the intervention group
33	Rosbergen et al (2017)	Enriched environment	90 stroke patients in acute unit in Australia were divided into 3 groups: usual care, enriched environment and sustainability	Controlled pre-post pilot study	Usual care participants received usual one-on-one allied health intervention and nursing care. The enriched environment participants were provided stimulating resources, communal areas for eating and socializing and daily group activities	Physical activity by behavioral mapping method, mobility index, QoL and ADLs	The enriched environment group engaged more in daily activity in any domain compared to the usual care. No difference between groups on the ADLs, QoL and mobility

34	Rosbergen et al (2019)	Enriched environment	60 stroke patients in acute unit in Australia were divided into 3 groups: usual care and enriched environment	Controlled pre-post pilot study	Usual care participants received usual one-on-one allied health intervention and nursing care. The enriched environment participants were provided stimulating resources, communal areas for eating and socializing and daily group activities	Physical activity by behavioral mapping method	The enriched environment group spent more time on upper-limb activities, iPad activities, communal socialisation and less time spent on lying, sitting and more time on standing
35	Sato et al (2019)	Built Environments	3133 older adults in USA	Correlational	N/A	Perceived environment and self-report Physical Activity Questionnaire	Access to parks and recreational facilities correlates with increased physical activity levels among older adults
36	Soma et al (2017)	Built Environments	509 older adults in Japan	Cross-sectional	N/A	Physical functions (grip strength, sit-to-stand, TUG, walking speed), population density and recreational facilities	Low population density, land use mix and recreational facilities were negative determinants of physical functions

37	Stevens et al (2001)	Environment modifications	1879 older adults with fall in Australia	Randomised control trials	The intervention was 12-month assessment and modifications of home environment	Fall rate and incident rate of hazards	No difference between groups on fall rate and proportion of fall due to hazards
38	Timmermans et al (2016)	Built Environments	247 older adults with and without lower-limb osteoarthritis in Holland	Correlational	N/A	Accelerometry and perceived environment	No measures of the neighbourhood built environment were significantly associated with total physical activity
39	Weber Corseuil Giehl et al (2016)	Built Environments	1705 older adults in Brazil	Correlational	N/A	Perceived environment and International Physical Activity Questionnaire	Street density was the only predictor of leisure walking activity
40	Winters et al (2015)	Built Environments	1309 older adults in Canada	Correlational	N/A	Self-report outdoor walking and perceived environment	Older adults living in neighbourhoods categorised as Walker's paradise were over three times more active than those living in car-dependent/very car dependent neighbourhoods
