

MOBILITY IMPACT AND WELL-BEING IN LATER LIFE: A MULTIDISCIPLINARY SYSTEMATIC REVIEW

Abstract

In modern societies, the understanding of how active mobility affects the elderly's psycho-physical well-being is crucial to design ageing-friendly transport measures. From a multidisciplinary perspective, this systematic review points out the mobility impact on three elements of the EU Active Ageing Index: health, independence and social connectedness. By scanning four databases (Scopus, Web of Science, PubMed, and TRID), 3,727 peer-reviewed papers published in the last decade were found, of which 57 met the inclusion criteria. The screening process was conducted following the PRISMA protocol and registered to the database PROSPERO, while the quality assessment was done using the Mixed Methods Appraisal Tool. More than 80% of the papers showed that an active mobility prevents psycho-physical harms, while only few papers study the relation of mobility with independence and social inclusion, to reduce the need for assistance and the related public expenditures. The findings of this review give important information both to transportation researchers and policymakers and companies, underlining the need for further research as well as investments in targeted age-friendly transport systems. The Covid-19 emergency has further underlined the importance of this issue, being the elderly one of the more disadvantaged and frailer social group.

Keywords: Mobility; Elderly; Active ageing; Multidisciplinary; Systematic review

JEL codes: I10, I31, J14, J18, R42

1. Introduction

Together with decreasing birth rates, advances in medicine and technology have pushed up life expectancy, resulting in ageing populations in both developing and developed countries (Cao and Zhang, 2016). In 2050, 25.1% of the total population in OECD countries will be over 65 years old, from 7.7% in 1950 (OECD, 2015), while life expectancy is overall projected to rise from 69 years in 2005-2010 to 76 years in 2045-2050 and to 82 years in 2095-2100 (UN, 2013). These projections on longevity made scholars and policymakers devote a growing attention on ageing studies for many reasons. From an economic perspective, ageing societies indeed raise concerns about an increasing segment of the population which would need an effective pension system and intense supportive health care (Abdullah et al., 2018). Furthermore, as people age they will have to adapt their homes in a sufficient way in order to compensate them for their decreasing capabilities or even relocate their place of living, thus, imposing financial pressure to the family expenses (Samuel et al., 2019).

Beyond the issues related to the provision of ageing-oriented products and services (Metz, 2000), this trend has strong implications on policies aimed at helping the elderly to remain healthy, active and socially included (Aguar and Macário, 2017; Musselwhite, 2017). Developed by the World Health Organization, the Active Ageing approach has emerged as the *process of optimizing opportunities for health, participation and security in order to enhance the quality of life as people age* (WHO, 2002). In 2012 the European Commission, together with the United Nations Economic Commission for Europe (UNECE), developed the Active Ageing Index (AAI) as an objective, supportive tool for policymakers to evaluate the challenges of ageing societies (European Commission, 2013). AAI is measured by considering 22 indicators belonging to four domains: employment (where the related rate is measured for different age ranges, from 55 to 74 years-old), participation in society (including voluntary activities, political participation, etc.), independent, healthy and secure living, and capacity and enabling environment (including mental well-being and social connectedness). In 2015 the concept of 'healthy ageing' replaced the 'active ageing' policy framework, as a way to further emphasize the need for action across sectors by 2030, in order to enable the older people to remain a resource to own families and communities (WHO, 2018). Nowadays, the importance of policies targeted to older adults

(together with other vulnerable social groups) is even stressed by the occurrence of the Covid-19 emergency, a pandemic which asks a specific attention to measures to avoid isolation and difficult access to necessary services (EU Commission, 2020).

Although the active-ageing framework refer to measurable factors that may affect well-being in later life (Kalache and Kickbusch, 1997; WHO, 2018), a multidisciplinary synthesis displaying how those intermediate aspects may be enhanced among older adults has not been conducted yet (Johnson et al., 2017). In order to contribute to fill that research gap, the aim of this paper is to focus on the indirect impacts of mobility on well-being: more specifically, to investigate how mobility can favour a healthy, independent and socially-connected living, thus increasing the older adults well-being.

The present systematic review gives two important contributions to the literature on this issue: first, it summarizes and classifies the main results of the studies belonging to different disciplines; second, it outlines the strengths and weaknesses of research efforts in health and social sciences, stimulating inter-disciplinary discussion and suggesting further research patterns and transport policy implications. Although mobility-related effects were provided within health and social sciences by using specific terminology and tailored tests (Musselwhite and Haddad, 2010; 2018), related findings rarely spilled over (Murray, 2015).

The paper is organized as follows. Section 2 and 3 outlines respectively the research background and the applied methodology. Key results are presented in Section 4, while a general discussion of the findings is provided in Section 5. Conclusions, future research suggestions and policy implications are finally presented in Section 6.

2. Background

The European active-ageing framework highlighted that physical activity and social participation (or health as an underlying cause) make people happy, and vice versa: Figure 1 shows that the two-way relationship between Active Ageing Index (AAI) and levels of life satisfaction for over 65 people in EU28 countries is often clear-cut (UNECE/European Commission, 2019). Specifically, social isolation was found to have a substantial impact upon well-being in older adults, accounting for around 70% of depression (Golden et al., 2009). In addition, physical activity (through functional ability) has been shown to improve other dimensions of well-being, such as quality of life (Hyde et al., 2003; Törnvall et al., 2016; McPhee et al., 2016; Jackson et al., 2019) or Health Related Quality of Life (HRQoL) (Kawecka-Jaszcz et al., 2013; Forte et al., 2015), and reduce depressive symptoms (Conn, 2010; Holmquist et al., 2017). Moreover, the Madrid International Plan of Action on Ageing and its Regional Implementation Strategy (MIPAA/RIS) for the 56 UNECE countries explicitly links AAI domains with recommendations emerging from policies aimed at promoting active ageing. As shown in Table 1, quality of life, independent living, health and well-being is connected to two AAI domains, i.e., 'independent, healthy and secure living' and 'capacity and enabling environment' (European Commission, 2019).

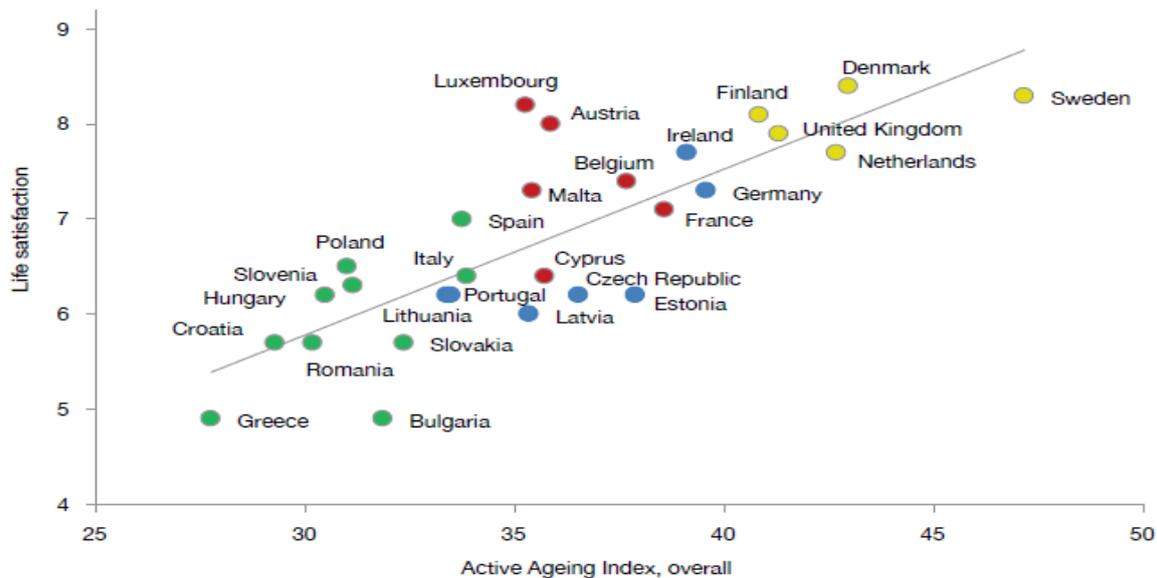


Figure 1 EU28: overall AAI scores and life satisfaction among 65+ in 2018 (colours represent clusters) (European Quality of Life Survey Integrated Data File, 2003-2016, as cited in UNECE / European Commission, 2019)

However, how mobility, in terms of functional capability, could affect well-being in later life? Overall, the concept of well-being in later life itself has been related to a set of feelings, emotions and habits consisting of three relevant dimensions: (i) “having”, i.e., income, housing standards, employment, health and education; (ii) “loving”, i.e., relations with family, friends, and other; and (iii) “being”, i.e., self-esteem, leisure activities, social reputation and political resources (Allardt, 1975; as cited in Hjorthol, 2013).

Table 1 Correspondence between AAI domains and MIPAA/RIS commitments (European Commission, 2019)

2017 Madrid International Plan of Action on Ageing and its Regional Implementation Strategy (MIPAA/RIS) areas of commitment	Active Ageing Index domains			
	Employment	Participation in society	Independent, healthy & secure living	Capacity and enabling environment
Full integration and participation of older Persons		<input checked="" type="checkbox"/>		
Equitable and sustainable economic growth			<input checked="" type="checkbox"/>	
Adjusted social protection systems	<input checked="" type="checkbox"/>			
Responsive labour markets	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>
Lifelong learning and education			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Quality of life, independent living, health and well-being			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Mainstreaming gender	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Supporting families providing care and promoting intergenerational		<input checked="" type="checkbox"/>		

According to this manifold notion of well-being, even the concept of mobility should be approached from a multidimensional perspective (Gagliardi et al., 2010; Ziegler and Schwanen, 2011; La Grow et

al., 2013), especially taking into consideration that ‘the ability to get out and about’ (Banister and Bowling, 2004) might have an impact on many psycho-social dimensions. In a seminal paper, Metz (2000) provide a notion of mobility of older people integrating five key attributes, i.e., travelling to achieve access to desired people and places, psychological benefits of movement, exercise benefits, involvement in the local community, and the potential to travel. Later, in other than health sciences, mobility in terms of functional capabilities, has been defined as actual or potential embodied movement through physical space (Schwanen et al., 2012) or the ability to move around safely and independently inside or outside the residence home (Ravulaparthi et al., 2013). Yet, following those approaches, various types of ‘demand for’ mobility by older adults might arise in many daily-life aspects, where mobility itself could have a positive effect on cognition and physical activity (Webber et al., 2010). As a result, mobility in later life should not be just considered as a way to reach desired places by using transport means (Mizokami et al., 2014; Yeoh et al., 2018), but also as a mediator to improve well-being through physical and mental factors, including independence and social connections (Spinney et al., 2009; Ziegler and Schwanen, 2011; Siren et al., 2015) or, in general, as a way to express freedom and remaining life force (Mollenkopf et al., 2011). Even when specific restraints limit the possibility to move freely (e.g., isolation due to the Covid-19 emergency), an active mobility to reduce frailty in later life (Avgerinou et al., 2019; Frost, 2018; Cadore et al., 2013) is of primary importance, and thus has to be strongly encouraged and supported (Hartmann-Boyce et al., 2020).

3. Methodology

3.1 Search strategy

In order to capture the large strand of published research in health and social sciences, this systematic review has been conducted by screening in the period January 2010 and December 2019 four electronic databases: Scopus, Web of Science, PubMed and Transportation Research International Documentation (TRID). We searched for the combination (in titles only) of keywords such as “mobility” and other terms (“elder*”, “old*”, “senior*”, “late*life”, “age*” and “aging”) by using an asterisk to get composite nouns (e.g., ‘ageing’ or ‘age-related’). Since this research is focused on health and social features as mediators between functional mobility and well-being, no terms related to transport means or travel were used. The effects on ageing well-being of the usage of transport means (e.g., private vehicles, public transit, etc.) and related policies for seniors, e.g., free bus pass, concessionary fares, etc. (see, among others, Rosenbloom, 2009; Shergold and Parkhurst, 2012; Shrestha et al., 2017; Laverty et al., 2018; Reinhard et al., 2018) are out of scope of this review.

3.2 Inclusion criteria

The review includes the studies meeting the following prior criteria: (i) published in peer-reviewed journals, (ii) published in (or translated into) English, (iii) studying effects of mobility on the three above cited dimensions of life quality, by using qualitative e.g. interviews’ text analysis, and/or quantitative methods e.g. objective or self-reported data analysis, (iv) published between January 2010 and December 2019, (v) having considered (as a study group) community-dwelling elderly people (i.e., persons over 60 not living in an institution, such as hospitals or nursing homes) living in developed countries according to the United Nations Conference on Trade and Development classification. Commentary articles, grey literature and other reviews of any type were excluded. Since the AAI was developed by the EU Commission in 2012, the publishing time-window used starts from papers published in 2010, allowing us to retrieve research studies recognizing the quantitative evolution of the active ageing framework.

3.3 Screening and classification

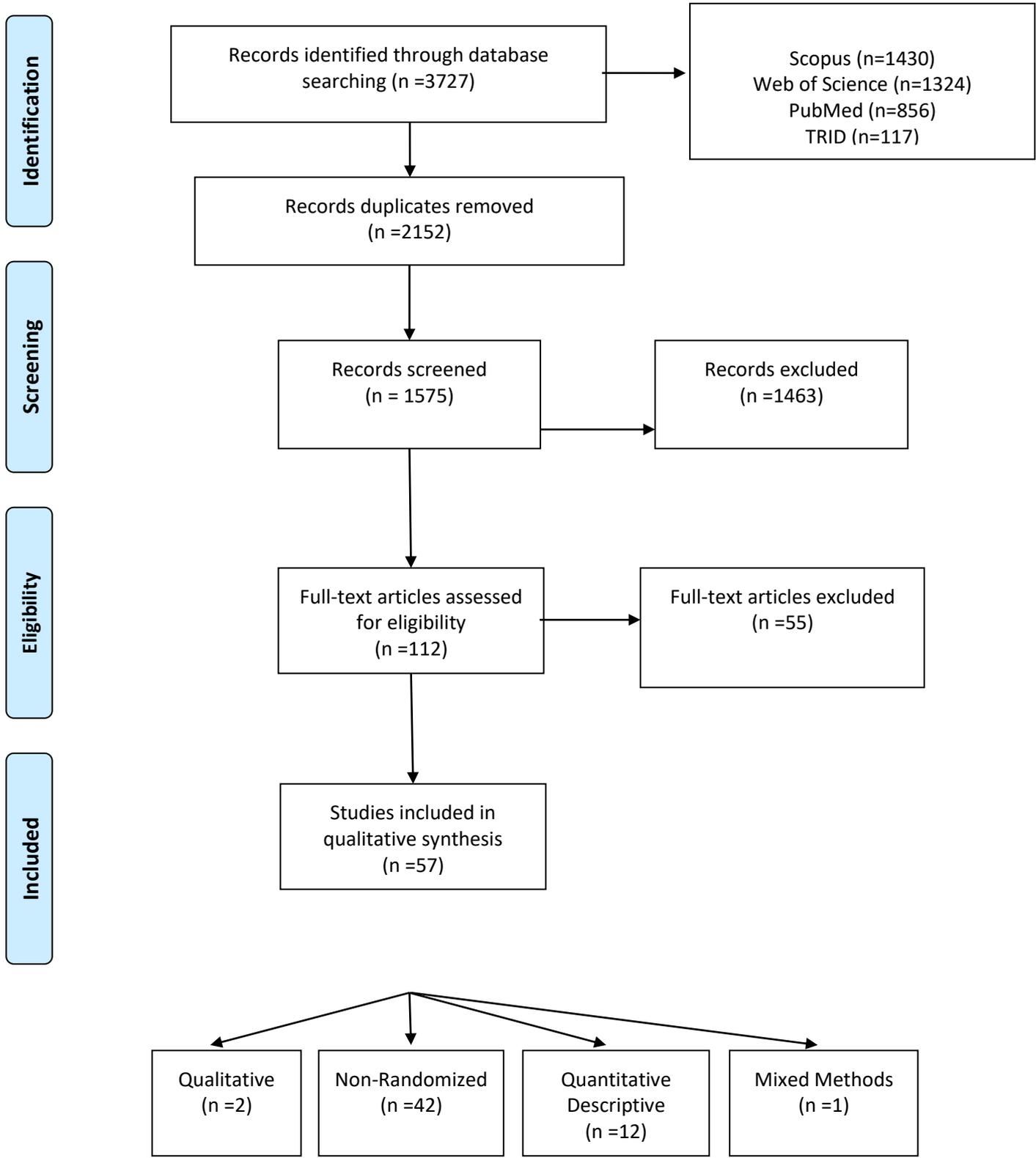
The screening process used in the review was conducted according to the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Moher et al., 2009; see [Electronic Supplementary Material 1](#)) and registered to PROSPERO, a database of systematic reviews (record CRD42019142194,

October 2019). Our search strategy retrieved first 3727 sources from the scanned electronic libraries (Scopus: 1430; Web of Science: 1324; PubMed: 856; TRID: 117). After removing the duplicates, 1575 studies remained for possible inclusion. As shown in [Figure 2](#), the screening phase was initially based on titles and abstracts, keeping only the articles satisfying all the above described criteria. As a result, 112 articles were found as eligible for full text reading. After skimming through the whole text (and again using the inclusion criteria), all the papers investigating the direct impact of mobility on well-being (i.e., without a specific analysis of mediate factors) were excluded. As a result, 57 articles were finally included for data extraction.

To best allocate the studies into a specific domain, we applied the journal classification adopted by Science Metrix (Archambault, 2016), distinguishing three different groups: Health Sciences, Economic & Social Sciences and General Science (where a multidisciplinary approach is explicitly identified). In case of papers that were impossible to associate to specific fields, as an alternative, the Web of Science Journal of Citation Reports and /or Scimago Journal Ranking were consulted.



Figure 2: PRISMA 2009 Flow Diagram



3.4. Assessing the risk of bias

To perform a quality assessment of the included studies, the Mixed Methods Appraisal Tool (MMAT; [Hong et al., 2018](#)) was used, because it allows to evaluate studies using different methodologies. MMAT, in fact, identifies five categories of papers according to the method used: (i) qualitative research, (ii) randomized controlled trials, (iii) non-randomized studies, (iv) quantitative descriptive studies, and (v) mixed methods studies. None of the reviewed paper belongs to the second category (see [Figure 2](#)). The most frequent category of studies found in the literature is the non-randomized (73.7%), followed by the quantitative descriptive papers (21%). The appraisal consists of two initial screening questions, applied to all the studies, about the clearness of the research inquiry and the appropriateness of the data to address it, and then, proceeds to five more specific questions for each category of study (see [Supplementary Material 2 Appendix A](#)). All the studies that fulfilled the inclusion criteria were considered for quality appraisal (see [section 5.2](#)).

4. Results

4.1 Characteristics of the included studies

The attention on effects of mobility on psycho-social status in later life had an increasing trend, except for 2019 (probably because some recent papers are still in process of publication; see [Figure 3](#)). Included articles belong to few domains: health sciences (clinical medicine, public health & health services; 53 studies, 93%); economic and social sciences (economics & business, social sciences; 3 studies, 5.2%); and general sciences (general science & technology; 1 study, 1.8%). Beyond the conceivable and large dominance of health sciences with respect to other domains, we notice that multidisciplinary contributions are almost absent while in economic and social sciences it seems that the research topic has concerned a bit more.

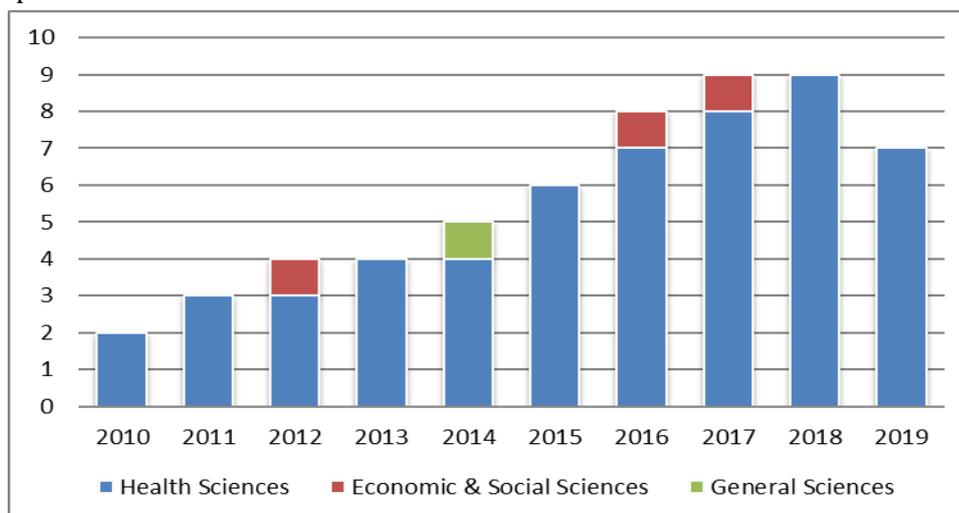


Figure 3 Number of studies (per domain) and year of publication

[Table 2](#) shows the location of included studies at a country-level: 35.1% belongs to European area, while 64.9% are not European. Scandinavian countries dominate the European research in this topic, with Finland (10.5%) and Sweden (7%), displaying a common high commitment to ageing-related social changes. Most of non-European studies indeed were conducted in the United States (47.4%).

Table 2 Study allocation by domain and country of research

Domain	Field	Studies/Country
Health Sciences	Clinical Medicine 29/57	15 (US), 4 (Finland), 2 (Canada, UK), 1 (Australia, France, Ireland, Japan, Poland, Sweden)
	Public Health & Health Services 24/57	11 (US), 2 (Selected EU, Finland, Italy), 1 (Australia, Belgium, Japan, Norway, Sweden, Canada Spain)
Economic & Social Sciences	Economics & Business 1/57	1 (Sweden)
	Social Sciences 2/57	1 (US, UK)
General Sciences	General Science & Technology 1/57	1 (Sweden)

In terms of sample size, more than half of the studies has considered samples with at most 1,000 participants (Table 3). Interestingly, three recent studies in health sciences are based on more than 20,000 observations, as they rely on large longitudinal datasets such as the Survey of Health, Ageing and Retirement in Europe (SHARE) database (Litwin et al., 2018; Litwin and Levinson, 2018) and the Canadian Longitudinal Study on Aging (Demnitz et al., 2018), containing micro-data on health status of older adults.

Table 3 Sample size by type of study

Type of study	Sample size participants					
	<200	200-1000	1000-3000	3000-5000	5000-20000	>20000
Qualitative	2					
Non-Randomized	8	15	12	3	1	3
Quantitative Descriptive	7	2	2	1		
Mixed Methods	1					
Total	31.6%	29.8%	24.6%	7.0%	1.8%	5.3%

4.3 The effects of mobility on health, independence and social inclusion

In this section, relevant findings of the systematic review are summarized to explicitly tackle our research questions by considering three domains (largely inspired by the AAI), such as health status (including physical and psychological conditions), independent living, and social connectedness (Table 5-7). All the included studies with their main characteristics are provided in the Supplementary Material 2 (Appendix B). Furthermore, for a more comprehensive description of the mobility tests used in the included literature, refer to Paz and West (2014) and Soubra et al.(2019).

4.3.1. Health status: physical and psychological conditions

Fifty papers found in this review investigate the impact of mobility on various health outcomes, highlighting its crucial role (Katz, 2000; Galloway and Jokl, 2000). Thirty-four papers use objective tests (including GPS metrics to track movements) to assess mobility functions in later life (different movement indicators are described in Kaspar et al., 2015 and Fillekes et al., 2019) while sixteen

studies are based on self-reported information (e.g., surveys, qualitative interviews, etc.) and/or mixed research strategies. Below detailed findings about the impact of mobility on health are provided, starting from the top three outcomes, i.e., falls (and risk of falling), mortality, and cognition.

Falls (and risk of falling)

About 20% of the reviewed papers analyse how falls and risk of falling could be reduced through higher levels of mobility. On that matter, scientific contributions which overall confirm that relationship have been detected in clinical medicine (Manty et al., 2010; Dai et al., 2012; Balasubramarian et al., 2015; Jefferis et al., 2015; Lo et al., 2016; Musich et al., 2018; Langeard et al., 2019) and public health (Panzer et al., 2011; Topuz et al., 2014; Mulasso et al., 2016; Litwin et al., 2018).

By using screening questions focused on difficulties with walking or climbing stairs, mobility limitations were investigated in Musich et al. (2018). In that case, analysing a sample of 4,661 U. people over 64 years old, the authors found that moderate or severe mobility constraint simply increasing falls, and (in turn) related higher healthcare expenditures. Similarly, mobility constraints were also considered in Jefferis et al. (2015), for which the association between baseline physical activity features (e.g., step counts, sedentary time, etc.) and mobility limitations in 3,137 UK elderly helped detecting fitness condition as a mediator to reduce falls risk. Controlling for several confounders, the Life-space Assessment Approach (LSA) was successfully used with 940 US residents over 65 in Lo et al. (2016), who found that falls odds increase in the presence of deprived neighbourhood-level characteristics (implying less accessible life spaces) and reduced out-of-home activities. Manty et al. (2010) consider a sample of 428 twin older community-living women in Finland and argue that the mobility decline can likely aggravate the fall history and increase the risk of future falls. Finally, Dai et al. (2012), instead, used a structural equation model to investigate the interactions among functional mobility and falls in 511 US older adults. Beyond finding that the TUG test is a good screening tool for mobility and fall risk, the authors highlight that satisfactory mobility rates can prevent the risk of falling. Interestingly, contrary to the above-mentioned studies were the positive link between mobility in non-disabled older adults and less risk of falling was detected, in case of mobility impairments (implying a movement loss due to functional abnormality), Langeard et al. (2019) did not get conclusive findings. By processing TUG test and other mobility scores (i.e., Gait Composite Score, Balance Composite Score, Physical Capacity Score) drawn from a sample of 26 Canadian older adults, their results suggest that mobility impairment does not significantly distinguish fallers and non-fallers.

From a public health perspective, Litwin et al. (2018) exploited 22,533 observations (19,023 controlling for the country, 20,654 without frailty variable) on over-65 people from the SHARE project in 13 European countries and conclude that mobility limitations act as moderators between fear of falling and falling. Panzer et al. (2011) found that the indicators related to different real-life mobility challenges perform better to identify the falls-related status, offering superior sensitivity in predicting injuries, for instance, with respect to the Performance Oriented Mobility Assessment test (POMA). Clearly, research findings about falls are in fact closely related to the more suitable type of mobility tests to be used in various fields, including the TUG test, the Timed Chair Stand test, the Functional Reach test, and the One-Leg Balance test (Topuz et al., 2014 for a multivariate testing framework). For instance, Mulasso et al. (2016) did not find it significantly associated with falls in a study based on 192 older adults over 65 living in a small area of Italy. The authors support that the multidimensional nature of frailty should be detected with a multidimensional tool like the Tilburg Frailty Indicator. In that sense, Balasubramarian et al. (2015) examine the predictive ability of various tests, i.e. TUG, Dynamic Gait Index (DGI), Short Physical Performance Battery (SPPB), and Community Balance and Mobility scale (CB&M). The authors concluded that the CB&M test detected fallers from non-fallers and more the DGI and CB&M recurrent fallers from those with fewer or no falls.

Mortality

Mortality is the second studied effect in health sciences (17.5% of the studies) and it can be seen as a tricky research target since it occurs naturally as people age, and sometimes the prediction of such an event is not a meaningful issue for this stage of life. Yet, beyond the concerning life expectancy rate

also included in the 'capacity and enabling environment' domain of the EU Commission's active-ageing framework, there is a consensus within health sciences that the scores of mobility tests can be a sounding indicator for the risk of mortality anyway. The papers listed in [Table 5](#), displayed that, controlling for other pertinent factors, mobility in later life reduces mortality odds by decreasing various co-morbidities.

As for clinical medicine, four studies were retrieved. Using survey data from 1,852 persons between 60 and 85 years old in the US, [Frith et al. \(2017\)](#) reported that older adults with difficulty in walking without special equipment (and with reduced cognition) are more prone to mortality risks. Comparing the size of the effect with the groups that are either mobility disadvantaged or suffer from cognitive deficiency, the results are not statistically significant.

Applying Walking While Talking test on 631 US over 70 people in the Bronx County (594 completed the survey), [Verghese et al. \(2012\)](#) found it to be a robust predictor of latent mobility abnormalities, in turn increasing mortality rates. Applying the Life-Space Assessment (LSA; [Baker et al., 2003](#)) in the US, [Mackey et al. \(2014; 2016\)](#) found evidence about the positive effect of mobility on health (gait speed) and reduction of mortality risk either among older men (3892 observations) or women (1498 observations).

[Bergland et al. \(2017\)](#) applied the TUG test in Norway (survey data about 1,005 people over 65, of which 846 complete), showing that TUG scores are important predictors for survival in both men and women. POMA test, indeed, was found to be effective in mortality prediction among 2,069 US older people by [Nam et al. \(2017\)](#). On the contrary, [Ensrud et al. \(2016\)](#) reported that the SPPB test applied on 1,495 US women (interviews) gave strong evidence of mobility as a predictor of mortality risk but the interaction with cognition was not enough to predict mortality rates. Finally, relying on interviews and/or the Usual Gait Speed (UGS) test about time to walk or mobility difficulty, ten studies found positive evidence of mobility capabilities as mediated parts of the association between social activity and mortality. In that sense, [Katja et al. \(2014\)](#) asked 1,181 Finnish older adults about own ability to walk indoors, outdoors, and climb stairs, while [Olaya et al. \(2018\)](#) got similar results by using 2,074 data from Collaborative Research on Ageing in Europe (COURAGE) survey, a longitudinal household survey of the non-institutionalized adult population in Spain. Lastly, mobility disability was investigated using the UGS test as a mortality predictor in [Yu et al. \(2019\)](#), where 1,262 US people (aged 75 years on average) did not predict a positive relationship of mobility alone but only after the incidence of mild cognitive impairment (even if mobility disability is more often from mild cognitive impairment).

Cognition

Positive (or improvement) effects of mobility on cognition were studied in some research papers (14% of the total), mainly based in the US and UK ([Cohen et al., 2016](#); [Tian et al., 2017](#); [Demnitz et al., 2017, 2018](#); [Donoghue et al., 2018](#); [Sunderaraman et al., 2019](#)). A recent exception was [Rajtar-Zembaty et al. \(2019\)](#), where a total of 800 older adults in Poland were recruited (653 with normal cognitive functioning and 147 participants with mild cognitive limitations) to test whether the relationship between the higher level of global cognition and some global cognitive subscales (including memory and fluency scores) were related to the better physical mobility performance. By applying both the TUG test and the 6-minutes' walk test, the obtained results revealed that higher levels of global cognition were related to better physical mobility performances. Gait assessment and the TUG test were also used by [Sunderaraman et al. \(2019\)](#), who gathered information from 124 older adults in the US. Overall, their findings suggested that, in healthy individuals, relatively lowered cognitive performance may be linked to increased risk of gait alterations during the performance of these complex motor functions, or that lowered cognition may represent a higher vulnerability to gait disturbances. The relationship between executive functions and specific aspects of mobility has been strikingly highlighted. Analogously, by interviewing 162 persons in the US between 50 and 89 years old, [Cohen et al. \(2016\)](#) showed a dissociation between motor and cognitive functions, where deficits in the former ones are associated with slow TUG performance, while episodic memory deficits were associated with less upright posture. Interestingly, in [Tian et al. \(2017\)](#), among initially unimpaired 412 older adults in the US, the temporal relationship between UGS and executive function is

bidirectional, with each predicting change in the other, while poor fast walking performance predicts future executive function and memory changes but not vice versa. Two studies conducted in Canada and Britain (Demnitz et al., 2017; 2018) used several measures – such as the walking time course, balance time in one-legged stand, and chair stands tests – to show how cognitive measures were significantly associated with mobility measures, thus concluding that objective measures of poor mobility are sensitive to indices of poorer cognitive function. In a similar fashion, Donoghue et al. (2018) studied the relationship between different tests (i.e., TUG test, UGS and Dual-task Gait Speed tests) and cognitive decline in 2,250 Irish older adults, predicting a slight decline in cognition when mobility is limited. Only one study about mobility and cognition was found in the sociology literature, where, applying 11 indicators of mobility limitations to an age-heterogeneous sample drawn from the Health and Retirement Study (1998–2008) in the US, Bishop et al. (2016) outlined that the elderly with fewer mobility limitations perform better in cognition and word recall.

Other physical conditions

The literature review highlights also other negative physical or mental effects that, according to the literature, could be prevented by mobility in ageing societies (see Table 5); different measurement tools and tests have been used. Often combined with either UGS test or walking time measures, the TUG test has been mainly used to assess frailty (Kim et al., 2010; Fallah et al., 2011), neuromuscular performance (Berryman et al., 2013), parkinson disease (Von Coelln et al., 2019) and urinary incontinence (Fritel et al., 2013), and kyphosis (Sugai et al., 2019). Specifically, Fallah et al. (2011) focused on the rapid gait test and, using data on 754 US people over 70 participating at the Yale Precipitating Events Project, they showed how mobility in later life can be significantly associated with changes in frailty status. By contrast, Kim et al. (2010) combined the TUG test with the 5-chair Sit-To-Stand (STS) test, alternate step, Timed Rapid Gait (TRG) test and UGS test to analyse the link between mobility and frailty in Japan (337 persons over 65). They found that, except for the 5-chair STS test, all the other tests detect lower risk of frailty for better performing mobility. Applied to 48 older adults between 60 and 85 in Canada, the TUG test combined with the 10-meters walking time test indicated that faster individuals display higher neuromuscular performances, as well as better aerobic capacity and executive function (Berryman et al., 2013). Von Coelln et al. (2019) used three mobility tests: 32 ft walk, modified TUG, standing posture with a sample of 683 (completed the survey) elderly (mean age 80,7 years old) in Chicago (US); they showed how mobility metrics can complement conventional gait tests and have potential to detect the risks of older adults who may develop parkinsonism. Risks of urinary incontinence have been also studied in Fritel et al. (2013), by combining the TUG test with other two mobility tests, i.e., a timed 6-mwalk test, and a test measuring the time taken to get up from a chair and sit down again five times without using the arms. By surveying 1,942 elderly women in some French cities (i.e., Paris, Boulogne-Billancourt, Lille, Reims, Montpellier, and Amiens), the authors showed a significant relationship between mobility-based limitations and urinary incontinence, thus offering new perspectives for the prevention and treatment of specific ageing-related diseases. Finally, a very recent study by Sugai et al. (2019) focused on the progression of kyphosis in older adults. Even though the causality of kyphosis progression has not been fully elucidated (i.e., the elderly may have a vicious cycle of the progression of kyphosis and generalized weakness, and the other way around), both low handgrip strength and low mobility were significantly associated with that physical trend.

In the last years, other tests contributed to find a positive correlation, between good mobility-related performances and physical activity (Tsai et al., 2015), executive functionality (Tian et al., 2015; Poranen-Clark et al., 2018), depressive symptoms (Polku et al. 2015), muscles strength (Reid et al., 2012; 2014; Curcio et al., 2016), hospitalization (Ensrud et al., 2017), and activities of daily living (ADL) disability (Heiland et al., 2016). For instance, the SPPB test was used in two studies in the US (Reid et al., 2014, 2012), showing that muscle power deteriorates significantly for mobility-limited older groups compared to non-limited (Reid et al., 2012). Later, Reid et al. (2014) elaborated longitudinal data and concluded that both groups presented similar muscle power performance, stressing that different underlining mechanisms are implied. From a general perspective about healthcare, the same test applied on 633 women in Portland (US) allowed Ensrud et al. (2017) to confirm that reduced mobility and poorer cognition should be important in clinical decision-making

and healthcare policy planning for ageing societies, considering their independent association with hospitalization days but no evidence for combined effects is detected. Effects of mobility on muscles strength were also studied by using the POMA test in [Curcio et al. \(2016\)](#), where scores about 337 older adults in Italy were found to be related to muscle mass and strength, independently of several factors including age. Focusing on ADL disability, [Heiland et al. \(2016\)](#) applied the one-leg balance stand test and assessed the walking speed in 2,4 and 6 m walk of 1,971 elderly living in the urban area of Stockholm (Sweden), finding that poor-performing mobility tests indicate hierarchical risk of disability in older adults, especially higher risk of developing disability in ADL.

Regarding the LSA test ([Baker et al., 2003](#)), its design has been useful to assess how life-space mobility can enhance physical activity and, therefore, help maintaining healthy people. By interviewing 174 Finnish people aged 75-90, [Tsai et al. \(2015\)](#) showed that a more intense life-space mobility is associated with objectively measured and positive indicators of physical activity (e.g., step count, activity and sedentary time). As for the effects of life-space mobility on executive functionality, both [Poranen-Clark et al. \(2018\)](#), using the LSA test with 169 Finnish people aged between 76 and 91), and [Tian et al. \(2015\)](#), applying a timed 400-m walking test to 347 over 60 persons interviewed in the US, detected significant positive effects. Instead, in a Finnish study involving 848 persons aged 75-90, [Polku et al. \(2015\)](#) studied the different dimensions of depression and their relations with life-space mobility, confirming their association (albeit not stating clearly the direction of the causality due to the cross sectional nature of the data used).

Finally, regarding the effects of mobility on health conditions, we found that sixteen studies in health sciences used self-reported information (e.g., subjective questions) about own mobility status ([Knaggs et al., 2011](#); [Kozakai et al., 2013](#); [Choi and DiNitto, 2016](#); [Asp et al. 2017](#)). When using Swedish survey data (2,409 respondents aged 65-99, 2,261 full data) with questions on the difficulty to walk-up stairs or take short walks, [Asp et al. \(2017\)](#) found a significant association between physical activity and obesity only among elderly with physical mobility. Among elderly with impaired mobility, indeed, the obesity was high and similar irrespectively of physical activity. [Choi and DiNitto \(2016\)](#) used a survey conducted in the US (more than 5,000 observations) related to over 65 adults to investigate how mobility could reduce depressive symptoms. Their findings show that non-driving elderly who used to walk as a transport option tend to report lower depressive symptoms than older adults who did not walk. Dealing with mobility limitations, [Kozakai et al. \(2013\)](#) analysed 846 interviews among Finnish adults between 66 and 98, where respondents self-reported perceived difficulty in 2-km walking and climbing one flight of stairs without resting. Since mobility limitations were found to strongly increase the need for inpatient care in the last year of life among men, the authors argued that a reduced mobility might accelerate the health decline, thus prolonging the inpatient care period in the late phase of life (with related higher healthcare spending). Metabolic costs of daily activities were studied by [Knaggs et al. \(2011\)](#), who using a sample of 42 elderly in the US (aged 70-90), reported on own difficulty when walking $\frac{1}{4}$ mile, getting up from a chair, climbing a flight of stairs, or performing light housework. As a result, mobility impairments were indeed found to increase metabolic costs of daily living.

As for research on mobility capabilities in the social sciences literature, three studies have assessed mobility without explicitly referring to the quality of transport means ([Chiatti et al., 2017](#); [Fristedt et al., 2014](#)). In a study focused on physical and psychological health associated to mobility, [Chiatti et al. \(2017\)](#) showed that, among about 2,400 elderly Swedish, walking at least $\frac{1}{2}$ km daily and being socially engaged have implications on mental self-reported health. Regarding to gender-related outcomes, the authors found that either male or female older adults report better ratings of subjective health associated with mobility. Yet, in another Swedish study, community mobility is associated with better subjective health for both genders ([Fristedt et al., 2014](#)). Interestingly, in this study, the 119 elderly men were more involved in sport activities, while the 147 women reported more out-of-home activities of daily living.

Table 5. Summary of the role of mobility on health issues

OUTCOME VARIABLES	DISCIPLINE	MOBILITY MEASURE(s)	AUTHOR(s)
Falls N=19.3% (11/57)	Clinical Medicine	LSA test (Baker et al. 2003)	(-) Lo et al. (2016)
		Self-reported information – Perceived difficulty and task modification in advanced mobility regarding the 2-km walk	(-) Manty et al. (2012)
		Self-reported information - Questions on difficulties with walking or climbing stairs	(-) Musich et al. (2018)
		Self-reported information – Reported grade of difficulty (no difficulty vs some difficulty, moderate difficulty, severe difficulty) getting about outdoors	(-) Jefferis et al. (2015)
		TUG test and Mobility Scores (Gait Composite Score, Balance Composite Score, Physical Capacity Score)	(n) Langeard et al. (2019)
		TUG test	(-) Dai et al. (2012)
	Public Health & Health Services	TUG test, DGI, SPPB and CB&M	(-) Balasubramanian et al. (2015)
		TUG test	(n) Mulasso et al. (2016)
		Composite scores of individual mobility variables such as quiet standing, maximal lean, sit-to-stand, gait, turn, step-in-tub and downstairs	(-) Panzer et al. (2011)
		TUG test, Timed Chair Stand test, Functional Reach test, One-Leg Balance test, and lower limb muscle strength	(-) Topuz et al. (2014)
		Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	(-) Litwin et al. (2018)
Mortality N=17.5% (10/57)	Clinical Medicine	LSA test (Baker et al., 2003)	(-) Mackey et al. (2014) (-) Mackey et al. (2016)
		Self-reported information – Difficulty walking without special equipment use, walking 0.25 miles (to convert to kilometer, multiply by 1.6), walking 10 steps without stopping; stooping, crouching, or kneeling, walking from one room to another on the same level, standing up from an armless straight chair; or standing or being on their feet for 2 hours	(-) Frith et al. (2017)
		WWT test, Speed (cm/s) during normal pace walking, SPPB	(-) Verghese et al. (2012)
		UGS test: time to walk 8 feet (2.4 m)	(-) Yu et al. (2019)
	Public Health	Self-reported information – Difficulties in the previous 30 days in 15 different mobility-related situations	(-) Olaya et al. (2018)

	& Health Services	POMA and self-reported information – If help is needed from another person or special equipment or a device for a walking across a small room	(-) Nam et al. (2017)
		Self-reported information – Questions on ability to walk indoors, outdoors, and climb stairs	(-) Katja et al. (2014)
		SPPB	(-) Ensrud et al. (2016)
		TUG test	(-) Bergland et al. (2017)
Muscles N=5.3% (3/57)	Clinical Medicine	SPPB	(n) Reid et al. (2014) (-) Reid et al. (2012)
	Public	POMA	(-) Curcio et al. (2016)
Frailty N=3.5% (2/57)	Clinical Medicine	TUG test, 5-chair STS test, alternate step, TRG test, UGS test	(-) Kim et al. (2010)
		Rapid gait test: back-and-forth walk over the 20-ft course as quickly as possible	(-) Fallah et al. (2011)
Kyphosis N=1.8% (1/57)	Public Health & Health Services	TUG test	(-) Sugai et al. (2019)
ADL disability N=1.8% (1/57)	Clinical Medicine	One-leg balance stand and assessment of walking speed (m/s) of 2.4 or 6 m walk	(-) Heiland et al. (2016)
Metabolic costs of daily activities N=1.8% (1/57)	Clinical Medicine	Self-reported information – Difficulty in walking ¼ mile, getting up from a chair, climbing a flight of stairs, or performing light housework	(+) Knaggs et al. (2011)
Neuromuscular performances, aerobic capacity and cognitive flexibility N=1.8% (1/57)	Public Health & Health Services	TUG test and 10m walking test	(+) Berryman et al. (2013)
Obesity N=1.8% (1/57)	Public Health & Health Services	Self-reported information – Ability to walk upstairs without difficulty (for example getting on a bus or a train) and take a short walk (about five min) at a reasonably fast pace	(?) Asp et al. (2017)
Parkinson N=1.8%	Clinical Medicine	Modified TUG test, 32 ft walk, Standing Posture	(-) von Coelln et al. (2019)

(1/57)			
Urinary incontinence N=1.8% (1/57)	Clinical Medicine	TUG test, Timed 6-m walk test and a test measuring the time taken to get up from a chair and sit down again five times without using the arms	(-) Fritel et al. (2013)
Physical activity N=1.8% (1/57)	Clinical Medicine	LSA test (Baker et al., 2003)	(+) Tsai et al. (2015)
Cognition N=14% (8/57)	Clinical Medicine	TUG test and Gait assessment	(+) Sunderaraman et al. (2019)
		TUG test and the 6 Minute Walk Test	(+) Raitar-Zembatv et al.
		TUG test, UGS test, and DTGS test	(?) Donoghue et al. (2018)
		TUG test	(+) Cohen et al. (2016)
		400-m walk test and usual gait speed for a 6-meter course	(?) Tian et al. (2017)
		Walking time (2.44 m) course, balance time in one-legged stand (cut-off 30s) and chair stands tests	(+) Demnitz et al. (2017)
	Walking time 4 m course, balance time in one-legged stand (cut-off 60s) and chair stands tests	(+) Demnitz et al. (2018)	
	Social Sciences	Self-reported information - Difficulty in stooping or crouching, climbing one flight of stairs without resting, climbing several flight of stairs without resting, moving large objects, sitting in a chair for two hours, getting up from a chair after sitting for long periods, lifting weights more than 10 pounds, raising arms above shoulder level, walking one block, walking several blocks, and picking up a dime	(+) Bishop et al. (2016)
Depression N=3.5% (2/57)	Clinical	LSA test (Baker et al., 2003)	(?) Polku et al. (2015)
	Public Health & Health Services	Self-reported information - How people (other than driving) got to places that are outside their home during the preceding month	(-) Choi and DiNitto (2016)
Executive function N=3.5%	Public Health & Health Services	LSA test (Baker et al., 2003)	(o) Poranen-Clark et al. (2018)
		400-m walk test and usual gait speed for a 6-meter course	(+) Tian et al. (2015)
Hospitalization and inpatient care N=3.5%	Clinical Medicine	Self-reported information-Difficulty in walking 2 km and climbing one flight of stairs without resting	(-) Kozakai et al. (2013)
	Public Health & Health Services	SPPB	(-) Ensrud et al. (2017)

Subjective health N=1.8% (1/57)	General Science & Technology	Self-reported information – Ability to transport yourself to places beyond walking distance”, i.e., community mobility by private or public transport, and including walking to and from the vehicle at origin and destination	(+) Fristedt et al. (2014)
Physical and mental health N=1.8% (1/57)	Economics & Business	Self-reported information – Frequency of walking 500 m or more, access and use of private car, bus stop distance from home and use of public transport	(+) Chiatti et al.(2017)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

4.3.2. Independent living

Beyond living a healthy and secure life, in order to enhance their well-being, the elderly have been expected by the Active Ageing Index to maintain their ability to be independent, that is, avoiding help in primary daily-life activities, or lifts in general. However, in that case, our review reported a scarce literature dealing with the role of mobility in such a key relationship. This research gap is mostly witnessed by very few studies (only three papers) drawn from either public health or social sciences literature.

From a more conceptual point of view, [Schwanen et al. \(2012\)](#) explored independence in later life and its relations with mobility (or embodied movements through physical space), using in-depth interviews with about 40 community-dwelling adults aged 70 and living mainly in the UK. In that study, independence is described as a qualitative 'complex and fuzzy notion' to be related to technologies, infrastructures, and social networks, but also to the idea that it allows getting rid of lifts by closer people, e.g., kin, friends, or nursing assistants. Of utmost importance when assessing public supportive policies for the elderly, the idea of mobility that comes out from this study is therefore primarily related to psychological and physical conditions which could help maintaining independence, instead of factors linked to technology or infrastructures.

Along this path, the maintenance of independence (defined as living in the community and being able to perform most basic ADLs without assistance) has been recently studied in [Diem et al. \(2018\)](#), where both mobility and cognition in 1,010 community-dwelling older women (mean age 88 years) in Minneapolis, Portland and Pittsburgh (US) were considered. A timed 6-m walking speed test was used to show that mobility and cognition (which could be enhanced by mobility itself) in older women are strong predictors of the maintenance of independence. Even though 41.9% of respondents were found to be independent at follow-up, those with slow walk speed, compared to women with good mobility, were less likely to be independent, after controlling for cognition and other risk factors. Despite some other early studies have focused on specific diseases and behaviours and their contribution to the risk of dependence in later life (notable examples are [Gregg et al., 2002](#); [Sauvaget et al., 2002](#); [Dodge et al., 2005](#); [Drewes et al., 2011](#)), still less is known about the combined effects of mobility and cognitive function on survival free of major assistance or lifts.

[Adorno et al. \(2018\)](#) conducted semi-structured interviews to 60 older people (15 of them ill) aged over 55 in Arlington (Texas, US). Their aim was to examine the experiences of the elderly regarding transportation mobility from a social justice and equity perspective. In that study, even if specific attributes of public/private means are not considered, older residents tend to describe the usage of public transit as vital to maintaining independence, however at the same time they perceive their own needs as not valued by local community structures. Although this outcome clearly depends on the study location, ageing-related mobility limitations are here described as health conditions that must be complemented with infrastructures and/or policies to help the elderly being independent in daily activities.

Table 6. Summary of the role of mobility on independent living

OUTCOME VARIABLE	DISCIPLINE	MOBILITY MEASURE(s)	AUTHOR(s)
Independent living N=5.3% (3/57)	Public Health & Health Services	Means of transport broadly	(+) Adorno et al. (2018)
		Walking speed (m/s) at 6 m	(+) Diem et al. (2018)
	Social Sciences	Actual and potential embodied movement through physical space	(+) Schwanen et al. (2012)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

4.3.3. Social connectedness

A little more evidence has been detected for the effects of mobility on another key pillar of active ageing: social connectedness. Among 4 papers (about 7% of total articles) included in the review, two of them confirm that mobility in later life facilitate social and community integration from a public health perspective (Rosso et al., 2013; Zeitler and Buys, 2015).

Rosso et al. (2013) investigated cross-sectional associations between life-space mobility with or without disability and social engagement in a sample of 676 adults over 65 based in Philadelphia (US). Using the LSA test, evidence has been found about the relationship between low mobility and low social engagement even in the absence of disability. In that case, the effect of mobility on community engagement is generalized and thus strengthens the idea for which mobile elderly are also more socially included. Lastly, also in suburban environments in Brisbane (Australia), Zeitler and Buys (2015) found that transportation choices influence social participation and the daily life of older citizens (aged 57-87 years). From a methodological perspective, this research used qualitative design methods integrating a range of data collection strategies (i.e., travel diaries, in-depth interviews) to explore the elderly's perceptions of community liveability and active ageing. Notably, key findings from this study suggest that establishing age-friendly suburban communities is critical not only because of the complexity of built environments to establish in peripheral neighbourhoods, but also due to the fact that within suburbs the lack of mobility displayed by the elderly translates into loneliness and health harms at a faster pace.

Social networks (Litwin and Levinson, 2018) and the use of community services (Lester et al., 2019) are other two issues about social inclusion that have been correlated with mobility. Based on the SHARE survey (with 23,295 respondents) Litwin and Levinson (2018) emphasized how social networks constitute a dominant factor in keeping the elderly connected to the society, thus contributing to successful ageing. After controlling for other confounders, the authors investigated how social networks are linked to activity participation independently of mobility level, or alternatively, if mobility moderates the relationship between networks and activity. Mobility limitations were measured by timed walking-km tests, climbing one flight of stairs without resting and lifting or carrying weights over ten pounds/five kilograms, and a two-fold outcome emerged. First, social networks are especially important in the promotion of activity participation among older adults with mobility limitations. Second, a higher risk of social exclusion is faced by mobility-restricted

elderly who are not embedded in resourceful social networks and, therefore, have high priority in efforts to increase active ageing.

Table 7. Summary of the role of mobility on social inclusion

OUTCOME VARIABLES	DISCIPLINE	MOBILITY MEASURE(s)	AUTHOR(s)
Community engagement N=1.8%	Public Health & Health Services	GPS tracking and daily travel diaries	(+) Zeitler and Buys (2015)
Social engagement N=1.8% (1/57)		LSA (Baker et al., 2013) modified	(+) Rosso et al. (2013)
Social networks N=1.8% (1/57)		Self-reported information - List of 10 difficulties such as getting up from a chair after sitting for long periods, climbing one flight of stairs without resting, and stooping, kneeling, or crouching, etc.	(+) Litwin and Levinson (2018)
Use of community services N=1.8% (1/57)		SPPB, FSST, gait speed and DeMMI	(+) Lester et al. (2019)

Notes: (-) the elderly with higher mobility levels decrease the probability of developing this outcome variable or show lower levels of it; (+) the elderly with higher mobility levels increase the probability of developing this outcome variable or show higher levels of it; (n) the level of mobility has no effect on the outcome variable; (?) it is not clear the causal relationship between mobility and the outcome variable; (o) the outcome variable is a determinant of mobility

Lester et al. (2019) considered 70 elderly over 80 years old in New South Wales (Australia), investigating the relationship between the objectively measured mobility status of rural community-dwelling older people and their use of formal and informal services, with variables such as SPPB, Four Square Step Test (FSST), gait speed, UGS test and the de Morton Mobility Index. In rural settings, older people may be indeed disadvantaged, compared to their peers in urban areas, by the geographic distribution of housing, family support and community assets and services. Using measurement tools such as the UGS test and the De Morton Mobility Index (DeMMI; de Morton et al., 2008) - which includes bed mobility, transfers and balance - this study provides strong evidence that the worse an older person's objectively measured mobility scores, the greater their need for community and publicly funded services to support living in their rural community. This finding confirms the increasing perception of risk to the older rural-dwelling person living at home and can influence decisions regarding the provision of community services. As mobility status is a key determinant for access to public-funded supports, related services are indeed typically provided to enable the elderly with mobility limitations to live in their home, thus having also an economic impact in terms of public finance and healthcare needs.

5. Discussion

5.1 *The indirect relationship between mobility and well-being*

The indirect relationship between mobility and well-being in later life has been investigated in this review by considering how the former might affect health conditions, independence, and social connectedness, which are identified within the EU Active Ageing Index as key drivers of the elderly's life satisfaction. Selected studies were considered in health sciences (clinical medicine, public health) and social sciences (economy, sociology and transportation) to analyse the topic from a multidisciplinary perspective.

As for the reviewed 50 studies on **health conditions**, mixed evidence arises about physical and cognitive effects of mobility, ranging from mortality to depressive symptoms. For what concerns physical aspects, various tests (the most widely used are the TUG test, the LSA test and the UGS test) display that, even controlling for other confounding factors, mobility for elderly people is particularly important in order to lower mortality and falls risks (together with frailty and in-patient hospitalization) and to improve neuromuscular performance or muscles strength. The effects of limited physical activity and reduced life-space mobility (measured either by quantitative tests or survey-based data processing) have been mostly studied in clinical medicine, but a few papers focused on the economic impact in terms of public health. Mobility limitations, in fact, increase the need of elderly people for early healthcare services (including long-term hospitalization), causing a growth of public expenditures. To fill this gap, future studies should investigate which specific physical harms evolving in chronic diseases could be effectively diminished by well-performing mobility, to tackle the increasing burden for public finance. The Parkinson disease is one notable example because it was detected as a potential outcome of deficient performances in mobility metrics (Von Coelln et al., 2019).

Although not focused on older adults with long-term handicaps, interestingly this review shows that mobility limitations might negatively affect other ADL activities, also increasing related metabolic costs. Hence, when dealing with public policies aimed at preserving health for ageing people, one insight is that more research should be done in order to clearly identify what daily activities are strikingly constrained by impairments which are mainly caused by poor mobility. Similarly, starting from the reported evidence of higher fear of falling in daily-life activities for older adults with lower mobility, even from a psychological perspective the lack of movement in later life may result in a reduced cognitive functionality, including the fact that the likelihood of depressive symptoms was found to be correlated with bad executive functionality in own life-space (Vallée et al., 2011).

As concerns the second indirect impact, albeit it has been studied in only three of the reviewed papers (based in the UK and the US), the relationship between mobility and **independence** in later life, is a topic that merits further research. The findings of these studies encourage the research to continue in this direction. In fact, independence has been recognized as a concept entangling physical and psychological dimensions (Schwanen et al., 2012). From a public-health perspective, the ability of older adults to feel comfortable and self-confident in daily activities without any assistance is first identified in the literature as linked to executive functionality (including cognitive performance). Although such a limited evidence cannot provide robust conclusions, high-level performances in mobility tests (e.g., in walking speed tests) are clearly correlated to feelings of independence, thus increasing the importance of maintaining active-ageing habits. Clearly, the reviewed literature (although scarce) pointed out also that independence goals deal with community-based conditions and built environment, such as especially the infrastructures which could help

the elderly to be free to move and getting out on their own (Adorno et al., 2018). A number of related studies focused on external factors would complement the reviewed papers, eventually controlling ageing mobility, and, as a result independent living (Busari et al., 2019). As such, the subjective valuation of out-of-home features has proved to be a crucial factor to allow people benefit from own mobility capabilities (Luoma-Halkola et al., 2020; Tilley et al., 2017). Another example regards structural elements, including ageing-friendly built environments and adequate transport infrastructures, detected by scholars as strongly linked to mobility performance and limitations, thus implying their localized improvement (Winters et al., 2015; Chudyk et al. 2015; Clarke, 2014). Beyond studies explicitly assessing the quality evaluation of public transit or private means of transport, hence significantly further research should be carried out to explore in-depth how transport systems (including vehicles and supportive devices) could strengthen the beneficial effects of mobility on the elderly's perception of independence.

Referring to the third indirect impact, the **social connectedness**, from a public health point of view, four papers have analysed the connection between mobility capabilities and social inclusion in later life, that is, the capability to participate in public activities interacting with other people and to maintain a social network. By using methods borrowed from clinical medicine, also in that case the reviewed literature displays a scarce (although growing) interest in exploring how mobility could help the elderly to keep on being part of society and, more interestingly, to have frequent interactions non only with other older people (Ormerod et al., 2015). All the reviewed studies (based in the US, Asia and Europe) highlight that preventing mobility limitations does emerge as a primary objective to maintain social connectedness. However, a wider (and more detailed) variety of out-of-home spaces should be studied to provide more evidence of what places the elderly consider as welfare-enhancing. Interesting evidence was also found on the fact that mobility impairments (e.g., limitations in ADL activities) should be first prevented to guarantee social life with kin and friends. Work activities are included as social dimensions to be safeguarded for the 'younger' elderly, while social networks (recognized as crucial sources of inclusion) must be sustained by reducing mobility constraints and by improving functionality features. Moreover, from an economic perspective, the local provision of community services was found to be affected by mobility conditions. Those services (including psychological assistance) are often made available to people unable to reach centres of social interactions, thus increasing the need for public funding even in case of potentially avoidable harms.

5.2 Quality appraisal

The results of the appraisal are presented in more details in Appendix A (see [Supplementary Material 2](#)) and presented in this section briefly.

According to the MMAT criteria, the quality of the qualitative studies and of the mixed methods papers included in this review is very high ([Table A.1 and A.4](#)). Regarding the non-randomized studies, the lower scores, either because the criterion was not satisfied or not enough information was provided by the authors, regard the representativeness of the samples, the collection of complete outcome data and the inclusion of the crucial confounders in the design of the analysis ([Table A.2](#)). The areas that the quantitative descriptive studies scored lower were the use of representative samples and the non-response bias ([Table A.3](#)). In general, however, the papers' quality was high, as it was expected from peer-reviewed works, which have passed the selection and review process of scientific journals.

The reviewed literature displays some relevant strengths. Firstly, all the considered active-ageing dimensions were covered (although at different extents) in the investigated scientific domains, with the only limitations already underlined. Secondly, most studies used heterogeneous datasets, combining primary data from interviews with information drawn from national surveys, but coming often to similar findings, reinforcing them. Since primary data are often lacking, the number of studies where questionnaires and measurable tests have been setup for a specific goal is high. Lastly, the variety of tests used is rather comparable in a quantitative and objective manner. As functional tests dealing with either the capability and the extension of movement in later life are detected in several papers (e.g., TUG, UGS, POMA, LSA, SPPB and different walking speed tests, etc.), related findings can be indeed generalized, especially in case of large samples, allowing comparison between different groups (e.g., over vs. under 65 people, seniors with or without mobility impairments, etc.). Moreover, in case of different geographical contexts, the usage of standard tests turns out to be helpful, especially when they are combined with subjective methods based on interview.

6. Conclusions and implications for future research

Findings from this systematic review give evidence that well-preserved mobility could improve ageing life satisfaction through three key dimensions of the EU Active Ageing Index: health conditions (including increasing life expectancy), independence and social connectedness. Whereas living a healthy and socially included life was already associated in the literature to higher levels of life satisfaction, this paper has the merit to be the first multidisciplinary review that systematically resume and compare the different findings of several studies, stressing the indirect effect of mobility on well-being. Moreover, the paper displays the different methodologies that could be used to measure how mobility capabilities can be related to physical and psychological status. The findings highlight that independence and social connectedness need more research efforts, in terms of both absolute number of studies (and thus robustness of results) and variety of countries of application.

This systematic review has some limitations related to the chosen inclusion criteria, that further research on the studied issue could eventually overcome. First, it focused on research studies published only in peer-reviewed journals, not considering non-academic literature (e.g. research reports commissioned by institutions). Second, by extending the scanning phase to other databases than the four considered or to a longer time period (before 2010) or by considering other keywords of selection, the number of studies could be increased. Referring to the period, we have decided to concentrate the attention on mainly the post-effects of the Active Ageing framework that was developed in 2012, but the inclusion of also the papers published in the two years before permits to partially show how research had anticipated the European Commission tool. As regards the keywords' selection, including words such as 'movement' or 'motility' could allow to consider also some clinical aspects related to the ability of older adults to get around, but were here out of the paper scope. Analogously, our research has analysed the impacts of 'mobility', while considering the topic from the point of view of 'immobility' (by searching for appropriate keywords) as a substantial element for impeding an independent and healthy life might sure deserve further investigation. Similarly, since our attention has been devoted to psycho-physical attributes (and performances) having the opportunity to either prevent ageing issues and easing the accessibility to transport systems, the analysis of the quality attributes of transportation means demanded by the elderly is out of the aim of this review and so they have been not included in the keywords' selection.

As regards the policy implications, the findings of this review give useful insights to policymakers and transport operators. Since the scientific studies highlight that impaired mobility in older adults has a negative impact on quality of life and a range of health and well-being outcomes, and also, as people age their activity space is getting restricted, further attention is required to the design and implementation of ageing-friendly transport measures for active mobility. Relevant transport policies should consider especially the elderly who were car-dependent when they were younger (Ahern and Hine, 2012) or the elderly women who are usually more transport disadvantaged, as they are highly dependent to men for lifts (Li et al., 2012). The burst of the pandemic Covid-19 recently opened a big challenge for the policy makers to handle active ageing within the framework of social distancing and plan for mobility actions under this perspective. When the limits to movement imposed by the sanitary emergency will be removed, the transport system should be ready to supply services tailored on elderly's every-day life needs. The over-65 people, who constitute a significant and increasing share of the total population, are one of the more disadvantaged and frailer social group. More investment and resources on travel demand management and transport policies for elderly should be strongly encouraged and supported to prevent phyco-physical diseases and avoid isolation, thus saving public health expenditures in the long term.

ABBREVIATIONS

AAI	Active Ageing Index
POMA	Performance Oriented Mobility Assessment
TUG test	Timed Up and Go test
SPPB	Short Physical Performance Battery
UNECE	United Nations Economic Commission for Europe
MIPAA/RIS	Madrid International Plan of Action on Ageing and its Regional Implementation Strategy
SHARE	Survey of Health, Ageing and Retirement in Europe
LSA	Life-space Assessment
DGI	Dynamic Gait Index
CB&M	Community Balance and Mobility scale
WWT	Walking While Talking test
UGS	Usual Gait Speed
STS	Sit-To-Stand test
ADL	Activities of Daily Living
TRG	Timed Rapid Gait Test
DTGS	Dual-task Gait Speed
DeMMI	de Morton Mobility Index
FSST	Four Square Step Test

8. References

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