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Research Article

What Is the Impact of Physical Activity and Physical Function on the Development of Multimorbidity in Older Adults Over Time? A Population-Based Cohort Study

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Abstract

Background: Multimorbidity is recognized internationally as having a serious impact on health outcomes. It is associated with reduced quality of life, increased health care utilization, and future functional decline. Physical activity is associated with good health and psychological well-being. The aim of this study was to identify the impact of physical activity and physical function on the development and worsening of multimorbidity over time.

Methods: Using The Irish Longitudinal Study on Ageing (TILDA), we analyzed 4,823 participants ≥50 years with and without multimorbidity. Multimorbidity was defined as the presence of ≥2 chronic conditions. Development of multimorbidity was measured as the accrual of additional conditions over a 2-year period. Physical activity and physical function were measured using the International Physical Activity Questionnaire (IPAQ), gait speed (m/sec), and grip strength (kg).

Results: Sixteen groups of chronic conditions were included in analyses. 53.7% of included participants had multimorbidity at baseline and 71.7% at follow-up. Six hundred and thirty-eight of 2,092 (30.4%) participants without multimorbidity and 1,005 of 2,415 (41.6%) with existing multimorbidity developed new condition/s. Gait speed (relative risk [RR] = 0.67, confidence interval [CI]: 0.49–0.90), grip strength (RR = 0.98, CI: 0.97–0.99), and age (compared to 50–59 years, 60–69: RR = 1.30, CI: 1.11–1.52; ≥70: RR = 1.35, CI: 1.03–1.77) were significantly associated with the development of multimorbidity and accrual of additional conditions.

Conclusion: These results show that physical function is associated with the development and worsening of multimorbidity over time. They support the recent National Institute for Health & Care Excellence (NICE) Guidance on multimorbidity that suggests that patients with multimorbidity and reduced gait speed should be identified and targeted for interventions to improve health outcomes.

Keywords: Multiple chronic conditions, Gait speed, Grip strength, Longitudinal study

Background

Average life expectancy is rising worldwide with increasing numbers of people living with multiple chronic medical conditions. Multimorbidity, commonly defined as the co-occurrence of two or more chronic medical conditions in an individual (1), affects up to one quarter of primary care populations (2,3). Higher prevalence is associated with socioeconomic deprivation and ageing (2). It is associated with reduced quality of life, increased health care utilization, and an increased risk of

mental health difficulties (1,2,4). Complex multimorbidity, defined as three or more chronic conditions affecting three or more body systems can be especially challenging with higher health care utilization and polypharmacy (5). Management of multimorbidity is a major challenge for health systems globally. It has been reported that one third of all consultations in general practice in the United Kingdom are for patients with more than one chronic condition (6).

The World Health Organization estimates that approximately 3.2 million deaths each year are attributable to insufficient physical inactivity (7). Older adults who are more physically active have lower rates of cardiovascular disease, cancer, and all-cause mortality along with improved cognition and reduced risk of falling (7). Physical activity prevents or reduces functional decline (8,9). The existing literature examining the association between multimorbidity and physical activity has demonstrated mixed results with two studies findings an association (10,11) and two reporting no link (12,13). However, these studies were all cross-sectional in design and did not assess the trends in multimorbidity over time. One previous longitudinal study investigated the prevalence of multimorbidity over time by levels of physical activity and identified an inverse dose–response relationship in that the odds of multimorbidity were lower in those who were physically active compared to those who were physically inactive (14). This study included refreshment samples at different time-points which may have affected estimates and the only outcome measure used was a study specific self-reported measure of physical activity.

Poor physical functioning is also linked to adverse health outcomes (15) and is addressed by the WHO's International Classification of Functioning, Disability and Health (ICF) (16). Grip strength and gait speed assessments are reliable measures of physical function (17). Grip strength has been reported to predict accelerated dependency in activities of daily living and cognitive decline in older people (18). Gait speed has been described as the sixth vital sign and labeled as a principal indicator of health and is an inexpensive, reliable measure of physical function (19).

We previously conducted a systematic review which demonstrated that multimorbidity is associated with poorer function and with future functional decline. The review indicated that there is greater functional decline in patients with higher numbers of conditions and greater disease severity (20). It is not known whether the effect also occurs in the opposite direction, that is, do poor levels of physical activity and function lead to the development of multimorbidity? Determining the impact of levels of physical activity and physical function on multimorbidity development will inform health care providers and aid the design of appropriate interventions that can improve health outcomes and reduce health care costs.

The primary aim of this study was to assess the impact of physical activity and function on the development of multimorbidity over a 2-year period in an older population without multimorbidity at baseline. Secondary aims were to assess the impact of physical activity and function on the worsening of multimorbidity over a 2-year period in a population of older adults with established multimorbidity and in those with complex multimorbidity at baseline.

Methods

Study Design

We completed secondary analysis of a longitudinal cohort study. The strengthening the reporting of observational studies in epidemiology (STROBE) guidelines were utilized in the conduct and reporting of this study (21).

Data Source and Study Population

The Irish Longitudinal Study on Ageing (TILDA) is a population-based cohort study assessing health, economic, and social aspects of ageing in the Republic of Ireland. TILDA is a nationally representative study of 8,175 community-dwelling residents aged 50 years and older (22). This study is an analysis of the first (2010) and second (2012) waves of TILDA. At Wave 1 participants completed a computer-assisted personal interview in their own home and subsequently were invited to attend a health centre for a comprehensive health assessment. Ethical approval for TILDA was obtained from the Trinity College Dublin Research Ethics Committee.

Included Conditions

Thirty individual chronic conditions were included in analyses. The 30 chronic conditions were chosen by TILDA as of their public health significance and their prevalence in those more than 50 years (23). These conditions were consolidated to 16 chronic conditions or groups of conditions: cardiac conditions; cerebrovascular disease; hypertension; diabetes; high cholesterol; chronic respiratory disease; liver disease; eye disease; cognitive impairment; arthritis; osteoporosis; cancer; Parkinson's disease; emotional /psychological condition; stomach ulcers; varicose veins (Supplementary Appendix A).

Multimorbidity was defined as two or more chronic conditions in the one individual. The study participants were grouped into two categories: no multimorbidity (zero or one condition) n = 2,235 and established multimorbidity (two or more conditions) n = 2,588 at Wave 1. These groups of participants were followed to Wave 2. Development of multimorbidity and worsening of multimorbidity was measured by accrual of new condition/s between Wave 1 and Wave 2. In addition, we completed a subgroup analysis, following participants with complex multimorbidity (≥3 chronic conditions) n = 2,415 at baseline to Wave 2.

Measures of Physical Activity and Function

Levels of physical activity and function were assessed using three validated outcome measures: the International Physical Activity Questionnaire (IPAQ), gait speed, and grip strength (22,24). The IPAQ is a self-reported measure and gait speed and grip strength are performance-based assessments. Only study participants with complete data recorded on all three measures were included (Figure 1).

Physical activity was measured using the short form of the IPAQ (25). Each participant was classified as having High, Moderate or Low activity levels based on agreed criteria (26).

Grip strength was measured using a grip dynamometer, two measures of handgrip strength were taken from the dominant hand and the mean of these readings was calculated. Gait speed was measured using the GAITRite portable electronic walkway system (24). Participants performed two walks at their usual pace along a 4.88 m (16ft) walkway. They started and finished walking 2.5 m before and 2 m after the walkway to allow for acceleration and deceleration. The two walks were combined and the average gait speed was calculated.

Statistical Analysis

A modified Poisson regression analysis with robust error variances was used to determine the relationship between levels of physical activity and function with both the development of multimorbidity and worsening of multimorbidity. Binary outcomes in cohort studies are commonly analyzed using a logistic regression model to obtain odds ratios. However, in order to estimate and report relative risks

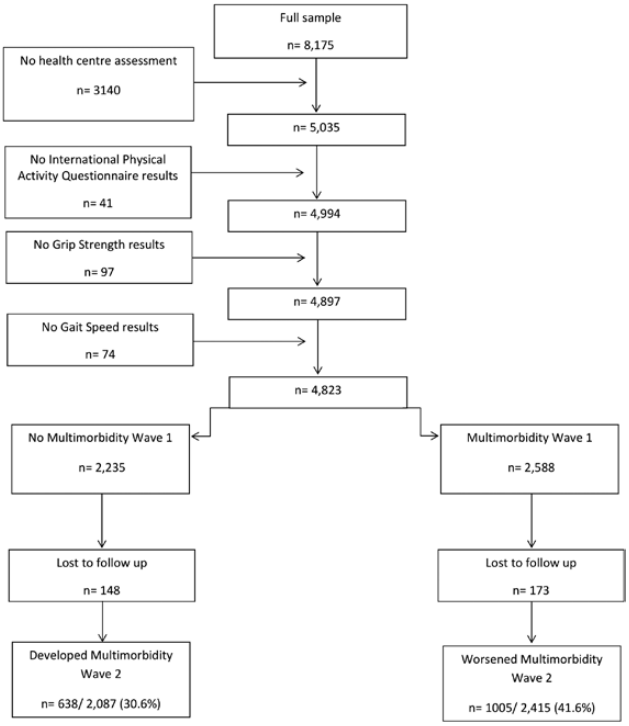

Figure 1. Study participants flow chart.

and confidence intervals, we used a modified Poisson regression analysis with robust error variances.

Confounders and Covariates

Age and sex were included in the models as covariates. To make analysis comparable to other similar studies age was categorized in 10-year age bands; 50–59 years; 60–69 years; ≥70 years (2,13). Additional confounders included in the analysis were education level, body mass index (BMI), and smoking (smoker, nonsmoker). Participants deemed as underweight (0.5%), were merged with the normal category for BMI. The presence of state financial support for health care was used as a proxy for socioeconomic status. Measurement for each of the variables has been described previously (22,24,26).

Results are presented as adjusted relative risks (RR) with associated 95% confidence intervals (CI). p Values ≤.05 were deemed significant. All analyses were conducted using Stata Version 13.0 (Stata Statistical Software: Release 13. College Station, TX: StataCorpLP).

Results

Characteristics of the Sample

Included participants (n = 4,823) are presented in Figure 1. The characteristics of the study population are displayed in Table 1. At Wave 1, 2,235 (46.3%) participants did not have multimorbidity and 2,588 (53.7%) had multimorbidity. The two groups were significantly different in all categories at baseline (Table 1). We completed a test of gender interaction and there was no significant difference between male and females and thus no evidence to warrant stratifying the data by gender. Those with multimorbidity were older than those without multimorbidity and the majority in both groups were nonsmokers and overweight or obese. The most common conditions in study participants were high cholesterol (41.3%), high blood pressure (33.6%) and arthritis (26.3%), while the prevalence of other conditions such as cardiac conditions, diabetes, respiratory disease, eye disease, and osteoporosis varied from 6.1% to 16.7%. These results are in keeping with previous research which demonstrated high blood pressure, arthritis, and cardiovascular disease to be the most prevalent conditions in a cohort aged 65 years or older (27).

Development of Multimorbidity

Of the 2,235 participants with no multimorbidity at baseline, 2,092 (93.6%) were followed up 2 years later. By Wave 2, 638 (30.4%) had developed multimorbidity. Multivariate analysis demonstrated that age (compared to 50–59 years, 60–69 years: RR = 1.30, 95% CI: 1.11–1.52; ≥70 years: RR = 1.35, 95% CI: 1.03–1.77), obesity (compared to normal and underweight: RR = 1.26, 95% CI: 1.05–1.51), gait speed (RR = 0.67, 95% CI: 0.49–0.90), and grip strength (RR = 0.98, 95% CI: 0.97–0.99) were significantly associated with the development of multimorbidity. There was no evidence of an association between IPAQ and the development of multimorbidity (Table 2). With every one kilogram increase in grip strength, the risk of developing multimorbidity decreases. Similarly, each meter per second increase in gait speed decreases the risk of developing multimorbidity (Table 2).

Worsening of Multimorbidity

Of the 2,588 participants with multimorbidity at baseline, 2,415 (93.3%) were followed up 2 years later. Of these, 1,005 (41.6%) had developed worsened multimorbidity in Wave 2. Age (compared to 50–59 years, 60–69 years: RR = 1.20, 95% CI: 1.07–1.34; ≥70 years: RR = 1.18, 95% CI: 1.01–1.37), access to government funded primary health care (RR = 1.20, 95% CI: 1.07–1.34), grip strength (RR = 0.990, 95% CI: 0.982–0.998), and gait speed (RR = 0.61, 95% CI: 0.50–0.82), were all significantly associated with worsening of multimorbidity. For every one kilogram increase in grip strength the incidence of worsening multimorbidity decreases. For each meter per second increase in gait speed, the risk of worsening multimorbidity also decreases. There was no significant association between the IPAQ and the worsening of multimorbidity (Table 2).

Complex Multimorbidity

1,488 participants presented with complex multimorbidity at baseline (Supplementary Appendix B), 1,391 of these participants were followed up in Wave 2. Six hundred of the 1,391 participants (43.1%) with complex multimorbidity had developed a new condition/s. Gait speed (RR = 0.59; 95% CI: 0.43–0.82), and age (compared to 50–59 years, 60–69 years: RR = 1.18, 95% CI: 1.02–1.36; ≥70 years: RR = 1.20, 95% CI: 1.10–1.44), were significantly associated with the development of new conditions but grip strength was not (Supplementary Appendix C).

Discussion

This study presents a longitudinal analysis of multimorbidity in a nationally-representative, population-based sample of older adults. Over a 2-year follow-up period, 30.4% developed multimorbidity and 41.6% with multimorbidity experienced worsening multimorbidity. Gait speed, grip strength, and increasing age were significantly associated both with the development of multimorbidity and the worsening of existing multimorbidity with evidence of a dose–response relationship.

Table 1. Baseline characteristics of study participants

	No multimorbidity 0/1 condition *n*= 2235 (46.3%)	*Multimorbidity* 2/more conditions *n*= 2588 (53.7%)	*p* Value
Age			
50–59	1282 (57.4%)	893 (34.5%)	<0.001
60–69	697 (31.2%)	995 (35.4%)	(c)
70+	252 (11.3%)	696 (26.9%)	
Sex			
Male	1115 (49.9%)	1106 (42.7%)	<0.001
Female	1120 (50.1%)	1482 (57.3%)	(c)
Education			
Primary/ none	401 (17.9%)	653 (25.2%)	<0.001
Secondary	1003 (44.9%)	1008 (38.9%)	(c)
Third/ higher	830 (37.1%)	926 (35.8%)	
Body Mass Index (kg/m^2)			
Underweight (< 18.5)	12 (0.5%)	9 (0.3%)	<0.001
Normal (18.5 -25)	566 (25.3%)	518 (20.0%)	(c)
Overweight (25.1 -30)	1021 (45.7%)	1097 (42.4%)	
Obese (≥30.1)	634 (28.4%)	963 (37.2%)	
Smoking Status			
Non-smoker	1865 (83.5%)	2244 (86.7%)	0.001
Smoker	370 (16.5%)	344 (13.3%)	(c)
State support			
No medical/ General Practitioner card	1628 (78.8%)	1338 (51.7%)	<0.001
Medical/ General Practitioner card	605 (27.1%)	1249 (48.3%)	(c)
International Physical Activity			
Questionnaire (IPAQ)			
Low exercise	539 (24.1%)	782 (30.2%)	<0.001
Moderate exercise	761 (34.1%)	994 (38.4%)	(c)
High exercise	935 (41.8%)	812 (31.4%)	
Grip Strength (kg)	Mean (SD)	Mean (SD)	
50–59	28.5 (9.9)	26.8 (9.8)	<0.001
60–69	27.0 (8.9)	24.8 (8.8)	(*t*)
70+	24.6 (8.6)	21.9 (8.3)	
Total	27.6 (9.5)	24.7 (9.2)	
Gait Speed (m/second)	Mean (SD)	Mean (SD)	
50–59	1.4 (0.2)	1.4 (0.2)	<0.001
60–69	1.4 (0.2)	1.3 (0.2)	(*t*)
70+	1.3 (0.2)	1.2 (0.2)	
Total	1.4 (0.2)	1.3 (0.2)	

Note: Confounder variables missing <0.2% data in all cases; c= chi-squared test; *t*= t-test.

Grip strength is a predictor of cognitive decline, disability and contributes to increasing dependency in old age (18). Our study highlighted that the stronger one's grip strength the less likely new chronic conditions will develop within 2 years. Gait speed assessment is also a valuable tool in the clinical assessment of frailty and lower gait speed is associated with reduced strength, power, coordination, and balance (19,28). Our results support the recent NICE Multimorbidity Guidance, which recommends using gait speed as an assessment measure to identify those patients who require prioritized/targeted care (29). NICE is the National Institute for Health Care and Excellence based in the United Kingdom. They provide evidence-based national guidance to all stakeholders with the aim to improve health and social care. While our study highlighted the clinical relevance of reduced gait speed, we did not identify a specific cut-point at which the risk of multimorbidity increased. Further research in this area is needed.

Dhalwanai et al. demonstrated an inverse dose–response association between levels of physical activity and multimorbidity using frequency of vigorous, moderate, and mild physical activity (14). They highlighted the potential that the existence of multimorbidity may limit physical activity, which could also have happened in our cohort. The Dhalwhani study had a similar definition of multimorbidity but only included 16 chronic conditions compared to 30 in our study. In addition, the only outcome measure used was a study-specific self-report measure which was shown to have moderate correlation with accelerometer data. In our study, there was no evidence that the self-reported outcome measure, the IPAQ, was associated with development or worsening of multimorbidity. It has been acknowledged in the literature that over-reporting amounts of physical activity when completing the IPAQ is common, with older adults having difficulty completing it accurately (30). The IPAQ is recommended for population level research, however is not intended to replace instruments which can be more responsive to changes in individual activity level such as gait speed. Comparisons with the previous cross-sectional studies (10–13) is difficult due to different measures of physical activity, differences in study population, and definitions of multimorbidity used. Accelerometer measurements would provide added value, however, gait speed and grip strength assessments are cost-effective and easily accessible measurements used in clinical practice.

In keeping with the evidence that obesity has negative impacts on health outcomes, individuals in our study with obesity were

Table 2. Multivariable Poisson Regression Model for Development of Multimorbidity in Those With no Multimorbidity at Baseline and Worsening Multimorbidity in Those With Multimorbidity at Baseline, Over a 2-y Period in Adults Aged 50 y and Over (TILDA Waves 1 and 2)

	No multimorbidity Relative risks and 95% confidence intervals of those with no multimorbidity at baseline	*p* Value	*Multimorbidity* Relative risks and 95% confidence intervals of those with multimorbidity at baseline	*p* Value
Age				
50–59	1.00		1.00	
60–69	1.30 (1.11–1.52)	**.001**	1.20 (1.07–1.34)	**.002**
70+	1.35 (1.03–1.77)	**.027**	1.18 (1.01–1.37)	**.039**
Sex				
Male	1.00		1.00	
Female	1.05 (0.86–1.27)	.649	0.95(0.83–1.09)	.468
Education				
Secondary	1.00		1.00	
Primary/none	1.10 (0.93–1.30)	.279	0.94 (0.84–1.06)	.314
Third/higher	0.96 (0.83–1.11)	.582	1.02 (0.91–1.14)	.760
Body Mass Index				
Normal: 18.5–25	1.00		1.00	
and underweight:<18.5	1.09 (0.92–1.28)	.319	0.96 (0.85–1.09)	.542
Overweight:25.1–30	1.26 (1.05–1.51)	**.011**	0.96 (0.84–1.10)	.572
Obese: ≥30.1				
Smoking				
Nonsmoker	1.00		1.00	
Smoker	1.08 (0.91–1.29)	.361	1.06 (0.92–1.22)	.457
State Support				
No medical/General Practitioner card	1.00		1.00	
Medical/ General Practitioner card	1.13 (0.97–1.31)	.130	1.20 (1.07–1.34)	**.002**
International Physical Activity Questionnaire (IPAQ)	1.00		1.00	.309
Low exercise				
Moderate	1.00 (0.85–1.19)	.969	0.94 (0.85–1.06)	.168
High exercise	1.04 (0.88–1.23)	.640	0.92 (0.81–1.04)	
Grip Strength (kg)	0.98 (0.97–0.99)	**.002**	0.990 (0.982–0.998)	**.014**
Gait Speed (m/s)	0.67 (0.49–0.90)	**.046**	0.61 (0.50–0.82)	**<.001**

The bold values indicate results demonstrating statistical significance.

more likely to develop multimorbidity compared to those of normal weight though obesity was not associated with worsening of multimorbidity over time. The results regarding socioeconomic status were mixed. This may relate to the higher prevalence of socioeconomic deprivation in those with established multimorbidity at baseline. These results may also relate to the measure used as it does not identify the most socioeconomically deprived groups within the cohort as income thresholds for access to government funded health care increases with age. Existing evidence highlights that, patients with higher levels of socioeconomic deprivation develop multimorbidity significantly earlier in life than their more affluent counterparts (2). Dhalwanai et al. included socioeconomic status and BMI as confounders but did not comment whether either impacted on the presence of multimorbidity over time (14).

Strengths and Limitations

TILDA is a nationally representative population based cohort study using validated measures and health assessments carried out by trained research nurses using standardized protocols (24). We included 30 different conditions in our analysis encompassing a broad range of conditions including mental health conditions which are commonly omitted in other studies.

A potential limitation of this study may relate to participant characteristics. The outcome measures used to measure physical activity and function dictated that TILDA participants who did not attend the health centre assessment were excluded. It has been demonstrated that those who were frail or disabled or more elderly were less inclined to attend the health centre for assessment and thus presents a potential source of bias (22). As with other longitudinal studies of ageing, all participants were required to provide written informed consent to participate in the study at Wave 1; this will have resulted in the exclusion of individuals with severe cognitive impairment. We also need to acknowledge those who were lost to follow up, though this was minimal with 6.6% (n = 148) participants with no multimorbidity and 7.2% (n = 173) participants with multimorbidity not available for analysis 2 years later. A further limitation is that the definition of multimorbidity used does not take into account disease severity. However, we did use the most commonly reported definition, that is, ≥2 chronic conditions and we also conducted analyses examining complex multimorbidity (≥3 chronic conditions) with complex multimorbid patients having higher care needs (5). The use of self-reported diagnoses in the analysis may be an additional limitation. However, evidence has demonstrated moderate to good agreement between self-reported and physician-reported chronic conditions among multimorbid patients (31). A final limitation was the use of State financial support as a proxy for socioeconomic status. While state financial support is an accurate proxy for socioeconomic status in Irish people under the age of 70, over this

age different income thresholds apply and there is nearly universal coverage for this age group. However, the majority of our cohort (80.3%) were less than 70 years.

Conclusion

With an ageing population, the management of chronic medical conditions is at the forefront of health care planning and policy. Our results have implications for clinical practice in that assessment of physical function and appropriate intervention may prevent an inevitable cascade toward poorer health outcomes. Future research should focus on the development of interventions which prioritize physical function for this patient group to prevent the poorer health outcomes and increased health care costs associated with multimorbidity.

Key points

- Gait speed, grip strength, and increasing age were shown to be significantly associated with the development of multimorbidity and the worsening of existing multimorbidity.
- Faster gait speed and stronger grip strength were found to be associated with a reduced risk of developing new conditions.
- Poor levels of physical function, as measured by grip strength and gait speed lead to the worsening of multimorbidity over time.
- These results support the NICE Multimorbidity Guidance (2016), which recommends using gait speed as an assessment measure to identify those patients who require prioritized/targeted care.

Supplementary Material

Supplementary data is available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None reported.

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