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Multimorbidity is associated with lower total 24-hour movement activity among US adults

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ABSTRACT

Objective: Having chronic conditions may result in reduced physical and cognitive function but less is known about multimorbidity with daily movement. We examined the association of multimorbidity and device-measured total daily movement in a nationally representative sample of US adults aged ≥ 30 years from the 2011–2014 National Health and Nutrition Examination Surveys.

Methods: Any multimorbidity (≥2 conditions) and complex multimorbidity (≥3 conditions across ≥ 3 body systems) were quantified using 16 chronic conditions via self-report and/or clinical thresholds. Total movement over 24-hours (Monitor-Independent Movement Summary units [MIMS-units]) was measured using a wrist-worn device (ActiGraph GT3X). Multivariable linear regression examined the association of 1) each chronic condition, 2) number of conditions, 3) any multimorbidity, and 4) complex multimorbidity with total movement. Covariates included age, gender, race/ethnicity, educational attainment, and smoking status.

Results: Among US adults (N = 7304, mean age: 53.2 ± 0.34 years, 53.2% female, 69.4% Non-Hispanic White), 62.2% had any multimorbidity with 34.2% having complex multimorbidity. After adjustment, a higher number of chronic conditions was associated with incrementally lower total movement (β MIMS-units [95% CI] compared to those with no chronic conditions; one: −419 [−772, −66], two: −605 [−933, −278], three: −1201 [−1506, −895], four: −1908 [−2351, −1465], 5+: −2972 [−3384, −2560]). Complex multimorbidity presence was associated with −1709 (95% CI: −2062, −1357) and −1269 (−1620, −918) lower total movement compared to those without multimorbidity and multimorbidity but not complex, respectively.

Conclusions: Multimorbidity was associated with lower 24-h movement among US adults and may be helpful for identifying adults at risk for low movement.

1. Introduction

Multimorbidity, a combination of chronic disease with at least one other disease, biopsychosocial, or somatic risk factor (Le Reste et al., 2013), is associated with increased healthcare utilization and substantial healthcare costs (Soley-Bori et al., 2021; Lehnert et al., 2011). Having chronic diseases across multiple anatomic systems (i.e., complex multimorbidity (Harrison et al., 2014)) is associated with an estimated average increase of $1444 USD in total outpatient healthcare costs, $577 USD for total inpatient healthcare costs, and $199 USD in pharmacy costs for each additional body system affected (Zulman et al., 2015). In a *meta*-analysis, the prevalence of multimorbidity in adults was estimated at 33.1% (Nguyen et al., 2019) with an accumulation of chronic conditions and the occurrence of multimorbidity increasing across the life course (Marengoni et al., 2011). This is concerning as the number of older adults in the US is rapidly increasing (Medina et al., 2020).

Multimorbidity can lead to functional limitations (Marengoni et al., 2011; Bowling et al., 2019; Makovski et al., 2019; Ryan et al., 2015;

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Storeng et al., 2020), lowering physical activity levels (Balogun et al., 2020). This is problematic, as evidence suggests physical activity may be a tertiary prevention strategy for chronic conditions—aimed to maximize health, restore functioning, or avoid complications after a diagnosis (U.S. Department of Health and Human Services, 2018; Kisling and Das, 2022). The association between multimorbidity and physical activity has been examined using self-reported physical activity (Vancampfort et al., 2017; Cimarras-Otal et al., 2014; Keats et al., 2017; Autenrieth et al., 2013; Chudasama et al., 2019) assessments which are prone to measurement error, rely on cognitive ability to recall activities (Troiano et al., 2012), and generally assess only leisure time physical activity (Pettee Gabriel et al., 2012).

Device-based assessments of physical activity, e.g., accelerometers, have found total physical activity volume and meeting physical activity guidelines of 150 min of moderate to vigorous intensity physical activity (MVPA) are associated with lower multimorbidity (Dankel et al., 2017), however MVPA comprises, on average, less than 2% of waking hours. Given the recent evidence of the health benefits of light intensity physical activity (LaMonte et al., 2017; Stubbs et al., 2017; Chastin et al., 2019), more studies are needed that capture all movement across all physical activity intensities. Utilizing devices allows examination of novel 24-hour total movement metrics (Dooley et al., 2022; Martinez-Amezcua et al., 2022; Zheng et al., 2023) that can expand our characterization of activity patterns that may be important for health. Leveraging the nationally representative National Health and Nutrition Examination Survey (NHANES) data, we investigated the association of multimorbidity and complex multimorbidity with a 24-hour accelerometer movement metric. We hypothesized that participants with multimorbidity and complex multimorbidity had lower total movement. Additionally, we explored the association of individual chronic diseases with total movement and the association of multimorbidity status with total movement across age groups.

2. Methods

2.1. Data source

NHANES uses a multistage stratified probability design to identify participants and can be weighted to provide estimates for the non-institutionalized US population (Johnson et al., 2014). Participants completed in-person home interviews and health measurements were performed in a mobile examination center (MEC). The current analysis used data from the NHANES 2011–2012 and 2013–2014 cycles (CDC, 2011, CDC, 2013). In these cycles, participants were invited to wear a physical activity monitor (PAM) on the wrist for 7 consecutive days after their MEC visit.

NHANES was approved by the National Center for Health Statistics (NCHS) Institutional Review Board and all participants provided written informed consent. The University of Alabama at Birmingham Institutional Review Board considered this secondary data analysis exempt as NHANES data are de-identified and publicly available. Data and materials used in this study can be accessed at https://www.cdc.gov/nchs/nhanes/.

For these analyses, we chose to restrict the sample to adults 30 years and older (n = 9,379) who attended the MEC exam (n = 9,034). An age of 30 years or older was chosen because the prevalence of chronic disease is low below this age.

2.2. Chronic conditions and multimorbidity

We used the Centers for Disease Control and Prevention (CDC) definitions of common chronic conditions, which included hypertension, congestive heart failure, coronary heart disease, high cholesterol, stroke, arthritis, asthma, cancer, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD), depression, hepatitis (viruses B & C), and diabetes (Goodman et al., 2013). We additionally included obesity and perceived memory problems as these conditions are associated with poor health outcomes (Bray et al., 2017; Petersen et al., 2018). We were not able to include cardiac arrhythmias, dementia, schizophrenia, autism spectrum disorders, human immunodeficiency virus (HIV), or osteoporosis as these conditions were either not assessed during one or both of the NHANES cycles used in the current analysis or were not assessed across the full age spectrum of interest (e.g., HIV antibody test was conducted only for participants who were 18–59 years of age).

Chronic conditions were assessed using self-report, clinical assessment, or a combination of both. The thresholds used to define each chronic condition used in this analysis are presented in eTable 1. Self-report measures included history of chronic medical conditions, use of medications, and depressive symptom severity (assessed via Patient Health Questionnaire [PHQ-9] (Kroenke and Spitzer, 2002)). Clinical assessment from the MEC medical evaluation included height and weight to calculate body mass index (BMI), systolic and diastolic blood pressure measurements taken after five minutes of seated rest, and blood and urine sample collection, which included plasma or serum glucose, total cholesterol, and urinary albumin and creatinine. The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation without race (Inker et al., 2021) was used to estimate glomerular filtration rate (eGFR). CKD was defined as eGFR < 60 ml/min/1.73 m^2 or an albumin-to-creatinine ratio (ACR) > 30 mg/g.

We created a count of the number of chronic conditions for each participant. Any multimorbidity was defined as having two or more chronic conditions (Le Reste et al., 2013). Complex multimorbidity was defined as three or more chronic conditions affecting three or more different body systems (Harrison et al., 2014). We defined body systems according to the World Health Organization's International Classification of Diseases, Tenth Revision (ICD-10) disease chapters, which has been done previously (Harrison et al., 2014). For example, high cholesterol, diabetes, and obesity were categorized under ICD-10 Chapter IV – Endocrine, nutritional and metabolic diseases.

2.3. 24-hour movement activity

24-hour movement was measured with the ActiGraph GT3X+ (*ActiGraph, LLC, Pensacola, FL, USA*) device for 24 h for 7 consecutive days, including during water-based activities such as bathing and swimming. NHANES PAM data were released in November 2020 are provided in daily Monitor-Independent Movement Summary (MIMS) triaxial units which are an aggregated triaxial sum of the processed signals from each axis (X, Y, Z) derived from an algorithm based on the raw 80 Hz acceleration data (John et al., 2019). Higher MIMS-unit values indicate more movement accumulated throughout the day. The PAM protocol and details on MIMS-units and have been previously described (John et al., 2019; Belcher et al., 2021).

Similar to previous studies (Belcher et al., 2021), we first removed the two partial days of wear (1st and 9th day; exam date and requested return date). A day was considered adherent if it had 1440 min (i.e., 24 h) of valid wear time, <5% non-wear time, and < 17 h of recorded sleep. Those with 0 adherent days were excluded. One day of data collection has been previously found to be sufficient for stable, population-level analyses (Wolff-Hughes et al., 2016). Overall, 92.7% of the NHANES sample had ≥ 3 adherent days. We excluded participants who did not have PAM data or who wore the device on their dominant wrist or with unknown wrist placement. Daily MIMS-units were averaged across all adherent days.

2.4. Covariates

Covariates were self-reported and include age (years), gender (male, female), race/ethnicity (Mexican American, non-Hispanic Asian, non-Hispanic Black, non-Hispanic White, other Hispanic, other race/multiracial), educational attainment (<high school, high school/GED, some

college/ associates, ≥college degree), and smoking status (never smoker, ever smoker, current smoker).

2.5. Statistical analysis

Characteristics of the sample, including prevalence and 95% confidence intervals (CI) of chronic conditions, any multimorbidity, and complex multimorbidity, were calculated. We conducted multivariable linear regression models to investigate the association between each chronic condition as exposures and 24-hour movement as the outcome, adjusting for age, sex, race/ethnicity, educational attainment, and smoking status (Model 1) and for the other chronic conditions under study (Model 2). In addition, multivariable linear regression models compared the mean 24-hour movement across 1) the number of conditions, where those who had no conditions served as the reference group, 2) any multimorbidity status (≥2 conditions vs < 2 conditions [reference]), and 3a) complex multimorbidity status (≥3 conditions across ≥ 3 different body systems; vs multimorbidity - not complex: ≥2 conditions across < 3 body systems); and 3b) complex multimorbidity vs those without multimorbidity. Lastly, we examined differences in 24-hour movement for those without multimorbidity, multimorbidity – not complex, and complex multimorbidity within 5-year age increments. All multivariable linear regression models were adjusted for age, sex, race/ethnicity, educational attainment, and smoking status. We also tested for possible interaction by sex and age.

Per the National Center for Health Statistics recommendations (CDC), variance estimates were derived using Taylor Series Linearization and missing values were treated as not missing completely at random. All analyses were conducted in SAS version 9.4 (*SAS Institute*) using the "Survey" procedure to account for the complex survey design and sampling weights.

3. Results

There were 9,034 adults aged 30 years and older who attended the MEC exam. After PAM exclusions (no data [n = 1,106]; wore the device on their dominant wrist or with unknown wrist placement [n = 91]; or who did not have at least one adherent day [n = 533]), a total of 7,304 participants were included in the analytical sample (eFig. 1). Compared to participants aged 30 years and older who attended the MEC exam, participants in the analytical sample with adherent accelerometer wear were slightly older (53.2 years vs 50.7 years, p < 0.001) and more likely to self-identify as Non-Hispanic White (p < 0.001) (eTable 2).

The participants had a mean age of 53.2 years (95% CI: 52.5, 53.9), 53.2% were female, and 69.4% were non-Hispanic White (Table 1). The participants wore the PAM an average of 5.6 (95% CI: 5.5, 5.6) days and had a median (IQR) daily MIMS-units value of 13,010 (10,649, 15,668). Participants had a median (IQR) of 1.6 (0.5, 3.0) chronic conditions. A total of 62.2% of participants had multimorbidity and 34.2% had complex multimorbidity.

3.1. Chronic conditions

Hypertension was the most common condition (53.2%, 95% CI: 50.8%, 55.5%) followed by obesity (38.9%, 95% CI: 36.9%, 40.9%), and high cholesterol (26.6%, 95% CI: 24.5%, 28.8%). Multivariable associations between individual chronic conditions and MIMS-units are presented in eTable 3. Each chronic condition, except hepatitis, osteoarthritis, and rheumatoid or psoriatic arthritis, was associated with lower 24-hour total movement after adjustment for age, sex, race/ethnicity, education, and smoking status (Model 1). After additional adjustment for the other chronic conditions under study (Model 2), the association of hypertension, high cholesterol, coronary heart disease, congestive heart failure, and COPD/ asthma were attenuated or null (Fig. 1). Having perceived cognitive problems (vs not) was associated with the strongest inverse relation with lower 24-hour total movement,

Table 1
Participant Characteristics of the Overall Analytical Sample of US Adults aged 30 years and older and Stratified by Multimorbidity Status, NHANES 2011–14.

Characteristics	Overall Analytical Sample N = 7304 % (95% CI)	Any Multimorbidity[a] n = 4632 % (95% CI)	No Multimorbidity n = 2672 % (95% CI)
Sociodemographic		62.2 (59.7, 64.8)	37.8 (35.2, 40.3)
Age (*y*), Mean (95% CI)	53.2 (52.5, 53.9)	57.5 (57.0, 58.0)	46.1 (45.2, 47.0)
Female	53.2 (51.5, 54.8)	55.1 (53.2, 57.0)	50.0 (47.8, 52.2)
Race/ethnicity			
Mexican American	7.5 (5.1, 9.9)	6.0 (4.0, 8.0)	10.1 (6.9, 13.3)
Non-Hispanic Asian	4.6 (3.5, 5.7)	2.8 (2.1, 3.6)	7.5 (5.7, 9.3)
Non-Hispanic Black	10.9 (8.2, 13.5)	11.6 (8.5, 14.7)	9.6 (7.4, 11.8)
Non-Hispanic White	69.4 (64.4, 74.3)	72.4 (67.4, 77.3)	64.3 (58.9, 69.8)
Other Hispanic	5.3 (3.5, 7.0)	4.5 (2.8, 6.2)	6.5 (4.3, 8.7)
Other Race/Multi-Racial	2.4 (1.8, 3.0)	2.7 (1.7, 3.6)	2.0 (1.3, 2.6)
Education level			
<High school	16.3 (13.8, 18.8)	17.9 (15.5, 20.2)	13.7 (10.7, 16.7)
High school/GED	21.3 (19.2, 23.3)	22.9 (20.8, 25.1)	18.5 (16.0, 21.0)
Some college/ Associates	30.2 (28.4, 32.1)	32.3 (30.0, 34.6)	26.8 (23.9, 29.7)
College degree or more	32.1 (28.5, 35.8)	26.8 (23.4, 30.2)	40.9 (36.2, 45.7)
Smoking status			
Never smoker	54.1 (52.1, 56.1)	48.7 (46.0, 51.4)	63.0 (60.4, 65.7)
Ever smoker	27.2 (25.2, 29.2)	32.1 (29.6, 34.5)	19.1 (16.6, 21.6)
Current smoker	18.7 (16.8, 20.5)	19.2 (17.0, 21.3)	17.8 (15.5, 20.2)
24-hour Movement			
MIMS-units, Median (95% CI)	13,010.0 (12,840.4, 13,179.2)	12,255.0 (12,082.1, 12,428.5)	14,137.0 (13,855.6, 14,418.7)
Observation Days, Mean (95% CI)	5.6 (5.5, 5.6)	5.7 (5.6, 5.8)	5.4 (5.3, 5.4)
Chronic Conditions			
Hepatitis (B & C)	1.8 (1.3, 2.3)	2.5 (1.7, 3.3)	NA[c]
Cancer (except nonmelanoma skin)	10.2 (9.3, 11.2)	15.1 (13.8, 16.4)	2.3 (1.6, 2.9)
High cholesterol	26.6 (24.5, 28.8)	38.3 (35.7, 40.9)	7.4 (5.9, 8.9)
Diabetes	10.6 (9.6, 11.6)	16.7 (15.2, 18.1)	0.6 (0.4, 0.9)
Obesity	38.9 (36.9, 40.9)	53.6 (51.2, 55.9)	14.7 (12.5, 17.0)
Depression	18.1 (16.4, 19.9)	27.0 (24.8, 29.2)	3.5 (2.5, 4.5)
Perceived memory problems	7.4 (6.5, 8.4)	11.4 (9.9, 12.8)	0.9 (0.5, 1.3)
Hypertension	53.2 (50.8, 55.5)	74.5 (72.8, 76.3)	17.9 (15.0, 20.8)
Stroke	3.5 (3.0, 4.1)	5.6 (4.9, 6.4)	NA[c]
Coronary heart disease	4.4 (3.6, 5.1)	7.0 (5.7, 8.2)	NA[c]
Congestive heart failure	3.3 (2.7, 3.9)	5.3 (4.4, 6.2)	NA[c]
Asthma/COPD	16.9 (15.2, 18.6)	23.2 (20.8, 25.6)	6.5 (5.3, 7.8)
Osteoarthritis	16.2 (14.9, 17.5)	24.4 (22.4, 26.3)	2.7 (1.5, 3.9)
Rheumatoid or Psoriatic arthritis	7.8 (6.6, 9.0)	11.7 (9.9, 13.4)	1.5 (0.8, 2.2)
Chronic Kidney Disease	15.8 (14.6, 17.0)	24.1 (22.5, 25.6)	2.1 (1.4, 2.9)
Complex Multimorbidity[b]	34.2 (31.8, 36.5)		

[a] Any multimorbidity defined as ≥ 2 chronic conditions.
[b] Complex multimorbidity defined as ≥ 3 chronic conditions affecting ≥ 3 body

systems.
[c] Data suppressed, n < 30.
Abbreviations: COPD, chronic obstructive pulmonary disease; MIMS-unit, Monitor-Independent Movement Summary units.

followed by obesity, CKD, depression, stroke, diabetes, and cancer.

3.2. Multimorbidity and complex multimorbidity

Having a higher number of chronic conditions was associated with incrementally lower 24-hour total movement (Fig. 2). Compared to those with no conditions and after adjustment for covariates, the 24-hour total movement count was 419.2 (95% CI: 772.2, 66.3), 605.3 (95% CI: 932.8, 278.0), 1,200.7 (95% CI: 1,506.1, 895.2), 1,907.8 (95% CI: 2,350.5, 1,465.2), and 2,971.9 (95% CI: 3,383.9, 2,560.0) lower among those with one, two, three, four, or five or more chronic conditions, respectively.

Having any multimorbidity was associated with 1,018.8 (95% CI: 1,276.7, 760.8) lower daily MIMS-units compared to those without multimorbidity, after adjustment for age, sex, race/ethnicity, education, and smoking status. Having complex multimorbidity was associated with 1,709.1 (95% CI: 2,061.6, 1,356.6) lower daily MIMS-units compared to those without multimorbidity and a 1,268.9 (95% CI: 1,619.9, 917.8) lower daily MIMS-units compared to those with multimorbidity – not complex, after covariate adjustment. There was a significant association by age ($p = 0.006$) but not by sex ($p = 0.884$). At each 5-year age increment categories, except for younger adults ages 30 to 34 years, those living with complex multimorbidity had the lowest daily MIMS-units (Fig. 3).

4. Discussion

In this large, nationally representative sample of US adults over 30 years old, almost two-thirds had any multimorbidity and one-third had complex multimorbidity. Diabetes, obesity, CKD, cancer, stroke, depression, and perceived cognitive problems were associated with lower 24-hour total movement after adjustment for covariates and the presence of other chronic conditions. Multimorbidity was associated with lower total 24-hour physical movement. Also, having complex multimorbidity was associated with even lower movement across all ages starting at 35 years old, compared to others of the same age without multimorbidity or with multimorbidity that was not complex (i.e., across less than 3 different body systems).

Multimorbidity has been associated with functional limitations and functional decline (Bowling et al., 2019; Ryan et al., 2015; Storeng et al., 2020), which may influence physical activity levels. Findings from the current study additionally suggest that those with diabetes, obesity, CKD, cancer, stroke, depression, or perceived cognitive problems have a higher likelihood for inactivity. This is concerning as these are common conditions in US adults. We also found incrementally lower 24-hour movement with increased chronic disease index. Our findings are similar to studies in Ireland and low- and middle-income countries (LMICs) which found that each additional chronic condition was associated with increased time spent in self-reported sedentary behaviors (Kandola et al., 2020; Vancampfort et al., 2017). In an Irish study using accelerometry, those with complex multimorbidity had higher odds of being inactive and sedentary with very few adults (3%) categorized as very active (O'Regan et al., 2021). One explanation for these findings may be the potential bidirectional pathway between chronic disease and functional limitations, which suggests an interplay between multimorbidity and reduced mobility, strength, and physical activity (Calderón-Larrañaga et al., 2019). Prospective cohort studies have

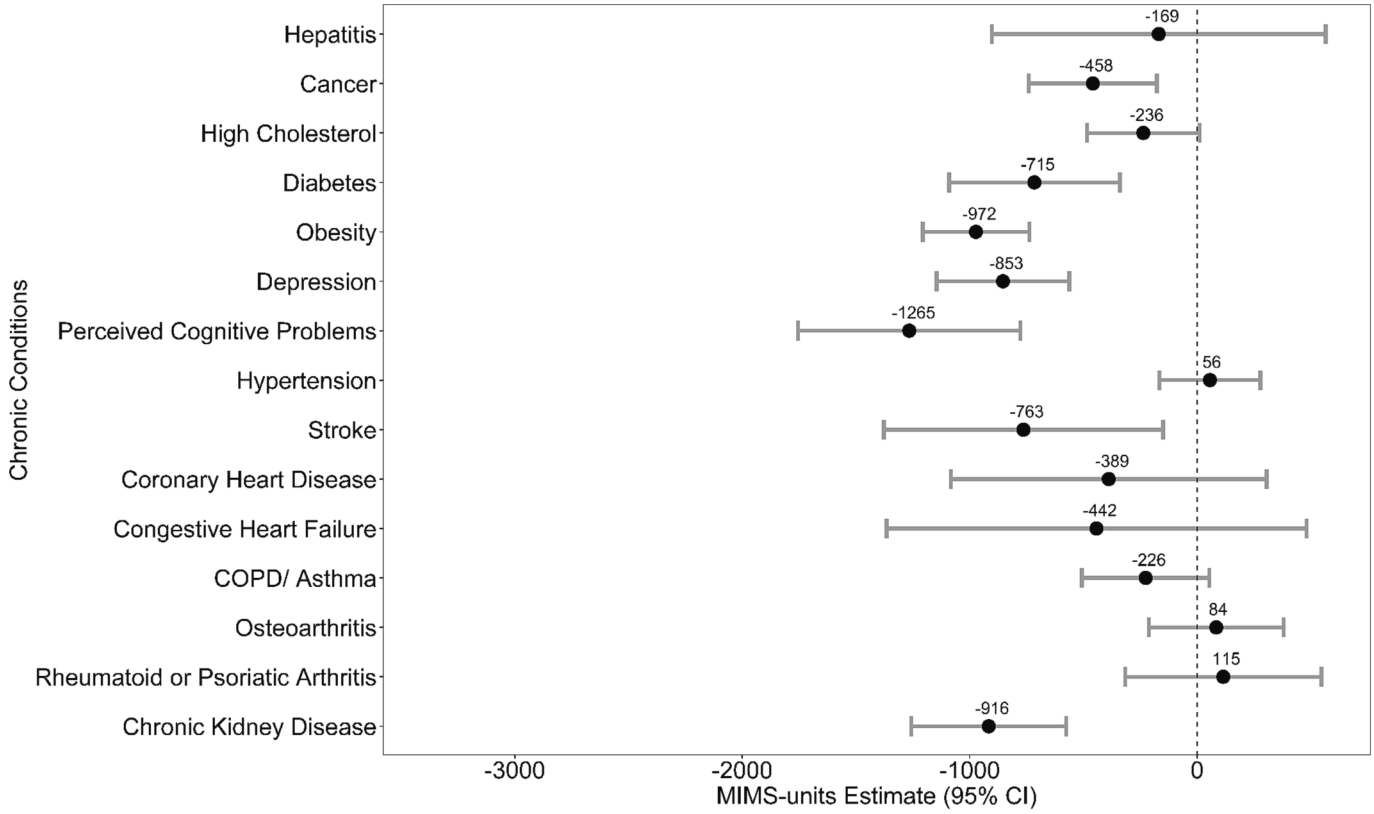


Fig. 1. Difference in 24-hour total movement activity for participants with versus without chronic conditions among US adults 30 + years, NHANES 2011–2014.

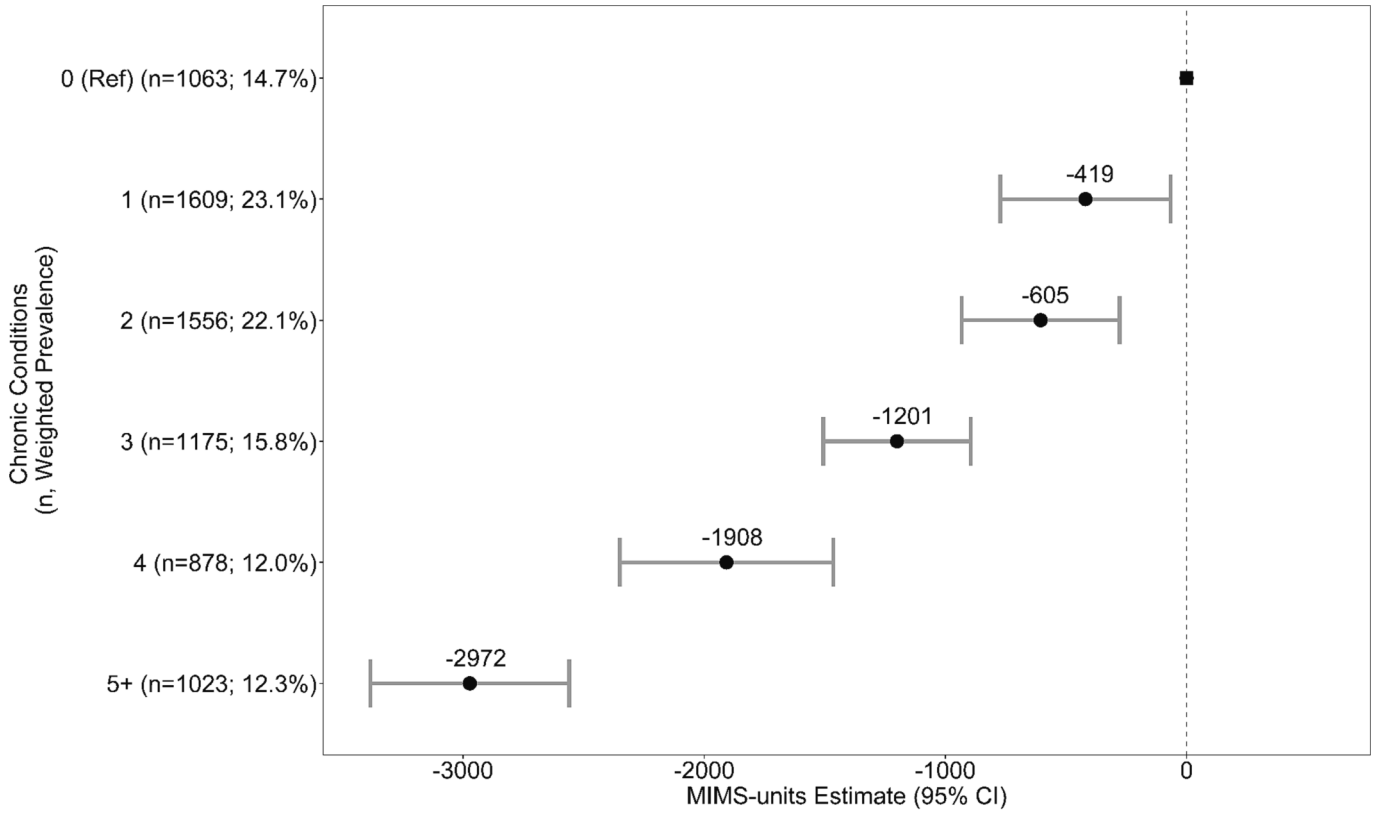


Fig. 2. Difference in 24-hour total movement activity associated with number of chronic conditions among US adults 30 + years, NHANES 2011–2014.

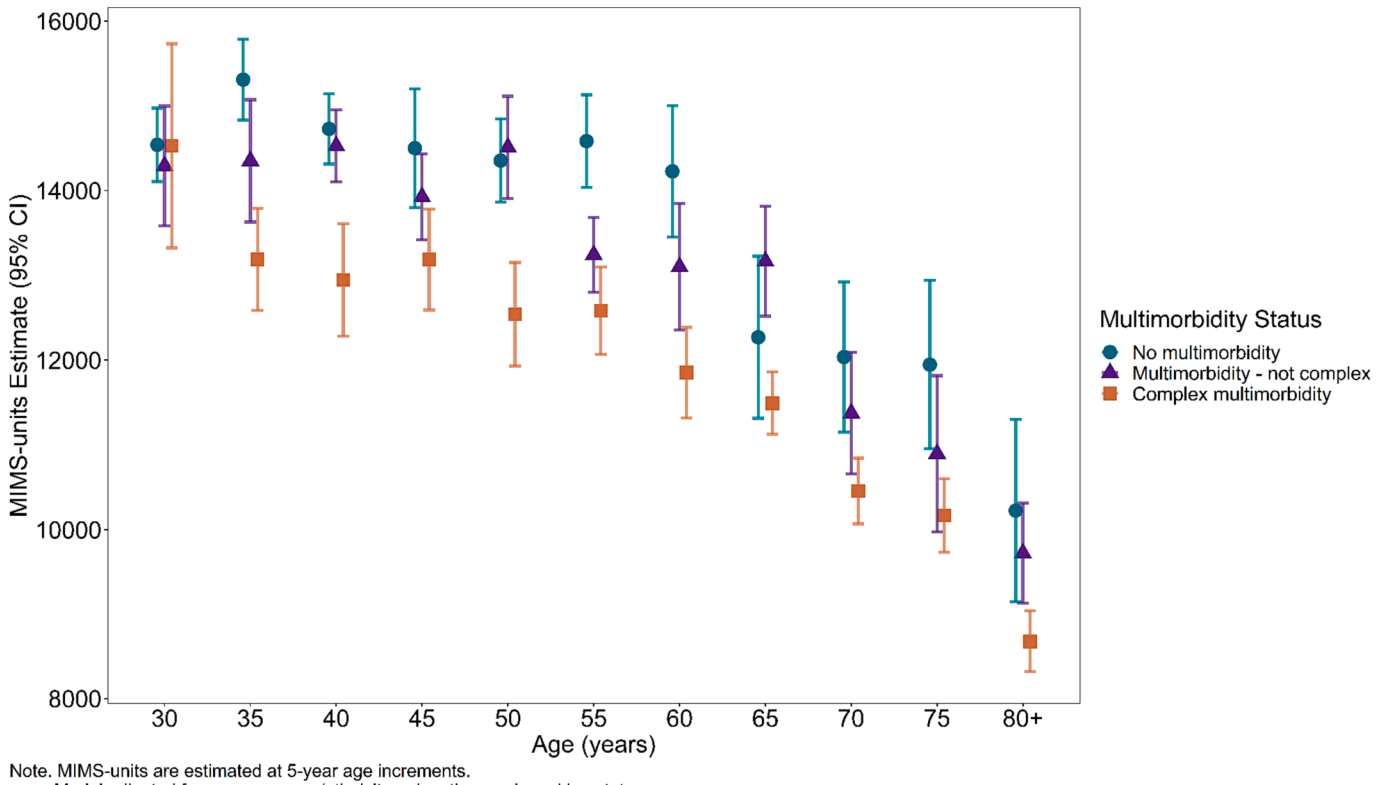
found multimorbidity is related to future functional decline (Ryan et al., 2015) and a cohort in Norway found those with complex multimorbidity were more likely to have functional disabilities and need for assistance 11 years later (Storeng et al., 2020). However, more longitudinal studies are needed to explore this interaction.

Older age is associated with a higher prevalence of individual chronic conditions and having multiple chronic conditions (Marengoni et al., 2011). Previous findings suggest an increase in multimorbidity prevalence starting around 35 to 40 years old, and plateauing around 75 years old (Fortin et al., 2012). We found similar findings, starting at 35 years and older, across the lifespan those with complex multimorbidity had lower movement compared to others of the same age with only 1 or fewer chronic disease conditions. Findings also suggested that those with complex multimorbidity had lower movement than those who had multimorbidity but that was not complex (i.e., across less than 3 different body systems). While these data are cross-sectional, early to midlife may be an important time to target for multimorbidity to prevent physical activity reduction and avert the bidirectional disease-inactivity-disease cycle and development of complex multimorbidity.

The biological plausibility suggesting a bidirectional association indicates that physical activity is applicable across stages of disease prevention from primary prevention strategies aimed to prevent development of disease to tertiary prevention strategies aimed to maximize health or restore optimal functioning *after* a diagnosis to manage long-term health problems (U.S. Department of Health and Human Services, 2018; Kisling and Das, 2022; Perry et al., 2023). Data from prospective observational studies provide evidence that physical activity across the lifecourse is inversely associated with disease onset (e.g., primary prevention) (U.S. Department of Health and Human Services, 2018). Yet, many adults are inactive (Whitfield et al., 2021) and physical activity continually declines across the lifespan (Belcher et al., 2021). We found a significant interaction with multimorbidity and age which suggests that having multimorbidity may further accelerate the age related decline in activity. Multimorbidity prevalence is steadily increasing (King et al., 2018; Dhalwani et al., 2016). For those with established chronic disease, physical activity can be an effective strategy for tertiary prevention as lifestyle interventions, such as structured exercise programs, are often recommended as nonpharmacological treatments for the prevention and management of diseases (U.S. Department of Health and Human Services, 2018; Whelton et al., 2018). For example, exercise-based cardiac rehabilitation programs after heart failure (Long et al., 2019) and CHD (Heran et al., 2019) have been found to reduce risk of hospitalization, improve health-related quality of life, and reduce risk of mortality. Clear scientific statements and clinical practice guidelines for physicians, such as prescribing exercise-based cardiac rehabilitation programs, may be one factor for why we did not observe less movement in individuals with heart-related diseases. However, for those experiencing diabetes, obesity, CKD, cancer, stroke, depression, or perceived cognitive problems, more support for adherence to exercise-based tertiary prevention programming (e.g., Exercise is Medicine (Thompson et al., 2020)) may be needed. For example, one lifestyle goal of the Diabetes Prevention Program (DPP) focuses on achieving 150 min per week of MVPA, however a review of community-based DPP programs found, that while there is success meeting the MVPA goal in 61.5 to 78% of participants (Eaglehouse et al., 2015), some people may still need further encouragement and support to move more.

4.1. Strengths and limitations

This study included a large, national sample of US adults and the inclusion of sample weights and complex sampling procedures allows for nationally representative prevalence estimates of multimorbidity and complex multimorbidity and their association with 24-h movement



Note. MIMS-units are estimated at 5-year age increments.
Model adjusted for age, sex, race/ethnicity, education, and smoking status.
No multimorbidity is 0 or 1 chronic conditions.
Multimorbidity - not complex is ≥2 chronic conditions but affecting ≤2 body systems.
Complex multimorbidity is ≥3 chronic conditions affecting ≥3 body systems.

Fig. 3. Total 24-hour total movement activity estimate (95% CIs) by age and multimorbidity status, among US adults 30 + years, NHANES 2011–2014.

behaviors. The use of device-based measures of movement and the ability to assess 16 chronic conditions using a variety of measures including self-report, clinical assessment, or a combination of both, to define multimorbidity and complex multimorbidity are also strengths of this study. In addition to multimorbidity and complex multimorbidity, examining the association of each individual chronic condition with movement is an additional strength of this study, given these conditions are also contained in index scores such as the Charlson Comorbidity Index (Charlson et al., 1987). However, there are limitations. We acknowledge that multimorbidity prevalence estimates may vary depending on definition and number of conditions measured, thus there may be bias in our estimates (Fortin et al., 2012). Another limitation of the NHANES dataset is that some diseases defined by the CDC as common chronic conditions are not assessed or not assessed across all ages. For example, the HIV antibody test was not conducted on those 60 years or older. This may impact multimorbidity prevalence estimates and comparison across surveillance systems. In addition, some conditions were only assessed via self-report. Due to the nature of data availability, we are unable to calculate more traditional accelerometer metrics such as time spent in physical activity intensity categories or vector magnitude counts. Despite this, MIMS-units are a metric of total physical activity and have been found to be highly correlated with ActiGraph counts (r = 0.998) (Karas et al., 2022). Data availability is also a limitation for computing other comorbidity index scores (e.g., Charlson Comorbidity Index). Finally, the serial cross-sectional nature of NHANES does not allow for examining the direction of associations or temporality of disease and physical activity, therefore future studies need to examine the possible cycle of chronic disease progression leading to low activity levels and low activity levels leading to worsened disease progression in large, prospective cohort studies.

4.2. Conclusions

This is the first study to investigate the association of multimorbidity and complex multimorbidity on total daily movement. This study found that multimorbidity was associated with lower 24-hour physical movement. Those with complex multimorbidity had even lower movement than those without multimorbidity or those who had multimorbidity that was not complex. In addition, multimorbidity may further accelerate the declines in physical activity that occur during natural aging. While these data are cross-sectional, they begin to address identified priority area research needs of the US 2018 Physical Activity Guidelines Advisory Committee Scientific Report regarding physical activity among individuals with chronic conditions to reduce the risk of developing additional chronic conditions (e.g., tertiary prevention strategies). Comorbidities such as having perceived cognitive problems, obesity, CKD, depression, stroke, diabetes, and cancer may be particularly susceptible to disease and inactivity accumulation. Exploring the potential bidirectional interplay between multimorbidity and daily movement in cohort studies is still needed.

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Data statement

All data and materials used in this study can be accessed at https://www.cdc.gov/nchs/nhanes/. The code used to analyze these data for this article is available via reasonable request to the corresponding author.

CRediT authorship contribution statement

Erin E. Dooley: Conceptualization, Formal analysis, Data curation, Writing – original draft, Visualization. **Ligong Chen:** Writing – review & editing. **Lama Ghazi:** Writing – review & editing. **Bjoern Hornikel:** Writing – review & editing. **Pablo Martinez-Amezcua:** Writing – review & editing. **Priya Palta:** Writing – review & editing. **C. Barrett Bowling:** Writing – review & editing. **Paul Muntner:** Writing – review & editing. **Cora E. Lewis:** Writing – review & editing. **Kelley Pettee Gabriel:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used in this study can be accessed at https://www.cdc.gov/nchs/nhanes/. The code used to analyze these data for this article is available via reasonable request to the corresponding author.

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Appendix A. Supplementary data

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