AMERICAN ACADEMY OF OPHTHALMOLOGY®

The Quantitative Impact of Visual Function on Accelerometer-measured Physical Activity in Older United States Adults: A Nationwide Cross-sectional Analysis

Louay Almidani, MD, MSc,[1] *Varshini Varadaraj, MD, MPH,*[2] *Seema Banerjee, PhD,*[1] *Jian-Yu E, MD, ScD, MPH,*[1] *Aleksandra Mihailovic, ScM,*[1] *Pradeep Y. Ramulu, MD, MHS, PhD*[1]

Purpose: To explore the impact of objective vision measures on novel metrics of objectively-measured physical activity (PA) in a nationally representative sample of United States (US) older adults.

Design: Cross-sectional analysis using data from the National Health and Aging Trends Study.

Participants: Adults had their distance and near visual acuity (VA) and contrast sensitivity (CS) tested. Any objective vision impairment (VI), defined as any VI in distance VA, near VA, or CS, was the primary exposure. Physical activity data were collected using the Actigraph CentrePoint Insight Watch worn for 7 days.

Methods: Multivariable regression models were used to investigate the association between vision and PA measures. All analyses accounted for the survey design and models were adjusted for age, sex, race, living arrangement, education, and comorbidities.

Main Outcome Measures: Physical activity metrics included (1) total daily activity (active minutes per day, number of active bouts, and mean length of active bouts), (2) activity fragmentation, and (3) time until 75% activity. An active bout was defined as ≥ 1 consecutive active minute. Activity fragmentation was defined as the probability of an active minute being followed by a sedentary minute, with higher values indicating more fragmented activity. Time until 75% activity was defined as the time taken to complete 75% of daily PA starting from their first active bout.

Results: Among 723 participants, sampled from 10 443 338 older adults in the US, 30% had any objective VI. Any objective VI was significantly associated with lower number of active minutes per day (7.8% fewer [95% confidence interval {CI}: −13.6% to −1.7%]), shorter active bouts (7.0% shorter [95% CI: −12.3% to −1.4%]), and greater activity fragmentation (2.5% [95% CI: 0.8% to 4.2%]), while no associations were found with number of active bouts. Time until 75% activity did not significantly differ between adults with any objective VI and those without ($P = 0.34$).

Conclusions: Older US adults with any objective VI displayed lower total daily activity, as well as more fragmented, shorter periods of PA, despite having a similar number of active bouts compared to their normally sighted counterparts. Implementing interventions that increase bout duration may help promote PA in adults with VI.

Financial Disclosure(s): Proprietary or commercial disclosure may be found in the Footnotes and Disclosures at the end of this article. *Ophthalmology Science 2024;4:100464 © 2023 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

Supplemental material available at www.ophthalmologyscience.org.

Physical activity (PA) is a well-established predictor of health and well-being,[1] and its restriction has been significantly associated with an increased risk of morbidity and mortality.[2–4] Identifying communities prone to reduced PA and promoting increased activity in these groups may improve health outcomes. Adults with vision impairment (VI) have emerged as one such potentially susceptible population.[5]

Vision impairment is significantly associated with PA restriction, with its impact on PA levels being equivalent to stroke and other serious medical conditions.[6] Previous studies have demonstrated that individuals with greater levels of vision loss tend to engage in less PA.[7] Yet, it is unclear how and why adults with VI restrict their PA, i.e., if they are intrinsically less active, or if their impairment led to diminished activity as a result of fear of falling or an inability to engage in walks or other daily activities.

Emerging evidence suggests that novel metrics of PA, including activity fragmentation, and patterns of daily PA

https://doi.org/10.1016/j.xops.2023.100464
ISSN 2666-9145/24

may provide valuable insights into health and functioning.[8,9] Activity patterns, such as the distribution of PA over the course of the day, or the duration adults require to complete varying proportions of their activity, may also further elucidate the underlying reasons for PA restriction in adults with VI, and may direct the nature of future interventions to improve PA in this group.

We previously explored activity fragmentation and activity patterns by visual field (VF) damage in glaucoma patients and found that worse levels of VF damage are associated with shorter, more fragmented bouts of PA throughout the day.[10] However, our findings were limited to glaucoma patients in a single center. To our knowledge, no studies have looked at the associations between fragmentation and patterns of PA with other measures of visual function, including distance and near visual acuity (VA) and contrast sensitivity (CS), in a nationally representative sample of United States (US) adults. Here, we examine impact of several objective visual function measures (distance and near VA and CS) on accelerometry-defined PA, including activity fragmentation and activity patterns, in a nationally representative sample of older US adults.

Methods

Study Design and Participants

This cross-sectional study utilized data from the National Health and Aging Trends Study (NHATS) Round 11 (2021) to explore the extent to which poor vision affects PA.[11] The NHATS is a nationally representative sample of Medicare beneficiaries aged $\geq$ 65 years living in the US.[12] However, since the sample included were primarily recruited in 2015 (and has aged since), 2021 NHATS did not include adults $<$ 71 years. Further details regarding survey sampling design have been previously described.[12] Performance-based tests, including vision testing, were conducted in person at individuals' homes.

For this study, approval from an institutional review board was not required as it uses publicly available, nonidentifiable data. The NHATS investigators obtained consent from all participants or their proxy respondents before collecting data, and the study was conducted in accordance with the tenets of the Declaration of Helsinki. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines for cross-sectional studies.

Vision Measures

Objective Vision. The NHATS introduced 3 objective vision tests (distance and near VA and CS) in 2021 that measured presenting binocular vision while wearing habitual correction (glasses or contacts). Monocular vision data were not available. Tests were conducted via Ridgevue Vision tablet-based tests (ridgevue.com), which show good agreement with corresponding gold standard tests (ETDRS distance acuity, MNRead near acuity, and Pelli-Robson contrast sensitivity), and offers the advantage of allowing standardized monitoring to take place in a range of environments, including at home or in rehabilitation facilities.[13,14]

For distance VA testing, participants sat at a distance of 5 feet away from the tablet and were instructed to read 5 letters per screen with each subsequent screen displaying reduced letter size. For near VA testing, participants were asked to hold the tablet at their usual reading distance and were instructed to read 5 letters per screen with each subsequent screen displaying smaller letters. For CS testing, participants were instructed to read 2 letters per screen, with the tone becoming lighter with each subsequent screen. Further details on how the tests were conducted have been described previously.[13,15] Distance and near VA were calculated as the logarithm of the minimum angle of resolution (logMAR), with near VA accounting for reading distance. Contrast sensitivity was measured in logCS units. We assessed vision on a continuous scale; distance and near VA (per 0.1 logMAR) and CS (per 0.1 logCS), and on a categorical scale; distance VI ($<$ 20/40), near VI ($<$ 20/40)—based on the US American Academy of Ophthalmology definitions,[16] and CS impairment ($<$ 1.55), as previously defined.[17] Any objective VI, defined as having VI in any measurement of distance VA, near VA, or CS, was taken as the primary exposure, as previously defined.[18]

Self-reported Vision. Self-reported VI was defined based on the vision status reported by participants or their proxies (n = 12) , including whether they were blind or had difficulty with distance or near vision when wearing glasses or contact lenses. Participants were considered to have self-reported visual difficulties if they answered "no" to any of the following questions: (1) "Can you recognize someone across the street when wearing glasses or contacts?" (2) "Can you watch television across the room when wearing glasses or contacts?" (3) "Can you read newspaper print when wearing glasses or contacts?" as previously described.[19] These questions were asked prior to administering the objective vision tests.

PA Measures

Physical activity data were collected using the Actigraph CentrePoint Insight Watch, an accelerometer designed for research purposes. During the in-home interview, participants were provided with the watch, instructed to wear it on their nondominant wrist, and keep it on 24 hours a day for a period of 7 consecutive days following the interview day. Further details are described elsewhere.[20] Although there is currently no consensus on the optimal duration of PA monitoring needed for obtaining reliable estimates, 4 days has been commonly used in previous studies.[21,22] Therefore, for this analysis, data were used from participants who wore the watch for a minimum of 4 valid days, where a valid day was defined as $>$ 90% wear (1296 minutes per day). We examined 4 accelerometry-defined PA metrics, each described in greater detail here: (1) active minutes per day, (2) number of active bouts per day, (3) mean length of active bouts, and (4) activity fragmentation.

Active Minutes per Day. We obtained overall total daily activity by summing the number of active minutes per day.[23] Active minutes were defined as the number of minutes per day spent above a threshold of 1853 counts per minute, as described in the NHATS Accelerometer protocol, and previously identified as the optimal vector magnitude cut-off point.[20,24] This cutoff is designed to capture most light to vigorous activity and was selected since the majority of older adults typically engage in light-intensity activity.[25]

Number of Active Bouts per Day and Mean Length of Active Bouts. Similar to previous studies, we explored number of active bouts, where a bout was defined as an uninterrupted sequence of $\geq$ 1 active minutes.[10,23] We also investigated the average length of each active bout across all valid days. Our interest in active bouts stemmed from prior studies demonstrating that a higher frequency of active bouts was associated with a significantly lower risk of death and frailty levels.[26,27]

Activity Fragmentation. Fragmentation was measured as the probability of an active minute being followed by a sedentary

minute. Fragmentation was computed for each study day, with values averaged across all valid days to derive a single value for each individual as previously described.[20,28] A higher fragmentation value reflects a higher probability of transitioning from an active state to a sedentary state.

Covariates

Demographic characteristic covariates included age (categorized into 5 age intervals: 70−74, 75−79, 80−84, 85−89, and ≥ 90; continuous age is not provided in the publicly available NHATS data), gender (male, female), race (Non-Hispanic White, Black, Hispanic, and other), living arrangement (alone, not alone), education (high school or less, some college, and college graduate and beyond), and number of comorbidities (0−1, 2, 3, and ≥ 4). Comorbidities included self-reported diagnoses of diabetes, hypertension, myocardial infarction, arthritis (osteoarthritis or rheumatoid arthritis), osteoporosis, stroke, lung disease (such as emphysema, asthma, or chronic bronchitis), cancer, and hip fracture. Covariates were included based on clinical relevance and/or previous demonstration of impact on VI and PA.

Statistical Analysis

Descriptive statistics were used to characterize the groups (any objective VI vs. no objective VI). Comparisons were performed using Pearson chi-squared test for categorical variables and Wilcoxon rank-sum test for continuous variables.

Multivariable regression models were used to investigate the association between various vision measures and PA, both categorically (any objective VI, self-reported VI, distance VI, near VI, and CS impairment) and continuously (distance and near VA and CS). Linear regression was used to evaluate activity fragmentation, while negative binomial regressions were used to assess total daily PA metrics (minutes active per day, number of active bouts per day, and mean length of active bouts) as they were in the form of count data that failed tests of normality and displayed signs of overdispersion. We performed separate regression models for each outcome measure with each vision measure, i.e., adults with VI in each single vision measure were compared to their counterparts without VI in that measure. For example, adults with distance VI were compared to those without distance VI as the reference group.

To analyze activity patterns, we calculated the time at which participants started their activity, defined as the first 2 consecutive active bouts during typical waking hours (5 AM−11 PM). This allowed us to understand whether adults with VI start at an earlier or later time in the day compared with their counterparts. We further explored the time at which various proportions (5%, 50%, and 75%) of daily PA are completed since their first active bout occurring after 5 AM. This enabled us to ascertain if adults with VI take longer to complete different percentages of their activity throughout the day. Since the distribution of the percentage of activity completed across the number of days device worn was skewed, the median times across valid days were taken. Multivariable linear regression models were used to investigate the association between time to complete different percentages of daily PA (dependent variable) and vision measures (independent variable).

Lastly, to further understand PA patterns over the course of the day, we calculated the number of active minutes taken during 3-hour intervals spanning typical waking hours (5:00 AM−7:59 AM, 8:00 AM−10:59 AM, 11:00 AM−1:59 PM, 2:00 PM−4:59 PM, 5:00 PM−7:59 PM, and 8:00 PM−10:59 PM) (Fig S1). Further, we plotted mean active minutes per hour for each 3-hour period across the spectrum of VA and CS (Fig S2). Next, we computed the percentage of total daily PA completed per hour for each participant (Fig 3). Median values across all valid days were used. Multivariable linear mixed-effect models were used, employing an unstructured covariance model to account for within-participant clustering and incorporating the varying effects of hours of the day, asking whether the adults with VI completed a lower/higher percentage of activity at certain intervals of the day as compared to visually normal adults.

In sensitivity analyses, we explored the impact of severe VI (defined as VA ≥ 1.00 logMAR—Snellen equivalent ≤ 20/200) on activity fragmentation. All analyses accounted for survey design and models were adjusted for age, sex, race, living arrangement, education, and comorbidities. "Do not know" and "Refuse" responses were treated as missing values and subjects were excluded from the regressions. Statistical significance was defined at $P < 0.05$. All analyses were performed using Stata/SE 16.1 (StatCorp LLC) and R (R Foundation for Statistical Computing) softwares.

Results

In NHATS Round 11, a total of 3817 participants were sampled, and interview data were obtained by direct contact with either the participant or a proxy respondent. Fig S4 describes the analytic population. A total of 723 participants, sampled from 10 443 338 older adults in the US, with complete vision and accelerometry data were included in this study. Of the total sample, 3 142 503 adults (30%) had any objective VI, and 548 950 (5%) had self-reported VI. Table 1 lists key demographic characteristics of adults included in this study. Overall, adults with any objective VI were older and had lower education compared to their counterparts ($P < 0.001$). Table S2 compares the characteristics of included and excluded participants.

Median number of total active minutes was 365 minutes/day (interquartile range, 280−431 minutes/day) for subjects with no objective VI, and 315 minutes/day (interquartile range: 230−414 minutes/day) for adults with any objective VI. In multivariable regression models, any objective VI was significantly associated with lower total active minutes per day (β = 7.8% fewer, [95% CI: −13.6%, −1.7%], $P = 0.01$), and shorter mean length of active bouts (β = −7.0%, [95% CI: −12.3%, −1.4%], $P = 0.02$), but not with number of active bouts (β = −2.4% [95% CI: −6.1%, 1.4%], $P = 0.20$). Positive findings were also observed for each vision measure, with the highest statistical significance observed with CS (Table 3).

Adults with any objective VI had greater activity fragmentation (mean: 30.0%, [95% confidence interval {CI}: 28.3%, 31.8%]) compared with no objective VI (mean: 26.9%, [95% CI: 26.0%, 27.8%]). In multivariable regression models, any objective VI was significantly associated with greater activity fragmentation (β = 2.5%, [95% CI: 0.8%, 4.2%], P-value = 0.004). Similar findings were also observed for each objective vision measure (refer to Table 3). Further, severe VI was also significantly associated with greater activity fragmentation (β = 3.5%, [95% CI: 0.8%, 6.2%], $P = 0.01$).

In completion hour analyses, any objective VI was not associated with a different amount of time to complete 75%

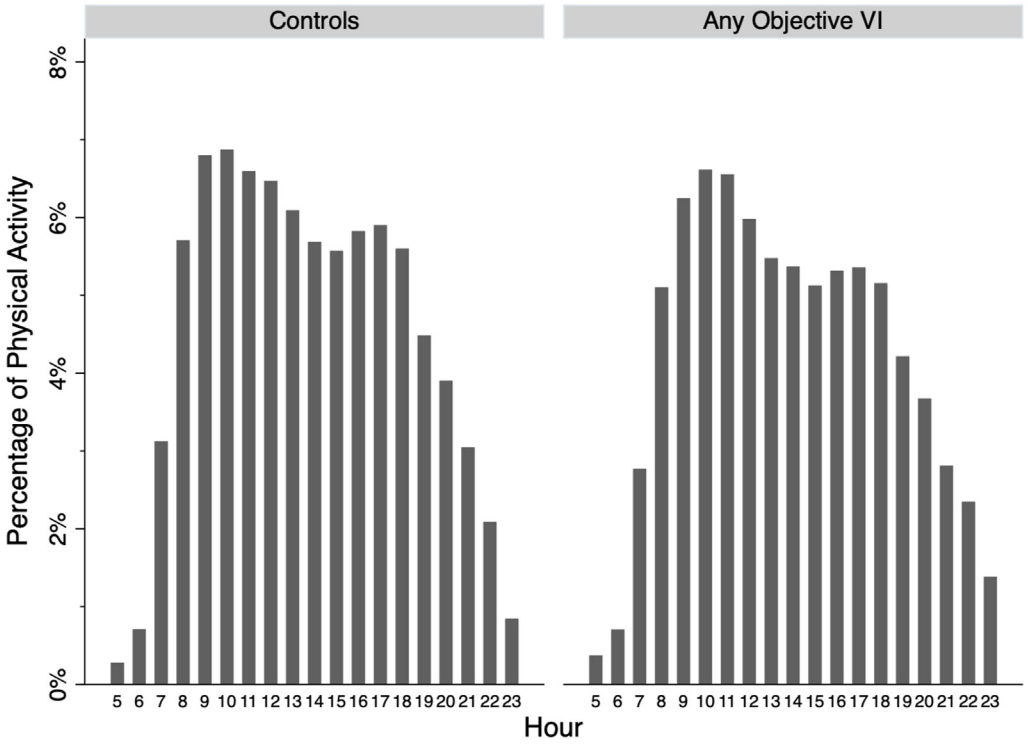

Figure 3. Median percentage of physical activity completed over typical waking hours for adults with and without objective vision impairment (VI).

of daily activity (95% CI: −8.4, 24.0, $P = 0.34$) as compared with normally sighted individuals (Table 4). However, near VA (−3.0 [95% CI: −5.0, −1.0], per 0.1 logMAR) was significantly associated with earlier completion of 5% of daily PA, while CS (+3.5 [95% CI: 0.05, 6.9], per 0.1 logCS) was significantly associated with delayed completion of 75% of daily PA.

When exploring percentage of daily activity completed at hour intervals (Table S5), compared with normally sighted individuals, adults with any objective VI did not significantly differ in PA percentage by hour analyses ($P > 0.05$). However, adults with distance VA (0.3%, [95% CI: 0.01%, 0.6%], per 0.1 logMAR) and near VA (0.4%, [95% CI: 0.1%, 0.7%], per 0.1 logMAR) completed a greater percentage of activity between hours 5:00 AM and 8:00 AM, while only adults with near VA (−0.2%, [95% CI: −0.4%, −0.03%], per 0.1 logMAR) completed a lower percentage of activity between hours 2:00 PM and 5:00 PM.

Discussion

Older US adults with objective VI engaged in less daily physical activity, with their bouts being shorter and activity more fragmented, despite having a similar number of daily activity bouts compared with their normally sighted counterparts. Patterns of activity over the course of the day were largely unaffected by VI, thought adults with objective VI tended to complete a greater percentage of their daily activity in the early morning as compared with normally sighted individuals. Overall, our results suggest that older adults with VI spend less overall time engaged in PA, largely as a result of shorter (but not less frequent) bouts of activity.

Our findings complement previous studies that found a significant association between VF damage and decreased PA in patients with glaucoma, age-related macular degeneration, and other conditions.[10,29] We further expanded upon the previous findings by examining a national sample of older adults in the US and including individuals with various types of VI, not limited to glaucoma alone. This allows for more generalizable estimates of the restriction of PA participation observed in adults with VI. Our findings also align with findings from the National Health and Nutritional Examination Survey which showed that VI, but not uncorrected refractive error, is associated with lower mean steps per day and daily minutes of moderate or vigorous PA.[6] Our findings also align with a recent analysis of the Baltimore Longitudinal Study of Aging, which showed significant associations between multiple measures of visual function (presenting and best-corrected VA, CS, stereo acuity, and VF damage) and PA metrics.[23]

While we could not distinguish uncorrectable change from refractive error in our study, we included CS, which may be more reflective of uncorrectable change, as it is relatively unaffected by refractive error.[30] Contrast sensitivity showed the highest significance of associations with total daily PA and was also significantly associated with a longer time taken to complete the 75% of daily PA. These findings suggest

Table 1. Weighted Participant Characteristics by VI Status, National Health and Aging Trends Study 2021

	Total	Any Objective VI	No Objective VI	*P* Value
Participants, n (%)	10 443 338	3 142 503 (30)	7 300 835 (70)	
Age Groups, n (%)				
70–74	4 484 183 (43)	1 054 280 (34)	3 429 903 (47)	< 0.001
75–79	3 488 193 (33)	1 068 037 (34)	2 420 157 (33)	
80–84	1 488 805 (14)	539 543 (17)	949 261 (13)	
85–89	708 241 (7)	317 651 (10)	390 590 (5)	
≥ 90	273 917 (3)	162 992 (5)	110 924 (2)	
Female, n (%)	5 480 737 (52)	1 691 944 (54)	3 788 793 (52)	0.71
Race/Ethnicity, n (%)				
White	8 446 022 (84)	2 495 098 (78)	6 040 924 (87)	0.07
African American	308 952 (3)	114 082 (4)	194 870 (3)	
Hispanic	815 167 (8)	336 886 (11)	478 280 (7)	
Other	476 910 (5)	213 961 (7)	262 949 (4)	
Living arrangement, n (%)				
Alone	3 126 822 (30)	1 021 317 (33)	2 105 505 (29)	0.33
Education, n (%)				
High school or less	3 238 740 (31)	1 359 606 (43)	1 879 135 (26)	< 0.001
Some college/vocational	2 436 416 (23)	534 879 (17)	1 901 537 (26)	
College graduate and beyond	4 762 058 (46)	1 241 896 (40)	3 520 163 (48)	
Number of comorbidities, n (%)				
0–1	2 180 613 (21)	508 539 (16)	1 672 075 (23)	0.21
2	3 116 475 (30)	902 639 (29)	2 213 836 (30)	
3	2 695 666 (26)	891 128 (28)	1 804 539 (25)	
≥ 4	2 450 583 (23)	840 198 (27)	1 610 386 (22)	
Visual functioning measures, median (IQR)				
Distance VA (logMAR)	0.10 (0, 0.20)	0.22 (0.14, 0.36)	0.04 (−0.02, 0.14)	< 0.001
Near VA (logMAR)	0.17 (0.09, 0.27)	0.35 (0.26, 0.45)	0.13 (0.06, 0.20)	< 0.001
CS (logCS)	1.80 (1.65, 1.85)	1.50 (1.30, 1.65)	1.85 (1.75, 1.85)	< 0.001
Self-reported VI, n (%)	548 950 (5)	404 350 (13)	144 600 (2)	< 0.001

CS = contrast sensitivity; IQR = interquartile range; logMAR = logarithm of the minimum angle of resolution; VA = visual acuity; VI = vision impairment.

that different types of VI may have varying effects on activity levels and daily functioning.

To our knowledge, this study is the first to quantify the relationship between VI and activity fragmentation in a nationally representative sample of older adults in the US. All examination-based measures of vision were significantly associated with more fragmented daily activity, which has significant implications for the wellbeing of older adults with VI. Wanigatunga et al (2019)[9] demonstrated that greater activity fragmentation was associated with a 49% higher mortality risk, while total daily PA was not. In another study of older adults, associations with frailty were more pronounced with activity fragmentation compared with total PA, such that each 1% increase in activity fragmentation was associated with a 7% higher likelihood of frailty.[31] As per the above-mentioned studies, a 2.5% greater activity fragmentation in adults with VI would translate to a 17.5% higher likelihood of frailty and 12.3% higher mortality risk. These estimates may be higher in adults with worse vision since there is greater activity fragmentation as the vision gets worse (evidenced by the continuous vision measures and severe VI showing stronger associations). These findings illustrate the importance of both overall activity, and the degree of continuity (i.e., bout length and fragmentation) in which this activity is accomplished.

In patterns of daily PA analyses, near VA was associated with less time to initiate their activity (complete 5% of daily activity), while CS was associated with greater time taken to complete 75% of daily PA. Similarly, distance and near VA were associated with greater percentage of daily PA completed between 5:00 AM and 8:00 AM, while near VA was associated with less percentage completed between 2:00 PM and 5:00 PM. These data suggest that adults with worse distance and near VA may be more active during the early morning hours, while adults with worse near VA may experience a decrease in activity in the afternoon. Similarly, adults with worse CS take more time to complete 75% of their activity. Caution should be applied to these findings, as the investigation of several visual measures with several activity outcomes is prone to false discovery, though the false discovery rate is likely mitigated by correlations between vision measures with each other. Overall, these data might suggest diminished reserve capacity in older adults with VI and therefore a reduced ability to sustain activity throughout the day.[28]

The temporal relationship between VI and PA remains unclear. Vision impairment may impede adults' ability to sustain prolonged activity due to factors such as fear of falling, which have been associated with VI and PA.[32–34] Additionally, restricted mobility and impaired driving ability may limit their ability to leave their homes, thereby

Table 3. Weighted Analyses Examining the Associations Between Vision Impairment and Various Activity Parameters, the National Health and Aging Trends Study 2021*

Activity Parameter/VI Measure	Reference	IRR (95% CI)	*P* Value
Active minutes per day		% Difference in minutes	
Categorical VI			
Any objective VI	No objective VI	−7.8% (−13.6%, −1.7%)	0.01
Self-reported VI	No self-reported VI	−11.4% (−24.4%, 3.8%)	0.13
Distance VI	No distance VI	−13.9% (−23.0%, −3.6%)	0.01
Near VI	No near VI	−6.8% (−13.5%, 0.4%)	0.06
CSI	No CSI	−12.4% (−18.9%, −5.5%)	0.001
Continuous vision measures			
Distance VA	0.1 logMAR worse	−2.2% (−3.5%, −0.6%)	0.01
Near VA	0.1 logMAR worse	−1.6% (−2.9%, −0.06%)	0.04
CS	0.1 logCS worse	−2.0% (−2. 9%, −1.1%)	<0.001
Number of active bouts		% Difference in bouts	
Categorical VI			
Any objective VI	No objective VI	−2.4% (−6.1%, 1.4%)	0.20
Self-reported VI	No self-reported VI	−0.8% (−11.6%, 11.3%)	0.89
Distance VI	No distance VI	−5.4% (−10.4%, −0.2%)	0.04
Near VI	No near VI	−1.1% (−5.9%, 4.0%)	0.67
CSI	No CSI	−5.8% (−9.7%, −1.7%)	0.007
Continuous vision measures			
Distance VA	0.1 logMAR worse	−0.6% (−1.5%, 0.5%)	0.28
Near VA	0.1 logMAR worse	−0.4% (−1.2%, 0.5%)	0.36
CS	0.1 logCS worse	−0.8% (−1.6%, −0.02%)	0.04
Length of active bouts		% Difference in minutes	
Categorical VI			
Any objective VI	No objective VI	−7.0% (−12.3%, −1.4%)	0.02
Self-reported VI	No self-reported VI	−14.4% (−25.6%, −1.5%)	0.03
Distance VI	No distance VI	−9.4% (−17.9%, 0.04%)	0.05
Near VI	No near VI	−5.9% (−11.9%, 0.5%)	0.07
CSI	No CSI	−9.2% (−15.5%, −2.5%)	0.009
Continuous vision measures			
Distance VA	0.1 logMAR worse	−2.1% (−3.1%, −0.7%)	0.004
Near VA	0.1 logMAR worse	−1.4% (−2.8%, 0.2%)	0.08
CS	0.1 logCS worse	−1.6% (−2.5%, −0.6%)	0.002
Activity fragmentation		β (95% CI) − %	
Categorical VI			
Any objective VI	No objective VI	2.5% (0.8%, 4.2%)	0.004
Self-reported VI	No self-reported VI	4.0% (−0.9%, 8.8%)	0.11
Distance VI	No distance VI	3.6% (1.0%, 6.3%)	0.008
Near VI	No near VI	2.2% (0.3%, 4.1%)	0.02
CSI	No CSI	3.0% (0.9%, 5.1%)	0.006
Continuous vision measures			
Distance VA	0.1 logMAR worse	0.8% (0.4%, 1.3%)	0.001
Near VA	0.1 logMAR worse	0.6% (0.2%, 1.0%)	0.005
CS	0.1 logCS worse	0.5% (0.2%, 0.8%)	0.001

CI = confidence interval; CS = contrast sensitivity; CSI = contrast sensitivity impairment; logMAR = logarithm of the minimum angle of resolution; VA = visual acuity; VI = vision impairment.
*All models accounted for survey design and were adjusted for age, sex, race, education, living arrangement, and comorbidities.

reducing opportunities for prolonged PA outside the home environment. Moreover, older adults with VI may face environmental barriers within their homes that hinder their ability to engage in sustained activity compared with outdoor or fitness center settings.[35–37] Alternatively, older adults may experience worsening vision partly because of declining PA levels. Previous studies have shown that exercise results in lowered intraocular pressure postexercise,[38] and was significantly associated with slower rates of VF loss,[39] suggesting that PA may have a favorable effect on intraocular pressure and VF. Physical activity has also been linked with improvements in vascular endothelial function,[40] proposing a potential protective role in the development of diabetic retinopathy.[41] Finally, those with lower mobility may be less likely to seek eye care, including refractive correction, addressing reversible causes of vision loss such as cataracts, and prevention of chronic diseases. With the ability to monitor real-world

Table 4. Multivariable Negative Binomial Regression Models Exploring the Associations Between Vision Measures and Time to Complete Different Portions of Daily Activity, the National Health and Aging Trends Study 2021*

Time (Minutes)	Measure	Interval	β (95% CI)	*P* Value
Time to complete 5% of daily activity			minutes	
	Categorical VI			
	Any objective VI	No objective VI	3.0 (−8.9, 14.9)	0.62
	Self-reported VI	No self-reported VI	−2.7 (−17.5, 12.0)	0.71
	Distance VI	No distance VI	−0.5 (−17.2, 16.2)	0.96
	Near VI	No near VI	−6.9 (−17.3, 3.5)	0.19
	CSI	No CSI	2.9 (−11.0, 16.8)	0.68
	Continuous vision measures			
	Distance VA	0.1 logMAR worse	−1.5 (−4.2, 1.1)	0.24
	Near VA	0.1 logMAR worse	−3.0 (−5.0, −1.0)	0.004
	CS	0.1 logCS worse	0.6 (−2.0, 3.1)	0.66
Time to complete 50% of daily activity			minutes	
	Categorical VI			
	Any objective VI	No objective VI	9.8 (−6.3, 25.9)	0.23
	Self-reported VI	No self-reported VI	−2.0 (−39.3, 35.3)	0.92
	Distance VI	No distance VI	13.6 (−10.1, 37.3)	0.25
	Near VI	No near VI	5.7 (−12.1, 23.5)	0.52
	CSI	No CSI	11.2 (−13.2, 35.5)	0.36
	Continuous vision measures			
	Distance VA	0.1 logMAR worse	−0.9 (−5.1, 3.4)	0.68
	Near VA	0.1 logMAR worse	−0.4 (−4.4, 3.6)	0.85
	CS	0.1 logCS worse	3.7 (−0.2, 7.5)	0.06
Time to complete 75% of daily activity			minutes	
	Categorical VI			
	Any objective VI	No objective VI	7.8 (−8.4, 24.0)	0.34
	Self-reported VI	No self-reported VI	3.3 (−32.2, 38.8)	0.85
	Distance VI	No distance VI	8.8 (−11.0, 28.5)	0.38
	Near VI	No near VI	3.2 (−13.6, 20.0)	0.71
	CSI	No CSI	10.7 (−13.4, 34.7)	0.38
	Continuous vision measures			
	Distance VA	0.1 logMAR worse	−0.3 (−3.9, 3.3)	0.88
	Near VA	0.1 logMAR worse	−0.05 (−3.6, 3.5)	0.98
	CS	0.1 logCS worse	3.5 (0.05, 6.9)	0.05

CI = confidence interval; CS = contrast sensitivity; CSI = contrast sensitivity impairment; logMAR = logarithm of the minimum angle of resolution; VA = visual acuity; VI = vision impairment.
*All models accounted for survey design and were adjusted for age, sex, race, education, living arrangement, and comorbidities.

activity objectively using wearable technology, future longitudinal studies and clinical trials should incorporate objective measures of PA to determine the temporality of these associations and to investigate the effectiveness of environmental or behavioral interventions in safely improving mobility and reducing PA restriction in older adults with VI.

Our study has a few limitations. First, the cross-sectional design of the analysis does not allow for determining the temporality of the association between VI and PA or whether higher fragmentation is a consequence of vision loss or precedes it. Given the longitudinal design of the NHATS, future studies will be able to assess these variables longitudinally, providing valuable insights into their trajectories. Second, older adults with VI may exhibit certain patterns of activity restriction, avoiding certain types of activities. While the activity watch objectively measures PA, the specific activities in which participants engage are not clearly defined. Investigating the various types of PA may help us identify those that offer the greatest benefits in relation to vision and may help us better understand this complex relationship. Third, we were unable to distinguish nonrefractive vision loss from uncorrected refractive error. Further, no data was available to the types and frequency of the various conditions underlying loss of vision. Future studies exploring different types of VI (i.e., loss of contrast or VF) are warranted.

Older US adults with VI engage in less daily activity, and their activity is more fragmented. Implementing interventions and promoting PA, perhaps with an emphasis on increasing the length of activity bouts, may have a beneficial role in adults with VI to prevent negative health outcomes.

Data Availability Statement

Data are publicly available at https://nhats.org/researcher.

Footnotes and Disclosures

Originally received: October 12, 2023.
Final revision: December 7, 2023.
Accepted: December 26, 2023.
Available online: ■■■. Manuscript no. XOPS-D-23-00257.

[1] Wilmer Eye Institute, Johns Hopkins University School of Medicine, Baltimore, Maryland.

[2] Johns Hopkins Disability Health Research Center, Johns Hopkins School of Nursing, Baltimore, Maryland.

Disclosure(s):

All authors have completed and submitted the ICMJE disclosures form.

The authors made the following disclosures:

P.Y.R.: Financial support - National Eye Institute, Perfuse Therapeutics; Consultant - WL Gore, Jannsen, Heru, Roche, Alcon; Leadership - World Glaucoma Association, Glaucoma Research Society, American Academy of Ophthalmology, National Advisory Eye Council.

HUMAN SUBJECTS: Human subjects data were included in this study. For this study, approval from an institutional review board was not required as it uses publicly available, non-identifiable data. The National Health and Aging Trends Study investigators obtained consent from all participants or their proxy respondents before collecting data, and the study was conducted in accordance with the tenets of the Declaration of Helsinki.

No animal subjects were included in this study.

Author Contributions:

Conception and design: Almidani, Varadaraj, Banerjee, Mihailovic, Ramulu

Data collection: Almidani

Analysis and interpretation: Almidani, Varadaraj, E, Mihailovic, Ramulu

Obtained funding: N/A; study was performed as part of regular employment duties at Johns Hopkins University. No additional funding was provided.

Overall responsibility: Almidani, Varadaraj, Banerjee, E, Mihailovic, Ramulu

Abbreviations and Acronyms:
CI = confidence interval; **CS** = contrast sensitivity; **logMAR** = logarithm of the minimum angle of resolution; **NHATS** = National Health and Aging Trends Study; **PA** = physical activity; **US** = United States; **VA** = visual acuity; **VF** = visual field; **VI** = vision impairment.

Keywords:
Vision impairment, Physical activity, Visual acuity, Contrast sensitivity, National data.

Correspondence:
Pradeep Y. Ramulu, MD, MHS, PhD, Sheila K. West Professor of Ophthalmology, Wilmer Eye Institute, Johns Hopkins University School of Medicine, 600 North Wolfe Street, Maumenee B120, Baltimore, MD 21287. E-mail: pramulu@jhmi.edu.

References

1. Warburton DER. Health benefits of physical activity: the evidence. *Can Med Assoc J*. 2006;174:801−809.
2. Thompson PD, Buchner D, Piña IL, et al. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease. *Circulation*. 2003;107:3109−3116.
3. Mokdad AH. Actual causes of death in the United States, 2000. *JAMA*. 2004;291:1238.
4. Fishman EI, Steeves JA, Zipunnikov V, et al. Association between objectively measured physical activity and mortality in NHANES. *Med Sci Sports Exerc*. 2016;48:1303−1311.
5. Ong SR, Crowston JG, Loprinzi PD, Ramulu PY. Physical activity, visual impairment, and eye disease. *Eye*. 2018;32:1296−1303.
6. Willis JR. Visual impairment, uncorrected refractive error, and accelerometer-defined physical activity in the United States. *Arch Ophthalmol*. 2012;130:329.
7. van Landingham SW, Willis JR, Vitale S, Ramulu PY. Visual field loss and accelerometer-measured physical activity in the United States. *Ophthalmology*. 2012;119:2486−2492.
8. Nastasi AJ, Ahuja A, Zipunnikov V, et al. Objectively measured physical activity and falls in well-functioning older adults. *Am J Phys Med Rehabil*. 2018;97:255−260.
9. Wanigatunga AA, Di J, Zipunnikov V, et al. Association of total daily physical activity and fragmented physical activity with mortality in older adults. *JAMA Netw Open*. 2019;2:e1912352.
10. E JY, Schrack JA, Mihailovic A, et al. Patterns of daily physical activity across the spectrum of visual field damage in glaucoma patients. *Ophthalmology*. 2021;128:70−77.
11. Freedman VA, Schrack JA, Skehan ME, Kasper JD. *National Health and Aging Trends Study User Guide: Rounds 1-11 Final Release*. Baltimore, MD: Johns Hopkins University School of Public Health; 2022.
12. Freedman VA, Kasper JD. Cohort profile: the National Health and Aging Trends Study (NHATS). *Int J Epidemiol*. 2019;48:1044−1045g.
13. Hu M, Ehrlich JR, Reed NS, Freedman VA. *National Health and Aging Trends Study (NHATS) Vision and Hearing Activities User Guide*. Baltimore, MD: Johns Hopkins University School of Public Health; 2022.
14. Varadaraj V, Assi L, Gajwani P, et al. Evaluation of tablet-based tests of visual acuity and contrast sensitivity in older adults. *Ophthalmic Epidemiol*. 2021;28:293.
15. Hu M, Freedman VA, Ehrlich JR, et al. Collecting objective measures of visual and auditory function in a national in-home survey of older adults. *J Surv Stat Methodol*. 2021;9:309−334.
16. Low vision - American Academy of Ophthalmology. https://www.aao.org/education/low-vision-and-vision-rehab. Accessed April 10, 2023.
17. Mäntyjärvi M, Laitinen T. Normal values for the Pelli-Robson contrast sensitivity test. *J Cataract Refract Surg*. 2001;27:261−266.
18. Almidani L, Varadaraj V, Mihailovic A, Ramulu PY. Using objective vision measures to explore the association of vision impairment with cognition among older adults in the United States. *Am J Ophthalmol*. 2023;255:18−29.
19. Varadaraj V, Swiatek KS, Chung SE, et al. Caring for older adults with self-reported vision impairment: findings from the national study of caregiving. *Am J Ophthalmol*. 2021;227:211−221.
20. Schrack JA, Skehan ME, Zipunnikov V, Freedman VA. *National Health and Aging Trends Study Accelerometry User Guide: Beta Release*. Baltimore, MD: Johns Hopkins University Bloomberg School of Public Health; 2022.
21. Colley RC, Garriguet D, Janssen I, et al. Physical activity of Canadian adults: accelerometer results from the 2007 to 2009

Canadian Health Measures Survey. *Health Rep*. 2011;22:7−14.
22. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc*. 2007;39:1502−1508.
23. Cai Y, Schrack JA, Wang H, et al. Visual impairment and objectively measured physical activity in middle-aged and older adults. *J Gerontol A Biol Sci Med Sci*. 2021;76:2194−2203.
24. Koster A, Shiroma EJ, Caserotti P, et al. Comparison of sedentary estimates between activPAL and hip- and wrist-worn ActiGraph. *Med Sci Sports Exerc*. 2016;48:1514−1522.
25. Buman MP, Hekler EB, Haskell WL, et al. Objective light-intensity physical activity associations with rated health in older adults. *Am J Epidemiol*. 2010;172:1155−1165.
26. Kehler DS, Clara I, Hiebert B, et al. Sex-differences in relation to the association between patterns of physical activity and sedentary behavior with frailty. *Arch Gerontol Geriatr*. 2020;87:103972.
27. Roe LS, Harrison S, Cawthon PM, et al. The association between daily sedentary and active bout frequency with mortality risk in older men using accelerometry. *J Am Geriatr Soc*. 2023;71:1547−1557.
28. Schrack JA, Kuo PL, Wanigatunga AA, et al. Active-to-sedentary behavior transitions, fatigability, and physical functioning in older adults. *J Gerontol A Biol Sci Med Sci*. 2019;74:560−567.
29. Sengupta S, Nguyen AM, van Landingham SW, et al. Evaluation of real-world mobility in age-related macular degeneration. *BMC Ophthalmol*. 2015;15:9.
30. Sun Y, Erdem E, Lyu A, et al. The SPARCS: a novel assessment of contrast sensitivity and its reliability in patients with corrected refractive error. *Br J Ophthalmol*. 2016;100:1421−1426.
31. Wanigatunga AA, Cai Y, Urbanek JK, et al. Objectively measured patterns of daily physical activity and phenotypic frailty. *J Gerontol A Biol Sci Med Sci*. 2022;77:1882−1889.
32. Ramulu PY, van Landingham SW, Massof RW, et al. Fear of falling and visual field loss from glaucoma. *Ophthalmology*. 2012;119:1352−1358.
33. E JY, Mihailovic A, Kuo PL, et al. Characterizing the impact of fear of falling on activity and falls in older adults with glaucoma. *J Am Geriatr Soc*. 2020;68:1847−1851.
34. Nguyen AM, Arora KS, Swenor BK, et al. Physical activity restriction in age-related eye disease: a cross-sectional study exploring fear of falling as a potential mediator. *BMC Geriatr*. 2015;15:64.
35. Ramulu PY, Hochberg C, Maul EA, et al. Glaucomatous visual field loss associated with less travel from home. *Optom Vis Sci*. 2014;91:187−193.
36. E JY, Mihailovic A, Garzon C, et al. Importance and severity dependence of physical activity by GPS-tracked location in glaucoma patients. *Am J Ophthalmol*. 2021;230:276−284.
37. Yonge AV, Swenor BK, Miller R, et al. Quantifying fall-related hazards in the homes of persons with glaucoma. *Ophthalmology*. 2017;124:562−571.
38. Risner D, Ehrlich R, Kheradiya NS, et al. Effects of exercise on intraocular pressure and ocular blood flow. *J Glaucoma*. 2009;18:429−436.
39. Lee MJ, Wang J, Friedman DS, et al. Greater physical activity is associated with slower visual field loss in glaucoma. *Ophthalmology*. 2019;126:958−964.
40. Di Francescomarino S, Sciartilli A, Di Valerio V, et al. The effect of physical exercise on endothelial function. *Sports Med*. 2009;39:797−812.
41. Ren C, Liu W, Li J, et al. Physical activity and risk of diabetic retinopathy: a systematic review and meta-analysis. *Acta Diabetol*. 2019;56:823−837.