Patterns of daily physical activity across the spectrum of visual field damage in glaucoma patients

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Abstract

**Purpose**—To define and quantify patterns of objectively measured daily physical activity by level of visual field (VF) damage in glaucoma patients including: (1) activity fragmentation, a metric of health and physiological decline, and (2) diurnal patterns of activity, a measure of rest/activity rhythms.

**Design**—Prospective cohort study.

**Subjects**—Older adults diagnosed with glaucoma or suspected glaucoma.

**Methods**—Degree of VF damage was defined by the average VF sensitivity within the integrated VF (IVF). Each participant wore a hip accelerometer for one week to measure daily minute-by-minute activity.
minute activity for seven consecutive days. Activity fragmentation was calculated as the reciprocal of the average activity bout duration in minutes, with higher fragmentation indicating more transient, rather than sustained, activity. Multivariable linear regression was used to test for cross-sectional associations between VF damage and activity fragmentation. Multivariable linear mixed-effects models were used to assess the associations between VF damage and accumulation of activity across six time periods (5am–8am, 8am–11am, 11am–2pm, 2pm–5pm, 5pm–8pm, 8pm–11pm).

**Main Outcome Measures**—Activity fragmentation and amount of activity (steps) over the course of the day.

**Results**—Each 5-unit (dB) decrement in IVF sensitivity was associated with 16.3 fewer active minutes/day (p<0.05), and 2% higher activity fragmentation (p<0.05), but not with the number of active bouts/day (p=0.30). In time-of-day analyses, lower IVF sensitivity was associated with fewer steps over the 11am–2pm, 2pm–5pm, and 5pm–8pm time periods (106.6, 93.1 and 89.2 fewer steps, respectively, p<0.05 for all), but not over other time periods. The activity midpoint (the time at which ½ of daily activity is completed) did not vary across level of VF damage.

**Conclusions**—At worse levels of VF damage, glaucoma patients demonstrate shorter, more fragmented bouts of physical activity throughout the day, and lower activity levels during typical waking hours, reflective of low physiological functioning. Further work is needed to establish the temporality of this association (i.e., whether these activity changes contribute to glaucoma disease severity, or are downstream effects), and whether glaucoma patients with such activity patterns are at a greater risk of the adverse health outcomes associated with activity fragmentation.

**Precis**

Glaucoma patients with worse vision field damage complete their activity in shorter bouts and demonstrate lower activity levels during typical waking hours; but their activity does not appear to diminish over the course of the day.

**Keywords**

activity fragmentation; activity patterns; mobility; physical activity; vision impairment; older adults

**INTRODUCTION**

Physical activity is a central feature of well-being and an essential component of quality of life, particularly in older adults, whose functional capability is often compromised, physical activity declines, and the risk of transitioning to assisted-living increases. Previous research has established the importance of daily physical activity intensity and duration to health, yet emerging evidence suggests patterns of daily physical activity may provide insights into health and functional status with aging beyond these traditional measures. Accelerometers are not only more precise and accurate than self-report of physical activity, they also allow minute-by-minute assessment of activity quantities and patterns throughout the day. These patterns of physical activity have been associated with physical functioning, fatigability, disability, poor energy utilization/regulation,
cognitive impairment, and overall mortality, independent of demographic, behavioral and medical history factors, and over and above traditional measures of physical activity.\textsuperscript{6, 12–15} Thus, understanding such complex patterns of activity in older adults who are largely affected by physical inactivity and sedentary behaviors, provides an indicator of future health and risk of functional decline.

Visual impairment from several conditions has been associated with lower physical activity,\textsuperscript{16–19} with studies specifically demonstrating associations between VF damage and lower amounts of objectively measured daily activity, and less time spent in moderate and vigorous physical activity (MVPA).\textsuperscript{3, 16, 20} Although previous research has found VF damage impacts time spent in MVPA to a similar degree as other systemic conditions (such as arthritis, diabetics, and stroke),\textsuperscript{3} the impact of visual damage on patterns of daily physical activity is less studied. For example, daily physical activity becomes less frequent and intense, shorter in length, and more fragmented with age,\textsuperscript{6} marking individuals with low physical capacity and endurance,\textsuperscript{6, 21} and higher future mortality.\textsuperscript{22, 23} However, the associations between visual deficits with novel measures of activity patterns, such as the degree of fragmentation (i.e., more rapid switching from an active state to a sedentary state) or diurnal patterns of activity, remain uncharacterized.

Previous research focusing on diurnal activity patterns,\textsuperscript{24} or how physical activity is accumulated throughout the day,\textsuperscript{15, 25} has also shown that older individuals reach their peak activity earlier in the day, and become less active as the day progresses.\textsuperscript{11} However, no evidence has reported whether VF damage affects physical activity at specific hours of the day, which could yield insights into the underlying mechanisms between VF damage and low daily physical activity,\textsuperscript{26} and highlight opportunities for future interventions.

This study compared two measures of daily activity patterns in glaucoma patients with VF damage: (1) activity fragmentation, and (2) diurnal patterns of activity. We used data from the Falls in Glaucoma Study (FIGS), an established population-based cohort of community-dwelling older adults with glaucoma.\textsuperscript{27} We hypothesized that glaucoma patients with worse VF would exhibit more fragmented activity, and show lower activity in certain times (i.e., afternoon vs. morning), which could indicate a predisposition of some glaucoma patients to adverse health outcomes.

\textbf{METHODS}

This research adhered to the Declaration of Helsinki. The study was approved by the Johns Hopkins Institutional Review Board, and written consent was obtained from all participants.

\textbf{Study Population}

The Falls in Glaucoma Study (FIGS) was a prospective and community-based cohort study conducted at Johns Hopkins Wilmer Eye Institute. The eligibility criteria of FIGS were described elsewhere.\textsuperscript{28, 29} In brief, participants were included if they were at least 60 years of age by study completion, lived within 60 miles from the hospital, could perform visual field (VF) testing, and were diagnosed with glaucoma or suspected glaucoma.\textsuperscript{28} Patients were excluded if they had evidence of severe activity restriction (i.e., bed or wheelchair...
Vision Assessment

Visual acuity was tested using ETDRS charts and converted to logMAR values. VF examination was performed using the Humphrey HFA-2 perimeter (Carl Zeiss Meditec, Carlsbad, California, USA). All VFs were screened for reliability by a glaucoma specialist (PR) based on reliability measures and consistency with prior testing results (i.e., excluding those with extraordinary changes inconsistent with a participant’s clinical course). Integrated VF (IVF) sensitivity was derived from right and left eye 24–2 VF tests by combining pointwise sensitivities for each VF location, and using the maximum sensitivity approach to generate the sensitivity at each spatial coordinate. Next, each decibel sensitivity value in the IVF was converted to a raw (unlogged) sensitivity value, averaged across all points in the full VF, and then reconverted to a decibel (dB) value to derive mean sensitivity. The mean IVF sensitivity for people with normal VFs falls in the range of 31 dB or above, with lower values indicating VF damage.

We categorized the degree of VF damage as: normal/mild (IVF >28 dB), moderate (IVF 23–28 dB), and severe (IVF <23 dB), with these categories roughly corresponding to the level of better-eye VF damage in normal/mild, moderate, and severe glaucoma as described by Hodapp, Parrish, and Anderson.

Physical Activity Measurements

FIGS participants wore a waist-bound accelerometer (Actical, Respironics Inc, Murrysville, PA) for seven days after their initial study visit during all waking hours except while swimming or bathing. Study coordinators called participants ≥2 times during their seven-day wear period to promote and maximize device adherence. For this analysis, data were used from participants who wore the device for a minimum of four valid days, ≥8 hours/day (97% of overall study participants). Steps from the minute-by-minute level accelerometer data were used to calculate total daily physical activity and the amount of activity at different periods of the day. Minutes with any steps were classified as active minutes while minutes with no steps recorded were considered sedentary minutes.

Similar to prior studies, active bouts were defined as consecutive minutes spent in an active state (i.e., any minute with one or more steps), and average bout duration was calculated as the total number of active minutes per day divided by the number of bouts per day. Activity fragmentation (i.e., the Active-to-Sedentary Transition Probability) was calculated as the probability of a transitioning from an active state to a sedentary state, which was equal to the reciprocal of the average bout duration (in minutes). Average activity fragmentation for a person was derived from averaging fragmentation per day across all valid days. Higher fragmentation values reflect shorter, more fractured bouts of continuous activity (i.e., briefer episodes of activity). For example, a fragmentation value of 0.4 (40%) indicates that, for that person/group, there is a 40% chance of an active minute being followed by a sedentary minute (as opposed to another active minute), while a value of 20% indicates a lower chance of an active minute being followed by a sedentary minute as a result of more sustained activity (longer activity bouts). For a given duration of physical activity...
activity (non-sedentary minutes), greater fragmentation would imply a larger number of bouts required to generate this physical activity, though greater fragmentation can also be seen with normal numbers of activity bouts in persons who spend less time in physical activity.

Average daily steps were derived by averaging total step counts across valid days. Additionally, for each participant, average steps taken during over 3-hour intervals spanning typical waking hours (5:00 am to 7:59 am, 8:00 am to 10:59 am, 11:00 am to 1:59 pm, 2:00 pm to 4:59 pm, 5:00 pm to 7:59 pm, and 8:00 pm to 10:59 pm) were calculated.\textsuperscript{11}

**Covariates**

Covariates including age, sex, race, living arrangement, and education were determined via questionnaires. We defined polypharmacy as taking ≥5 systemic prescription medications through the use of directly observed medications or a self-reported questionnaire.\textsuperscript{35} We described the number of non-visual comorbidities from a previously-described list of comorbid conditions, including diabetes, stroke, arthritis, hip fracture, back problems, heart attack, angina, congestive heart failure, peripheral vascular disease, hypertension, emphysema, asthma, Parkinson’s, non-skin cancer, and vertigo/Meniere’s.\textsuperscript{33} We evaluated cognitive function using the Mini-Mental State Examination-Vision Impairment (MMSE-VI, maximum score=22), which classified dementia as a score ≤16 and no dementia as 17–22.\textsuperscript{36}

**Statistical Analysis**

Participant characteristics and activity metrics were described as means and proportions. Differences in activity across the range of IVF sensitivity were evaluated using Pearson’s χ\textsuperscript{2} testing for categorical variables and t-test for continuous variables.

We fit a locally weighted scatterplot smoothing (LOWESS) plot to visualize activity fragmentation across the severity of glaucoma damage (Figure 1). Multivariable linear regression was used to test for associations between IVF sensitivity and active minutes and active bouts per day, and activity fragmentation, adjusting for the following covariates: age, sex, race, living arrangement, education, polypharmacy, number of comorbidities, and MMSE-VI.

To examine activity patterns over the day, mean unadjusted steps per hour were evaluated for persons with no/mild, moderate, and severe VF damage (Figure 2) and mean steps per hour for each 3-hour period of the day were plotted across the spectrum of IVF sensitivity (Supplementary Figure 1). Multivariable linear mixed effect models accounting for correlations between daily time periods and days of the week were used to examine how physical activity levels differed across six time intervals of the day varied by IVF sensitivity. Time-of-day intervals were treated as random effects and an unstructured covariance model was used to account for within-participant clustering. An interaction term between the fixed effect variables of time-of-day intervals and IVF sensitivity was added to evaluate whether average steps differed across the time-of-day intervals by VF groups.\textsuperscript{15} The contrast statements were used to compute the coefficients and 95% confidence intervals (CIs) to test average steps differences between VF damage groups at each time-of-day interval, respectively. To examine whether persons with worse VF damage shift their activity to an
earlier or later time of the day, we used multivariable linear regression to assess whether IVF sensitivity was associated with activity initiation (the time at which 5% of daily activity is completed since first step after midnight), midpoint (the time at which 50% of daily activity is completed) and completion (the time at which 95% of daily activity is completed). Statistical significance was determined using two-tailed hypothesis testing with an alpha of 0.05. All analyses were conducted using STATA 15.0 (StataCorp LP, College Station, Texas, USA).

RESULTS

For the 237 participants in the study population, the mean age was 70.6 (SD=7.6), 51.5% were men, and 70.9% had bachelor’s degrees or higher. Roughly two-thirds (65%) of participants had at least two comorbidities, 4% had stroke and 46% had arthritis. 45.1% used five or more prescription medications, and the average MMSE-VI score was 20 (SD=1.6). Roughly half (48.9%) of participants had mild or normal IVF sensitivity, while 42% and 11% had IVF sensitivity reflecting moderate and severe VF damage, respectively (Table 1). Participants with moderate and severe VF damage were more likely to be African American, to live alone and have diabetes. With regards to activity measures, the number of active minutes varied across persons with normal/mild, moderate and severe VF damage (ANOVA p<0.01), with the lowest number of active minutes noted in persons with severe VF damage. However, the number of active bouts per day remained similar across three VF damage groups (ANOVA p=0.10). Activity fragmentation was noted to vary across persons with severe, moderate and normal/mild VF damage (ANOVA p<0.01), with the highest fragmentation seen in those with severe VF damage (41%, SD=12%), and less fragmentation seen in those with moderate VF damage (33%, SD=9%) and normal VFs/mild VF damage (30%, SD=6%). Over the observed range of VF damage, greater fragmentation was observed with greater VF damage (Figure 1).

In continuous analyses, after adjusting for age, sex, race, living arrangement, education, polypharmacy, number of comorbidities, and MMSE-VI, each 5-unit (dB) decrement in IVF sensitivity was associated with 16.3 fewer active minutes per day (95% CI, −28.4 to −7.1). No associations were noted, however, between IVF sensitivity and the number of active bouts per day (mean=−7.7/5 dB decrement in IVF sensitivity, 95% CI, −15.7 to 0.3). More fragmented daily activity was present at greater levels of VF damage (2% higher/5 dB decrement in IVF sensitivity, 95% CI, 1% to 4%) (Table 2). In comparisons across level of VF damage, participants with more severe VF damage spent 67.6 fewer active minutes per day (95% CI, −103.4 to −31.8) compared to those with normal/mild VF damage, but had a similar number of active bouts per day (mean=−7.7/5 dB decrement in IVF sensitivity, 95% CI, −15.7 to 0.3). More fragmented activity was found in participants with severe VF damage (9% higher, 95% CI, 6% to 12%) compared to those with normal/mild VF damage; those with moderate VF group, however, did not show significant differences in any of the three activity outcomes (daily active minutes, daily activity bouts, and fragmentation). Other covariates associated with one or more activity outcomes included age, sex, education and comorbidity.
VF damage and diurnal activity patterns

For the full study population, average steps per hour began to increase between 7:00 am to 8:00 am, peaked between 12:00 pm to 2:00 pm, and declined between 5:00 pm to 6:00 pm (Figure 2). Participants with less VF damage took more steps between 11:00 am and 8:00 pm (Supplementary Figure 1). After adjusting for age, sex, race, living arrangement, education, polypharmacy, number of comorbidities, and MMSE-VI, each 5-unit (dB) decrement in IVF sensitivity was associated with 106.6 (95% CI, −197.1 to −16.1), 93.1 (95% CI, −182.1 to −4.2) and 89.2 (95% CI, −174.4 to 0) fewer steps between 11:00 am −2:00 pm, 2:00 pm − 5:00 pm, and 5:00 pm − 8:00 pm, respectively (Table 3). In categorical analyses of VF groups, participants with severe VF damage were significantly less active in each 3-hour time period between 11:00 am to 8:00 pm as compared to those with normal VFs/mild VF damage (Figure 2) exhibiting: 379.1 fewer steps per hour (95% CI, −649.6 to −108.5) from 11:00 am to 2:00 pm; 339.0 fewer steps per hour (95% CI, −604.9 to −73.2) from 2:00 pm to 5:00 pm; and 254.9 fewer steps per hour (−518.7 to −0.9) from 5:00 pm to 8:00 pm (Table 3). Participants with moderate VF damage group had similar amounts of activity over each 3-hour interval as compared to those with normal VFs/mild VF damage (p>0.05 for all).

Over the 11:00 am to 8:00 pm period when most activity occurred, no interactions were noted between the degree of VF damage and time period with regards to activity participation, suggesting that persons with more advanced damage were uniformly less active throughout the day. Additional analyses of the time required to complete various portions of total daily activity, which reflect easier fatigability over the course of the day, did not show an association with VF damage, i.e., participants reached activity initiation (5% of daily activity), midpoint (50% of daily activity) and completion (95% of daily activity) at similar times across the spectrum of VF severity (Table 4).

DISCUSSION

In the present study, we examined patterns of daily activity in persons with a range of VF damage from glaucoma using two novel measures of physical activity: activity fragmentation (i.e., the probability of an active state to an inactive state), and diurnal patterns of daily activity. At worse levels of VF damage, physical activity was lower and more fragmented during typical waking hours, despite having a similar number of active bouts, demonstrating less sustained activity throughout the day. However, the activity midpoint (the time at which ½ of daily activity is completed) did not vary across level of VF damage, suggesting that although those with more advanced damage were less active overall, they did not frontload or backload their daily activity. Collectively, these results demonstrate that glaucoma patients have a tendency to perform less daily activity and transition out of an active state to a sedentary state more quickly.

Our findings support prior research that found VF damage to be associated with lower physical activity in glaucoma patients,16, 20 and extend these findings by demonstrating that restriction of activity participation occurs roughly equally across the period of the day when activity typically takes place (i.e. 11 am – 8 pm). While some prior studies used subjective activity assessments (e.g., recall surveys and activity diaries),37–39 data from these
instruments are often subject to recall bias and activity misclassification. More recent work has demonstrated that VF damage is associated with lower overall objectively-defined physical activity, but activity patterns across the full spectrum of the day were not explored.

While previous research mainly focused on total volume of activity (e.g., steps or counts) or time spent in more intense activity (e.g., MVPA), our study examined patterns of activity accumulation throughout the day. Importantly, we found that worse VF damage was associated with more fragmented daily activity (i.e., active bouts were shorter), resulting in lower accumulation of activity. While previous research has not looked at the relationship between vision and activity fragmentation, others have noted that more fragmented activity is associated with older age, slower gait, higher fatigability, lower functioning and higher risk of mortality. These results suggest that activity fragmentation is an important measure of health independent of total activity performed, and suggest that specific glaucoma patients, i.e. those with more fragmented activity associated with worse VF damage, might be at higher risk of adverse outcomes that have been associated with activity fragmentation, i.e., poor physical functioning and death.

Previous studies have suggested that altered or lower diurnal activity patterns are indicative of a greater risk of falls and higher fatigability. Our evaluation of differences in diurnal patterns of activity by VF damage were found to be in line with prior studies using wearable devices, with participants beginning their activities around 7:00 am, reaching maximum activity around noon, and decreasing activity late in the afternoon or evening. Of note, persons with greater VF damage were not observed to restrict their activity more during the later period of the day; in other words, activity was not shifted to the hours closer to waking time at worse levels of VF damage. Of note, if late-day declines in activity occur as a result of fatigue later in the day, such declines may not be present in those with greater VF damage given their low levels of activity. Likewise, greater declines in activity may have been expected later in the day because of greater difficulty with activity in poor lighting in glaucoma patients; though it is possible that such difficulties can be overcome this with proper home lighting, or that they are just difficult to observe in our data due to the low level of late day activity even in persons with minimal or normal VF damage.

The meaning of our findings would ideally shed light on the temporal relationship between glaucoma damage and physical activity. However, the relationship between glaucoma damage and activity in humans remains unclear. While mouse studies have suggested that exercise can prevent IOP-induced damage to the optic nerve, human studies relating physical activity to glaucoma damage are cross-sectional or inconclusive regarding whether VF damage precedes lower physical activity or vice versa. If physical activity is indeed protective against glaucoma damage in humans, and our study participants with worse VF experience this damage partially as a result of their declining activity levels, then our results raise the question of whether the pattern of activity is also relevant to the onset and worsening of glaucoma. In this model, less fragmented activity (i.e. longer bouts of activity) would be important in protecting against glaucoma – ideas that need to be further explored in longitudinal studies and/or clinical trials. If low physical activity is a downstream consequence of visual field damage from glaucoma, then our results suggest that this visual damage may lead individuals to engage in shorter bouts of activity, contributing to lower
activity levels overall. Identifying the factors leading to greater VF damage, including higher fatigability or intraocular pressure, may help increase activity levels, which in turn could improve overall health. Finally, common factors, i.e. poor fitness or energetics, may lead to both glaucomatous VF damage and further declines in physical activity. In this model, improving this latent factor would hold potential both for reducing glaucoma damage and improving physical activity, which may enhance overall well-being.

Our study has limitations. First, our study has limited generalizability as study participants were enrolled from a single center with a single visual condition - glaucoma. Second, the cross-sectional design limits the ability to assess whether higher activity fragmentation follows or proceeds VF damage in glaucoma, which warrants further testing in longitudinal analyses. Third, we did not obtain more details of comorbidities that could impact physical activity, that is, the severity and duration of each comorbid condition, and any interactions between these comorbidities. Fourth, although fragmentation captures the reduced and altered activity patterns, it may not provide insights into other patterns of activity which represent all aspects of declining health, e.g., aerobic activity and metabolic capacity. Fifth, the accelerometer does not capture upper body movement and other types of activities, e.g., swimming and bicycling. Sixth, fragmentation is perhaps an imprecise term, as it considers how much a specific amount of activity is broken up, as opposed to the activity done by the individual. However, given that fragmentation was created by scientists at the National Institute on Aging to describe changes in patterns of physical activity that manifest with aging, we adopted this terminology so that it might best be integrated into the existing literature. Finally, we gave higher weighting to defects in areas of higher sensitivity — corresponding to the more central VF, which have been suggested to have a greater impact on quality of life and activities of daily living, although the best methodology of calculating the amount of extra weighting remained unclear.

In summary, our study found that glaucoma patients with worse levels of VF damage complete their activity in shorter bouts and demonstrate lower activity levels during typical waking hours. However, their activity does not appear to diminish over the course of the day. Further work is needed to establish the temporality of the cross-sectional findings, i.e., whether these activity changes contribute to glaucoma disease severity, or are downstream effects. Additional future studies are necessary to assess whether these results could apply to other ocular disorders (e.g., cataract, diabetic retinopathy). Given the associations between more fragmented activity and physiological decline, our findings suggest possible physical health consequences in some glaucoma patients, i.e. those with more fragmented activity due to severe VF damage.

**Supplementary Material**

Refer to Web version on PubMed Central for supplementary material.

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The founding organization play no role in the design and conduct of this research.

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Figure 1.
Locally weighted scatterplot smoothing (LOWESS) plot of activity fragmentation by severity of glaucoma damage.
Figure 2.
Mean steps per hour during 5:00 am to 11:00 pm stratified by severity of glaucoma damage.
Table 1.

Participant characteristics and activity metrics by severity of glaucoma damage (N=237)

| Demographic and clinical characteristics | Normal/Mild VF damage (IVF: >28 dB) N = 116 | Moderate VF damage (IVF: 23-28 dB) N = 96 | Severe VF damage (IVF: <23 dB) N = 25 | P-value |
|----------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|---------|
| Age, mean (SD)                         | 69.15 (6.45)                             | 72.33 (8.75)                             | 70.40 (7.09)                             | 0.04    |
| Male, n (%)                            | 58 (50)                                  | 52 (54)                                  | 12 (48)                                  | 0.78    |
| African American, n (%)                | 28 (24)                                  | 24 (25)                                  | 17 (68)                                  | <0.01   |
| Living alone, n (%)                    | 19 (16)                                  | 22 (23)                                  | 7 (28)                                   | 0.03    |
| Education                              |                                          |                                          |                                          | 0.14    |
| ≤ High school, n (%)                   | 15 (13)                                  | 16 (18)                                  | 6 (24)                                   |         |
| Some college, n (%)                    | 14 (12)                                  | 13 (14)                                  | 5 (20)                                   |         |
| Bachelor, n (%)                        | 34 (29)                                  | 19 (20)                                  | 6 (24)                                   |         |
| > Master, n (%)                        | 53 (46)                                  | 48 (50)                                  | 8 (32)                                   |         |
| Polypharmacy, n (%)                    | 47 (41)                                  | 44 (46)                                  | 16 (64)                                  | 0.10    |
| No. of comorbidities                   |                                          |                                          |                                          | 0.88    |
| ≤ 1, n (%)                             | 38 (33)                                  | 36 (38)                                  | 9 (36)                                   |         |
| 2–3, n (%)                             | 52 (45)                                  | 42 (43)                                  | 11 (44)                                  |         |
| 4–5, n (%)                             | 26 (22)                                  | 18 (19)                                  | 5 (20)                                   |         |
| Diabetes (%)                           | 21 (18)                                  | 27 (28)                                  | 10 (40)                                  | 0.04    |
| Stroke (%)                             | 3 (3)                                    | 5 (5)                                    | 1 (4)                                    | 0.60    |
| Arthritis (%)                          | 55 (47)                                  | 45 (47)                                  | 10 (40)                                  | 0.79    |
| MMSE-VI, mean (SD)                     | 20.32 (1.50)                             | 19.66 (2.18)                             | 19.84 (1.84)                             | 0.03    |

Activity variables

| Activity variables | Normal/Mild VF damage (IVF: >28 dB) N = 116 | Moderate VF damage (IVF: 23-28 dB) N = 96 | Severe VF damage (IVF: <23 dB) N = 25 | P-value |
|--------------------|------------------------------------------|------------------------------------------|------------------------------------------|---------|
| Active minutes per day | 252.04 (76.64)                          | 237.08 (88.24)                           | 176.02 (83.21)                           | <0.01   |
| No. of bouts per day  | 70.07 (15.32)                           | 69.68 (18.10)                           | 63.00 (24.25)                           | 0.10    |
| Fragmentation       | 0.30 (0.06)                             | 0.33 (0.09)                             | 0.41 (0.12)                             | <0.01   |

VF: vision field; SD: standard deviation; Polypharmacy: ≥5 systemic prescription medications; MMSE-VI: Mini-Mental State Examination-Vision Impairment (maximum as 22); dB: decibels; Fragmentation: probability of an active state to an inactive state; IVF: integrated vision field.
Table 2.
Associations between severity of glaucoma damage and activity outcomes in multivariable models (N=237)

| Variables              | Active minutes per day \( \beta \) (95% CI) | No. of bouts per day \( \beta \) (95% CI) | Fragmentation \( \beta \) (95% CI) |
|------------------------|---------------------------------------------|------------------------------------------|-----------------------------------|
| 5-unit (dB) decrement in IVF sensitivity\(^a\) | -16.26 (−28.43,−4.09) ** | -1.15 (−3.85,1.55) | 0.02(0.01,0.04) ** |
| VF damage\(^a\) | | | |
| Normal/Mild | Reference | Reference | Reference |
| Moderate | -4.72 (−26.55,17.10) | 0.43 (−4.45, 5.31) | 0.01 (−0.01,0.03) |
| Severe | -67.60 (−103.43,-31.78) ** | -7.711–15.73,0.30) | 0.09 (0.06,0.12) ** |

\(^a\) Severity of VF damage on continuous and categorical scale were derived from different models, each containing the same covariates: age, race, sex, living arrangement, education, comorbidity, polypharmacy, and cognitive function.

Fragmentation: probability of an active state to an inactive state; VF: vision field; IVF: integrated vision field; dB: decibels; CI: confidence interval; Polypharmacy: ≥ 5 systemic prescription medications; Mini-Mental State Examination-Vision Impairment (maximum as 22).

* p <0.05,
** p <0.01
Table 3.

Interaction between time-of-day intervals (5:00 am to 11:00 pm) and severity of glaucoma damage on daily steps (N=237)

| Time       | 5-unit (dB) decrement In IVF (β, 95% CI) | VF damage (β, 95% CI) |
|------------|------------------------------------------|------------------------|
|            | Normal/Mild | Moderate | Severe |
| 5:00 am–8:00 am | −6.38 (−102.34, 89.78) | Reference | −46.81 (−224.96, 131.33) | −23.84 (−311.17, 263.49) |
| 8:00 am–11:00 am | −49.83 (−142.67, 43.02) | Reference | −9.55 (−181.66, 162.56) | −244.29 (−522.07, 33.49) |
| 11:00 am–2:00 pm | −106.61 (−197.09, −16.12) * | Reference | 59.97 (−107.57, 227.52) | −379.08 (−649.64, −108.52) ** |
| 2:00 pm–5:00 pm | −93.12 (−182.05, −4.19) * | Reference | −4.33 (−168.90, 160.24) | −339.04 (−604.89, −73.19) * |
| 5:00 pm–8:00 pm | −89.19 (−174.41, −0.04) * | Reference | −57.93 (−221.20, 105.35) | −254.92 (−518.72, −80.89) * |
| 8:00 pm–11:00 pm | −14.73 (−102.12, 73.66) | Reference | −5.51 (−169.20, 158.13) | −76.25 (−340.71, 188.21) |

Mixed effects estimates adjusted for age, race, sex, living arrangement, education, comorbidity, polypharmacy, and cognitive function.

VF: vision field; IVF: integrated vision field; dB: decibels; CI: confidence interval.

* p <0.05,

** p <0.01

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Table 4.
Severity of glaucoma damage on time to accumulate total daily activity (N=237)

| Time (hour)                        | 5-unit (dB) decrement in IVF (β, 95% CI) | Vision field damage (β, 95% CI) |
|-----------------------------------|------------------------------------------|---------------------------------|
|                                   |                                          | Normal/Mild | Moderate | Severe     |
| Time to reach 5% of daily activity| −0.13 (−0.45, 0.19)                      | Reference   | 0.16 (−0.80, 1.12) | 0.04 (−0.92, 0.99) |
| Time to reach 50% of daily activity| 0.02 (−0.37, 0.42)                      | Reference   | 0.03 (−1.15, 1.21) | −0.14 (−1.31, 1.04) |
| Time to reach 95% of daily activity| 0.06 (−0.33, 0.44)                      | Reference   | 0.03 (−1.12, 1.18) | −0.22 (−1.36, 0.92) |

Adjusted for age, race, sex, living arrangement, education, comorbidity, polypharmacy, and cognitive function.

IVF: integrated vision field; dB: decibels; CI: confidence interval.