# Physical activity patterns in patients with early and late age-related macular degeneration

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## ABSTRACT

**INTRODUCTION:** Age-related macular degeneration (AMD) leads to visual impairment that affects visual functioning and thereby the ability to be physically active. We investigated physical activity patterns in patients with AMD.

**METHODS:** Patients with early and late AMD and elderly controls were recruited for this hospital-based cross-sectional study. All participants had their best-corrected visual acuity measured and were interviewed about their physical activity based on questions that covered regular physical activity, physical activity that would work up sweat, climbing the stairs and time spent on walking outdoors.

**RESULTS:** We recruited 198 participants of whom 196 were eligible for inclusion in the analyses (68 controls, 25 with early AMD and 103 with late AMD). The frequency of regular physical activity did not differ between patients with early and late AMD and elderly controls. Lower best-corrected visual acuity in the best-seeing and the worse-seeing eye was associated with less engagement in physical activities that would work up sweat and a lower number of steps taken daily. Patients with bilateral vision loss from late AMD engaged in physical activities that were more controlled and less demanding of sharp central vision.

**CONCLUSION:** Patients with late AMD may still be physically active even when the disease progresses and vision is lost, but activities may change into more controlled and less central vision-demanding ones.

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Age-related macular degeneration (AMD) is the most frequent cause of irreversible visual impairment among the elderly in the developed countries [1]. Early stages of AMD have only limited impact on vision, but 5% will develop the late stage of the disease within five years, and 15% within 15 years [1]. Late AMD is defined by either development of geographic atrophic areas in the neuroretina or choroidal neovascularisations that break through Bruch's membrane and into the neuroretina [1]. Choroidal neovascularisations can be impeded using intravitreal treatment with antibodies against vascular endothelial growth factors, while geographic atrophy is currently untreatable [1, 2]. These changes significantly affect the central vision, predispose to Charles-Bonnet hallucinations [3] and affect the overall visual function [4].

Visual impairment in late AMD may lead to physical inactivity [5-7]. Physical activity is an important lifestyle factor because it affects morbidity and mortality at a relatively large effect size [8, 9]. For the elderly in particular, another important benefit is that physical activity maintains physical fitness that is crucial for independency in daily living and for the ability to socialise, both of which are essential in sustaining a high quality of life in the senescence.

The aim of this study was to investigate physical activity patterns in patients with early and late AMD. Our study population was elderly Danish individuals. More than half of elderly Danes engage in regular physical activity and many elderly individuals comply with the Danish Health Authority's recommendations of being physically active a minimum of 30 minutes per day [10]. In the present study, we found that patients with early or late AMD are as physically active as others, but patients with late AMD entailing significant visual impairment engage in activities that are less demanding of a sharp central vision.

## METHODS

We consecutively recruited participants between May 2011 and January 2013 for this cross-sectional study. We explained the nature of the study and obtained oral and written consent prior to participation. The study was approved by the Regional Committee of Ethics in Research of the Region of Zealand (record number: SJ-142) and the Danish Data Protection Agency. We followed the ethical principles of the Declaration of Helsinki.

### Study sample

Patients with AMD and age-matched healthy visitors were invited to participate. Patients were recruited consecutively from our outpatient retinal clinic. Healthy visitors were typically spouses, friends or family members accompanying the patients. This study utilised patients who were recruited for immune studies of AMD [11, 12], which means that we excluded patients with any active immune diseases. No power calculations were done due to the exploratory nature of the study. All patients were examined using slit-lamp, fundus photography, optical coherence tomography and angiography for suspected choroidal neovascularisation. Best-corrected visual acu-

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**TABLE 1**

Participant characteristics.

| | No AMD (N = 68) | Early AMD (N = 25) | Late AMD (N = 103) | p-value |
|---|---|---|---|---|
| Age, yrs, mean (SD) | 70.5 (7.5) | 77.1 (5.6) | 75.9 (7.6) | > 0.001[a] |
| *Gender, n (%)* | | | | 0.478[b] |
| Female | 43 (63) | 13 (52) | 66 (64) | |
| Male | 25 (37) | 12 (48) | 37 (36) | |
| *Best-corrected visual acuity, ETDRS letters, median (IQR)[c]* | | | | |
| Best-seeing eye | 85 (80-85) | 82 (77-85) | 75 (62-80) | > 0.001[d] |
| Worse-seeing eye | 78 (68-85) | 70 (60-77) | 48 (23-65) | > 0.001[d] |

AMD = age-related macular degeneration; ETDRS = Early Treatment of Diabetic Retinopathy Study chart; IQR = interquartile range; SD = standard deviation.
a) 1-way analysis of variance; b) $\chi^2$-test; c) Missing data for 1 participant; d) Kruskal-Wallis test.

**TABLE 2**

Physical activity in relation to stages of age-related macular degeneration (AMD). The values are n (%).

| | No AMD (N = 68) | Early AMD (N = 25) | Late AMD (N = 103) | p-value |
|---|---|---|---|---|
| *Regularly physically active* | | | | 0.938[a] |
| Yes | 38 (56) | 15 (60) | 59 (57) | |
| No | 30 (44) | 10 (40) | 44 (43) | |
| *Works up sweat weekly[b]* | | | | 0.364[a] |
| Yes | 34 (50) | 8 (32) | 39 (38) | |
| No | 34 (50) | 17 (69) | 63 (61) | |
| *Weekly frequency* | | | | 0.378[c] |
| < 1 | 34 (50) | 17 (68) | 65 (63) | |
| 1-3 | 24 (35) | 5 (20) | 25 (24) | |
| > 3 | 10 (15) | 3 (12) | 12 (12) | |
| *Stairs taken daily* | | | | 0.100[a] |
| ≤ 10 steps | 24 (35) | 10 (40) | 50 (49) | |
| 11-50 steps | 15 (22) | 6 (24) | 9 (9) | |
| > 50 steps | 22 (35) | 8 (32) | 32 (31) | |
| Do not know | 7 (10) | 1 (4) | 12 (12) | |
| *Weekly time walked* | | | | 0.667[c] |
| ≤ 1 h | 14 (21) | 6 (24) | 20 (19) | |
| 1-3 h | 11 (16) | 1 (4) | 13 (13) | |
| 3-7 h | 19 (28) | 9 (36) | 36 (35) | |
| > 7 h | 22 (32) | 7 (28) | 24 (23) | |
| Do not know | 2 (3) | 2 (8) | 10 (10) | |

a) $\chi^2$-test; b) Missing data for 1 participant; c) Fisher's exact test.

ity (BCVA) in each eye was measured using the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart [13]. Eyes were graded into one of three stages:

- No AMD: Presence of < 10 small drusen without any pigment abnormalities.
- Early AMD: Presence of ≥ 10 drusen, pigment abnormalities or any large drusen.
- Late AMD: Presence of geographic atrophy, non-drusenoid pigment epithelial detachments, serous retinal detachments or neovascular membrane.

Participants were categorised into one of these three categories based on the most severe stage of AMD observed, considering both eyes. Minor general co-morbidities (e.g. hypertension, Type 2 diabetes, hypercholesterolaemia) and eye co-morbidities (e.g. dry eyes, myopia, mild cataract) were allowed, but not co-morbidities that severely affected mobility (e.g. limb amputation, recent bone fracture, paralysis) or vision (e.g. diabetic retinopathy, retinal detachment, severe cataract).

**Physical activity assessment**

We assessed physical activity using five questions. The first question was "Do you currently participate in any regular activity or programme (either on your own or in a formal class) designed to improve or maintain your physical fitness?" (answer: yes or no). This question has been validated previously and has been tested in a Danish setting [11, 14]. The other questions were inspired by the population-based Beaver Dam Eye Study in Wisconsin, USA [15], which we translated into Danish using forward and backward translation [16]. The questions were: "How many stairs do you climb daily?" (answer: number or do not know), "How much time do you spend walking outside weekly?" (answer: number or do not know), "Do you participate in any regular activity that lasts long enough for you to sweat at least once a week?" (answer: yes/no), "If yes to previous question, how many times in a week?" (answer: number or do not know). Participants were encouraged to elaborate on their physical activities and any comments made were noted in free-text in the questionnaire sheets.

**Data analyses**

Categorical variables are presented as numbers and percentages and compared using the chi-squared test or Fisher's exact test when numbers were small. Normally distributed continuous variables are presented with mean and standard deviation and compared between groups using parametric tests. Non-normally distributed continuous variables are presented with median and interquartile range and compared using non-parametric tests. Data were analysed using SPSS 23 (IBM Corporation, Armonk, NY, USA). We considered p-values below 0.05 statistically significant.

For summaries of the physical activities, we generated word clouds using WordItOut (Enideo, Antwerp, Belgium) to provide a visual representation of keywords in the free-text data where higher frequency of a keyword leads to larger font size. Keywords composed of more than one word that describe a single activity were put together with hyphens to avoid separate categorisa-

Unlike patients with early age-related macular degeneration (AMD) who rarely experience visual symptoms, patients with late AMD have impaired central vision with scotoma and metamorphopsia due to choroidal neovascularisation that distorts and damages the macula and due to geographic atrophy in which photoreceptors are lost.

tion. Word clouds were generated for healthy participants, for patients with early AMD, and for patients with late AMD in two groups based on the BCVA in the best-seeing eye (> 60 ETDRS letters and ≤ 60 ETDRS letters) so that patients with late AMD that have bilateral poor vision (n = 24) could be studied as a separate entity.

*Trial registration:* not relevant.

## RESULTS

A total of 198 participants were recruited of whom two were excluded due to other retinal disease (diabetic retinopathy) with a severe impact on their vision. Included in the analyses were the remaining 196 of whom 68 were healthy participants, 25 had early AMD and 103 had late AMD. Of the 103 patients with late AMD, 86 had choroidal neovascularisation in one or both eyes and 17 had only geographic atrophy. Participant characteristics are summarised in **Table 1**. We attempted to age-match participants without AMD by only recruiting healthy control participants who were elderly and at least as old as the youngest participant in the study. Still, the overall mean age in the group with no AMD was significantly lower than the mean age of patients with early AMD and late AMD. Furthermore, BCVA in the best- and worse-seeing eye were significantly lower among patients with late AMD.

We found that physical activity did not differ between participants at different stages of AMD (**Table 2**). Slightly more than half of the participants were engaged in regular physical activity and slightly less than half of the participants were active enough to work up sweat. A third of all participants took more than 50 stair steps daily and walked more than seven hours weekly. Differences in physical activity were observed when we compared participants according to BCVA in their best- and worse-seeing eye (**Table 3**). Participants did not differ when grouped according to whether they were regularly physically active or not, but those who engaged in activities that made them work up sweat had a better BCVA in both the best- and worse-seeing eye. This trend was also observed for the weekly frequency of activities that would work up sweat and BCVA in the best- and worse-seeing eye; however, the differences were only significant when comparing < 1 times weekly with ≥ 1 times weekly. Similarly, BCVA in the best- and worse-seeing eye did not differ when patients were stratified by weekly time spent on walking outside, but did differ significantly when patients were stratified by number of stairs taken daily. This difference was only significant when comparing ≤ 10 steps daily with 11-50 steps and > 50 steps, but not when comparing 11-50 steps and > 50 steps.

We summarised the physical activities of all participants in word clouds (**Figure 1**). Overall, healthy participants and patients with early and late AMD engaged in a rather wide range of activities. Patients with late AMD even engaged in activities such as badminton, bicycling and dancing that demand a significant visual function. However, in the group of patients with late AMD who

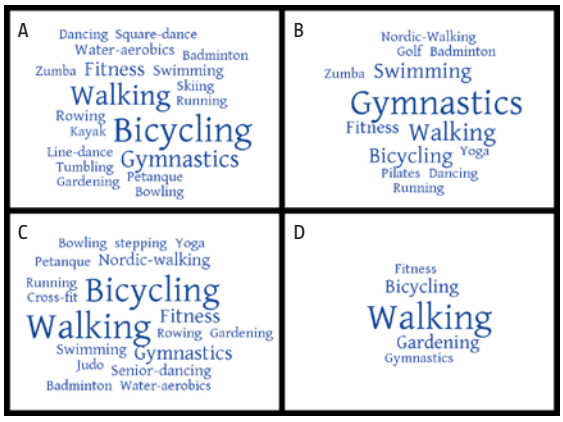
**TABLE 3**

Physical activity in relation to best-corrected visual acuity in the best- and worse-seeing eye among all participants.

| | Best-seeing eye | | Worse-seeing eye | |
|---|---|---|---|---|
| | BCVA, median (IQR) | p-value | BCVA, median (IQR) | p-value |
| *Regularly physically active* | | 0.300[a] | | 0.463[a] |
| Yes | 80 (73-85) | | 63 (47-78) | |
| No | 78 (66-85) | | 65 (29-78) | |
| *Works up sweat weekly*[b] | | 0.022[a] | | 0.002[a] |
| Yes | 80 (73-85) | | 70 (52-82) | |
| No | 78 (65-85) | | 59 (30-76) | |
| *Weekly frequency* | | 0.022[a] | | 0.002[c] |
| < 1 | 77 (65-85) | | 59 (30-76) | |
| 1-3 | 82 (75-85) | | 72 (57-82) | |
| > 3 | 78 (69-84) | | 65 (47-84) | |
| *Stairs taken daily* | | 0.017[c] | | 0.002[c] |
| ≤ 10 steps | 78 (69-84) | | 55 (29-75) | |
| 11-50 steps | 85 (72-85) | | 72 (62-85) | |
| > 50 steps | 80 (72-85) | | 68 (52-79) | |
| *Weekly time walked* | | 0.453[c] | | 0.410[c] |
| ≤ 1 h | 80 (71-85) | | 62 (30-76) | |
| 1-3 h | 75 (67-84) | | 62 (30-77) | |
| 3-7 h | 78 (71-85) | | 65 (46-78) | |
| > 7 h | 82 (72-85) | | 68 (52-82) | |

BCVA = best-corrected visual acuity; IQR = interquartile range.
a) Mann-Whitney U test; b) Missing data for 1 participant; c) Kruskal-Wallis test.

FIGURE 1




Summary of different physical activities visualized in word clouds. **A.** Healthy aged participants (n = 68). **B.** Patients with early age-related macular degeneration (AMD) (n = 25). **C.** Patients with late AMD with best-corrected visual acuity (BCVA) in the best-seeing eye > 60 Early Treatment of Diabetic Retinopathy Study (ETDRS) letters (n = 79). **D.** Patients with late AMD and a BCVA in the best-seeing eye ≤ 60 ETDRS letters (n = 24).

had bilateral poor vision, activities seemed less demanding of sharp vision and activities were generally more controlled.

## DISCUSSION

In this study, we found that early or late AMD were not associated with a lower level of physical activity. The intensities of some physical activities (working up a sweat and climbing many steps) were correlated with BCVA in the best- and worse-seeing eye, but being regularly physically active or walking were not correlated with BCVA. In patients with late AMD with bilateral poor vision, we saw a trend towards engagement in more controlled activities that do not to the same extent require a sharp central vision.

Some of our findings confirm observations seen in patients with AMD in other populations. Loprinzi et al investigated daily movement patterns and intensity of engaged physical activity of patients with early and late AMD compared with healthy control individuals [5]. Patients with late AMD were significantly less physically active and engaged in less moderate-to-vigorous physical activity, which was explained by a lower visual acuity. Sengupta et al investigated excursions and time spent away from home among patients with late AMD [6]. Patients with late AMD walked less and spent less time on moderate-to-vigorous physical activity, which was explained by lower visual acuity and contrast sensitivity. However, the time spent away from home on excursions did not differ between patients with AMD and controls. Curriero et al investigated travel patterns as part of the real-world routines of patients with AMD [7]. AMD stage was not included in the analyses, but the study only included patients with 20/32 (equivalent to 75 ETDRS letters) or worse in both eyes or 20/200 (equivalent to 35 ETDRS letters) or worse in one eye. They found that the visual acuity of the best-seeing eye, and not AMD, predicted the excursion distance and span. Findings from these studies are in line with what we observed in patients with late AMD; viz. that visual impairment from late AMD may influence the intensity and type of physical activity, but also that time spent on physical activity in general may not necessarily differ due to AMD alone.

Several studies have sought to explain why visual impairment in late AMD may influence physical activity. Nguyen et al investigated the relationship between visual acuity and physical activity in patients with AMD and explored the fear of falling as a potential mediator [17]. AMD stage was not included in the analyses, but the study only included patients with 20/32 (equivalent to 75 ETDRS letters) or worse in both eyes or 20/200 (equivalent to 35 ETDRS letters) or worse in one eye, which would suggest a population predominantly characterised by late AMD. The authors found that patients with AMD spent less time on moderate-to-vigorous physical activity than controls, which was explained by an increased fear of falling. Landingham et al found that in patients with AMD fear of falling is predicted by visual acuity and contrast sensitivity [18]. Popescu et al investigated mobility limitations in patients with late AMD and found that these patients had poor balance, an increased frequency of falls within the past year and lower life-space scores, which measures the degree of independence in the ability to engage in physical activities [19]. Willis et al compared balance measures with visual impairment and found that reduced visual inputs may weaken the vestibulo-ocular system that maintains balance [20]. All these observations considered, one would assume that increasing visual impairment in patients with late AMD would lead to less engagement in vigorous and sight-demanding activities and more engagement in controlled activities, which is what we found in our study.

The strengths and limitations of this study should be noted. Accelerometers yield accurate objective measurements of all activities, while questionnaires and interviews, which we used in our study, enable insight into the self-perceived physical activities and the spectrum of the activities. This study was a hospital-based study, which means that we saw patients who were referred for retinal treatment. Patients who are not eligible for treatment, such as patients with large fibrotic scars from old neovascular AMD, are less likely to be seen at the departments so we would theoretically underestimate restrictions in physical activity in patients with late AMD compared with the general population of patients with late AMD. Although recruitment was consecutive to minimise selection bias, a population-based sample of healthy individuals and patients with early and late AMD would provide a more representative picture of the gen-

eral AMD population and the differences between the disease stages.

## CONCLUSION

We found that patients with late AMD may still be physically active and that the degree of visual impairment plays a significant role in determining the type of physical activity in which the patient engage. Thus, the results of this study not only reveal restrictions, but also demonstrate that the patients work around these obstacles. We hope that our work may pave the way for future studies on physical activity and AMD.

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**CONFLICTS OF INTEREST:** Disclosure forms provided by the authors are available with the full text of this article at www.danmedj.dk

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