



HAL
open science

Short postural training session improves stability in patients with age-related macular degeneration

Hortense Chatard, Laure Tepenier, Talal Beydoun, Olivier Offret, Sawsen Salah, José-Alain Sahel, Saddek Mohand-Saïd, Maria Pia Bucci

► To cite this version:

Hortense Chatard, Laure Tepenier, Talal Beydoun, Olivier Offret, Sawsen Salah, et al.. Short postural training session improves stability in patients with age-related macular degeneration. *Journal of International Medical Research*, 2021, 10.1177/03000605211037901 . hal-03703919

HAL Id: hal-03703919

<https://hal.science/hal-03703919>

Submitted on 9 May 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.





Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

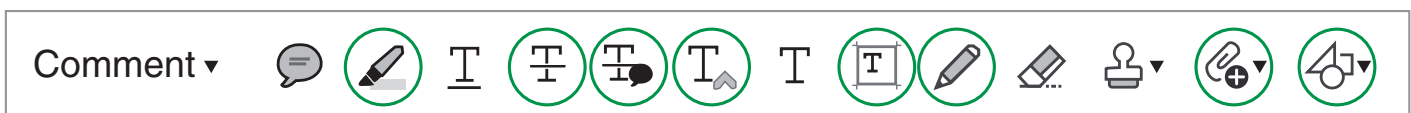
Page Proof Instructions and Queries

Journal Title: Journal of International Medical Research (IMR)

Article Number: 1037901

Thank you for choosing to publish with us. This is your final opportunity to ensure your article will be accurate at publication. Please review your proof carefully and respond to the queries using the circled tools in the image below, which are available in Adobe Reader DC* by clicking **Tools** from the top menu, then clicking **Comment**.

Please use *only* the tools circled in the image, as edits via other tools/methods can be lost during file conversion. For comments, questions, or formatting requests, please use . Please do *not* use comment bubbles/sticky notes .



*If you do not see these tools, please ensure you have opened this file with Adobe Reader DC, available for free at get.adobe.com/reader or by going to Help > Check for Updates within other versions of Reader. For more detailed instructions, please see us.sagepub.com/ReaderXProofs.

No.	Query
	Please note that we cannot add/amend ORCID iDs for any article at the proof stage. Following ORCID's guidelines, the publisher can include only ORCID iDs that the authors have specifically validated for each manuscript prior to official acceptance for publication.
	Please confirm that all author information, including names, affiliations, sequence, and contact details, is correct.
	Please review the entire document for typographical errors, mathematical errors, and any other necessary corrections; check headings, tables, and figures.
	Please confirm that the Funding and Conflict of Interest statements are accurate.
	Please ensure that you have obtained and enclosed all necessary permissions for the reproduction of artistic works, (e.g. illustrations, photographs, charts, maps, other visual material, etc.) not owned by yourself. Please refer to your publishing agreement for further information.
	Please note that this proof represents your final opportunity to review your article prior to publication, so please do send all of your changes now.
AQ: 1	Please check that the correct license type appears on your article and matches what you had specified in the SAGE Open Access Portal. Please ensure that, where applicable, the responsible bill payer has paid the Article Processing Charge (APC) via the SAGE Open Access Portal for timely publication of your article.

Short postural training session improves stability in patients with age-related macular degeneration

Hortense Chatard^{1,2}, Laure Tepenier³,
Talal Beydoun³, Olivier Offret³, Sawsen Salah³,
José-Alain Sahel⁴, Saddek Mohand-Said⁴ and
Maria Pia Bucci^{1,2} 

Abstract

Objective: To explore the impact of unilateral versus bilateral age-related macular degeneration (AMD) on postural sway using a wavelet analysis, and to examine the effects of short-term postural training on postural stability in subjects with AMD.

Methods: This was a cross-sectional study in which 13 subjects with unilateral AMD, 18 subjects with bilateral AMD, and 16 healthy age-matched controls participated in a short postural training session. Postural performance was measured before and after training using a force platform under seven visual conditions. We analyzed the surface area and mean velocity of the center of pressure (CoP), the postural instability index (PII), and the number of falls and collisions during postural training.

Results: Bilateral AMD subjects were more unstable than healthy controls, with increased CoP surface area and PII. Visual acuity affected postural sway. After training, all subjects (both AMD and healthy) had improved postural stability.

Conclusion: This study confirmed that AMD subjects are more unstable than healthy older adults, which is most likely because of their poor visual capabilities. A short training session improved postural performance in older adults (both healthy and subjects with AMD), which suggests that these subjects can use compensatory mechanisms for balance control.

¹UMR 7114 MoDyCo, CNRS-Université Paris Nanterre, Nanterre, France

²Vestibular and Oculomotor Evaluation Unit, ENT Department, Robert Debré University Hospital, Paris, France

³Groupe Hospitalier Cochin-Hôtel-Dieu, Department of Ophthalmology, Assistance Publique-Hôpitaux de Paris, Paris Descartes University, Paris, France

⁴Sorbonne Universités, University Pierre et Marie Curie (UPMC), Institut de la Vision, Centre Hospitalier National d'Ophthalmologie (CHNO) des Quinze-Vingts, Paris, France

Corresponding author:

Maria Pia Bucci, UMR 7114 MoDyCo, CNRS-Université Paris Nanterre, 200 Av. de la République, Nanterre 92001, France.

Email: mariapia.bucci@gmail.com



Keywords

Age-related macular degeneration, training, postural control, compensatory mechanism, older adult, postural stability, visual acuity

Date received: 14 December 2020; accepted: 16 July 2021

Introduction

Age-related macular degeneration (AMD) is the most common cause of visual impairment and blindness in older adults in developed countries.¹ According to Wong et al.,² AMD will affect 288 million older adults by 2040. This pathology is defined by a unilateral or bilateral progressive degeneration of photoreceptors in the central retina. At present, treatment is limited and there is no cure for AMD.^{3,4} Subjects with AMD gradually lose visual acuity and autonomy (e.g., risk of falling, driving restrictions, and reading difficulty). Rehabilitation that is designed to help individuals with low vision currently holds great promise to reduce these outcomes and maintain the autonomy of subjects with AMD.⁵ In the current study, we explored a low-vision rehabilitation program composed of different visual exercises (oculomotor and visual attentional tasks) that aimed to improve visual performance in subjects with AMD.

Postural stability relies on somatosensory/proprioceptive, visual, and vestibular inputs for the appropriate coordination of body segments.⁶ Visual impairment decreases postural control, especially in older adults,⁷ and poor postural stability is the main risk factor for falling.^{8,9} Lamoureux et al.¹⁰ studied the impact of visual impairment on the risk of falling in adults aged between 40 and 80 years with moderate or severe visual impairment in one or both eyes, and compared the results with those of age-matched controls. They demonstrated that severe visual impairment

in the worse eye increases the risk of falling, and that severe visual impairment in one eye and moderate visual impairment in the other eye doubles the risk of falling. Furthermore, in our previous study,¹¹ we reported that subjects with AMD are more unstable than healthy age-matched control subjects (with increased anterior–posterior displacement of the center of pressure [CoP]), most likely because of their poor visual capabilities and poor adaptive mechanisms.¹¹

Few studies have explored the impact of postural training in older adults with visual impairment. Radvay et al.¹² tested the impact of balance training on visuomotor functions and reading speed in subjects with AMD compared with age-matched older adults. Balance training included five 25-minute sessions using the same type of platform that was used in the present study (the Multitest Equilibre), and each of three sensorial inputs (somatosensory, visual, and vestibular) was stimulated randomly. To stimulate the somatosensory system, subjects were asked to alternately close and open their eyes while standing on stable and unstable platforms. To stimulate the visual system, participants experienced perturbed vision via optokinetic stimulation. To stimulate the vestibular system, subjects were asked to move their head horizontally and vertically while fixating on a small target in front of them. The subjects with AMD used significantly more somatosensory inputs and less vestibular inputs to control their stability than healthy subjects.

After training, subjects with AMD had a significant improvement in vestibular input only. In contrast, control subjects had a significant improvement in somatosensory input and a reduction in visual input, as well as a significant reduction in the number of falls. Notably, these results were not maintained over time. The authors suggested that postural training may be a useful tool to prevent some deleterious consequences of low vision and aging, such as the risk of falling, in subjects with AMD.

The aim of the present study was two-fold. First, we aimed to explore the impact of unilateral versus bilateral AMD on postural sway using a wavelet analysis, which allows for the evaluation of temporal fluctuations in body sway. Second, we aimed to examine the effects of a short postural training session on postural stability in subjects with AMD. We decided to test postural control separately for each eye to refine our previous results.¹¹ Our overall goal was to further understand the impact of AMD levels on postural stability to aid in the development of new training techniques.

Based on previous studies, we hypothesized that subjects with AMD might show poor postural control with respect to healthy older adults because they have difficulties using sensory compensatory strategies when visual inputs are not available. For this reason, we also expected to identify different postural instability between subjects with unilateral and bilateral AMD because vision inputs are likely to be less available in subjects with bilateral AMD than in subjects with unilateral AMD. The added value of the current study is that we also tested postural sway under three visual conditions (eyes open and fixated on a target, eyes closed, and eyes open with vision that was perturbed by optokinetic stimulation). In sighted subjects, visual input is the most important factor for controlling balance;⁶ thus, we further explored

the role of visual input in postural control in subjects with AMD.

We also explored whether a short postural training period was able to improve postural performance in subjects with AMD. We hypothesized that these subjects would be able to improve their baseline postural instability by undergoing a short training program based on their sensory abilities (somatosensory, visual, and vestibular).

Materials and methods

Participants

The present work was a cross-sectional study. Subjects with unilateral or bilateral AMD were included along with age-matched healthy controls. All participants were recruited from the Department of Ophthalmology in Hôtel-Dieu Hospital (Paris, France) and the Department of Ophthalmology in Quinze-Vingts Hospital (Paris, France). Participation was not compensated. All participants were Caucasians, for whom the prevalence of AMD is higher.^{13,14}

The exclusion criteria were as follows: ametropia greater than 5 diopters (spherical equivalent), history of ocular surgery, retina laser treatment, other ophthalmologic pathologies (e.g., glaucoma or cataracts), diabetes, known cognitive loss, known vestibular abnormality, and known orthopedic surgeries or abnormalities.

The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.¹⁵ The investigation adhered to the principles of the Declaration of Helsinki and was approved by our Institutional Human Experimentation Committee (ID-RCB: 2016-A01728-23, CPP Ile-de-France: 16187, 2016). Written informed consent was obtained from each participant after

the nature of the experimental procedure was explained.

Ophthalmologic evaluation

All participants underwent a standard ophthalmologic evaluation (intraocular pressure, anterior segment, and dilated fundus examination) to evaluate their visual function.

The AMD severity scale of Age-Related Eye Disease Studies (AREDS) was used for each eye. The AMD stage was determined for each eye according to the AREDS classification,¹⁶ and an optical coherence tomography (OCT) was performed using Spectralis® (Heidelberg Engineering, Heidelberg, Germany). This imaging technique produces high-resolution cross sections of retinal tissue in vivo (5–10 µm), which are comparable to histological sections. This rapid and non-invasive technique is used routinely in the clinic to monitor AMD, and allows the visualization of the structure of various retinal layers at a µm scale, as well as their possible changes. To precisely analyze the retinal abnormalities of each participant, macular mapping of 96 sections was performed for each eye. Based on the 2001 AREDS classification, an ophthalmologist then determined the stage of AMD for each eye (level 1: “normal macula,” level 2: “early AMD,” level 3: “intermediate AMD,” and level 4: “advanced AMD”). All control subjects had level 1 for each eye, and we defined an eye as having AMD only if it was classified as level 3 or 4; an eye with level 2 was considered to have normal visual acuity. Note that the AMD stage can be asymmetrical between the two eyes. In our study, subjects with bilateral AMD had both eyes at level 3 or 4, while subjects with unilateral AMD had one eye at level 3 or 4 (the eye with AMD) and one healthy eye at level 1 or 2. Therefore, the “healthy” eye of

subjects with monocular AMD may show some drusen.

The eyes with AMD were further classified into those with choroidal neovascularization AMD and those with atrophic AMD. In the current study, we chose to specifically analyze the impact of visual acuity on postural stability, beyond the binocular visual field (which is variable depending on the level of AMD). For logistical reasons, we did not analyze the contrast sensitivity of the patients. No participants had a history of binocular vision disorder (i.e., strabismus, anisometropia, or amblyopia). Stereoscopic acuity was measured using the TNO test. Visual acuity for each participant was measured separately for each eye at a 5 m distance using the Monoyer chart, and was then translated to an Early Treatment Diabetic Retinopathy Study (ETDRS) acuity score using an adapted scale. All control subjects had a corrected monocular visual acuity of 20/20.

Posturography

A force platform (Multitest Equilibre; Framiral, Grasse, France) was used to measure postural performance. Displacement of the CoP was recorded for 30 s, sampled at 40 Hz, and digitized with 16-bit precision. Several previous studies from our^{17–19} and other groups^{20,21} have used this platform to quantify postural balance.

Postural recording procedure. In a dark room, participants stood on the Multitest platform, positioned their bare feet on the platform footprints, and fixated on a small bright red target of 0.5° (identical for all subjects) at a distance of 2.5 m. During the experiment, the participant was unable to see anything in the room except for the red target or the optokinetic stimulation on the wall. The position of the feet was fixed and marked on the platform; the heels were 4 cm apart and the feet were spread symmetrically at a 30°

angle with respect to the sagittal axis of the participant. Participants were instructed to stay as still as possible, with their arms alongside their body, and to fixate on the target. Note that the Multitest platform has a special structure in front of the subjects to avoid any falls. We tested seven visual conditions: eye(s) open while fixating on the target (both eyes viewing [EV], better eye viewing [BEV], and worse eye viewing [WEV]), eyes closed (EC), and eye(s) open with perturbed vision by optokinetic stimulation (both eyes viewing [OPTO], better eye viewing [B-OPTO], and worse eye viewing [W-OPTO]). The optokinetic stimulation was performed using an optokinetic ball that was projected onto the wall at a distance of 2.5 m in front the participant's eyes, and turned at an angular speed of $158^\circ/\text{s}$.²² We tested this visual condition because it represents a perturbed visual condition. During the optokinetic stimulation, participants had to look forward without fixating on a target while the optokinetic field rotated on all walls of the room, giving a visual sensation ofvection. This impaired visual input affects balance, leaving only vestibular inputs for the control of postural sway.

In the monocular viewing conditions, an occlusion patch was used in front of the non-viewing eye. For the healthy older adults, the "better" eye was the dominant eye, as detected using the "hole-in-card" technique.^{23,24}

The duration of each postural recording was 30 s, with a 15 s rest period between conditions to reduce the possible effects of tiredness. The order between the different visual conditions was randomized. Measurements were performed both before and after the training period.

Training protocol

After the first postural recording, the participants had a 5-minute break before starting the training. The protocol for each

training type (two different tasks) was explained and a 30 s test was performed to verify that the participant had understood the instructions. The training duration was then 3 minutes for each type of training. Each participant stood on the Multitest platform and looked at a screen ($340\text{ cm} \times 170\text{ cm}$) projected at a distance of 2.5 m. A buoy ($130\text{ cm} \times 130\text{ cm}$) in the sea was projected onto the screen (Figure 1a). The body movements of the participants were represented by a green point on the buoy. The objective was to move the body (represented by the green point) onto specific sections of the buoy while avoiding falling off the buoy and into the sea.²⁵ The number of falls into the water was recorded.

The second training type consisted of a crowd simulator¹⁷ (Figure 1b). In this simulation, bystanders were walking toward the participant on a street, with a mean velocity ranging from 0.5 mm/s to 1.5 mm/s. Participants had to move their body efficiently to avoid the bystanders. The number of collisions was recorded.

This postural training technique was chosen based on our previous studies that used the same postural paradigms to improve postural control in children with dyslexia¹⁷ and autism spectrum disorder.²⁵ The first exercise (the buoy simulation) was quite a difficult exercise in which the subject had to maintain equilibrium, while the second exercise (the crowd simulation) was more natural and represented difficulties that are faced on a daily basis by subjects. In our previous studies,^{17,25} these two exercises improved postural control in children with neurodevelopmental disorders that involve difficulties in controlling somatosensory inputs to eliminate body sway (probably because of their poor cerebellar integration). Thus, we wondered whether this training type might also be useful for subjects with poor visual input, to improve

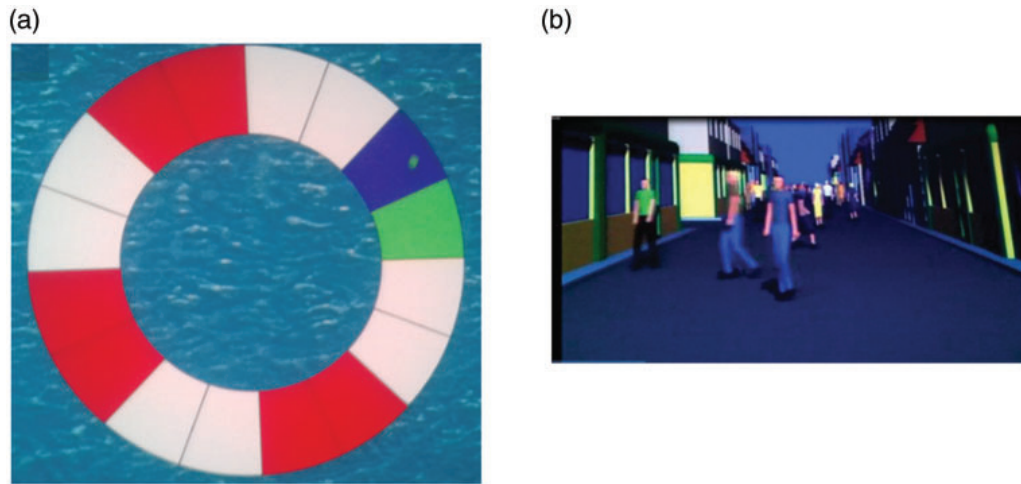


Figure 1. Paradigm of the postural training. Buoy (a) and crowd simulator (b) paradigms.

the use of other inputs available for controlling posture.

After the training session, participants had another 5-minute break before undergoing the second set of postural recordings. We then analyzed the impact of the short training session on postural control by comparing postural performances before and after postural training.

To summarize, the tests were all performed over the course of 1 day for each subject, as follows:

T1: postural recording before training

6 minutes of training (the two exercises were performed)

T2: postural recording after training

Data processing: spatial domain analysis

To quantify the effects of AMD and visual conditions on postural control, we analyzed the surface area covered by the displacement of the CoP (cm²) and its mean velocity (mm/s). Surface area is an effective measurement of CoP variability and corresponds to an ellipse with 90% of CoP.^{26–28} In addition, mean velocity is an efficient indicator to quantify the neuromuscular activity required to regulate postural control.²⁹ Note that Framiral software analyzed the displacement of the CoP without

splitting it into anterior–posterior and medial–lateral directions.

Data processing: wavelet analysis

A wavelet non-linear analysis using Morlet waves was applied to the CoP displacement measurements to elaborate a time–frequency chart of body sways.^{17,30} This analysis allows for the evaluation of temporal fluctuations in the body sway spectrum by measuring the postural instability index (PII). This parameter can quantify postural stability using the spectral power index (PI) and the canceling time (CT) for both the medial–lateral (x) and anterior–posterior (y) directions. The PII was calculated as follows: $PII = \sum_x \sum_y PI(F1, F2, F3)/CT(F1, F2, F3)$, where the PI and CT were included for each of the three frequencies (low: F1, medium: F2, and high: F3). This parameter is a global postural index that is used during routine testing by clinicians. A higher PII denotes poorer postural stability.³¹

Data processing: correlation between visual acuity and postural stability

We analyzed the correlation between the visual acuity of the worse eye (ETDRS chart) and each postural parameter in the

three eye viewing conditions (surface area and mean velocity of CoP, and PII) for all participants (controls, subjects with unilateral AMD, and subjects with bilateral AMD).

Statistical analysis

Statistical analysis was performed using Statistica software (TIBCO Software, Palo Alto, CA, USA). First, the data were analyzed with analysis of variance (ANOVA)/multivariate ANOVA using the three groups of participants (subjects with unilateral AMD, subjects with bilateral AMD, and control subjects) as the inter-subject factor, and the seven visual conditions (EV, BEV, WEV, EC, OPTO, B-OPTO, and W-OPTO) and training effect (before/after) as the within-subject factors. Second, a Spearman correlation analysis was performed in which the dependent variables were the surface area of CoP, mean velocity of CoP, and the PII, and the predictor variable was the visual acuity (ETDRS chart) of the worse eye.

The effect of a factor was considered significant when the P-value was below 0.05. In the case of significant effects, the post-hoc Bonferroni test was performed.

Results

In the present study, 13 subjects with unilateral AMD (mean age: 72.5 ± 1.36 years), 18 subjects with bilateral AMD (mean age: 74.0 ± 1.02 years), and 16 age-matched healthy controls (mean age: 70.3 ± 1.36 years) were included. There were no significant differences in age between the three groups ($F_{(2,44)} = 1.61$, $P = 0.21$). Clinical data from each AMD participant are shown in Tables 1 and 2. Among the 49 AMD eyes that were included in the present study, 29 had choroidal neovascularization AMD and 20 had atrophic AMD. It has previously been reported that choroidal

neovascularization affects 10% to 15% of subjects with AMD.³

Surface area of the CoP

Figure 2 shows the surface area of the CoP (in cm²) for each visual condition tested (EV, BEV, WEV, EC, OPTO, B-OPTO, and W-OPTO) for the three groups of subjects (control, unilateral AMD, and bilateral AMD) before and after postural training.

Analysis using ANOVA revealed a significant group effect ($F_{(2,42)} = 4.05$, $P < 0.02$, $\eta = 0.16$). Post-hoc comparison demonstrated a significant difference between the control and bilateral AMD groups only ($P < 0.04$); subjects with bilateral AMD had a larger CoP surface area than control subjects. In contrast, the difference between the control and unilateral AMD groups failed to reach significance. Moreover, there was a significant effect of visual condition ($F_{(6,252)} = 2.17$, $P < 0.04$, $\eta = 0.05$); the CoP surface area was larger in the WEV and W-OPTO visual conditions (both $P < 0.02$) compared with the other visual conditions. ANOVA also revealed a significant interaction between visual condition and training ($F_{(6,252)} = 4.00$, $P < 0.0007$, $\eta = 0.08$); after training, the CoP surface area was reduced in the BEV, WEV, and EC conditions (all $P < 0.01$). ANOVA did not show any significant effects of training ($F_{(1,42)} = 1.08$), nor any other interactions.

Mean velocity of CoP

Figure 3 shows the mean velocity of the CoP (mm/s) for each visual condition tested (EV, BEV, WEV, EC, OPTO, B-OPTO, and W-OPTO) for the three groups of subjects (control, unilateral AMD, and bilateral AMD) before and after postural training.

Analysis using ANOVA revealed a significant effect of the visual condition

Table 1. Corrected visual acuity, AMD level, type of AMD, type of scotoma, stereoscopic acuity, and “better seeing eye” for each subject with unilateral AMD.

Patient (age, years)	Corrected visual acuity (ETDRS)		AMD level		Type of AMD		Scotoma type	Stereoscopic acuity (seconds of arc, TNO)	Better seeing eye
S1 (69.3)	RE	20/25	RE	4	RE	CNV	Absolute	>480	RE
	LE	20/630	LE	2	LE	/			
S2 (79.4)	RE	20/20	RE	1	RE	/	Relative	120	RE
	LE	20/40	LE	4	LE	CNV			
S3 (84.8)	RE	20/20	RE	1	RE	/	Absolute	120	RE
	LE	20/20	LE	4	LE	GA			
S4 (77.1)	RE	20/25	RE	1	RE	/	Relative	>480	RE
	LE	20/100	LE	4	LE	CNV			
S5 (70.8)	RE	20/20	RE	1	RE	/	Relative	120	RE
	LE	20/40	LE	3	LE	CNV			
S6 (74.7)	RE	20/630	RE	3	RE	CNV	Absolute	>480	LE
	LE	20/20	LE	2	LE	/			
S7 (68.9)	RE	20/40	RE	4	RE	CNV	Relative	120	LE
	LE	20/20	LE	2	LE	/			
S8 (76.1)	RE	20/40	RE	4	RE	CNV	Relative	200	LE
	LE	20/20	LE	2	LE	/			
S9 (67.2)	RE	20/80	RE	4	RE	GA	Absolute	200	LE
	LE	20/20	LE	2	LE	/			
S10 (75.6)	RE	20/20	RE	2	RE	/	Relative	120	RE
	LE	20/80	LE	4	LE	CNV			
S11 (69.1)	RE	20/20	RE	2	RE	/	Absolute	>480	RE
	LE	20/125	LE	4	LE	CNV			
S12 (56.7)	RE	20/20	RE	2	RE	/	Absolute	>480	RE
	LE	20/125	LE	4	LE	CNV			
S13 (72.3)	RE	20/80	RE	4	RE	CNV	Relative	200	LE
	LE	20/20	LE	2	LE	/			

AMD, age-related macular degeneration; CNV, choroidal neovascularization; ETDRS, Early Treatment Diabetic Retinopathy Study; GA, geographic atrophy; LE, left eye; RE, right eye.

($F_{(6,246)} = 6.21$, $P < 10^{-5}$, $\eta = 0.13$); post-hoc comparison demonstrated a higher mean velocity in the OPTO and W-OPTO conditions (both $P < 0.001$). Moreover, there was a significant effect of training ($F_{(1,41)} = 6.51$, $P < 0.01$, $\eta = 0.12$); the mean velocity was lower after training. ANOVA also revealed a significant interaction between training and visual condition ($F_{(2,246)} = 2.27$, $P < 0.03$, $\eta = 0.05$). Post-hoc comparisons demonstrated that training decreased the mean velocity in

several visual conditions (EV, BEV, EC, and OPTO, all $P < 0.01$). ANOVA did not show any significant group effects ($F_{(2,41)} = 1.18$), nor any other interactions.

PII

Figure 4 shows the PII for each visual condition tested (EV, BEV, WEV, EC, OPTO, B-OPTO, and W-OPTO) for the three groups of subjects (control, unilateral

Table 2. Corrected visual acuity, AMD level, type of AMD, type of scotoma, stereoscopic acuity, and “better seeing eye” for each subject with bilateral AMD.

Patient (age, years)	Corrected visual acuity (ETDRS)		AMD level		Type of AMD		Scotoma type	Stereoscopic acuity (seconds of arc, TNO)	Better seeing eye																																																																																																																																																																																																																																																																												
S1 (71.2)	RE	20/63	RE	4	RE	GA	Absolute	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/63	LE	3	LE	GA				S2 (83.7)	RE	20/32	RE	3	RE	GA	Absolute	>480	RE	LE	20/630	LE	4	LE	CNV	S3 (80.4)	RE	20/63	RE	3	RE	CNV	Relative	>480	RE	LE	20/630	LE	4	LE	CNV	S4 (78.0)	RE	20/25	RE	3	RE	GA	Absolute	200	RE	LE	20/32	LE	3	LE	GA	S5 (65.2)	RE	20/25	RE	3	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	CNV	S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE	LE	20/50	LE	4	LE	CNV	S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100
S2 (83.7)	RE	20/32	RE	3	RE	GA	Absolute	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/630	LE	4	LE	CNV				S3 (80.4)	RE	20/63	RE	3	RE	CNV	Relative	>480	RE	LE	20/630	LE	4	LE	CNV	S4 (78.0)	RE	20/25	RE	3	RE	GA	Absolute	200	RE	LE	20/32	LE	3	LE	GA	S5 (65.2)	RE	20/25	RE	3	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	CNV	S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE	LE	20/50	LE	4	LE	CNV	S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV												
S3 (80.4)	RE	20/63	RE	3	RE	CNV	Relative	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/630	LE	4	LE	CNV				S4 (78.0)	RE	20/25	RE	3	RE	GA	Absolute	200	RE	LE	20/32	LE	3	LE	GA	S5 (65.2)	RE	20/25	RE	3	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	CNV	S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE	LE	20/50	LE	4	LE	CNV	S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																												
S4 (78.0)	RE	20/25	RE	3	RE	GA	Absolute	200	RE																																																																																																																																																																																																																																																																												
	LE	20/32	LE	3	LE	GA				S5 (65.2)	RE	20/25	RE	3	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	CNV	S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE	LE	20/50	LE	4	LE	CNV	S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																												
S5 (65.2)	RE	20/25	RE	3	RE	GA	Absolute	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/500	LE	4	LE	CNV				S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE	LE	20/50	LE	4	LE	CNV	S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																												
S6 (75.9)	RE	20/320	RE	4	RE	CNV	Relative	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/50	LE	4	LE	CNV				S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE	LE	20/100	LE	4	LE	GA	S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																												
S7 (72.0)	RE	20/125	RE	4	RE	CNV	Absolute	200	LE																																																																																																																																																																																																																																																																												
	LE	20/100	LE	4	LE	GA				S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE	LE	20/63	LE	3	LE	GA	S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																												
S8 (75.7)	RE	20/20	RE	3	RE	GA	Absolute	200	RE																																																																																																																																																																																																																																																																												
	LE	20/63	LE	3	LE	GA				S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE	LE	20/100	LE	4	LE	CNV	S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																												
S9 (71.5)	RE	20/200	RE	4	RE	GA	Absolute	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/100	LE	4	LE	CNV				S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE	LE	20/400	LE	4	LE	CNV	S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																												
S10 (69.7)	RE	20/400	RE	4	RE	CNV	Absolute	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/400	LE	4	LE	CNV				S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE	LE	20/100	LE	4	LE	GA	S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																												
S11 (74.5)	RE	20/63	RE	4	RE	GA	Absolute	200	RE																																																																																																																																																																																																																																																																												
	LE	20/100	LE	4	LE	GA				S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE	LE	20/63	LE	4	LE	GA	S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																												
S12 (75.7)	RE	20/125	RE	4	RE	GA	Absolute	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/63	LE	4	LE	GA				S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE	LE	20/500	LE	4	LE	GA	S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																												
S13 (75.8)	RE	20/400	RE	4	RE	GA	Absolute	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/500	LE	4	LE	GA				S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE	LE	20/200	LE	4	LE	GA	S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																												
S14 (71.1)	RE	20/200	RE	4	RE	GA	Absolute	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/200	LE	4	LE	GA				S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE	LE	20/125	LE	3	LE	CNV	S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																																												
S15 (74.8)	RE	20/40	RE	4	RE	CNV	Relative	200	LE																																																																																																																																																																																																																																																																												
	LE	20/125	LE	3	LE	CNV				S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE	LE	20/63	LE	4	LE	CNV	S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																																																												
S16 (71.4)	RE	20/63	RE	4	RE	CNV	Relative	>480	RE																																																																																																																																																																																																																																																																												
	LE	20/63	LE	4	LE	CNV				S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE	LE	20/630	LE	4	LE	CNV	S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																																																																												
S17 (71.4)	RE	20/80	RE	4	RE	CNV	Absolute	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/630	LE	4	LE	CNV				S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																																																																																												
S18 (72.7)	RE	20/160	RE	4	RE	CNV	Relative	>480	LE																																																																																																																																																																																																																																																																												
	LE	20/100	LE	4	LE	CNV																																																																																																																																																																																																																																																																															

AMD, age-related macular degeneration; CNV, choroidal neovascularization; ETDRS, Early Treatment Diabetic Retinopathy Study; GA, geographic atrophy; LE, left eye; RE, right eye.

AMD, and bilateral AMD) before and after the postural training.

Analysis using ANOVA revealed a significant group effect ($F_{(2,38)} = 5.66$,

$P < 0.007$, $\eta = 0.22$). Post-hoc comparison demonstrated a significant difference between the control and bilateral AMD groups ($P < 0.006$); subjects with bilateral

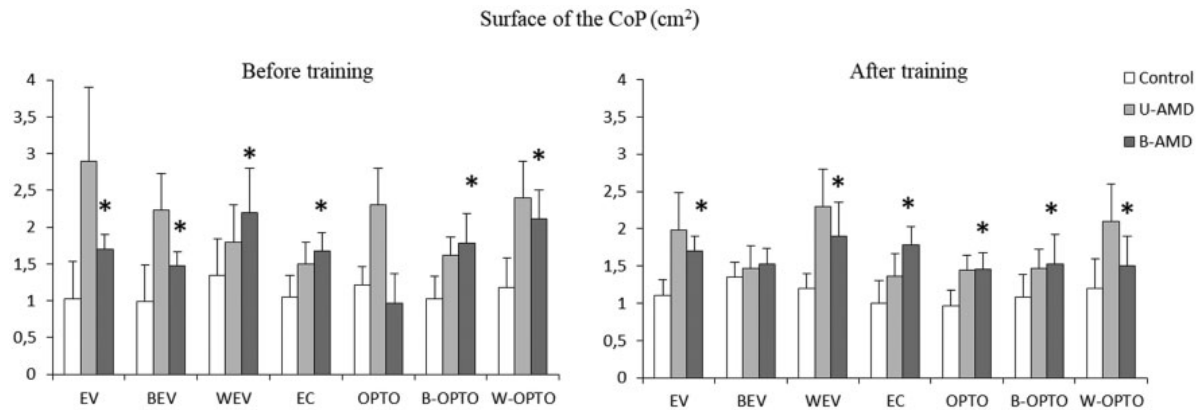


Figure 2. Surface area of the center of pressure (CoP, in cm²) for each visual condition tested. The surface area is shown for each group of subjects tested (16 control age-matched older adults before training [Control BT], 13 subjects with unilateral age-related macular degeneration (AMD) before training [U-AMD BT], 18 subjects with bilateral AMD before training [B-AMD BT], control age-matched older adults after training [Control AT], subjects with unilateral AMD after training [U-AMD AT], and subjects with bilateral AMD after training [B-AMD AT]) and for each visual condition tested (binocular eye viewing [EV], dominant eye viewing [BEV], non-dominant eye viewing [WEV], eyes closed [EC], and perturbed vision by optokinetic stimulation [both eye viewing (OPTO), dominant eye viewing (B-OPTO), and non-dominant eye viewing (W-OPTO)]). Analysis of variance (ANOVA) indicated a significant group effect ($P < 0.02$), a significant effect of visual condition ($P < 0.04$), and a significant interaction between visual condition and training ($P < 0.0007$). Asterisks indicate significant differences between the control group and the bilateral AMD group. Vertical bars indicate the standard error.

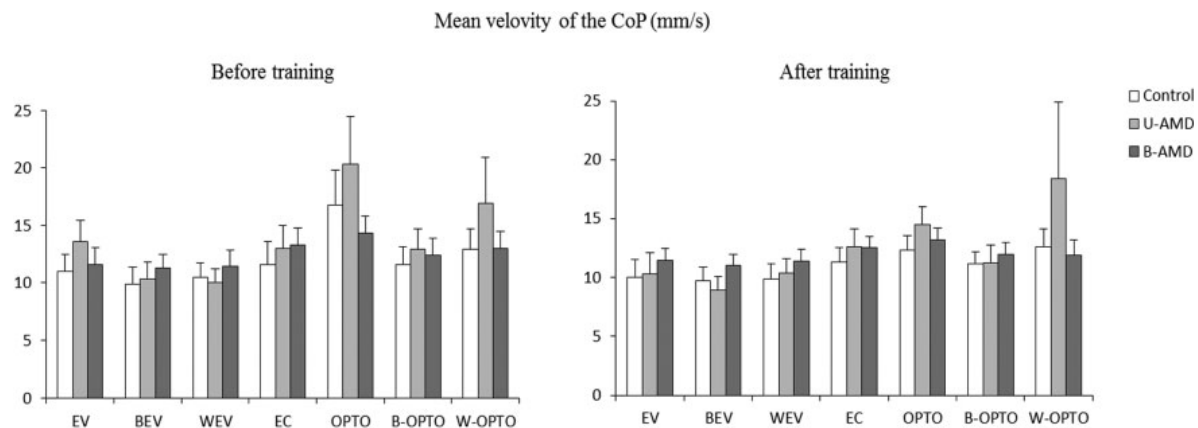


Figure 3. Mean velocity of center of pressure (CoP, in mm/s). Mean velocity is shown for each group of subjects tested (16 control age-matched older adults before training [Control BT], 13 subjects with unilateral age-related macular degeneration (AMD) before training [U-AMD BT], 18 subjects with bilateral AMD before training [B-AMD BT], control age-matched older adults after training [Control AT], subjects with unilateral AMD after training [U-AMD AT], and subjects with bilateral AMD after training [B-AMD AT]) and for each visual condition (binocular eye viewing [EV], dominant eye viewing [BEV], non-dominant eye viewing [WEV], eyes closed [EC], and perturbed vision by optokinetic stimulation [both eye viewing (OPTO), dominant eye viewing (B-OPTO), and non-dominant eye viewing (W-OPTO)]). Analysis of variance (ANOVA) indicated a significant effect of visual condition ($P < 10^{-5}$), and a significant effect of training ($P < 0.01$). Vertical bars indicate the standard error.

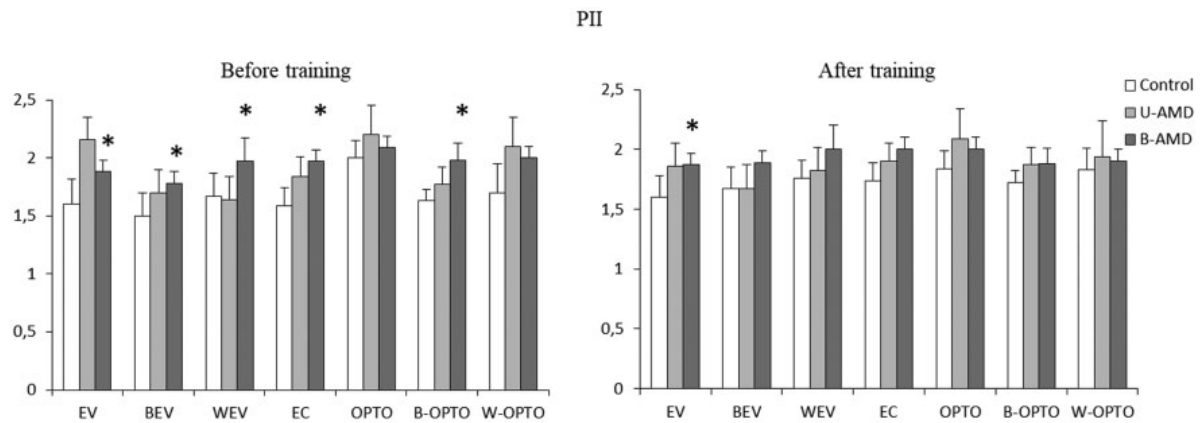


Figure 4. Postural instability index (PII). The PII is shown for each group of subjects tested (16 control age-matched older adults before training [Control BT], 13 subjects with unilateral age-related macular degeneration (AMD) before training [U-AMD BT], 18 subjects with bilateral AMD before training [B-AMD BT], control age-matched older adults after training [Control AT], subjects with unilateral AMD after training [U-AMD AT], and subjects with bilateral AMD after training [B-AMD AT]) and for each visual condition (binocular eye viewing [EV], dominant eye viewing [BEV], non-dominant eye viewing [WEV], eyes closed [EC], and perturbed vision by optokinetic stimulation [both eye viewing (OPTO), dominant eye viewing (B-OPTO) and non-dominant eye viewing (W-OPTO)]). Analysis of variance (ANOVA) showed a significant group effect ($P < 0.007$), a significant effect of visual condition ($P < 0.00002$), and a significant interaction between training and visual condition ($P < 0.02$). Asterisks indicate significant differences between the control group and the bilateral AMD group. Vertical bars indicate the standard error.

AMD had a higher PII than control subjects. There was also a significant effect of visual condition ($F(6,228) = 5.60$, $P < 0.00002$, $\eta = 0.12$); post-hoc comparison revealed that PII was higher in the OPTO condition ($P < 10^{-5}$). Moreover, ANOVA indicated a significant interaction between training and visual condition ($F(6,228) = 2.45$, $P < 0.02$, $\eta = 0.06$). Post-hoc comparisons demonstrated a decrease in the PII after training in the EV, OPTO, and W-OPTO conditions (all $P < 0.02$). ANOVA did not show any significant effects of training ($F(1,38) = 0.26$), nor any other interactions.

Number of falls into the water and number of collisions

Analysis using ANOVA revealed a group effect for both the number of falls into the water and the number of collisions ($F(2,44) = 4.54$, $P < 0.03$ and $F(2,44) = 3.32$,

$P < 0.04$, respectively). Post-hoc comparisons demonstrated that subjects with AMD had significantly more falls into the water and collisions than control subjects (both $P < 0.01$) (Table 3).

Correlations between AMD levels and visual acuity

Figure 5 shows the surface area of CoP, the mean velocity of CoP, and the PII in both eye viewing conditions as a function of the visual acuity of the worse eye of each subject (controls, subjects with unilateral AMD, and subjects with bilateral AMD). The regression line is also shown. There was a significant effect of visual acuity of the worse eye on the CoP surface area (Spearman's rank correlation = -0.48) and the PII (Spearman's rank correlation = -0.43), but not on the mean CoP velocity (Spearman's rank correlation = -0.15).

Table 3. Number of falls into the water and number of collisions for each group of subjects during postural training.

Group	Number of falls into the water	Number of collisions
Controls	10 ± 2.4	6.9 ± 1.1
Subjects with unilateral AMD	13 ± 3.1	10.8 ± 1.3
Subjects with bilateral AMD	18 ± 3.2*	14.3 ± 2.6*

Data are shown as the mean ± standard deviation. *P < 0.01 vs. control group. AMD, age-related macular degeneration.

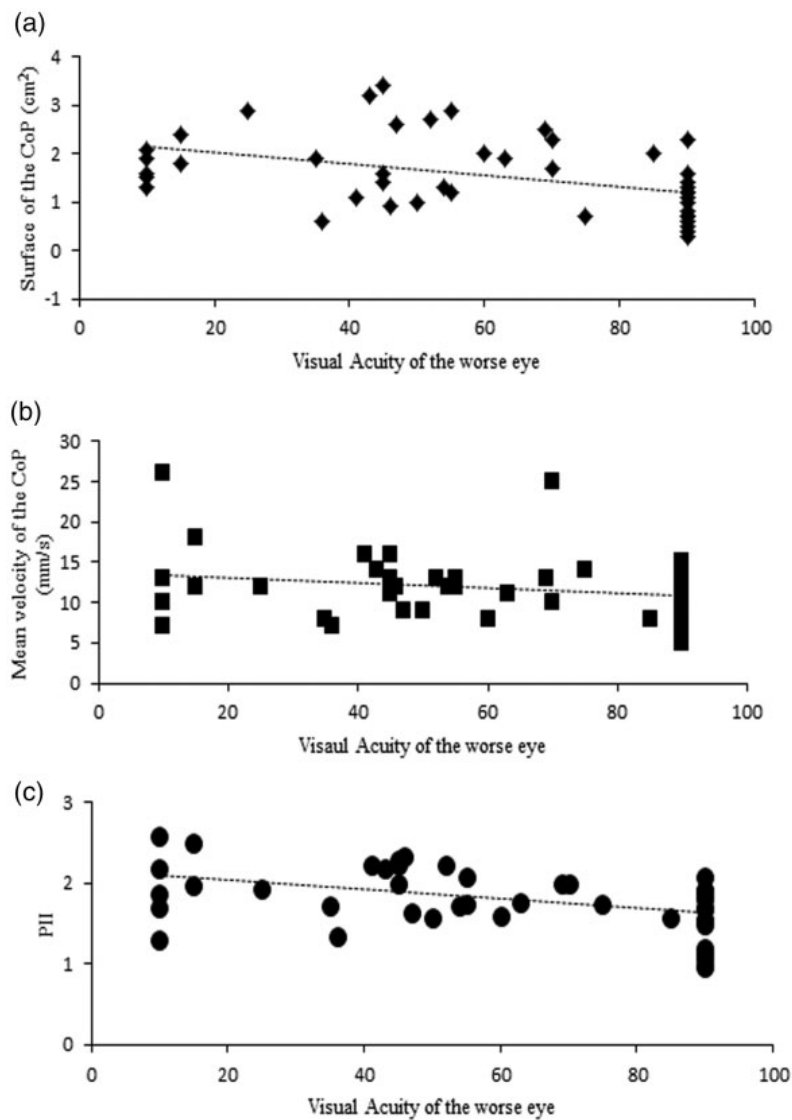


Figure 5. Correlations between visual acuity and postural parameters. Mean surface area of the center of pressure (CoP) (A), mean velocity of CoP (B), and postural instability index (PII) (C) for each subject as a function of the visual acuity of the worse eye (Early Treatment Diabetic Retinopathy Study [ETDRS] chart). The line represents the corresponding regression.

Discussion

The main findings of the present study on static postural evaluation in subjects with AMD were as follows: (i) subjects with bilateral AMD, but not subjects with unilateral AMD, were significantly more unstable than healthy age-matched subjects; (ii) older adults (both healthy subjects and those with AMD) were able to improve their postural performance after training in several of the viewing conditions that were tested; and (iii) visual acuity affected postural measures. Each of these findings will be discussed in the following sections.

Subjects with bilateral AMD are more unstable than healthy age-matched subjects on a static platform

In the current study, subjects with bilateral AMD had a larger surface area of the CoP compared with age-matched healthy subjects. This finding is consistent with the results of previous studies from our group¹² and from other researchers.^{32,33} Moreover, the wavelet analysis of postural control (which was performed for the first time in the present study) revealed that subjects with bilateral AMD had a higher PII than healthy subjects. In contrast, we failed to show any significant postural control impairment in subjects with unilateral AMD. Taken together, these findings suggest that vision has an important role in maintaining balance, particularly in older adults. Although the predominant role of visual input with respect to other somatosensory information is well known for posture (see work from Brandt and colleagues³⁴), in older subjects, vision is even more important for controlling postural sway.³⁴ To the best of our knowledge, few studies have explored balance performance in patients with different types of visual deficits. For example, some authors^{35,36} have reported that glaucoma

(a peripheral visual field deficit in older adults) generates postural instability. In 2013, Kotecha et al.³³ compared postural sway in subjects with AMD, subjects with glaucoma, and age-matched healthy subjects. They demonstrated that, compared with the healthy subjects, both groups of subjects with visual impairment (AMD and glaucoma) required more somatosensory inputs to maintain efficient postural stability. Moreover, Agostini et al.³⁷ compared the impact of central visual deficit on postural stability in subjects with Stargardt's disease (young adults) and healthy age-matched controls. Stargardt's disease is a genetic bilateral maculopathy that appears in the teenage years, and anatomic lesions in this disease are comparable with those in AMD. These authors revealed a larger postural sway in Stargardt's subjects in the eyes-closed condition only, while postural stability was similar to that of the control group in the other viewing conditions that were tested. These results suggest that subjects with Stargardt's disease are able to adapt and control their postural sway using other somatosensory inputs (e.g., vestibular and proprioceptive inputs). According to a study by Peterka,³⁸ when one sensory input is defective, the other subsystems compensate for the impairment by playing a more important role (i.e., reweighting of the sensory system occurs), although such mechanisms seem to work better in young subjects.³⁹ However, the present finding is in line with the hypothesis that vision, together with proprioceptive and vestibular inputs, is important for the control of posture.

Finally, the reader might ask why there was not a significant difference between subjects with unilateral AMD and control subjects. The surface area of the CoP had a tendency toward being larger in subjects with unilateral AMD compared with older adults, but this difference was not significant. Note that binocular visual acuity

was better in subjects with unilateral AMD than in subjects with bilateral AMD, but was worse in subjects with unilateral AMD than in healthy older adults. Thus, a larger number of subjects with unilateral AMD may be necessary to better understand the degree of postural deficit and the role of visual inputs in these patients.

Effects of the short postural training session

In the present study, after a short postural training period, all subjects (subjects with AMD as well as healthy older adults) improved their postural control; both the mean velocity and surface area of the CoP decreased in several of the visual conditions that were tested, as did the PII. To the best of our knowledge, this is the first report that a short postural training period (of about 6 minutes) can improve balance.

Previous studies have investigated the impact of a long period of balance training in healthy older adults. For example, Prasertsakul et al.⁴⁰ compared the effects of conventional exercise or virtual reality on postural control in 10 healthy subjects (mean age 53 years old). The training was composed of twelve 45-minute sessions (one session per week). They reported an increase in postural stability, which was higher after virtual reality training than after conventional exercises. Furthermore, Schättin et al.⁴¹ compared the effects of a conventional long period of balance training (group I) or video game-based physical exercise (group II) on executive function, prefrontal brain activity, and gait performance in healthy older adults (mean age 79.2 years old). The training was composed of 24 sessions (three 30-minute sessions per week). The authors reported that executive function and gait parameters improved in group II only, while prefrontal activity decreased in both groups. According to Segev-Jacobovski et al.⁴² the results of

these two studies highlight the importance of combining cognitive and motor training in older subjects to optimize the benefits. However, in all of these studies the subjects were older adults without visual deficits; thus, they could train their vision, vestibular, and proprioceptive inputs to improve their postural stability. More recently, Varin et al.⁴³ reported that cognitive activity in subjects with AMD is significantly lower than in control subjects, leading to a risk of cognitive impairment. Studies testing the impact of cognitive training on daily life abilities are therefore likely to be useful for these kinds of patients.

There are few studies in which the impact of postural training in visually impaired older adults has been measured; more importantly, no studies have objectively measured the impact of training sessions. Kovács et al.⁴⁴ compared the effects of two exercise programs on balance in older women with age-related visual dysfunction (the precise dysfunction was not specified in the study) for 6 months. Group I received a standard osteoporosis exercise program (four 30-minute sessions per week), while group II received a tailored multimodal exercise program (two 30-minute sessions per week) in addition to the standard program (two 30-minute sessions per week). The authors reported that group II had a significant reduction in the Timed Up and Go score, which was associated with a decreased risk of falling. They suggested that older subjects who are visually impaired may need specific strength and balance exercises to improve their postural control and reduce their risk of falling.

In the present study, we chose a short period of postural training that was composed of one training session only, which lasted 6 minutes. The postural training involved both cognitive and motor tasks, and we reported an improvement in the postural control of all subjects tested. This result may have been caused by

compensatory mechanisms that occurred in these subjects. However, postural improvement did not occur for all parameters in all visual conditions tested, which suggests that such compensatory mechanisms are less efficient in older adults (both healthy and with AMD). A longer period of postural training may facilitate the improvement of postural control for the other parameters, and should be investigated in further studies. In the future, it would also be worthwhile to include more training sessions as well as a follow-up session, in an attempt to optimize the benefits of training and evaluate the duration of the effects after training is finished.

Visual acuity affects postural measures

In the current study, we reported a relationship between visual acuity of the worse eye and postural parameters that were recorded while participants were standing with both eyes open; lower visual acuity was associated with greater instability. This finding is in line with previous studies^{7,10,11} (see Introduction) that demonstrated the important role of visual input for maintaining postural stability. Note, however, that contrast sensitivity, stereoacuity, or viewing eccentricity might have an important role in postural control in subjects with AMD.^{45,46} Furthermore, it has previously been reported that peripheral visual information is used by patients with bilateral AMD for controlling postural sway.⁴⁷ Thus, further studies on such issues need to be conducted to better understand the role of visual inputs in patients with AMD in the control of their bodies in the environment.

Limitations

One limitation of the current study was its relatively small sample size. Further studies with a larger number of subjects with

unilateral AMD are needed to precisely evaluate their postural deficits. It is possible that the lack of significance in the unilateral AMD group in the present study was a result of the relatively intact vision of these subjects; thus, a larger group of subjects with different levels of unilateral AMD is likely to provide more insight into the role of visual inputs in postural sway in these patients. In addition, well-designed case-control studies are needed to ensure the scientific validity of postural rehabilitation training programs. Finally, it should also be noted that the platform used in the present study had a sampling frequency of 40 Hz, and the CoP was recorded for 30 s only, despite other studies recommending a standardized sample duration of at least 60 s for CoP measures.⁴⁸ It is therefore possible that, with a longer postural time recording, subjects with AMD may show more postural sway and eventual changes in the anterior-posterior and medial-lateral direction of the CoP.

Conclusions

Our study confirms and builds on (by means of the wavelet analysis) the results of previous studies, demonstrating that subjects with bilateral AMD are more unstable than healthy age-matched subjects when tested on a static platform. Visual acuity of the worse eye in addition to postural measures should be considered as a potential marker for studying balance control in subjects with AMD. Moreover, a short postural training period was able to increase postural performance in older adults (both healthy and those with AMD), which suggests that subjects with AMD are able to use compensatory mechanisms to control their balance. Further studies should aim to quantify the improvements in postural control after specific training techniques and explore the benefits of training over time.

Acknowledgements

The authors gratefully acknowledge the orthopodists, nurses, and secretaries of the Departments of Ophthalmology in Hôtel-Dieu Hospital and Quinze-Vingts Hospital in Paris for their participation and logistical support. The authors also wish to thank all participants for their participation, and especially thank the “Blouses Roses” association.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by the Société Francophone Posture, Équilibre et Locomotion (SOFPEL) 2018 (“Professionnel de Santé” grant to HC).

Author contributions

Conceptualization: HC and MPB. Selection of patients: HC, LT, OO, TB, SS, JS, and SM. Postural measure, data and statistical analysis: HC. Investigation: MPB. Writing original draft: HC and MPB. Review and editing: LT, OO, TB, SS, JS, and SM.

ORCID iD

Maria Pia Bucci  <https://orcid.org/0000-0001-6673-2026>

References

1. Klein R, Chou CF, Klein BE, et al. Prevalence of age-related macular degeneration in the US population. *Arch Ophthalmol* 2011; 129: 75–80. doi: 10.1001/archophthalmol.2010.318
2. Wong WL, Su X, Li X, et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. *Lancet Glob Health* 2014; 2: e106–e116. doi: 10.1016/S2214-109X(13)70145-1
3. Wong TY, Chakravarthy U, Klein R, et al. The natural history and prognosis of neovascular age-related macular degeneration: a systematic review of the literature and meta-analysis. *Ophthalmology* 2008; 115: 116–126. doi: 10.1016/j.ophtha.2007.03.008
4. Colijn JM, Buitendijk GHS, Prokofyeva E, et al. Prevalence of age-related macular degeneration in Europe: the past and the future. *Ophthalmology* 2017; 124: 1753–1763. doi: 10.1016/j.ophtha.2017.05.035
5. Chatard H and Bucci MP. Postural training in age-related macular degeneration subjects: issues and impact. *Biomed J Sci Tech Res* 2018; 9: 7211–7212. doi: 10.26717/BJSTR.2018.09.001816
6. Brandt T. *Vertigo: Its Multisensory Syndromes*. New York: Springer, 2003.
7. Harwood RH. Visual problems and falls. *Age Ageing* 2001; 3: 13–18.
8. Piirtola M and Era P. Force platform measurements as predictors of falls among older people a review. *Gerontology* 2006; 52: 1–16. doi: 10.1159/000089820
9. Mahoney JR, Oh-Park M, Ayers E, et al. Quantitative trunk sway and prediction of incident falls in older adults. *Gait Posture* 2017; 58: 183–187. doi: 10.1016/j.gaitpost.2017.07.115
10. Lamoureux EL, Chong E, Wang JJ, et al. Visual impairment, causes of vision loss, and falls: the Singapore Malay Eye Study. *Invest Ophthalmol Vis Sci* 2008; 49: 528–533. doi: 10.1167/iovs.07-1036
11. Chatard H, Tepenier L, Jankowski O, et al. Effects of age-related macular degeneration on postural sway. *Front Hum Neurosci* 2017; 11: 158. doi: 10.3389/fnhum.2017.0015
12. Radvay X, Duhoux S, Koenig-Supiot F, et al. Balance training and visual rehabilitation of age-related macular degeneration patients. *J Vestib Res* 2007; 17: 1831–1893.
13. Bressler SB, Munoz B, Solomon SD, et al. Racial differences in the prevalence of age-related macular degeneration: the Salisbury Eye Evaluation (SEE) Project. *Arch Ophthalmol* 2008; 126: 241–245. doi: 10.1001/archophthalmol.2007.53
14. Kawasaki R, Yasuda M, Song SJ, et al. The prevalence of age-related macular degeneration in Asians: a systematic review and meta-

- analysis. *Ophthalmology* 2010; 117: 921–927. doi: 10.1016/j.ophtha.2009.10.007
15. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007; 147: 573–577. doi: 10.1016/j.ijisu.2014.07.013
 16. Age-Related Eye Disease Study Research Group (AREDS). The Age-Related Eye Disease Study system for classifying age-related macular degeneration from stereoscopic color fundus photographs: the Age-Related Eye Disease Study Report Number 6. *Am J Ophthalmol* 2001; 132: 668–681. doi: 10.1016/S0002-9394(01)01218-1
 17. Goulème N, Gérard CL and Bucci MP. Training effect on postural control in dyslexic children. *PLoS One* 2015; 10: e0130196. doi: 10.1371/journal.pone.0130196
 18. Bucci MP, Seassau M, Larger S, et al. Effect of visual attention on postural control in children with attention-deficit/hyperactivity disorder. *Res Dev Disabil* 2014; 35: 1292–1300. doi: 10.1016/j.ridd.2014.03.029
 19. Bucci MP, Stordeur C, Acquaviva E, et al. Postural instability in children with ADHD is improved by methylphenidate. *Front Neurosci* 2016; 10: 163. doi: 10.3389/fnins.2016.00163
 20. Dumitrescu M and Lacour M. Nouveaux critères quantitatifs d'analyse du contrôle postural. In: Pérennou D and Lacour M (eds) *Efficiences et Déficiences du Contrôle Postural*. Marseille: Solal, 2006, pp.65–75.
 21. Lacour M, Bernard-Demanze L and Dumitrescu M. Posture control, aging, and attention resources: models and posture analysis methods. *Neurophysiol Clin* 2008; 3: 411–421. doi: 10.1016/j.neucli.2008.09.005
 22. Ionescu E, Morlet T, Froehlich P, et al. Vestibular assessment with Balance Quest Normative data for children and young adults. *Int J Pediatr Otorhinolaryngol* 2006; 70: 1457–1465. doi: 10.1016/j.ijporl.2006.03.012
 23. Handa T, Mukuno K, Uozato H, et al. Effects of dominant and nondominant eyes in binocular rivalry. *Optom Vis Sci* 2004; 81: 377–383. doi: 10.1097/01.opx.0000135085.54136.65
 24. Seijas O, Gomez De Liano P, Gomez De Liano R, et al. Ocular dominance diagnosis and its influence in monovision. *Am J Ophthalmol* 2007; 144: 209–216. doi: 10.1016/j.ajo.2007.03.053
 25. Caldani S, Atzori P, Peyre H, et al. Short rehabilitation training program may improve postural control in children with autism spectrum disorders: preliminary evidences. *Sci Rep* 2020; 10: 7917. doi: 10.1038/s41598-020-64922-4
 26. Chiari L, Rocchi L and Cappello A. Stabilometric parameters are affected by anthropometry and foot placement. *Clin Biomech* 2002; 17: 666–677. doi: 10.1016/s0268-0033(02)00107-9
 27. Gagey PM and Weber B. *Posturologie: Régulation et Dérèglements de la Station Debout*. 3rd ed. Paris: Masson, 2005.
 28. Vuillerme N, Chenu O, Pinsault N, et al. Can a plantar pressure-based tongue-placed electrotactile biofeedback improve postural control under altered vestibular and neck proprioceptive conditions? *Neuroscience* 2008; 155: 291–296. doi: 10.1016/j.neuroscience.2008.05.018
 29. Geurts AC, Nienhuis B and Mulder TW. Intrasubject variability of selected force-platform parameters in the quantification of postural control. *Arch Phys Med Rehabil* 1993; 74: 1144–1150.
 30. Bernard-Demanze L, Dumitrescu M, Jimeno P, et al. Age-related changes in posture control are differentially affected by postural and cognitive task complexity. *Curr Aging Sci* 2009; 2: 139–149.
 31. Bucci MP, Goulème N, Stordeur C, et al. Discriminant validity of spatial and temporal postural index in children with neurodevelopmental disorders. *Int J Dev Neurosci* 2017; 61: 51–57. doi: 10.1016/j.ijdevneu.2017.06.010
 32. Elliott DB, Patla AE, Flanagan JG, et al. The Waterloo Vision and Mobility Study: postural control strategies in subjects with ARM. *Ophthalmic Physiol Opt* 1995; 15: 556–559. doi: 10.1016/0275-5408(95)00025-9
 33. Kotecha A, Chopra R, Fahy RT, et al. Dual tasking and balance in those with central

- and peripheral vision loss. *Invest Ophthalmol Vis Sci* 2013; 54: 5408–5415. doi: 10.1167/iovs.12-12026
34. Jahn K, Kressig RW, Bridenbaugh SA, et al. Dizziness and unstable gait in old age: etiology, diagnosis and treatment. *Dtsch Arztebl Int* 2015; 112: 387–393. doi: 10.3238/arztebl.2015.0387
35. Black AA, Wood JM, Lovie-Kitchin JE, et al. Visual impairment and postural sway among older adults with glaucoma. *Optom Vis Sci* 2008; 85: 489–497. doi: 10.1097/OPX.0b013e31817882db
36. Kotecha A, Richardson G, Chopra R, et al. Balance control in glaucoma. *Invest Ophthalmol Vis Sci* 2012; 53: 7795–7801. doi: 10.1167/iovs.12-10866
37. Agostini V, Sbröllini A, Cavallini C, et al. The role of central vision in posture: postural sway in Stargardt patients. *Gait Posture* 2016; 43: 233–238. doi: 10.1016/j.gaitpost.2015.10.00
38. Peterka RJ. Sensorimotor integration in human postural control. *J Neurophysiol* 2002; 88: 1097–1118.
39. Eikema DJ, Hatzitaki V, Konstantakos V, et al. Elderly adults delay proprioceptive reweighting during the anticipation of collision avoidance when standing. *Neuroscience* 2013; 234: 22–30. doi: 10.1016/j.neuroscience.2012.12.053
40. Prasertsakull T, Kaimuk P, Chinjenpradit W, et al. The effect of virtual reality training on motor learning and postural control in healthy adults: a randomized preliminary study. *Biomed Eng Online* 2018; 17: 124. doi: 10.1186/s12938-018-0550-0
41. Schättin A, Arner R, Gennaro F, et al. Adaptations of prefrontal brain activity, executive functions, and gait in healthy elderly following exergame and balance training: a randomized-controlled study. *Front Aging Neurosci* 2016; 8: 278. doi: 10.3389/fnagi.2016.00278
42. Segev-Jacobovski O, Herman T, Yogeve-Seligmann G, et al. The interplay between gait, falls and cognition: can cognitive therapy reduce fall risk? *Expert Rev Neurother* 2011; 11: 1057–1075. doi: 10.1586/ern.11.69
43. Varin M, Kergoat MJ, Belleville S, et al. Age-related eye disease and participation in cognitive activities. *Sci Rep* 2017; 7: 17980. doi: 10.1038/s41598-017-18419-2.
44. Kovács E, Tóth K, Dénes L, et al. Effects of exercise programs on balance in older women with age-related visual problems: a pilot study. *Arch Gerontol Geriatr* 2012; 55: 446–452. doi: 10.1016/j.archger.2012.01.009
45. Fletcher DC and Schuchard RA. Visual function in patients with choroidal neovascularization resulting from age-related macular degeneration: the importance of looking beyond visual acuity. *Optom Vis Sci* 2006; 83: 178–189. doi: 10.1097/01.opx.0000204510.08026.7f.
46. Haegerstrom-Portnoy G, Schneck M and Brabyn J. Seeing into old age: vision function beyond acuity. *Optom Vis Sci* 1999; 76: 141–158. doi: 10.1097/00006324-199903000-00014
47. Tarita-Nistor L, González EG, Markowitz SN, et al. Increased role of peripheral vision in self-induced motion in patients with age-related macular degeneration. *Invest Ophthalmol Vis Sci* 2008; 49: 3253–3258 doi: 10.1167/iovs.07-1290.
48. Van Der Kooij H, Campbell AD and Carpenter MG. Sampling duration effects on centre of pressure descriptive measures. *Gait Posture* 2011; 34: 19–24. doi: 10.1016/j.gaitpost.2011.02.025.