Visual Psychophysics and Physiological Optics

Myopes Show Greater Visually Induced Postural Responses Than Emmetropes

Diane N. Sayah,[1] Kristin Asaad,[1] Jean-Marie Hanssens,[1] Guillaume Giraudet,[1,2] and Jocelyn Faubert[1]

[1]École d'optométrie, Université de Montréal, Montréal, Québec, Canada
[2]Essilor Canada Ltd., Montréal, Québec, Canada

Correspondence: Guillaume Giraudet, Visual Psychophysics and Perception Laboratory, École d'optométrie - Université de Montréal, CP 6128, succ. Centre-ville, Montréal, Québec, H3C 3J7 Canada; guillaume.giraudet@umontreal.ca.

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Purpose. The literature already establishes that vision plays a crucial role in postural control and that this visual dependence shows intra- and interindividual variability. However, does ametropia also have an effect on postural control? This question leads to our study, which aims primarily to determine if myopes and emmetropes behave differently in terms of postural control when subjected to visual stimulation, and secondarily, if this difference persists in the presence of barrel and pincushion distortions. The results could lead, among other things, to improved lens design.

Methods. Twenty-four subjects (12 myopes of −2.00 to −9.00 diopters [D] and 12 emmetropes of −0.50 to +0.50 D), between 19 and 35 years of age, participated in the study after comprehensive eye examinations were carried out. Of the 12 myopes, the preferred type of correction was divided equally within the group. While standing in front of a projection system and fixating on an immobile point, a checkerboard stimulus was displayed in their peripheral visual field, in either a static or dynamic state. Three conditions of optical distortion (plan, pincushion, and barrel distortions) were presented to the subjects. Their postural response was measured and recorded using a system of infrared cameras and optical sensors positioned on a helmet.

Results. The results show that postural instability induced by a dynamic peripheral stimulus is higher for myopes compared with emmetropes (ANOVA Refractive Error, $F_{1,22} = 5.92$, $P = 0.0235$). When exposed to optical distortions, the two groups also have significant differences in postural behaviors (ANOVA Refractive Error*Optical Distortion, $F_{2,44} = 5.67$, $P = 0.0064$).

Conclusions. These results suggest that refractive error could be a factor in explaining individual variations of the role of vision in postural control.

Keywords: postural control, optical distortion, interindividual, sensory-motor

Proper postural control is essential in maintaining a healthy and stable body, ensuring safety and preventing injuries. The visual system is evidently involved in postural stability[1,2] and many studies have already demonstrated that visual impairment is a factor that can significantly increase the risk of falls, especially in the elderly.[3–5] Moreover, Reinstein et al.[6] found that more than one-third of elderly patients who were hospitalized due to a fall presented visual acuity deficit that could be easily corrected with an adapted prescription.

Although other sensory systems are involved in maintaining the stability of the body in space,[7] the role of vision is crucial in postural control, especially in the upright position.[1,2] The literature already provides insight into how intraindividual factors, such as image resolution,[8] viewing distance,[9] movement velocity,[10] and the nature of the task or instructions,[11] may affect the role of vision in postural control. However, until now, the only interindividual factor examined and found to influence the role of vision in postural stability is age,[12–14] but the role of refractive error on postural control was never examined.

According to studies on the effect of age on postural control, visually driven postural reactivity in dynamic conditions changes over time. Vision seems to be overrepresented in children (5–16 years old)[12] and in the elderly (65 years and older),[14] whereas its influence decreases and stabilizes between the ages of 18 and 19 years[12] up to approximately 45 years.[13]

In parallel with the period at which postural control develops and is more dependent on vision in children (5–19 years), there is a concurrent development of "youth-onset myopia" (6–19 years of age) according to Grosvenor's[15] myopia review.

The coinciding periods of development of postural control and myopia can lead us to believe that refractive error could have an effect on posture as an interindividual factor.

Some studies suggest that refractive error and postural control could indeed be correlated. Charman,[16] for example, proposes that posture may be important in regulating the risk of developing myopia in children, through a mechanism involving the peripheral retina. A number of studies involving current correction modalities, including methods for myopia control, also suggest that the peripheral retina may play a role in the development and progression of myopia.[17–19] In addition, the literature provides evidence that myopes and emmetropes possess intrinsic differences.[20]

Knowing that the peripheral visual experience differs between myopes and emmetropes and that peripheral quality may potentially affect posture, it is reasonable to believe, as

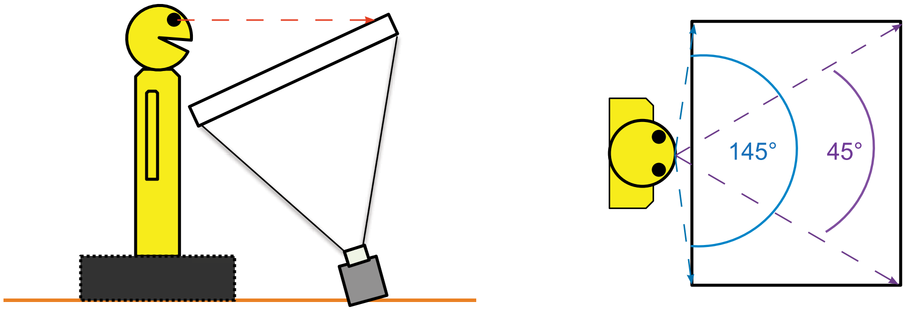

Figure 1. *Left*: Illustration of a subject facing the projection surface and fixating the red target at eye level. *Right*: Illustration of the stimulated lower visual field during the experiment.

previously mentioned, that refractive error could therefore have an effect on postural control. This leads to the primary objective of this study, which aims to determine if there is a difference in terms of visually induced postural response between myopes and emmetropes, when considering a visual stimulus in motion that is presented in the peripheral visual field.

In youth-onset myopia, changes in refractive error usually occur progressively and must be corrected to provide clear vision. The progression of myopia can expose subjects to blur, whereas spectacles as a correction modality can expose them to distortions. Therefore, myopes also differ from emmetropes from their exposition to blur and distortions. Many studies have evaluated blur and posture and show that a large quantity of blur is required to significantly increase postural instability.[8] Although the progression of myopia can sometimes occur rapidly, it is rare for a subject to be undercorrected by multiple diopters, therefore this condition is not representative of the visual exposition of most myopes.

Dynamic distortions, however, are interesting because they are induced by ophthalmic lenses, but not by contact lenses, and because they create a movement of the image in the same or opposite direction as the movement of an ophthalmic lens. Moreover, in our study, most individuals would instantly report a subjective effect on posture when asked to wear distortion-inducing spectacles.

Contrarily to blur, very few studies, if any, have looked at optical distortions in isolation from blur and their impact on posture. This leads to the second objective of our study, which is to determine if there is a difference in postural reactivity between myopes and emmetropes when subjected to various optical distortions, mainly barrel and pincushion distortions of approximately −10% and +10%, respectively.

METHODS

Stimuli

Stimuli were displayed on a flat opaque projection surface measuring 90 × 115 cm, with a 17-degree inclination. The visual field covered by the screen is of 45 degrees superiorly (the superior portion is the farthest portion from the subject) and 145 degrees inferiorly (the closest portion to the subject). The latter consists of 80% of the total inferior visual field (Fig. 1B). While fixating a red still target placed at eye level in the center of the projection surface (Fig. 1A), a peripheral stimulus consisting of a checkerboard was presented in either a static (stationary) condition, or a dynamic (in motion) condition with a periodic sinusoidal translation movement of amplitude of 15 degrees (Fig. 2). This translation movement could have two directions: anteroposterior (AP) or mediolateral (ML). The black-and-white checkerboard's oscillation frequency was 0.25 Hz, and the projected stimulation had an average luminance of 6.0 cd/m^2, a spatial resolution of 100 pixels/cm^2, and a contrast of 0.929 based on Michelson contrast. The experiment was done under low light conditions (10 lux).

Subjects

Twenty-four subjects participated in this study: 12 emmetropes, including 3 males and 9 females, and 12 myopes, including 4 males and 8 females. Participants were between 19 and 35 years of age, had 20/20 monocular corrected Snellen acuity, no binocular vision disorders, and absence of ocular or systemic disease that could have an impact on balance. Before the study, each participant had to pass a complete eye examination at the university's optometry clinic, which ensured the eligibility of participants as well as all information regarding their refractive error, binocular vision, and general health. The participants were fitted in soft contact lenses under the supervision of an optometrist. Patients with anisometropia or astigmatism greater than 1.00 diopter (D) were excluded. The group of myopes included subjects with ametropia of −2.00 to −9.00 D (mostly between −2.00 and −4.50 D, with only one participant with a −9.00 D myopia), whereas all subjects having a refractive error between +0.50 and −0.50 D were considered in the group of emmetropes. In the group of myopes, 6 subjects were corrected with spectacles and 6 subjects were corrected with contact lenses for more than 50% of the time; however, all 12 subjects were accustomed to both types of correction.

Experimental Procedure

The research followed the tenets of the Declaration of Helsinki and was approved by the institutional review board. Informed consent was obtained following the presentation of the project, and before testing. The subjects were asked to stand in an upright position facing the prototype, feet touching, without shoes, and with their arms hanging along the sides of their body. A helmet with six optical marker sensors (whose signal was captured by nearby infrared cameras) was placed on

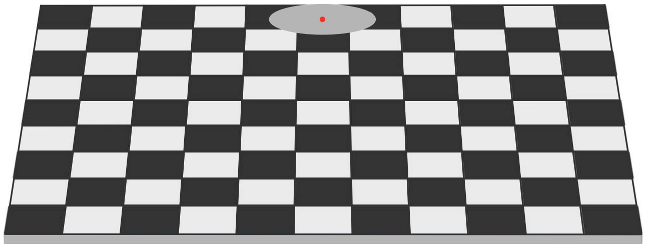

Figure 2. Scheme of the checkerboard stimulus and red fixation target presented during the experiment.

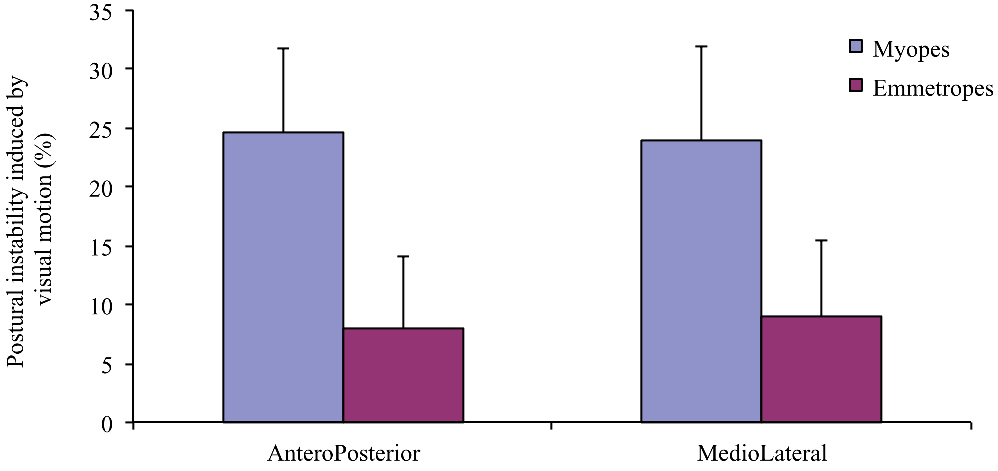

FIGURE 3. Increase in postural instability, expressed in percentage of the dynamic/static stimulus, in function of the direction of motion of the stimuli (AP versus ML) in the plano condition; the *error bars* represent SEs.

the head, and glasses inducing a set amount of distortion were placed in front of the participant's eyes. The pupillary distance for each participant was measured to allow proper centration of the ophthalmic lenses. Moreover, previous testing with a sample of participants ensured that the frame used in the study allowed an average of 13.75-mm vertex distance. The experiment included three blocks in which the effects of various distortions (0%, +10%, and –10%) were tested in a random order. Each trial lasted 64 seconds and each condition was repeated three times. A pause of a few seconds was established between each trial. Thus, three conditions were repeated three times each and given the preliminary examination; the experiment lasted approximately 1 hour.

Static distortion, or magnification, is expressed as a percentage, which characterizes the entire surface of a lens. Both barrel (–10%) and pincushion (+10%) distortions, which were induced in this experiment, result in a change of magnification of the perceived image.[21] The power of the lenses producing the required amount of distortion (D) was determined by using the following equation:

$$D = 100(W - w)/w$$

W is the real angular magnification of peripheral rays, and w is the paraxial angular magnification, such as:

$$W = h'/h \quad \text{and} \quad w = \frac{1}{(1 - t/n \cdot D_1)\cdot(1 - z \cdot F'_f)},$$

where t is the central thickness of the lens, n the refractive index, D_1 the front surface power, z the distance between the back surface of the lens and the entrance pupil, and F'_f the back vertex power.

In the context of this experiment, the power of the best form ophthalmic lenses inducing a +10% distortion was calculated to be +4.00 D, whereas the power of the lenses inducing a –10% distortion was –7.00 D. To keep the stimulus in focus and provide 20/20 vision during the experiment, the dioptric power of the ophthalmic lenses as well as the subject's refractive errors were corrected through carefully chosen contact lenses. The power of the contact lenses considered a 13.75-mm vertex distance and was compensated for it.

Data Analysis

Two within-subject (direction of motion; optical distortion) and one between-subject (refractive error) independent variables were considered. The postural perturbations to the various stimuli conditions are quantified by using the velocity root mean squared or VRMS. This is a measure of velocity indicating the total body displacement in the horizontal plane (AP "z-axis" and ML displacements "x-axis") in meters per second.[14,22,23]

The data analysis for postural instability is expressed as a ratio of the global postural reactivity in dynamic conditions over the reactivity in static conditions for each subject. Knowing that postural reactivity varies from one individual to another, this method of comparison allows using participants as their own control. Thus, the results, which are expressed as a percentage of the increase in instability, reflect the effects of the dynamic stimulus on postural stability.

RESULTS

Three-way repeated-measures ANOVA was conducted with optical distortion (plano, +10%, –10%) and movement direction (AP and ML) as within-subject variables and refractive error (emmetropes and myopes) as between-subject variable. The results showed that global postural instability induced by visual movement was significantly higher for myopes than emmetropes (ANOVA Refractive Error, $F_{1,22} = 5.92$, $P = 0.0235$). This disparity in postural reactions between both groups was not different when stimuli moved in AP and ML directions (ANOVA Refractive Error*Movement Direction, $F_{1,22} = 0.14$, $P = 0.7157$) (Fig. 3). The average VRMS in static condition was 0.0139 m/s (SD = 0.0055) for myopes and 0.0128 m/s (SD = 0.0038) for emmetropes. When the dynamic stimulus was shown, postural reactivity increased and the VRMS values for AP and ML translation were of 0.0182 m/s (SD = 0.0058) and 0.0173 m/s (SD = 0.005), respectively, for myopes and 0.0138 m/s (SD = 0.0045) and 0.0145 m/s (SD = 0.0049) for emmetropes.

In the following figures (Figs. 3, 4), postural instability for each subject is expressed as a ratio of their reactivity in dynamic conditions over their reactivity in static conditions. Therefore, a higher percentage of postural instability signifies that the subject is more reactive, from a postural point of view, in the dynamic condition than in the static condition.

Overall postural stability did not change when optical distortions were added to the visual stimulation (ANOVA Optical Distortion, $F_{2,44} = 1.73$, $P = 0.1897$); however, the interaction between Refractive Error and Optical Distortion factors was significant ($F_{2,44} = 5.67$, $P = 0.0064$).

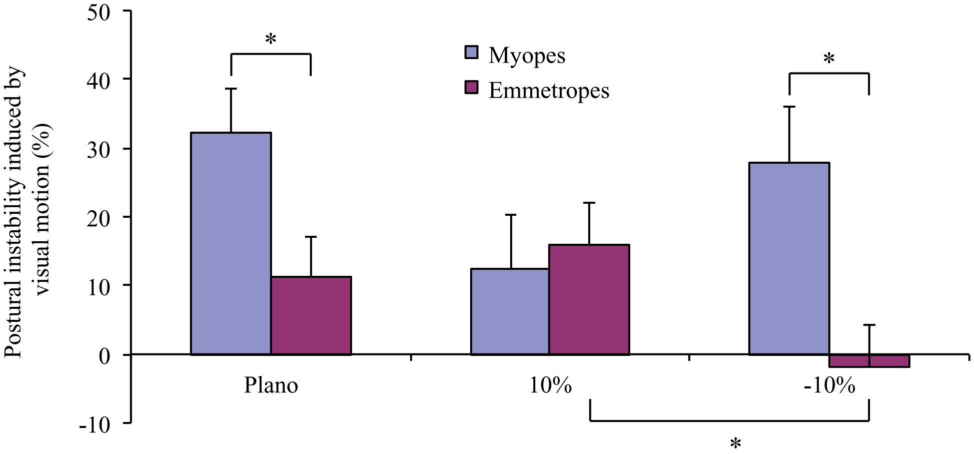

FIGURE 4. Increase in postural instability, expressed in percentage of the dynamic/static stimulus, in function of the spectacle-induced optical distortions (0, +10%, and –10%); the *error bars* represent SEs and the *stars* represent significant differences obtained with post hoc Fisher test.

The results suggested that the posture of myopes was more affected by visual movement than the posture of emmetropes in both plano and –10% conditions; however, this relative difference in postural instability between both groups changed when they were exposed to the optical distortion of +10% (Fig. 4).

DISCUSSION

The results of the present study represent novel information with regard to the specific effects of refractive error on postural control. The global postural response induced by a moving visual stimulus presented in the peripheral visual field was indeed more pronounced for the myope versus the emmetrope group.

This result might be explained by the differences in eye shape and properties of the peripheral retina between myopes and emmetropes. Indeed, the literature provides evidence that the peripheral retina plays a role in the development of myopia,[17–19] but also that it is involved in visually induced postural control.

When exposed to peripheral visual stimulation, posture control differs in children as compared with young adults.[16]

The visually induced postural responses of myopes and emmetropes also could be different because of different developmental conditions. Numerous studies indicate that the visual system develops over multiple sensitive periods.[24] Although many aspects of vision are developed before the age of 6, such as orientation, spatial frequency, and contrast perception, many others develop later. This subsequent period is of interest because the development of motion sensitivity and visuo-postural interactions continue during this stage. According to Greffou et al.,[12] visually dependent postural control continues to change up to 16 years of age and even later for some conditions. "Youth-onset myopia," as defined by Grosvenor,[15] falls within the same age bracket. The concomitance of these two periods, namely of postural control and of myopia onset, suggests the interesting hypothesis that posture and refractive error could be associated.

Some studies have already indicated that exposure to blur, as experienced in myopes, could lead to improved performance in blurry conditions.[25] Giraudet and Azavant[26] also showed that myopes had better abilities for localizing targets in briefly displayed blurred images. Myopes were more efficient than emmetropes for using contextual information provided by the surrounding scenes. More recently, Giraudet and Faubert[27] suggested that differences between myopes and emmetropes also could be evident in visual functions other than spatial resolution. They reported enhanced dynamic visual acuity as well as decreased motion sensitivity thresholds for myopes. These studies suggest that myopes and emmetropes show dissimilar behaviors, including visual perception processing differences, which could be related to alternate developments and visual history. Therefore, myopes, who have a greater sensitivity to dynamic stimuli, also could have greater visually induced postural reactions to dynamic stimuli than emmetropes.

The results of our experiment show for the first time that there is a difference between myopes and emmetropes in terms of postural response induced by a peripheral stimulus in motion. Our study does not, however, determine the exact origin of this difference. To link it to developmental changes of the postural control system, a longitudinal study would have to be led to measure the visuo-postural interaction as the myopia progresses over the childhood and teenage years. Similarly, to investigate the anatomical hypothesis, the study should include precise measurements of anatomical characteristics of the eyes of the subjects and determine the properties of the images as they are projected on the retina and thus perceived by the observers.

The second part of the experiment, which consisted of inducing barrel and pincushion distortions and measuring postural reactivity, was also never previously tested, and very few studies, if any, are available on the subject. Morgan[28] defines optical distortions as monochromatic aberrations that affect the proportions of an image without changing its focus. These aberrations, which are expressed as a percentage and characterize the entire surface of a lens, result in a stretching or magnification of the perceived image, especially noticeable when looking through the periphery of a lens. Because a contact lens is placed on the ocular surface, the optical axis remains aligned with the visual axis of the wearer in all viewing directions, resulting in minimal distortion. According to Bennett and Rabbetts,[29] this contact lens–induced amount of distortion should vary from "approximately 1% to no more than 2%," rendering the values of 10% used in our experiment approximate. Optical distortions can vary depending on the parameters of ophthalmic lenses (power, front and back curvature, thickness, and refractive index), as well as their adjustment on the wearer (e.g., distance from the eye). Negative lenses, usually worn by myopes, induce a negative or barrel distortion (Fig. 5), and although the perceived field of vision through the lens is larger, the size of the image seems

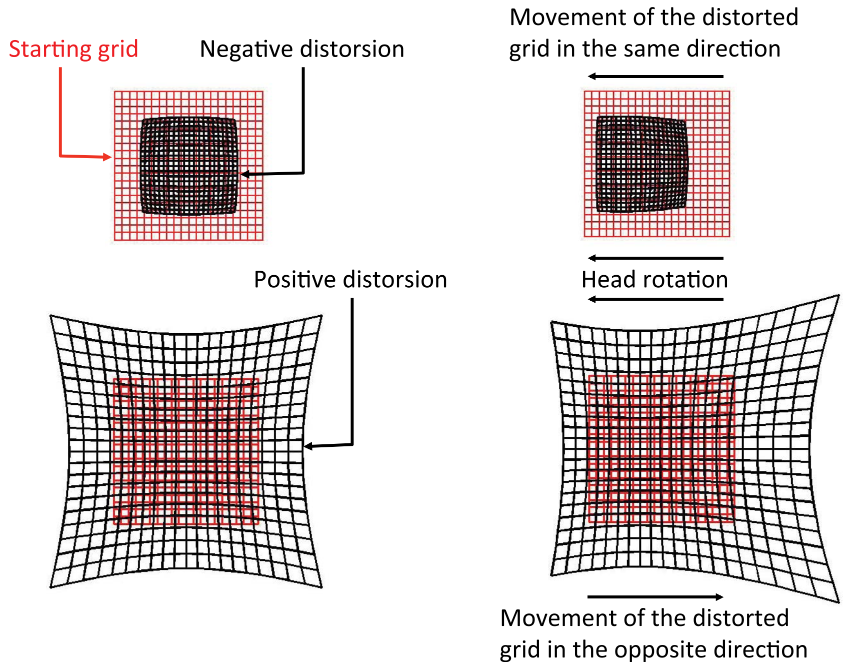

FIGURE 5. Illustration showing types of distortions (barrel or pincushion) and direction of displacement of the image (direct or indirect, respectively) for both types of induced distortions.

smaller. These lenses also generate a direct displacement of the image when the wearer rotates his or her head while fixating a stationary target; this means that the image seems to move in the same direction as the head rotation.[29] On the contrary, positive lenses, which can correct hyperopia, induce a positive or pincushion distortion (Fig. 5), and show an enlarged image of the object and a smaller field of vision. The displacement of the image in this case is indirect; it is made in the direction opposite to the head rotation.[30,31] These elements mean that the velocity of the movement of the stimulus seems reduced for negative lenses and increased for positive lenses. This can result in a different visual perception of motion for both lenses and consequently modify the body's postural response to the stimulus.

Our results showed that −10% distortion followed the same trend as for the plano condition; the postural control of myopes exhibited more instability compared with emmetropes. However, the results for the +10% distortion condition do not correspond with what was expected. For emmetropes, an increase in postural instability is detected when compared with the condition of −10% distortion. This could be explained by the characteristics of positive lenses, which increase the amplitude of the movement and cause an indirect displacement of the image when the head moves. Although this visual disturbance is unusual for emmetropes, it did not significantly alter the average postural behavior of this population compared with the condition of 0% distortion. For myopes, the condition of +10% distortion represents the opposite of their visual habits. Considering the opposing characteristics of +10% distortions and −10% distortions, we would expect myopes to exhibit even more postural reactivity; however, although our data do not show statistical differences between the groups, myopes tended to adopt a rigidity behavior toward a body-stiffening strategy rather than an increased instability to limit the oscillations and risk of falling. This rigidification strategy has been described in the literature as a strategy that can be adopted when "risky" situations take place and can indicate a tighter anticipatory neuromuscular control of posture.[32]

One possible explanation for the adoption of the difference in postural strategy shown by myopes is perhaps that the changes induced in the +10% condition are so unusual to myopes that, if they were not reined in, would produce high levels of oscillations and a risk of falling. However, because both myopes and emmetropes are unaccustomed to positive distortions, the same kind of postural behavior should be expected from both groups. An alternative explanation could then involve anatomical variations between myopic and emmetropic eyes, including longer axial lengths and different peripheral retinal shapes in myopic eyes, which could amplify the perception of distortions and consequently generate a different postural strategy in myopes.

Following this reasoning, this could indicate that distortions in the peripheral retina are amplified for myopes due to a longer axial length and different retinal shape compared with emmetropes.

As mentioned previously, the evaluation of this hypothesis would require precise measurements of ocular anatomical characteristics of the participants. This constitutes a limitation of our study, as these values were not measured in this experiment. Further studies are necessary to confirm the exact mechanism by which the postural strategy is adopted in myopes when positive distortions are presented. Despite the small variation in the exact amount of distortion induced due to the contact lenses, the gross amount of distortion induced remains close to the desired 10% value and the quantity of distortion induced remains significant to give a global idea of the effect of barrel and pincushion distortions on posture. Therefore, sufficient evidence remains to clearly indicate that there is a difference in the postural behavior of myopes and emmetropes in all conditions tested in this experiment.

CONCLUSIONS

The results of the present study demonstrate that visually induced postural reactivity differs according to ametropia. Myopes exhibit more postural instability than emmetropes when subjected to peripheral dynamic visual stimuli. In the presence of barrel distortions (–10%), myopes remain more reactive than emmetropes from a postural point of view. This study allows us to confirm that a correlation between refractive error and postural control indeed exists, even in the presence of optical distortions, and opens the door for more studies about the extent of this relation and its underlying mechanisms.

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References

1. Mahboobin A, Loughlin PJ, Redfern MS, Sparto PJ. Sensory re-weighting in human postural control during moving-scene perturbations. *Exp Brain Res*. 2005;167:260–267.
2. Oie KS, Kiemel T, Jeka JJ. Multisensory fusion: simultaneous re-weighting of vision and touch for the control of human posture. *Cog Brain Res*. 2002;14:164–176.
3. Harwood, RH. Visual problems and falls. *Age Ageing*. 2001;30:13–18.
4. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med*. 1988;319:1701–1707.
5. Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the Blue Mountains Eye Study. *J Am Geriatr Soc*. 1998;46:58–64.
6. Reinstein DZ, Dorward NL, Wormald RP, et al. 'Correctable undetected visual acuity deficit' in patients aged 65 and over attending an accident and emergency department. *Br J Ophthalmol*. 1993;77:293–296.
7. Perteka RJ, Benolken MS. Role of somatosensory and vestibular cues in attenuating visually induced human postural sway. *Exp Brain Res*. 1995;105:101–110.
8. Straube A, Paulus W, Brandt T. Influence of visual blur on object-motion detection, self-motion detection and postural balance. *Behav Brain Res*. 1990;40:1–6.
9. Paulus WM, Straube A, Brandt T. Visual stabilization of posture. *Brain*. 1984;107:1143–1163.
10. Hanssens JM, Allard R, Giraudet G, Faubert J. Visually induced postural reactivity is velocity-dependent at low temporal frequencies and frequency-dependent at high temporal frequencies. *Exp Brain Res*. 2013;229:75–84.
11. Stins JF, Beek PJA. Critical evaluation of the cognitive penetrability of posture. *Exp Aging Res*. 2012;38:208–219.
12. Greffou S, Bertone A, Hanssens JM, Faubert J. Development of visually driven postural reactivity: a fully immersive virtual reality study. *J Vis*. 2008;15:1–10.
13. Poulain I, Giraudet G. Age-related changes of visual contribution in posture control. *Gait Post*. 2008;2:1–7.
14. Lord SR, Menz HB. Visual contributions to postural stability in older adults. *Gerontol*. 2000;46:306–310.
15. Grosvenor T. A review and a suggested classification system for myopia on the basis of age-related prevalence and age of onset. *Am J Optom Physiol Opt*. 1987;64:545–554.
16. Charman WN. Myopia, posture and the visual environment. *Ophthalmic Physiol Opt*. 2011;31:494–501.
17. Bernsten DA, Barr CD, Mutti DO, Zadnik K. Peripheral defocus and myopia progression in myopic children randomly assigned to wear single vision and progressive addition lenses. *Invest Ophthalmol Vis Sci*. 2013;54:5761–5770.
18. Benavente-Pérez A, Nour A, Troila D. Axial eye growth and refractive error development can be modified by exposing the peripheral retina to relative myopic and hyperopic defocus. *Invest Ophthalmol Vis Sci*. 2014;55:6765–6773.
19. Lin Z, Martinez A, Chen X, et al. Peripheral defocus with single-vision spectacle lenses in myopic children. *Optom Vis Sci*. 2010;87:4–9.
20. Lundström L, Mira-Agudelo A, Artal P. Peripheral optical errors and their change with accommodation differ between emmetropic and myopic eyes. *J Vis*. 2009;9(6):17.
21. Jalie M. *The Principles of Ophthalmic Lenses*. London: The Association of Dispensing Opticians; 1977.
22. Faubert J, Allard R. In: AJ Woods, JO Merrit, SA Benton, MT Bolas, ed. Effect of visual distortion on postural balance in a full immersion stereoscopic environment. *In Stereoscopic Displays and Virtual Reality Systems XI (SPIE)*. San Jose, CA; 2004:5291–5294.
23. Piponnier JC, Hanssens JM, Faubert J. Effects of visual field locus and oscillation frequencies on posture control in an ecological environment. *J Vis*. 2009;9(1):1–10.
24. Lewis, TL, Maurer D. Multiple sensitive periods in human visual development: evidence from visually deprived children. *Dev Psychobiol*. 2005;46:163–183.
25. Rosenfield M, Hong SE, George S. Blur adaptation in myopes. *Optom Vis Sci*. 2004;81:657–662.
26. Giraudet G, Azavant L. Object localization in blurred and jumbled scenes: differences between myopic and emmetropic observers. *Invest Ophthalmol Vis Sci*. 2006;47:4146–4151.
27. Giraudet G, Faubert J. Myopes exhibit better performances than emmetropes for dynamic visual perception tasks. *Invest Ophthalmol Vis Sci*. 2011;52:E2812.
28. Morgan M. *The optics of ophthalmics lenses*. University of California, Berkeley: Professional Press, Inc.; 1978.
29. Bennett AG, Rabbetts RB. Subsidiary effects of correcting lenses; magnifying devices. In: *Clinical Visual Optics*. London, UK: Butterworths; 1984;244.
30. Fry GA. Displaying distortion in ophthalmic lenses. *Am J Optom Physiol Opt*. 1977;54:282–285.
31. Faubert J. The influence of optical distortions and transverse chromatic aberration on motion parallax and stereopsis in natural and artificial environments. In: Javidi B, Okano F, eds. *Three-dimensional Television, Video and Display Technologies*. Berlin, Germany: Springer Verlag, Physics Edition ed. 2002:359–396.
32. Stins JF, Roerdink M, Beek PJ. To freeze or not to freeze? Affective and cognitive perturbations have markedly different effects on postural control. *Hum Mov Sci*. 2011;30:190–202.