The Influence of Corrective Lenses on Foot Displacement During Gait: Implications on Falling and Disability

R2D2 Center Rehabilitation Research Design & Disability
University of Wisconsin–Milwaukee

Dennis Tomashek, MS, Kevin Keenan, PhD, Kurt Beschorner, PhD, Caitlin Moore, MS, Roger O. Smith, PhD

UNIVERSITY of WISCONSIN UWMILWAUKEE

Abstract

Objectives: Pilot study to explore a method to measure the amount of foot placement error caused by varying strength multifocal lens eyeglasses when stepping down from a raised surface onto a target while walking and identify changes in gait that may lead to increased risk rate for falls.
Design: A within-subjects repeated measures design with random order of conditions. (Lens Strength, Target Position, & Walking vs. Standing).
Setting: Gait Analysis & Biodynamics Laboratory on the UWM campus.
Participants: 12 young adult (18-25) non-multifocal lens wearers Participants with eye, balance, or gait pathology were excluded.
Interventions: Multifocal reading eyeglasses with +1.75, +2.50, and +3.50 diopter add lenses in the lower portion of progressive lens glasses and non-corrective clear eyeglasses.
Main Outcome Measures: Distance of foot placement from the target, measured with motion capture markers on the foot. Head flexion, overall gait speed, and step speed were also explored using motion data.

Background

- Falls are a leading cause of accidental deaths, and a major cause of hospitalization.
- Blurred or distorted vision in the lower visual field is a key factor leading to gait impairments (Marigold & Patla, 2007) associated with increased risk rate for falls.
- Presbyopia is a natural aging process in which the lens of the eye loses the ability to flex, leading to an inability to accommodate for near distance viewing, and occurs in 85-100% of adults over 45. Troubles viewing near objects require glasses with magnification, including reading glasses and multifocal lens glasses (MfLs), such as lined bifocals and unlined progressives.
- MfLs blur and distort vision in the lower visual field, and lead to changes in gait due to the magnification in the lower lens field, such as increased toe clearance when stepping up (Elliott & Chapman, 2010; Johnson, et al., 2008), and a cautious gait strategy when stepping down (Buckley, et al., 2005).
- Multifocal lens glasses may double the chance of falling (Lord & Dayhew, 2002).
- approximately 10% of fatal falls in older adults occur on stairs and steps, with inappropriate foot placement considered a major reason Lord et al. (2007).

Methods

The authors proposed to test 4 Hypotheses:
1. The amount of foot placement error, measured as the distance if the toe from a target (in millimeters) when stepping down can be reliably measured.
2. The strength of the add lens will be directly and positively correlated to the amount of foot displacement; the stronger the add lens magnification, the greater the amount of placement error.
3. Participants will use a more cautious, slower step down as the lens strength increases.
4. Participants will exhibit greater head flexion as the lens strength increases. This effect will be greatest for the target nearest the step.

Participants

12 young adults with normal or corrected to normal vision with contact lenses have participated.

Procedure

Participants step down from a 6" platform onto 1 of 3 targets at near, middle, and far stepping distances (all reachable in 1 step) projected randomly onto a force plate. Participants alternate stepping down from a standing position or walking to the edge of the platform.
4 lens conditions were used, clear (no prescription), +175, +2.50, and +3.50 diopter progressive lens glasses. Higher numbers indicate greater magnification. 96 trials for each participant: 2 (walking or standing) X 3 (target positions) X 4(Lens conditions); 4 trials of each condition

Instrumentation

Data collection took place at the GABL lab on the UWM campus. The lab is instrumented with force plates (AMTI) and motion capture equipment (Motion Analysis Corporation ©, 14 camera Raptor ® system). Foot displacement was measured by analyzing the ball of the foot position on the force plate in relation to the pre-calculated target. Distance from the target, gait speed, and head flexion were analyzed through motion capture analysis.

Data Analysis:

The main measures to evaluate the hypotheses were center of pressure of the foot while stepping to the target. The center of pressure is determined immediately after the ball of the foot contact at the first time point that the subject is applying more than 15% of their weight on the force plate. The distance between the center of pressure at this time point and the center of the target were recorded and the error was calculated as the distance from the target to the center of pressure. Toe clearance was calculated based on a marker placed at the most anterior part of the subject's shoe. Time to step to the target was the time that it took the subject from when their toe left the platform to when their foot first struck the force plate.

Results

	Figure 1: Means and Standard Deviations for outcome variables by condition				
	Lens Strength		Target Position		
Walking	No Correction	+3.50	Near	Middle	Far
Toe Distance*	23.05(15.87)	30.61(16.96)	17.77(11.21)	24.35 (13.64)	37.33 (18.27)
Head Flexion‡	-6.78 (7.01)	-9.54 (6.56)	-9.33 (8.20)	-7.79 (6.86)	-7.46 (5.68)
Walking Speed			1235.2 (142.1)	1153.9(169.81)	959.37 (255.03)
Standing	Lens Strength		Target Position		
Toe Distance*	17.72 (12.30)	24.87(14.06)	20.43 (13.91)	21.17(13.58)	22.30 (13.87)
Head Flexion‡	-9.59 (4.78)	-12.23 (3.48)	-14.91 (3.63)	-9.51 (3.78)	-10.86 (4.37)

* Toe Distance measured in millimeters; ‡ Head Flexion as angle of head relative to body; Walking Speed measured as millimeters per second

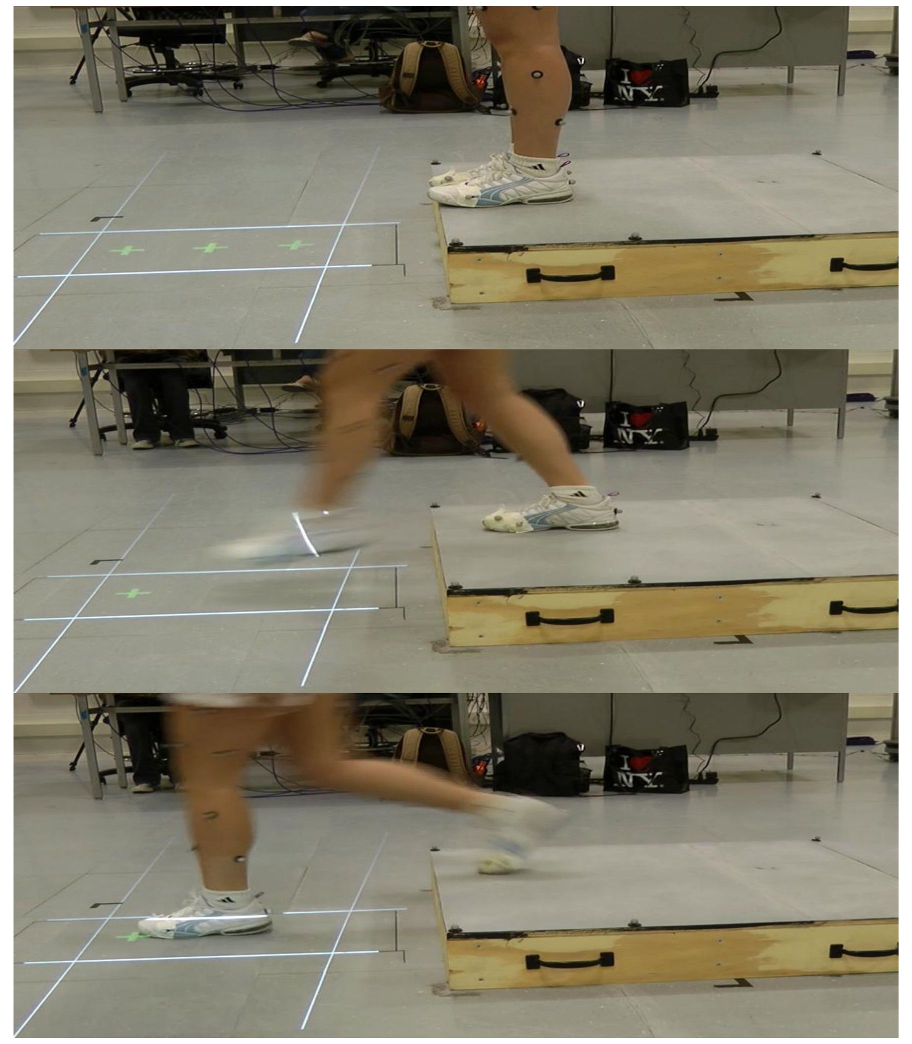

Figure 2: Participant completing stepping accuracy task.
Picture 1) All three possible targets are presented.
Picture 2) Far target presented, participant steps down while walking.
Picture 3) Participant steps down onto far target while walking.

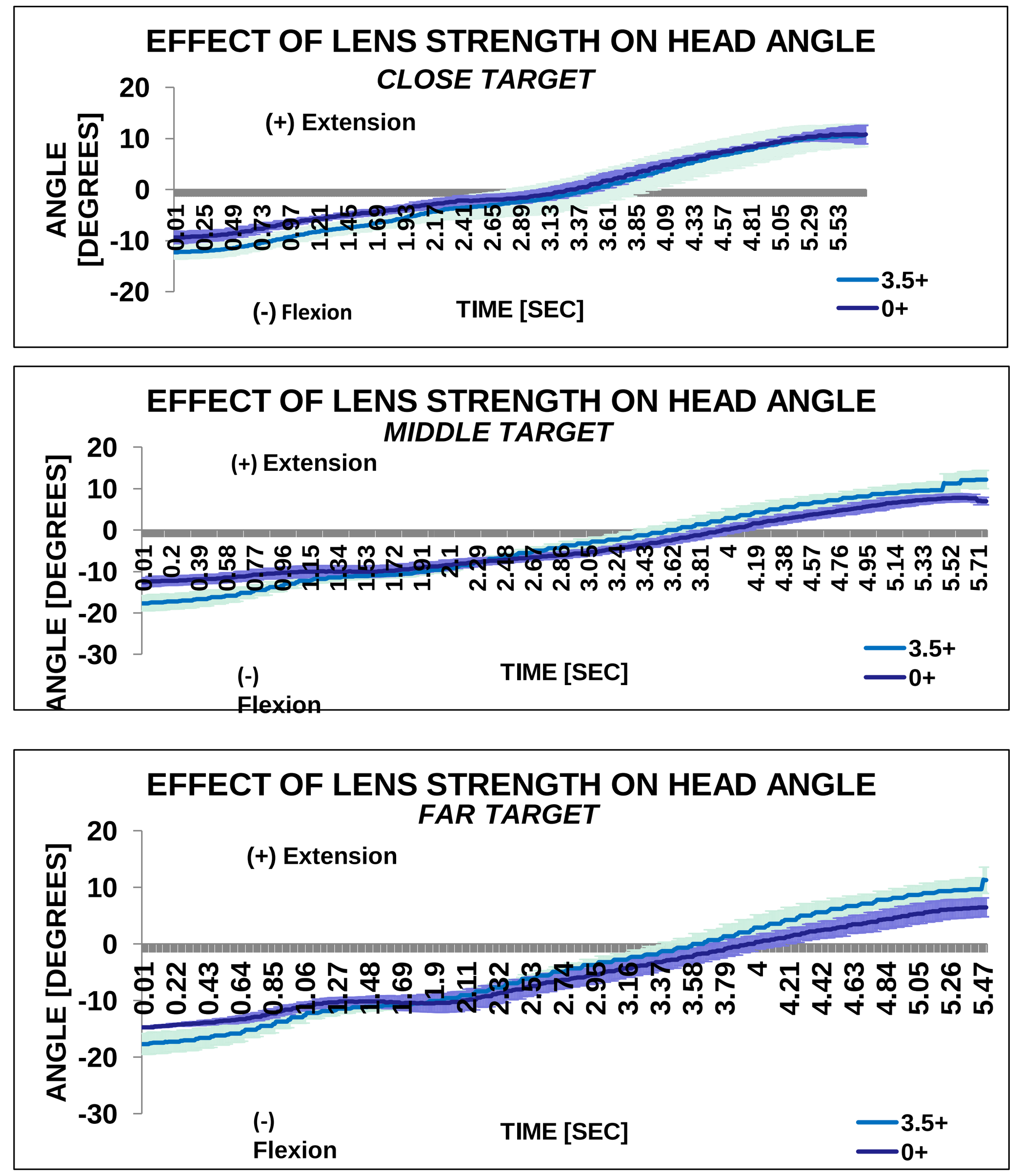

Figure 3: Results for head flexion by lens strength and stepping target distance measured with motion capture markers placed on the head for 1 participant.

Variable	Toe Distance	Head Flexion	Walking Speed
Walking Vs Standing Trials	F=.824, Sig=.366	F=8.027, Sig=.005	NA
Walking Trials			
Lens Strength (0 vs +3.50)	F=12.318, Sig=.001	F=2.806, Sig=.099	F=1.749, Sig=.192
Target Position (Near, Middle, & Far)	F=15.794, Sig=.000	F=.477, Sig=.623	F=10.429, Sig=.000
Lens x Target Interaction	F=.627, Sig=.538	F=.165, Sig=.849	F=2.073, Sig=.136
Standing Trials			
Lens Strength (0 vs +3.50)	F=4.246, Sig=.044	F=10.545, Sig=.002	NA
Target Position (Near, Middle, & Far)	F=.216, Sig=.807	F=23.243, Sig=.000	NA
Lens x Target Interaction	F=.630, Sig=.536	F=.461, Sig=.633	NA

Figure 4: Results of MANOVA comparing Walking vs Standing Trials, Lens Strength, & Target Position.

Conclusion

Hypothesis 1: Foot displacement error can be reliably detected using motion capture technology.

Hypothesis 2: A significant difference was found in the amount of foot displacement as the add lens strength changed.

Hypothesis 3: There was not a significant difference in walking speed for lens conditions.

Hypothesis 4: There was a significant difference in head flexion by both lens and target position for standing trials, but no significant differences in walking trials.

- MfLs can effect a person's perception when walking, which may lead to missteps, trips, or stumbles. These can be detrimental to safe ambulation, and may lead to an increased rate of falls, especially in aging adults.

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Contact:

R_2D_2 Center
UW-Milwaukee
PO Box 413
Milwaukee, WI 53201

Voice (414) 229-6803
Fax (414) 229-6843
TTY (414) 229-5628
www.r2d2.uwm.edu