Is the Gaze Behavior During Stair Walking Affected by Pregnancy?

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Abstract

During stair walking, there is an increased risk of falling among pregnant women. A substantial contribution for the foot placement and balance control during stair walking is provided by vision. The purpose of this study was to determine whether there are any pregnancy-related changes in gaze behavior during the stair ascending and stair descending. Six women participated in this study during their pregnancy, at the 14, 27, 31and 38 gestational weeks. Each data collection consisted of descending and ascending a 22-treads staircase, one tread at a time. To monitor the gaze location, a SensoMotoric Instruments eye-tracking glasses system (SMI, Inc.) was used. To compare the differences in the stair descent and stair ascent between the first, second, third and fourth data collection sessions effect size obtained by Cohen's d was used. Results of the gaze vector analysis revealed the turn of the gaze toward the handrail placement (gaze vector x) and toward the stair treads (gaze vector y), suggesting a wider awareness of the safety facility and a stronger need of the foot placement control during advanced phases of pregnancy.

Keywords: eye tracking, pregnancy, stair ascending, stair descending

1. Introduction

The eye tracking and gaze behavior analysis may serve as an indirect measure of brain function, mainly used in decision-making process studies (Dospinescu & Perca-Robu, 2017; Eckstein et al., 2017). The gaze analysis also provides information on attentional focus strategies as looking at particular location reflects both the time needed to process the stimulus and the attention engagement (Eckstein et al., 2017). During locomotion, vision has been observed to be a key factor contributing for foot placement and balance control (Den Otter et al, 2011; Patla, & Vickers, 1997; Hollands, & Maple-Horvat, 2001) and the deficit in gaze control was observed to increase the risk of falls during stair climbing (Di Fabio et al., 2008).

During pregnancy, the balance is altered and an increased incidence of falling has been reported. About 39 % of the falls happen on the stairs and the risk of falling is increasing with the advancing of the pregnancy. (Dunning, Lemasters, & Bhattacharya, 2010; Krkeljas, 2017; Inanir et al., 2014) Studies on non-pregnant subjects show that during a stair descent stairs edges are fixated for about 69 % of the total time spent on the stairs. The gaze is usually fixated three to five treads ahead during both stair descending and ascending condition. (Den Otter, et al, 2011; Zietz, Johannsen, & Hollands, 2011; Zietz, & Hollands, 2009) During stair ascent, the stair edges are fixated for about 48 % of the total time spent at the stairs (Den Otter et al, 2011) which is in accordance with previous studies showing a substantial contribution of peripheral visual information during the stair ascending (Zietz, & Hollands, 2009; Graci, Rabuffetti, & Ferrarin, 2017; Miyasike-daSilva, & McIlroy, 2012).

The aim of this study is to determine whether there are any pregnancy-related changes in gaze behavior during the stair ascending and descending that can contribute to the understanding of increase fall incidence on stairs in this period of women‘s life.

2. Material and Methods

6 women participated in this study during their pregnancies: at the 14 (±1.74), 27 (±2.45), 31 (±2.42) and 38 (± 1.23) gestational weeks (g.w.). Their mean age was 30 years (±2.23), mean height was 167.80 cm (±8.72), and mean body mass at the first, second, third and fourth data collection was 67.09 kg (±8.00), 74.69 kg (±8.93), 77.15 kg (±9.11) and 79.57 kg (±9.37), respectively. Inclusion criteria consisted of no medical condition affecting the vision or gait. An informed consent was provided by all participants before the first data collection and Ethical board of the Faculty of Sports Studies, Masaryk University, Brno, Czech Republic approved the study.

At each data collection, participants walked the same U-shaped staircase descending a 22-treads (riser: 0.16 m, run: 0.33 m, and width: 1.15 m), making a short U-turn downstairs and ascending back the staircase, one tread at a time (Figure 1). Only the data of stair walking were taken for further analysis. The staircase was equipped with a handrail on one side but none of the participants used it. To monitor the gaze a SensoMotoric Instruments (SMI) eye-tracking glasses (ETG) system (SMI, Inc.) at a frequency of 60 frames per second and 1280x960 pixel picture was used. Calibration was performed using a matrix of 3 points placed on a board in different highs and different horizontal placement. Mean gaze vectors of the right eye (x, y, z) for stair descent and stair ascent were obtained for each data collection session. Gaze vector x, y, z starts at the eye and heads off in mediolateral, up and down, and anterior-posterior direction, respectively (Figure 2) (Haffegee, Alexandrov, & Barrow, 2007; Scheel, & Staadt, 2015).

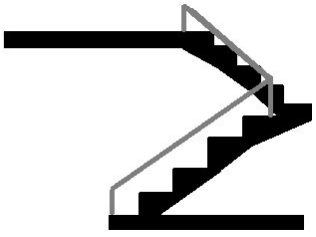

Figure 1. A simplified representation of the analysed staircase path

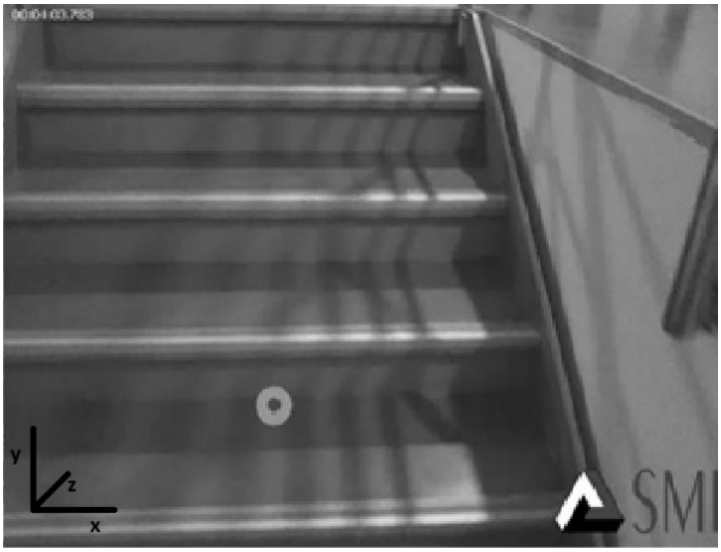

Figure 2. Eye-tracking glasses image showing the gaze location during stair ascent.

3. Statistical analysis

Effect size obtained by Cohen's *d* was used to compare the differences between the first, second, third and fourth data collection sessions for the stair descent and stair ascent. Cohen's d is interpreted as ≥ 0.20 small, ≥ 0.50 medium or clinically significant, and ≥ 0.80 large effect (Cohen, 1977).

4. Results

Means and standard deviations of gaze vector *x, y* and *z* for stair descending and stair ascending at analysed gestational weeks are shown in Table 1.

Table 1: Means and standard deviations (SD) of analyzed variables during the stair descent and stair ascent at 14, 27, 31 and 38 gestational weeks.

		Stair descending			**Stair ascending**		
		Vector x	**Vector y**	**Vector z**	**Vector x**	**Vector y**	**Vector z**
14 g.w.	mean	-0.08	-0.23	0.86	0.05	-0.11	0.91
	SD	0.14	0.2	0.17	0.14	0.18	0.21
27 g.w.	mean	-0.13	-0.35	0.84	0.01	-0.2	0.9
	SD	0.14	0.19	0.17	0.13	0.19	0.21
31 g.w.	mean	-0.14	-0.34	0.85	0.04	-0.16	0.91
	SD	0.15	0.21	0.17	0.15	0.21	0.2
38 g.w.	mean	-0.15	-0.33	0.85	-0.01	-0.16	0.93
	SD	0.13	0.2	0.18	0.15	0.2	0.18

For the stair descending, the effect size analysis showed a small or medium effect of pregnancy on gaze vector x and y (Table 2). Significant changes in gaze vector x, i.e. changes in the mediolateral direction of the gaze, showed that with advancing pregnancy the gaze turns noticeably towards the handrail location. The clinically significant effect was observed comparing 14 and 38 g.w. For the gaze vector y, i.e. up and down gaze characteristic, the moderately significant effect of pregnancy on the gaze turning towards the stairs was observed comparing the 14 g.w. with 27, 31 and 38 g.w. No effect of advancing pregnancy on gaze vector z, the anterior-posterior direction, was found.

Table 2: Results of Cohen's *d* and confidence intervals for analyzed variables for stair descending. Cohen's d is interpreted as ≥ 0.20 small (*), ≥ 0.50 medium, clinically significant (**), ≥ 0.80 large effect (***) (Cohen, 1977).

	Vector x	**Vector y**	**Vector z**
	Cohen's d	**Cohen's d**	**Cohen's d**
14 – 27 g.w.	-0.36 (-0.47; -0.25) *	-0.62 (-0.78; -0.46) **	0.12 (-0.02; 0.25)
14 – 31 g.w.	-0.41 (-0.53; -0.29) *	-0.54 (-0.70; -0.37) **	0.06 (-0.08; 0.19)
14 – 38 g.w.	-0.52 (-0.63; -0.41) **	-0.50 (-0.66; -0.34) **	0.06 (-0.08; 0.20)

For the stair ascending, a small effect of advancing pregnancy on gaze vector x and y was observed (Table 3). A small effect of advancing pregnancy was observed in gaze vector x comparing 14 and 27 and 38 g.w. For the gaze vector y, a small effect of pregnancy was found comparing the first measurement with all three following measurements. For gaze vector z no significant changes were found.

Table 3: Results of Cohen's d and confidence intervals for analyzed variables for stair ascending. Cohen's d is interpreted as ≥ 0.20 small (*), ≥ 0.50 medium, clinically significant (**), ≥ 0.80 large effect (***) (Cohen, 1977).

	Vector x	**Vector y**	**Vector z**
	Cohen's d	**Cohen's d**	**Cohen's d**
14 – 27 g.w.	0.30 (0.18; 0.40) *	-0.49 (-0.63; -0.33) *	0.05 (-0.12; 0.22)
14 – 31 g.w.	0.07 (-0.04; 0.19)	-0.26 (-0.40; -0.09) *	0.00 (-0.17; 0.16)
14 – 38 g.w.	0.28 (0.16; 0.40) *	-0.26 (-0.41; -0.10) *	-0.10 (-0.27; 0.04)

5. Discussion

Increased risk of falling during stair walking was observed in pregnant women in previous studies (Dunning, Lemasters, & Bhattacharya, 2010; Inanir et al., 2014).The purpose of this study was to capture pregnancy-related changes in gaze behavior during the stair ascending and descending as the stair ascent and descent is a challenging type of locomotion also in other populations with increased risk of falling, e.g. older adults (Verghese et al., 2008). Mean gaze vectors of the right eye (x, y, z) for stair descent and stair ascent were analysed as the gaze vector enables the integrated analysis of gaze behavior during locomotion (Müller-Feldmeth et al., 2014).

During stair descending, a clinically significant effect was observed in this study comparing the first measurement with more advanced phases of pregnancy by gaze vector y, i.e. up and down direction of gaze, when the gaze was turning more towards the stairs. Similarly, during the stair ascent, a small effect of advancing pregnancy on gaze vector y was observed. A previous study by Den Otter et al. (2011) showed that fixating the treads do not simply control the foot placement but may also contributing to the postural control (Den Otter et al, 2011), suggesting an increased need for both the foot placement and postural control during advances phases of pregnancy. Changes in the gaze vector x, i.e. the medio-lateral direction of the gaze, during the stair descent and ascent observed in this study were suggested to be caused by the handrail placement as it provided the sense of security to the participants in advanced phases of pregnancy.

The gaze vector analysis of present study provides an important, however, limited understanding of pregnancy-related gaze behavior changes as visual attention includes also gaze fixations and saccade movements of eyes. Another limitation of the present study is the same laboratory environment used for all four data collection sessions and the sample of healthy pregnant women with no fall history during their pregnancy. Future studies comparing the gaze characteristics of pregnant women with and without the fall history would reveal the pregnancy-related changes of the visual input relevant for safety stepping.

6. Conclusions

The presented study analysed the pregnancy-related changes in gaze behavior during the stair ascending and descending as during stair walking the risk of falling is increased during pregnancy. Results of gaze vector analysis revealed the turn of the gaze toward the handrail placement (gaze vector x), suggesting a stronger need for awareness of the safety facility, and toward the stair treads (gaze vector y), suggesting a stronger need for the foot placement and postural control during advanced phases of pregnancy as the deficit of visual control is associated with an increased risk of falling.

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