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The influence of ambient lighting levels on postural sway in healthy children

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Abstract

The purpose of this study was to determine whether postural sway in healthy children varied in different levels of ambient lighting. Twelve boys and 26 girls with a mean age of 118 months stood on a force platform under three conditions: eyes closed, eyes opened in regular light (200 lx) and eyes opened in dim light (3 lx). Analysis of variance and pairwise comparisons revealed significantly more postural sway with the eyes closed condition compared to the regular and dim light conditions but no differences between the regular and dim light conditions. While our results on postural sway during the eyes closed condition are consistent with current findings in the pediatric and adult literature, our findings comparing postural sway during regular and dim light conditions differ from those found in older adults. It appears that the visual system of children is efficient in dim light conditions, adding support to the view that quiet standing is more dependent on vision in older adults than in younger individuals.
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Keywords: Postural sway; Lighting; Visual environment; Postural stability; Children

1. Introduction

The purpose of this study was to determine whether postural sway in healthy children aged 9–11 years varies according to the level of ambient lighting. Postural control can be defined as the ability to control the center of mass over the base of support and can be measured by quantifying the amount of postural sway on a force platform [1]. Usui et al. [2] examined developmental changes in postural sway in children and showed that postural sway decreases markedly from 3 to 5 years of age, then more slowly after 6 years of age. Adult-like sway characteristics with less variability in muscle responses are present from 7 to 11 years of age [2,3] while an increase in postural sway is shown in elderly people [4,5]. Multiple factors are related to postural stability and may include muscular strength, proprioception, reaction time and the integrity of the tactile, vestibular and visual systems [1,6,7]. Studies by Shumway-Cook and Horak [8] together with Deitz et al. [9] have shown less sway and variability in performance with age under conditions of sensory conflict [9]. There is also preliminary evidence that children and adults sway more when their eyes are closed compared with eyes open [4,5,11,12].

The efficiency of the visual system for the maintenance of posture may depend on levels of ambient lighting and visual acuity. Brooke-Wavell et al. [5] reported that postural sway in older women increased with reductions in ambient light. With an increase in age and accompanying decline in visual acuity, a higher intensity of light was needed for the maintenance of postural stability [12,13]. Kinsella-Shaw et al. [14] also reported that ambient lighting affects postural sway in older adults [13] and suggested that visual contrast sensitivity may be important for postural control in older people. Christina and Cavanagh [15] demonstrated that older people use more cautious strategies during stair descent in dim light [15]. Moreover young adults had greater foot clearance during stair descent in dim light conditions

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when compared to bright ambient light conditions [16]. This adaptation was not seen in older adults [16].

The effects of ambient lighting on postural control has not been studied in children, despite investigations on postural control in clinical populations such as children with learning disabilities, motor delays [17] and spastic diplegia [19]. The current experiment examined the effects of different levels of ambient lighting on postural sway during quiet standing in children aged 9–11 years. We hypothesized that children would sway more in conditions of reduced ambient lighting (dim light at 3 lx) and with eyes closed compared to regular lighting conditions (200 lx).

2. Methods

2.1. Participants

All children in grades 4 and 5 from the University of Hartford Magnet School were invited to participate in the study. This age group was targeted for this study as literature has suggested that children between the ages of 9 and 11 demonstrate adult-like sway characteristics [3] with less variability than younger children. Pilot testing also showed that children this age had a greater likelihood of completing the task than younger children. From this sample of convenience, 38 students from grades 4 and 5 participated after providing informed consent from their parents. There were 12 boys and 26 girls, with a mean age of 118 months. They were typical healthy children who were able to walk independently and were free of conditions affecting their vision, gait or standing balance. Of the 38 subjects, five used glasses and were asked to keep their glasses on during the data collection procedure. Approval from the University of Hartford Human Subjects Review committee was obtained prior to data collection.

2.2. Apparatus

Center of pressure data (COP) data were collected using an AMTI Accusway System for Balance and Postural Sway Measurements (Advanced Mechanical Technology, Inc., Watertown, MA). A portable force platform was used to collect the postural sway data and Swaywin software loaded on a Hewlett-Packard laptop was used to acquire and analyze the data. The software uses established algorithms to calculate the location of the COP and related variables from the forces and moments applied to the platform. A report of validation tests of data acquisition and analysis of the AccuSway system [19] indicated an absolute COP error (which comprises noise, drift, and absolute accuracy) of less than 0.061 cm over a 40 s trial period. Trial to trial error due to noise (e.g. electrical or mechanical) was found to be 0.025 cm.

Four incandescent light sources on 8 ft. stands connected to a control circuit were used as a source of illumination and a EXTECH Model 407026 heavy duty light meter was used to measure the different levels of illumination in the room.

2.3. Procedures

Each participant was tested individually in a room reserved for the purposes of data collection at the University of Hartford Magnet School. Prior to data collection, two practice trials of 15 s were performed. Children were asked to stand on the floor in a comfortable posture with their arms at their side. For the first practice trial, they were instructed to look at a vertical line projected on a wall 5 ft. away in regular light. They performed the second practice trial with their eyes closed. Each child was then tested in the following three experimental conditions: eyes opened in regular light (200 lx), eyes opened in dim light (3 lx) and eyes closed in regular light. The order of presentation of the three conditions was randomly assigned and each condition was performed three times for a total of 30 s each. There was a 3-min accommodation period in between regular and dim light conditions to allow the eyes to accommodate to the new lighting conditions. The same instructions used during the practice trials were given during each condition for the actual experiment. The duration of testing was approximately 20 min.

2.4. Data analysis

Swaywin software was used to calculate the five dependent measures: length of the center of pressure (LCOP); sway range and sway variability in antero-posterior (SRAP, SVAP) and medio-lateral (SRML, SVML) directions. The LCOP is the distance that the center of pressure (COP) traveled from its start point over the 30 s trial period. Sway range is the difference between the two extreme position values in the specified AP or ML direction. Sway variability is the standard deviation of the COP in the specified direction. Mean values for all dependent measures were determined for the three trials of each condition performed by each subject. Repeated measures analyses of variance (ANOVA) were used to examine the effects of lighting (eyes closed, eyes open in regular light, eyes open in dim light) on the dependent measures. Level of statistical significance was set at 0.05. Mauchly's test of sphericity was used to ensure that the assumption of sphericity was not violated. When ANOVA revealed significant effects, pairwise comparisons with significance levels adjusted using the Bonferonni method were used to determine differences among means.

3. Results

Each of the ANOVAs for repeated measures performed met the assumption of sphericity ($p > 0.05$). The ANOVA for LCOP revealed a main effect of lighting condition

Table 1
Means, standard deviations and results of ANOVA for length of center of pressure (LCOP), sway range and sway variability in the antero-posterior (SRAP, SVAP) and medio-lateral (SRML, SVML) directions in the three conditions: eyes closed (EC), dim light (DL) and regular light (RL)

Condition	Mean	S.D.	*F*-value	*p*-Value
ANOVA				
ECLCOP	71.1463	13.37091	24.92	<0.005
DLLCOP	67.8816	14.62611		
RLLCOP	66.4511	14.92137		
ECSRAP	2.3500	0.7845	10.043	<0.005
DLSRAP	1.9858	0.52257		
RLSRAP	1.9332	0.59513		
ECSRML	1.3239	0.5623	0.385	0.683
DLSRML	1.3211	0.57455		
RLSRML	1.2742	0.69315		
ECSVAP	0.4497	0.16421	6.342	<0.005
DLSVAP	0.3929	0.12645		
RLSVAP	0.3876	0.13742		
ECSVML	0.2387	0.12285	0.452	0.64
DLSVML	0.2479	0.13437		
RLSVML	0.2368	0.16493		

($F = 24.92$, $p < 0.005$, Table 1). Pairwise comparisons revealed significantly more LCOP for the eyes closed condition than for the regular and dim light conditions but no difference between the dim and regular light conditions (Table 2).

The ANOVA for sway range in the antero-posterior direction revealed an effect of lighting condition ($F = 10.04$, $p < 0.005$), but no effect in the medio-lateral direction (Table 1). Again, pairwise comparisons revealed significantly more SRAP with eyes closed when compared to the regular and dim light conditions with no differences between those two latter conditions. Similar findings were found with sway variability (Table 2) where the ANOVA revealed a main effect of lighting conditions for the antero-posterior direction ($F = 6.34$, $p < 0.005$) but not in the medio-lateral direction. The findings from the pairwise comparisons showed similar findings as with the sway range with differences found between eyes closed and regular and dim light conditions but not between the two lighting conditions.

Table 2
Results of pairwise comparisons comparing length of center of pressure (LCOP), sway range and sway variability in the antero-posterior (SRAP, SVAP) and medio-lateral (SRML, SVML) directions between the three conditions: eyes closed (EC), dim light (DL) and regular light (RL)

Condition	Mean difference	*p*-Value
Pairwise comparison		
ECLCOP–DLLCOP	3.265	0.001
ECLCOP–RLLCOP	4.695	0.000
DLLCOP–RLLCOP	1.431	0.214
ECSVAP–DLSVAP	0.057	0.004
ECSVAP–RLSVAP	0.062	0.001
DLSVAP–RLSVAP	0.005	1.000
ECSRAP–DLSRAP	0.364	0.001
ECSRAP–RLSRAP	0.417	0.000
DLSRAP–DLSRAP	0.053	1.000

4. Discussion

Similar to earlier reports on postural sway with eyes closed [4–6,9–11] our findings highlight the importance of the visual system in the maintenance of postural stability in steady stance in children. Previous studies on the effects of ambient lighting on postural sway with eyes open have suggested reduced efficiency of the visual system under reduced lighting conditions in older adults [5,14–16]. Previous studies on ambient lighting where old and young people were compared examined dynamic postural control, with differences in performance favoring younger adults [17,18]. We hypothesized that children would be similarly affected by reduced lighting and this would manifest as increased postural sway. Contrary to this prediction, our results showed postural sway during quiet standing for children between the ages 9–11 years to be unaffected by the dim lighting conditions.

A possible explanation for the differences in performance between the children in our study and elderly people in previous investigations could be related to the integrity of the visual system. None of the parents reported problems with vision that could impact their child's ability to maintain a quiet standing position so it was therefore assumed that children were within close range of 20/20 vision. The five subjects in this study with corrected vision wore their glasses during data collection to eliminate the potential effect of diminished visual acuity on postural sway. It could therefore be argued that the visual systems of the children in our study were not sufficiently challenged during the dim lighting condition and that their visual systems were able to adjust to the reduced lighting condition without added cost to postural stability. Decreased visual acuity in the elderly has been thought to play a role in the incidence of falls in the dark [20]. Kinsella-Shaw et al. [14] have recently proposed that the degree of visual contrast sensitivity may contribute most to postural control. So while at first hand it appears that visual acuity could explain changes in adaptation in the dark for the elderly, it appears that visual contrast sensitivity is a better predictor of postural control in quiet standing in reduced lighting conditions.

Our study provides preliminary information on the effects of illumination on postural stability in children. Our sample of convenience was relatively small and selected from one urban school setting. All children were developing typically with good vision and no diagnosis as reported by their parents. The age range selected for this study was limited to the 9–11 years range thus limiting our ability to generalize our findings to groups of children of younger or older ages. Nevertheless, our study provides unique information on the effects of ambient lighting conditions on postural stability in typical children and adds support to the view that quiet standing is more dependent on vision in older adults than for younger people. Whether younger and older children or children with disabilities have similar responses remains to be determined.

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