CENTER OF MASS MOVEMENT OF PRESCHOOLER DURING OBSTACLE-CROSSING WALKING

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Obstacle-crossing walking (OW) activated a specify compensation strategy in motion, which was indicator to children's development. Therefore, we aimed to comprehend features of center of mass (COM) of preschooler crossing over obstacles, so as to explicit their compensation strategies in motion. The COM of ten healthy preschoolers aged 3-6 and nine adults were recruited and their straight and obstacle-crossing walking was measured by Codamotion system, where four markers being set on the pelvis. Trajectory, range of motion (ROM) and Time to peak value (TPV) of COM were calculated and used for further analysis. One sample T test was applied to explore the distinctions between preschoolers and adults. Significant group differences were found in medio-lateral (M/L) and vertical motion of the COM. Preschoolers demonstrated significantly greater motion of the COM when crossing obstacle, and their TPV advanced in both sagittal and coronal planes, which indicates efforts made by them to finish the task and maintain balance. Overall, distinctions found between preschoolers and adults demonstrated compensative strategies in motion of those children required further development to the level of adult-like style.

Keywords: center of mass, obstacle crossing, compensative strategies

INTRODUCTION

Obstacle-crossing walking (OW) is often required in our daily activity. It demands precise postural and balance control (Deconinck *et al.*, 2010) and activates a specify compensation strategy in motion, while little is known about whether preschoolers' can make successful gait adjustments to safely stride over the obstacle. In this study, we compared the obstacle crossing behavior between a group of typically developing preschoolers and a group of healthy adults. The motion of the center of mass (COM) during OW can demonstrate their compensation strategies. We believe that an adult-like compensation strategy could be regarded as one of the references to normal development of preschoolers and provide a basis for assessing the development of them.

Obstacle-crossing gait of physically or mentally injured crowd was widely reported this few years. Some diseases involved in the literature such as Parkinson's disease (PD) (Galna *et al.*, 2010) and Paralytic stroke (Said *et al.*, 2008) are commonly find in elderly crowd while some others like Developmental Coordination Disorder (DCD) (Deconinck *et al.*, 2010), Cerebral Palsy (CP) (Malone *et al.*, 2016) or Down syndrome (DS) (Chen *et al.*, 2015) are more common among children. These researches do help the protection and treatment of the related patients. In addition, studies on the healthy crowd have also gone very far. Both Hahn & Chou (2004) and Chou *et al.* (2003) studied the center of mass motion in sagittal plane during obstacle crossing. Likewise, Huang *et al.* (2008) investigated the influence of age and obstacle height on the center of mass of during obstacle-crossing. They mainly targeted at elderly person over the age of 65 as they are usual victims of accidental fall (Hahn & Chou, 2004).

Throughout the researches above, few studies aimed at preschoolers, studies carried out on children mainly focused on those who aged over 6 year old (Boonyong *et al.*,

2012) or suffering from DCD, CP or DS. However, on the other side, it is also necessary to learn obstacle-crossing gait of healthy preschoolers as they are at a critical period of growth (Bosch *et al.* 2010). The study can help us comprehend how compensation strategies of average children developed and matured, so as to sum up the common regularity which may become an indicator to children's development.

In summary, the purpose of current study was to investigate the motion of COM of preschoolers in both sagittal plane and coronal plane during OW. It was hypothesized that there would be age-related differences between the patterns of COM and energy of preschoolers and adults. Furthermore, preschoolers may have preliminarily mastered the gait of OW and their compensation strategies are close to those of adult.

METHOD

Ten healthy preschoolers (5 male/5 female, age:6.0(0.0) years, weight:19.0(4.2)kg, height: 112.5(8)cm, leg length:59.3(7.8)cm) and nine healthy adults(5 male/4 female, age 34.6(11.0) years, weight 58.3(21.8)kg, height: 166.4(1.0)cm, leg length 84.5(8.5)cm) as control group were recruited for this study. Before the test, the experimental procedures were explained to all Participants/Guardians, and then verbal and written approvals were obtained.

Subjects were asked to walk at their self-selected speed for obstacle-crossing task along a 6-m walking track (Fig. 1). According to the leg length(LL) measured during the subject's enrollment process, an obstacle at a height of 24 cm (40%LL) was set for preschooler, while 33 cm (40%LL) were set for adults respectively. Straight Walking (SW) and Obstacle-crossing Walking (OW) were each measured randomly. For each subject, a complete crossing stride in each OW was required. The crossing stride was defined as the heel-strike of the right/leading limb before the obstacle to the heel-strike of the same limb after clearing the obstacle. At least five successful trails were obtained in each task.

Figure 1. Illustration of Obstacle-crossing Walking

Figure 2. Demonstration of Markers' Installation

Motion data of COM was collected using a two camera Coda Motion System (Coda Motion cx1, Charnwood Dynamics Ltd., United Kingdom), two collectors were aligned on the two sides of the walking track, facing at an angle of 120 degrees. The COM was defined as the central point of the pelvic model consisting of four markers (Fig.2, marker1: the posterior right of pelvic; marker2: the posterior left of pelvic; marker3: anterior right of pelvic; marker4: the anterior left of pelvic).

A low-pass filtered with the cutoff frequency set at 6 Hz on the Three-dimensional marker trajectory data of COM was applied. Tempero-spatial parameters were first considered, then M/L(X) and vertical(Z) displacement of the COM, velocities of the COM, as well as the range of motion (ROM) and time to peak value (TPV) in the crossing stride were calculated. A normalization procedure was executed in order to achieve a comparable result: X and Z displacement of COM was divided by leg length of each subject and transfer into X-rel and Z-rel variables (Scrutton, 1969). Gait cycle of each test was also normalized into 100 points (%GC).

All statistical models were executed under SPSS 22 with a significance level of 0.05 and a confidence interval of 95%.

RESULT

All subjects were able to complete the obstacle-crossing task without tripping. In contrast with FW, both preschoolers and adults decreased their stance phase ($p<0.001$) and increased their swing phase ($p<0.001$) in OW. Further, they prolonged their time of gait cycle ($p<0.001$) and step length ($p=0.364$), and lowered walking speed ($p=0.434$). During OW, significant group difference was found only in step length ($p<0.001$). Stride time ($p=0.301$), step length ($p<0.003$) and frond number ($p=0.226$) of preschoolers were smaller than that of adults. The ratio for stance phase of children was greater than that of adults ($p=0.021$) and the ratio for swing phase was smaller ($p=0.022$).

Table 1. Tempero-spatial Parameters during SW and OW

	SW		OW		p-values	
	Preschooler	Adult	Preschooler	Adult	Pg*	Pt*
Stride Time (s)	0.97(0.11)	1.09(0.10)	1.26(0.19)	1.31(0.27)	0.301	0.000
Step Length (m)	0.71(0.10)	1.03(0.13)	0.78(0.11)	1.07(0.05)	0.003	0.364
Frond Number*	0.15(0.03)	0.20(0.02)	0.18(0.04)	0.21(0.05)	0.226	0.434
Stance Phase	56.7(5.5%)	54.4(3.0%)	43.2(3.9%)	40.2(2.9%)	0.021	0.000
Swing Phase	43.3(5.5%)	45.6(3.0%)	56.8(3.9%)	59.8(3.9%)	0.022	0.000

*Frond Number is used to characterize walking velocity ($Fr=V^2/gL$, V represents walking velocity, L represent leg length). *Pg represents group effect in OW, Pt represents gait type effect

When stepping over obstacles, M/L ROM of the COM in both preschooler and adult groups decreased, however, vertical ROM of both two groups increased. In Coronal plane, obstacle-crossing condition advanced the first TPV in both preschooler (the peak of SW is 28%GC, OW is 19% GC) and adult (the peak of SW is 40%GC, OW is 29% GC) groups; such regularity was also found in sagittal plane where the first TPV in preschooler was advanced from 28%GC to 24% GC for preschoolers and from 30%GC to 24% GC for adults; further, the second TPV were also both advanced (the 2nd peak of SW is 77%GC, OW is 70% GC for preschoolers, the 2nd peak of SW is 77%GC, OW is 74% GC for adults.)

Moreover, similar COM trajectory of the two groups in M/L direction was found for OW, as well as ROM and TPV of the COM, totally adults showed larger ROM and displacement than children. In terms of sagittal plane, compared with adult group, amplitude of COM, as well as its ROM were smaller in preschoolers while TPV was nearly the same.

Figure 3. Trajectory of the COM during SW and OW in (A) M/L and (B) vertical direction

DISCUSSION

Current study investigated the trajectory of COM in sagittal and coronal plane during OW. Results from this study revealed that when coping with the obstacle-crossing task, preschoolers would prolong their movement time, lengthen their stride and decrease their speed. Moreover, their M/L and vertical ROM of the COM changed and their TPV advanced, which is similar to that of adult. Such result supported our hypotheses that preschoolers have preliminary mastered the gait of OW. Those findings were helpful for us to comprehend the mechanism of gait adjustment in children, so as to understand their development in motion.

The result of spatiotemporal parameters showed preschoolers' adjustment of gait in order to trip over the obstacle. Such result was similar to previous studies (Chou *et al.*, 2001; Austin *et al.*, 1999). The prolonged time of gait and step length revealed their awareness and effort to cross the obstacle. In contrast with adults, spatiotemporal parameters of preschoolers changed much greater, which demonstrated that the obstacle-crossing task has led to trouble for them. That is to say their compensation strategy in OW is not fully mature yet.

The present study found that the M/L and vertical trajectory of the COM was affected by obstacle-crossing task. In general, at the beginning of a gait cycle, the leading leg was contacting with the ground and trailing leg went forward, so COM showed a tendency towards the right side (leading leg), and it reversed following the toe-off of the leading leg. When tripping over the obstacle, this process was advance for an early preparation for the obstacle (Fig. 3A). Whereafter, an additional stretch of leg was required to cross over the obstacle so as to increase the height of COM (Fig. 3B). While we can see from Fig. 3 that adults had an earlier TPV in M/L direction and a higher vertical displacement which means their compensation strategies in OW is more perfect than preschoolers. The above findings suggested that an adult-like compensation strategy in motion have not completely mastered in preschoolers and it was consistent

with Beerse *et al.* (2005) and Jianhua *et al.* (2009), who reported that children's motion ability is still developing after the age of 5 and 10 more years was need for them to gain an adult like variability-partitioning capability.

In terms of ROM of the COM, M/L ROM was slightly affected, which indicated that preschoolers succeed to maintain balance and gait stability during OW. Similar result was reported by Chou *et al.* (2001), they summarized that slight changes in COM M/L displacement and the M/L distance between the COM and the corresponding during OW may represent a successful effort to maintain the line of progression within the base of support and to avoid imbalance.

CONCLUSION

When tripping over an obstacle, COM of healthy preschoolers in either coronal and sagittal plane showed partly similar to those of adult. But some distinctions existed which indicated that compensative strategies of those children were still developing.

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