Gait & Posture 40 (2014) 113–117

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Direction of single obstacle circumvention in middle-aged children

Amy L. Hackney [a], Nicole Van Ruymbeke [b], Pamela J. Bryden [b], Michael E. Cinelli [b,*]

[a] Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada
[b] Department of Kinesiology & Physical Education, Wilfrid Laurier University, Waterloo, ON, Canada

ARTICLE INFO

Article history:
Received 20 September 2013
Received in revised form 12 February 2014
Accepted 3 March 2014

Keywords:
Obstacle circumvention
Children
Human locomotion
Perception of space
Kinematics

ABSTRACT

When required to walk around a stationary object, adults use the location of the goal to set up their locomotor axis and obstacles presented along the locomotor axis will repel the individual towards the side that affords more space [1]. Research has yet to examine whether children can identify the locomotor axis and choose their paths accordingly. Therefore, the current study examined the factors that influence the direction in which children choose to deviate around a single obstacle and whether the presence or absence of a goal influences path selection and trajectory. Ten children (age: 7.1 years ±0.8) walked along a 9 m path and avoided a single obstacle that was located in one of three locations (midline, 15 cm to the right or 15 cm to the left). On half the trials, an end-goal was visible from the start of the path while the other half of the trials had no visible goal. The results demonstrate that: (1) children are able to perceive and move towards more open space but are more variable when the end-goal is not visible; (2) children are capable of maintaining an elliptical-shaped protective envelope when avoiding a single obstacle regardless of whether or not the locomotor axis is established; and (3) although children are capable of choosing paths that afford the most space, the manner in which they arrive at their goal is not driven by factors similar to adults.

1. Introduction

Avoiding obstacles along the travel path is a requirement of daily locomotion. When faced with a stationary object too large to be stepped over, individuals must walk around it in order to continue along their intended path. Obstacle circumvention requires the ability to determine when to deviate from the straight walking trajectory, whether to walk to the left or the right of the obstacle and how much space is needed between the obstacle and the body when passing by the object. Fajen and Warren [1] demonstrated that these modifications to straight walking are influenced by the location of the obstacle relative to the end-goal. Individuals use the location of the goal to set up their locomotor axis and obstacles located on one side of the locomotor axis will repel the individual towards the other side because it affords more space and produces the minimum deviation from the locomotor axis [1]. This finding suggests that as when a locomotor axis is established, the side of obstacle circumvention is trivial because vision will guide actions. However, what is not known is whether children are able to establish a locomotor axis and use it to circumvent an obstacle in the direction of more space even in the absence of a goal.

Unlike adults who make alterations to their locomotor pattern well in advance of an upcoming obstacle [2–6], children make more last minute adjustments to their steering strategy [7,8]. Middle-aged children (9–12 years of age) will reduce their gait speed and step length only two steps and one step prior to obstacle circumvention respectively, while adults maintain a constant speed and step length [8]. Additionally, children will initiate movement of the head and trunk segments prior to changing their centre of mass (COM) trajectory, whereas this series of events occurs simultaneously in adults [8]. This last minute strategy suggests that children approach obstacle circumvention differently than adults and may point towards a locomotor system that has not yet reached full maturity.

Research examining other types of obstacle avoidance, such as obstacle stepping or aperture crossing has also revealed differences in actions between children and adults. Children exhibit more variable toe clearances during obstacle stepping [9], maintain a larger margin of safety when passing through apertures [10] and are highly variable in their choice to pass through or circumvent an aperture when given the freedom to decide between the two avoidance strategies [11]. A difference in obstacle avoidance behaviour between children and adults is not surprising

* Corresponding author. Tel.: +1 5198840710; fax: +1 519 747 4594.
E-mail addresses: mcinelli@wlu.ca, mecinelli@gmail.com (M.E. Cinelli).

http://dx.doi.org/10.1016/j.gaitpost.2014.03.005
0966-6362/

as research suggests that anticipatory locomotor adjustments and control of dynamic stability during locomotion are still maturing in mid-childhood. McFadyen and colleagues [12] demonstrated that during obstacle stepping, children displayed a more complex and variable relationship between hip, knee and ankle patterns than adults. Although children modified their lower limb displacement in a similar manner as adults, no antagonistic knee extensor power preceding toe-off occurred. The absence of this knee extensor power burst suggests that children are not yet capable of producing a locomotor pattern exactly like adults and suggests that anticipatory locomotor adjustments are still maturing in childhood [12].

Although the literature reveals that children act differently from adults but are able to successfully adapt their locomotion to avoid obstacles, research considering single obstacle circumvention in children is still limited. Previous work examining children's behaviours while approaching a single stationary obstacle [8] failed to examine determinants for direction of obstacle avoidance. Assessing side of avoidance demonstrates whether children are able to establish a locomotor axis and use visual information to guide their actions consistently or whether their actions were inconsistent and based on non-visual information. The current study aimed to extend the obstacle circumvention literature by examining the factors (i.e. perception of open space, biomechanical, and consistency) that influence the direction in which children choose to circumvent a single obstacle and whether the presence or absence of a goal affects the establishment of a locomotor axis thereby affecting consistency in path selection. It was hypothesized that when a visible goal was present from the start of the trial it would serve as an attractor and children would be better able to establish their locomotor axis (i.e., to align body with future path direction). In the absence of an explicit goal, children would align their locomotor axis towards variable goals/attractors and may even align their locomotor axis towards the obstacle, which should serve as a repeller rather than an attractor [1]. It was also hypothesized that the establishment of a locomotor axis would guide actions such that an obstacle located on one side of the axis would produce consistent travel paths in the opposite direction [1]. Finally, it was hypothesized that when the obstacle was in-line with the locomotor axis and the amount of open space on either side of the obstacle was equal, children would use non-visual information (i.e., dynamic stability, foot dominance, etc.) to guide actions and deviate equally towards both sides of the obstacle.

2. Methodology

2.1. Participants

Ten typically developing children (four girls, 7.1 ± 0.8 years, shoulder width = 32.4 ± 3.2 cm) participated in the study. Children diagnosed with any neurological disorders (e.g. autism) or any functional neurological deficits were excluded from participation. Guardians of each participant provided written consent in addition to the verbal consent of the participants. This study was reviewed and accepted by the university's Research Ethics Board.

2.2. Apparatus

The current study was conducted along a 9 m by 6 m walkway with a single pole obstacle (1.4 m tall × 0.15 m wide) located 5 m from the start. The obstacle was placed in one of three locations: midline or 15 cm to the left or right (Fig. 1). On half the trials, a pole served as a goal (1.6 m tall × 0.15 m wide) was located at the end of the walkway and participants were told to walk to the goal. During the remaining trials, the goal pole was replaced with a mark on the ground such that it was not visible from the starting position. The purpose of removing the pole goal on half the trials was to determine whether children would use the obstacle rather than the goal to establish their locomotor axis and if this was the case proportion of avoidances to either side would be equal regardless of the location of the obstacle. Participants began each trial at one of three randomized locations, separated by 20 cm, to ensure that each trial was unique.

Kinematic data was collected using the Optotrak (Northern Digital Inc., Waterloo, ON, Canada) system. Each participant was outfitted with eight infrared light emitting diodes located on his/her posterior surface on the following locations: (1) three on the head; (2) left and right posterior-lateral aspects of the spinous processes of the scapula; (3) 12th thoracic vertebrae; and (4) the calcaneus of each foot.

2.3. Procedure

Participants began each experimental trial facing away from the obstacles while one of the experimenters manually set up the path while another experimenter stood in close proximity of the child to prevent prior knowledge of obstacle location and goal visibility. Children were then instructed to turn around and prior to walking

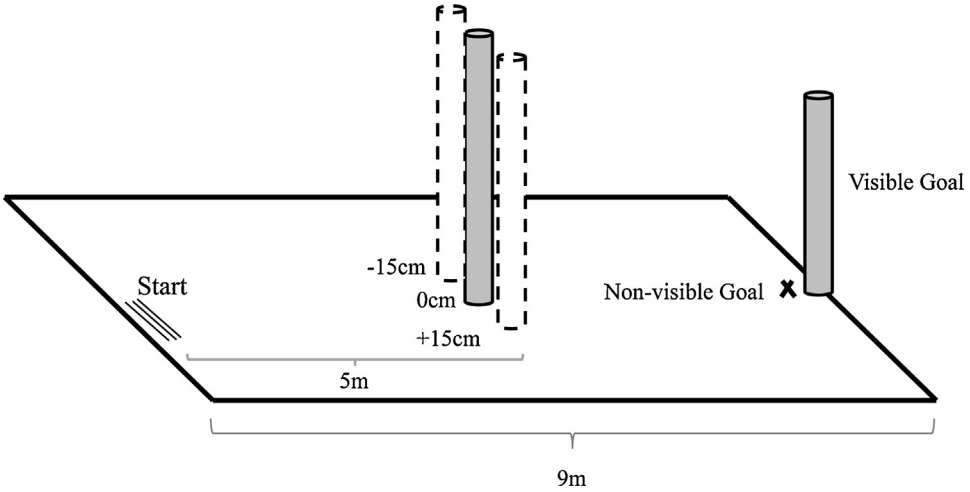

Fig. 1. Experimental set-up including a 9 m path with an obstacle located 5 m from the start and placed either on the midline or 15 cm to the left or the right. Goal was either visible or not-visible from the start of the path.