Kinematic Analysis of Gait while Stepping over Obstacles

Nuanlaor Thawinchai[a], Margo N. Orlin[a,c], Adrian B. Liggins[b], Carrie A. Laughton[c], James J. McCarthy[c]
[a]Drexel University, Programs in Rehabilitation Sciences, Philadelphia, PA, USA; [b]Glenrose Rehabilitation Hospital, Alberta, CANADA; [c]Shriners Hospitals for Children, Philadelphia,PA,USA

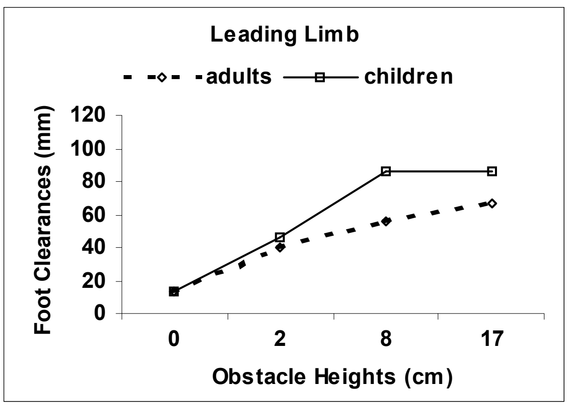
Introduction: Gait capacity has been found to be available at birth[1], but the adult-like gait characteristics emerge by the age of 4[2]. Joint angles, joint moments, and mechanical power bursts during level walking are suggested to be similar to adults as early as 5 years old[3]. However, the question remains whether the capacity for negotiating obstacles is equally established. It has been shown that young children aged 14-30 months of age were inconsistent in their choice to step over or go around obstacles of different heights[4], and children under 8 years old made more errors in the obstacle path than children over 8 years[5]. The risk of tripping, stumbling, or falling may arise from lack of ability to judge how much to clear the foot off the floor or over an obstacle. Previous studies[6-8] have determined foot clearances for the leading limb or trailing limb, not both, using a reflective marker system which does not give the true amount of foot clearance. In this study, true foot clearance was determined by the distance between the bottom of foot and the floor or obstacle.
The purposes of this study were to evaluate the effect of leading vs. trailing limbs, obstacle heights, and age-related changes, on the kinematic characteristics of gait while stepping over the obstacles.

Statement of Clinical Significance: Evidence about gait characteristics in stepping over obstacles in children has not been clearly addressed to date. It is believed that there will be differences, from adults, in how children with TD are able to control their gait characteristics while stepping over obstacle because of influences in growth (anthropometrics) and maturation (neural).

Methodology: Eight healthy adults (mean age 28 years 3 months, range 24 to 35 years) and eight children with TD (mean age 10 year 8 months, range 8 to 12) participated in this study. A repeated measures design was used to determine the following variables: (1) the minimum foot clearance distance; (2) movement speed; (3) movement time; and (4) the maximum angle of the hip, knee and ankle during stepping over the obstacle (in sagittal plane). A six-camera Vicon 370 motion capture system (Oxford Metrics, Oxford, England) and two video cameras were utilized collaboratively to get both quantitative kinematic data and a visual image of a subject stepping over an obstacle. The information from the visual image was digitized and process using the Peak Motus motion analysis software (Englewood, CO, USA) in order to get foot clearances quantitatively. Repeated measures analysis of variance (ANOVA) were used to determine if there were statistically significant differences among limb sides (leading and trailing), different obstacles height (unobstructed gait, 2, 8, and 17-cm), and age-related changes (adults and children with TD). To account for a total of 12 variables a Bonferroni correction was made so that only values of $p < 0.004$ were considered significant.

Results: Significant differences were found for all variables for both adults and children ($p < 0.0001$) as obstacle height increased. There was a significant main effect for limbs for all variables for both adults and children ($p < 0.0001$), except maximum ankle dorsiflexion angle during stepping over the obstacle. There was a significant interaction between limbs and obstacle height for movement speed, movement time, and maximum hip flexion angle ($p < 0.0001$). Comparing the children to the adults, significant differences were found between groups for only maximum ankle dorsiflexion angle during stepping over ($p = 0.02$).

Discussion: This study demonstrated that children with TD are capable of stepping over obstacles in a coordinated adult-like manner. As the obstacle height increased, both children and adults had significantly increased foot clearance, reduced movement speed, increased movement time, and increased maximum angle of the hip, knee, and ankle during stepping over the obstacle. However, children performed a different ankle dorsiflexion pattern during stepping over the obstacle. This might be because there are several factors in strategy choices such as anthropometrics, strength, maturation, motivation, and attention. Both children and adults were significantly lower in movement speed, greater movement time, and higher maximum angle of the hip, knee, and ankle when stepping over the obstacle with the trailing limb compared to the leading limb. Foot clearances in this study were found to have different patterns to those found in an earlier study[8] in which obstacle height was not found to affect trailing limb clearance. However, another study[6] did find similar patterns to those demonstrated here in Figures1 and 2 in which both leading and trailing limb clearances were affected by obstacle height.



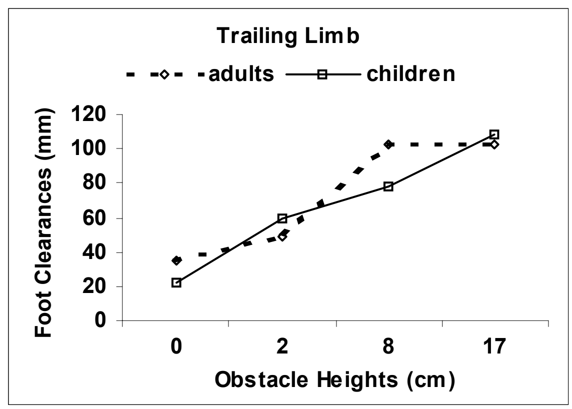


Figure 1: Leading and trailing limb clearances during stepping over different heights of the obstacle for both children and adults.

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