INTRA-LIMB COORDINATION DURING OBSTACLE CROSSING OVER DIFFERENT OBSTACLE HEIGHTS

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ABSTRACT
Objective: The aim of the study was to investigate the intra-limb coordination of the lead limb (LL) and trial limb (TL) during obstacle crossing over different heights of obstacle.
Methods: Single healthy young female participated in the study. Obstacle crossing characteristics were collected by three dimension motion analysis system. Intra-limb coordination of the lower extremity was plotted with cyclogram. Three different heights (5-cm, 20-cm, and 30-cm) of obstacles crossing and no obstacle condition were performed for assessing the intra-limb coordination patterns. Cyclograms were illustrated for the relationships between two and three joint motions. Data were qualitatively analyzed on illustrations.
Results: Without obstacle, cyclograms demonstrated almost the same degree of motion for the hip, knee, and ankle joints between the LL and TL. For obstacle crossing in different obstacle heights, the hip range of motion was required for obstacle crossing in the LL more than the TL. Almost the same degree of knee flexion angle was necessary for both the LL and TL. Alternated ankle plantarflexion and dorsiflexion occurred in obstacle crossing task.
Conclusion: Intra-limb coordination during obstacle crossing altered following height of the obstacle and different patterns existed between the LL and TL.

KEY WORDS
Intra-limb coordination, Obstacle crossing, Cyclogram, Lead limb, Trail limb.

1. Introduction

A locomotor coordination was defined by Krasovsky and Levin as “an ability to maintain a context-dependent and phase-dependent cyclical relationship between different body segments or joints in both spatial and temporal domains” [1]. Coordination behaviors during different motor tasks were varied depended on the task demands [1, 2]. Coordination of locomotion requires proper sequential of the motion and accomplishment of the task. Previous studies have examined movement pattern while stepping over obstacles [3-5]. The movement patterns were changed following increasing age or having pathology [6-8].

Cyclical representations of locomotion can be presented by the phase diagram, moment-angle plot, angle-angle diagram, and velocity-velocity curve [1, 2, 4]. Phase space or phase diagram demonstrated a dynamic system in its phase space. It usually described locomotion coordination features by displacement and velocity contexts. A planar angle-angle cyclogram provides information about the posture of the leg and the coordination of two adjacent joints. Both cyclogram and phase diagram are important signatures of locomotion and each has its own merits. Cyclogram has been used as the analytical tool in several movement tasks such as walking, running, stair climbing, hopping, and obstacle crossing [2, 4]. It is used to indicate movement behavior and very useful for comparing the movement patterns that deviated from the normal as well as the effectiveness of the intervention [1, 9].

Obstacle crossing task is a complex motor task, requiring precise swing foot to step over obstacle while maintaining body balance through highly coordinated joint movements of the LL and TL [4, 5]. Currently, several proposed models used to analyze the relationship of movement qualitatively and quantitatively. However, coordination of the multijoints of the legs should be determined when crossing the obstacle. Intra-limb coordination provided information of the intrinsic context of the segments or joints relationship. Hence, the present study aimed to investigate the effect of different heights of obstacle on intra-limb coordination pattern during obstacle crossing.

2. Methods

2.1 Participants

Single healthy young female who had no history of lower extremity injury participated in the study. Her age, weight, and height were 18 years, 53 kg, and 157.5 cm. Prior to participate the study, participant signed an informed consent approval by University research review board. Anthropometric data included the body weight, height, joint widths, and leg lengths were assessed. Thirty five retro-reflective markers of 14 mm diameter were placed on bony prominence following Plug in Gait model.

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2.2 Obstacle crossing test

Ten cameras (series T20s) of Vicon motion analysis system were used for collecting obstacle crossing characteristics. Obstacles were placed on the middle part of 8-meter walkway. Participant was asked to walk through the walkway and cross the obstacle with the right limb and then the left was followed. Walking practice was allowed until she felt comfortably cross the obstacle. Three different heights (5-cm, 20-cm, and 30-cm) of the obstacle boxes (5-cm in width and 80-cm in length) were placed on the middle path of walkway. No obstacle condition was also tested and 3 different obstacle heights were tested consecutively. Motion data were collected at 100 Hz and trajectories were filtered by Woltring routine method.

2.3 Data tracking and analysis

A cycle from toe off to toe off events was tracked for each of the LL and TL. ASCII files were exported for the joint angular displacements of the hip, knee, and ankle in the sagittal plane by the Vicon Nexus software version 1.8.4.60176h. The cyclograms were plotted by MATLAB software version R2013a (S/N 891627) for evaluate the coordination of the hip, knee, and ankle joints during cross the obstacle. Two dimensional cyclograms were illustrated for the relationships of the hip and knee, the knee and ankle, and the hip and ankle angles. Three dimensional cyclogram was illustrated for the relationships of the hip, knee, and ankle angles.

3. Results and Discussion

The findings demonstrated useful information related to intra-limb coordination during obstacle crossing. Analysis of the relationship between joints has been used for monitoring abnormal motion which may exist in a variety of cases [1, 9, 10].

Figure 1 shows three dimensional cyclograms of the hip, knee, and ankle joints for the LL and TL during walking with and without obstacle. Cyclogram of the present study showed similar pattern to those of previous published [10]. Without obstacle, cyclograms demonstrated almost the same degree of motion for the hip, knee, and ankle joints between the LL and TL. Among different heights of obstacle, the characteristics of hip, knee, and ankle joints demonstrated similar pattern. However, the degree performed by each joint was different between the LL and TL.

Figures 2-4 show two dimensional cyclograms of hip and knee, knee and ankle, and hip and ankle of the LL and TL, respectively. For no obstacle walking condition, cyclograms of hip and knee, knee and ankle, and hip and ankle demonstrated similar patterns for the LL and TL. For the hip and knee cyclogram, the degree of hip and knee flexion motions of the LL increased when obstacle heights were increased. However, the degree of knee flexion increased more than hip flexion. For the knee and ankle cyclogram, obviously distinct patterns were demonstrated between the LL and TL. Abruptly alternated ankle dorsiflexion and plantarflexion angles were presented together with gradual knee flexion and extension angles in the LL. For the TL, ankle plantarflexion presented in the early period followed by ankle dorsiflexion in the last period particularly for the 20 cm and 30 cm obstacle heights together with increased knee flexion as increased obstacle heights. For the hip and ankle cyclogram, different patterns were indicated between the LL and TL for all obstacle heights. Within the TL, altered patterns were demonstrated with increased obstacle heights. For the LL, similar cyclograms were observed across obstacle heights. Alternated ankle plantarflexion and dorsiflexion were observed during obstacle crossing while increased hip flexion as increased obstacle heights.

As described in the above mentions, these complicated segmental movements are controlled by the nervous system which can be detected by cyclogram displays. Cyclograms demonstrate the ability to adjust the degree of movement orientation in several planes for fitting the challenged environments as reported in previous researches [2, 10].

4. Conclusion

Cyclogram was used to explained intra-limb coordination. With increasing the obstacle heights, the degree of hip and knee motion were increased. The hip range of motion was required for obstacle crossing in the LL more than the TL. Almost the same degree of knee flexion angle was necessary for both the LL and TL. Alternated ankle plantarflexion and dorsiflexion occurred in obstacle crossing task.

Limitation of the Study

More samples are required and further analysis should be determined quantitatively for assessing the effect of obstacle heights on intra-limb coordination during obstacle crossing.

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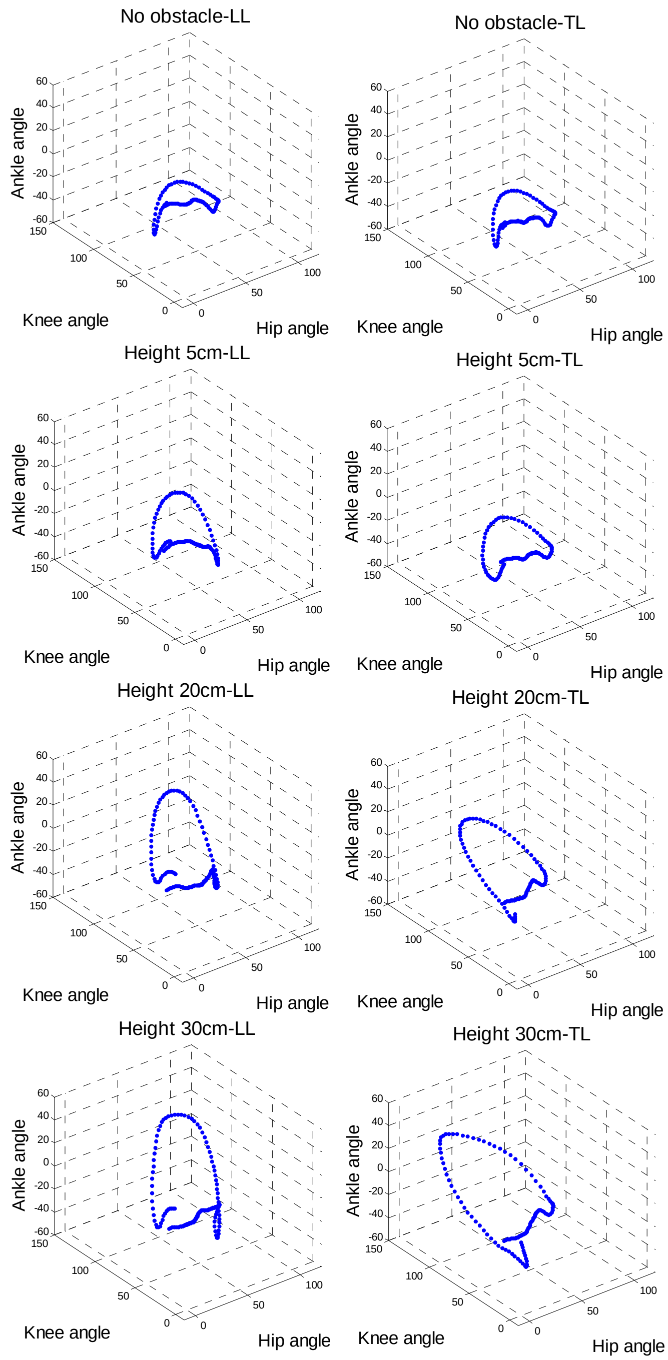

Figure 1: Cyclogram of the hip, knee, and ankle joints of the LL and TL.

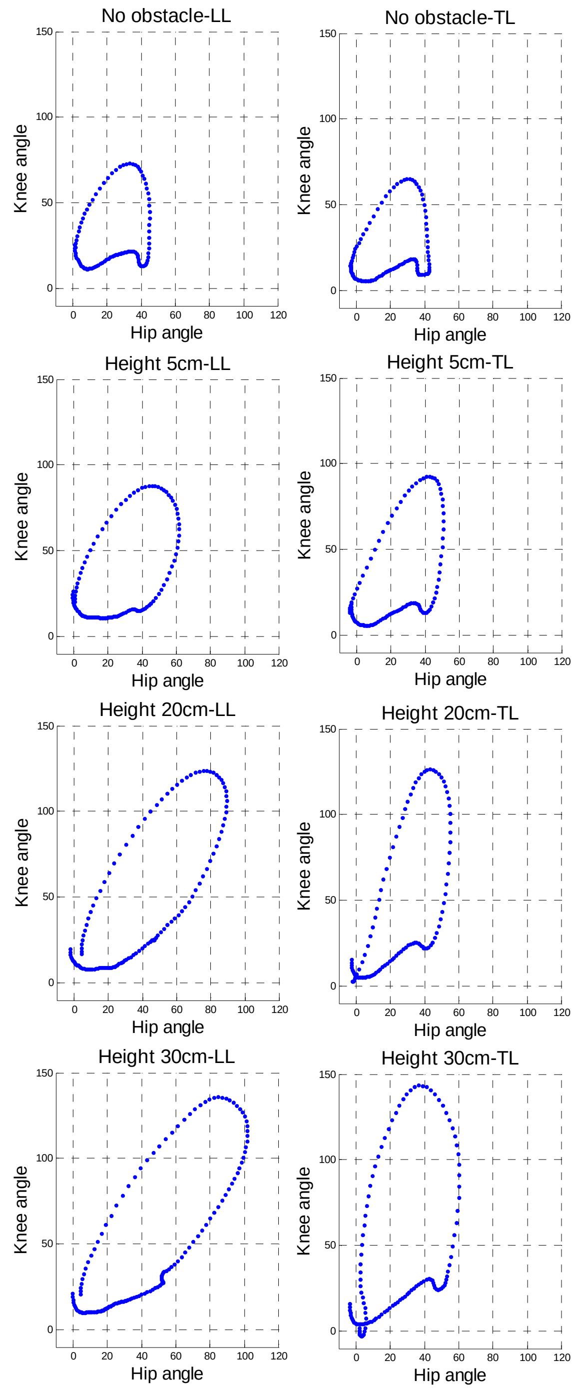

Figure 2: Cyclogram of the hip and knee joints of the LL and TL.

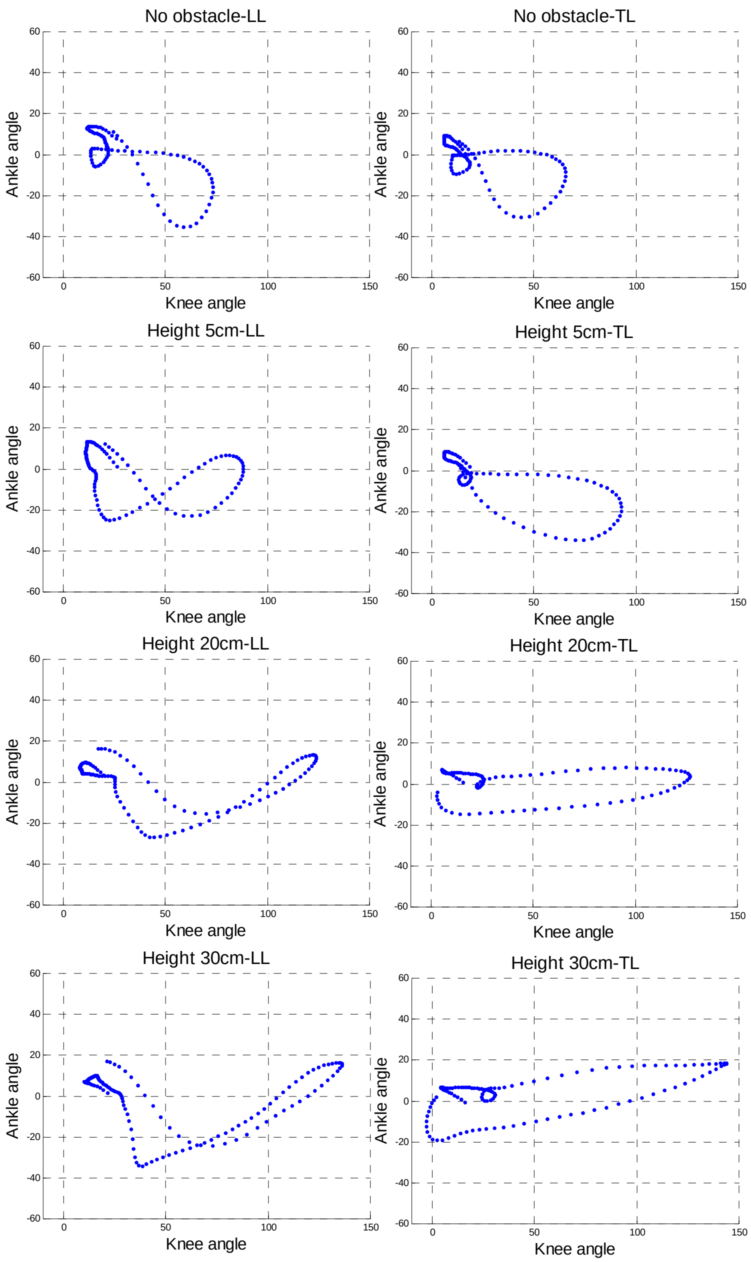

Figure 3: Cyclogram of the knee and ankle joints of the LL and TL.

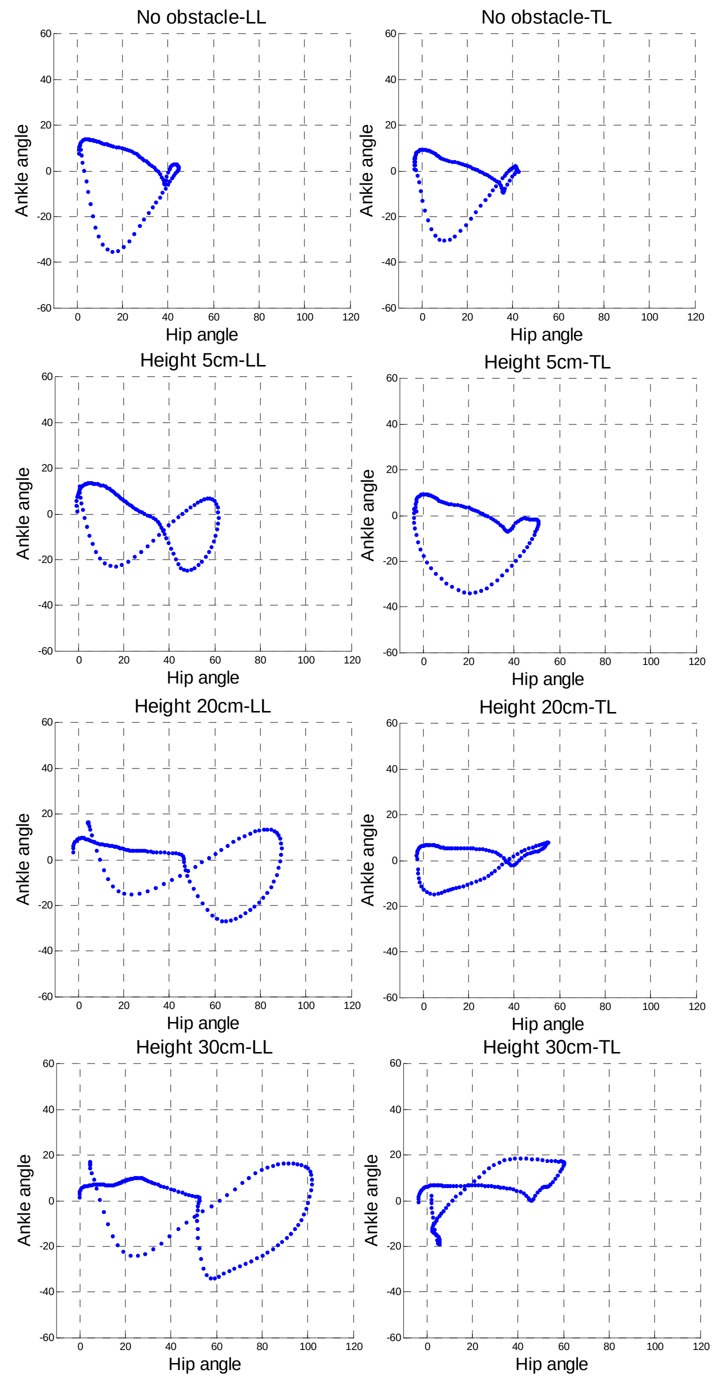

Figure 4: Cyclogram of the hip and ankle joints of the LL and TL.

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