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Walking Kinematics Approaching Stairs

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ABSTRACT- Walkers encounter surfaces of varying angles every day, from shallow accessible ramps to steep outdoor hills. These individuals must constantly alter their joint mechanics to safely transition between surfaces and avoid falling. The present study aimed to evaluate walking kinematics when encountering a staircase. A total of 30 participants participated in this study. They were all college students. The results showed that when encountering the stairs, participant decreased their heel velocity, but, did not decrease their walking velocity.

KEYWORDS- Gait, Stairs, Com, Heel Velocity, Kinematics

I. INTRODUCTION

Walking is the main and most repeated movement in human daily life[1]. Walking is usually regarded as a highly automated behavior[2], but in recent years, more and more malefactors have found that walking is a complex behavior, which requires continuous sensory information and constant adaptation to changes in the road environment during the walking process, involves the participation of multiple senses, and requires executive ability to complete. Gait is an expression of human walking characteristics, and normal human gait is characterized by a smooth body, appropriate step length and low energy consumption.

The human locomotor pattern has been shown to be highly adaptable to different environments such as stair climbing[3] , changes in walking speed[4] or slope[5, 6].Thus people have different walking strategies on flat ground, uphill, downhill, in plane transitions, and when performing different tasks. Walkers encounter surfaces of varying angles every day, from shallow accessible ramps to steep outdoor hills. These individuals must constantly alter their joint mechanics to safely transition between surfaces and avoid falling. People transition between flat surfaces and slopes in the complex external world while walking at different speeds. These plane transitions have the potential to affect dynamic balance in the anterior-posterior and medial-lateral directions. Therefore, it is possible to adopt unique gait strategies to maintain safe and stable walking patterns during transitional strides.

The present study investigated what the transitional gait patterns of young people are, when responding to transitions between surfaces, to understand the transitional gait patterns when responding to sudden changes in the environment

II. METHOD

A. Participants

We recruited 30 participants (15 males and 15 females) from within the University for the study. Participants were screened to exclude any potential orthopedic issues that might limit their ability to complete the walking tasks or affect aspects of gait variability and balance. Written informed consent was obtained from each participant prior to the experiment. Before participating in the study, all participants completed a brief questionnaire regarding their personal information such as height, weight, and age.

B. Procedure

Trial data collection Thirteen infrared cameras (Prime 17W, OptiTrack, Natural Point, Inc., Corvallis, OR, USA) were used to capture the kinematic data of each participant at a sampling rate of 120 Hz. In the experiment, the matching marker was a 14 mm reflective marker, and each subject was marked with 57 reflective skin markers[61]. Ground reaction force data was collected at 1200 Hz using an OR6-6-2000 force platform (AMTI Inc.) from Newton, MD, MA, USA, with a maximum delay time of 6 ms.

Before the formal testing phase, participants were instructed to change into tight-fitting clothing and shoes provided by the laboratory, followed by morphological data measurements. Subsequently, experimenters affixed 57 reflective marker balls to the participants (Fig.1). After the preparatory procedures were completed, participants engaged in approximately 5 minutes of warm-up exercises and familiarized themselves with the experimental environment. At the commencement of the test, participants waited at an appropriate starting position and, upon hearing the command "start" ascended and descended the stairs one step at a time at their comfortable pace until completion.

Visual-3D software was used for the analysis and processing of the collected three-dimensional kinematic and kinetic data. Both kinematic and kinetic data underwent a fourth-order Butterworth digital low-pass filtering, with cutoff frequencies of 6 Hz and 10 Hz. During data analysis, gait parameters and the center of mass (CoM) height were normalized based on the participant's height.

III. RESULTS

Through T-test analysis, it was determined that participants' COM velocity along the X-axis significantly decreased during stair ascent (P < 0.001).The average velocity during level walking was recorded at 123.41 ± 20.977 cm/s, while it decreased to 102.23 ± 16.520 cm/s during stair ascent.

Table 1. COM velocity at heel contact

	Mean±SD（cm/s） level ground	up stair	t	P
X	123.41±20.97	102.23±16.52	9.640	< 0.001***
Y	1.368±5.20	-1.578±0.06	30.81	< 0.001***
Z	-0.06±0.035	1.32±3.71	3.901	< 0.001***

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Table 2. Velocity at heel contact

	Mean±SD（cm/s） level ground	up stair	t	P
X	12.31±6.79	15.02±10.40	2.242	<0.027*
Y	0.09±3.32	1.02±3.81	2.130	0.036*
Z	13.29±3.85	7.93±5.33	7.571	< 0.001***

Through T-test analysis, it was observed that during stair ascent, participants' heel contact velocity on the X-axis demonstrated a significant increase (P < 0.027). The average velocity during level walking was recorded at 12.31 ± 6.79 cm/s, while it increased to 15.02 ± 10.40 cm/s during stair ascent.

IV. DISCUSSION

Transitions between walking on flat ground and climbing stairs anticipate the upcoming stride[1]. The body adapts its strategies to accommodate task variations, including decreased walking speeds[2] .In contrast to walking on a flat surface, ascending stairs necessitates enhanced stability, as the body must overcome vertical height changes while preserving equilibrium. Prior to ascending stairs, as the foot first lands on the stair, the reduction in COM velocity primarily stems from self-adjustment. Consistent with prior research, the alterations in height during stair climbing demand heightened control for stability maintenance, hence lowering COM velocity[3-5], The decrease in COM velocity during stair ascent is a preparatory measure for the imminent height change. Alterations in leg muscle activation patterns[6]during stair climbing similarly impact the adjustment of COM velocity, which, when reduced, facilitates enhanced body control to sustain gait stability.

The angles of heel and foot contact, along with the velocity of heel contact, have been deemed significant indicators for anticipating forward slipping incidents[7, 8] .The increase in heel contact velocity during stair ascent is intended to provide ample thrust to overcome the resistance posed by the incline.The augmentation of heel contact velocity aids in more efficiently propelling the body upward during stair ascent, thereby sustaining the continuity of gait[9], yet it concurrently heightens the risk of slipping, consistent with findings from other scholars[10, 11].

V. CONCLUSION

COM velocity increased as heel velocity decreased when approaching stairs.

VI. RESEARCH QUESTION

1. What gait characteristics will be changing when facing stairs during walking?
2. What will differ among the different age groups when facing stairs during walking?
3. Will other variable be affected when facing stairs?

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