Prognostic method for tripping over when walking for controlling the robotic ankle prosthetics

Y. Lee[1], D.H. Hwang[2]

[1,2] *Korea Institute of Machinery and Materials, Daegu, 42994, Korea*
ylee2012@kimm.re.kr
dh0746@kimm.re.kr

ABSTRACT

Generally, the walking road includes many bumps. In order to wear a robotic ankle prosthesis and walk on a general walkway, it is necessary to control the robotic ankle prosthesis so that it can cope with tripping over when it is caught by a bump. The purpose of this study was to analyze the kinetic behavior of the ankle and to determine the discrimination method of the case of tripping over by unevenness. The ankle is in bent toward plantar more than general walking toe-off when it is caught by unevenness. and the thigh is bent toward body, the ankle is in dorsiflexion to prevent from tripping over. When tripping over, it can be discriminated according to the degree of the ankle angle and then the robot's ankle can be bent in dorsiflexion to prepare for the next movement of the body to prevent from tripping over.

1. INTRODUCTION

Gait is defined as “ the coordinated and cyclic combination of movements that result in human locomotion” When the flow of the periodic motion is broken by the external force, it takes a reflexive action to recover the periodic motion.

Many people are having difficulty exercising this cyclic movements due to loss of legs. The patients with limb amputation are divided into 7 types depending on the cutting site.

In this study, we tried to derive a control algorithm for recovering to normal walking when it is caught on obstacles that can be applied to the robot - type including only ankle joints. To do this, we analyzed the behavior of normal people when they trip over. Especially, we tried to discriminate normal walking and tripping over by comparing the normal walking and tripping over of the normal person motion analysis.

2. METHOD

2.1. Subject

The experiment was conducted by a normal male 23-year-old(weight : 61.4 kg, height : 174 cm, BMI : 20.28) who had no surgical problems.

2.2. Experimental set up

Kinetic and kinematic information was calculated and obtained by using T10s * 8 (Vicon) and Force plate * 2 (Amti).

The obstacle was designed and configured to be activated by a switch to describe an unexpected situation. The obstacle was activated randomly by pressing the switch after the obstacle was disappeared from the subject's field of vision.

A general gait experiment was performed prior to the gait experiment with the obstacle. The subjects were allowed to walk for 5 minutes to induce the most comfortable walking velocity. And its bit per minute was measured. The experiment was performed five times by controlling the walking velocity using the metronome.

The obstacle was installed in front of the force plate. In the case of deactivation, the height was set to be equal to the ground level. And the heights during activation were set to 20 mm, 30 mm, and 50 mm. The obstacle was randomly activated when the subject approached it, causing the dominant foot to trip over.

2.3. Data acquisition and analysis

Walking data were obtained from the toe-off to the next heal-strike of the normal walking, and the walking data on the walking road with obstacle were obtained from the toe-off before tripping over to heal-strike after tripping over. The acquired data was scaled by sampling.

3. RESULTS

In this study, There is an action to not tripping over, and recovering movements to normal walking when a normal person tripping over from an obstacle in a walk.

In experiments with obstacles, the tripping over movements of the subject is induced when the oppsite foot(of the dominant foot) heal-strike zone overlaps the obstacle zone in the walking direction. And also when the obstacle height was 20mm and 30mm, there was not a significant change in the subject's gait cycle but a significant change was observed in the obstacle height of 50mm.

3.1. Ankle, knee, hip angle comparing normal walking and walking road with the obstacle

Compared with normal walking, the ankle suddenly becomes plantar flexion when tripping over an obstacle. Immediately after tripping over, the knee and hip become flexion and the ankle becomes dorsi-flexion.

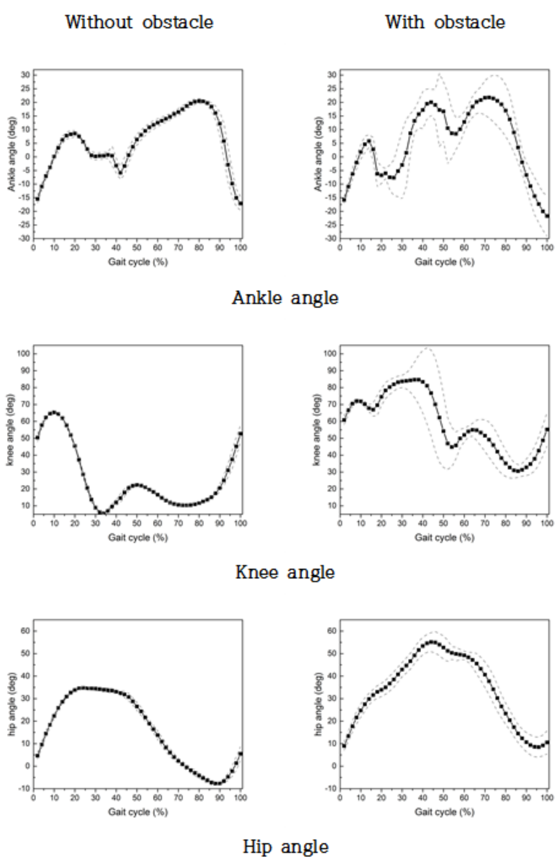

Figure 1. Ankle, knee, hip angle comparing normal walking and walking road with the obstacle.

3.2. Maximum angular velocity of the lower limb joints at swing phase

In the normal walking (from toe-off to the next heel strike), the ankle angular velocity is maximum immediately after toe-off in the swing phase, the rotational direction is in dorsi-flexion. The knee angular velocity is maximum when the knee was passed by the CoM in the swing phase, the rotational direction is in extension. And the hip angular velocity is maximum immediately after toe-off, the rotational direction is in flexion.

In the walking road with the obstacle (from toe-off to the next heel strike), the ankle angular velocity is maximum immediately after tripping over in the swing phase, the rotational direction is in dorsi-flexion. The knee angular velocity is maximum before heal-strike, the rotational direction is in extension. And The hip angular velocity is maximum immediately after toe-off , the rotational direction is in flexion.

Table 1. Maximum angular velocity of the lower limb joints at swing phase.

	Without the obstacle [deg/sec]	With the obstacle [deg/sec]
Ankle	402.49 ± 20.28	-1262.84 ± 326.46
Knee	-903.291 ± 29.90	-1225.42 ± 399.33
Hip	492.85 ± 26.56	464.85 ± 52.28

3.3. Maximum angular acceleration of the lower limb joints at swing phase

In the normal walking (from toe-off to the next heel strike), the ankle angular acceleration is maximum midway in the swing phase, the rotational direction is in plantar-flexion. The knee angular acceleration is maximum before heal-strike, the rotational direction is in flexion. And the hip angular acceleration is maximum immediately after toe-off, the rotational direction is in extension.

In the walking road with the obstacle (from toe-off to the next heel strike), the ankle angular acceleration is maximum immediately after tripping over in the swing phase, the rotational direction is in plantar-flexion. The knee angular velocity is maximum immediately after tripping over, the rotational direction is in flexion. And the hip angular velocity is maximum before heal-striker, the rotational direction is in extension.

Table 2. Maximum angular acceleration of the lower limb joints at swing phase.

	Without the obstacle [deg/sec²]	With the obstacle [deg/sec²]
Ankle	-24512.45 ± 6488.20	-132472.43 ± 44878.66
Knee	27330.28 ± 2262.523	66568.70 ± 20433.56
Hip	-10751.99 ± 1903.52	42812.50 ± 21345.32

4. CONCLUSION

In the hip angular velocity, it was found that there was not significant difference between the walking without obstacle and with obstacle. The angular velocity of the knee was different in the maximum range, but the difference was not significant. In the ankle, the maximum value was 860.35 [deg/sec] difference and rotated in the opposite direction.

In the hip angular acceleration, the maximum value occurred at different positions, and the difference was 32060.49 $[\mathrm{deg/sec^2}]$. The knee had a maximum value at different places and the difference was 39238.42 $[\mathrm{deg/sec^2}]$ and rotated in the same direction. The difference between the maximum values of the ankles was 107959.98 $[\mathrm{deg/sec^2}]$, which was the largest, and rotated in the same direction.

It is necessary to discriminate the emergency situation such as when the patient is tripping over when walking while wearing the robot prosthesis, and the reaction of the robot to cope with the body movements. As the result of this study, the determination of the tripping over situation will be possible by the sensing of the ankle angular acceleration, ankle angular velocity, the hip angular velocity, and the knee angular acceleration.

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NOMENCLATURE

deg degree [°]
sec second

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