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WALKING AND GRASPING COMBINED: WALKING STABILITY IS AFFECTED BY ADDING DIFFICULTY IN THE GRASPING TASK

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SUMMARY

Stability control is essential walking. Margin of dynamic stability (MDS) is an important parameter for stability evaluation during locomotion. It is important to understand how stability is affected in challenging situations, such as, when walking is combined with grasping an object. The aim of this study was to analyze the adjustments in MDS when walking was combined with grasping an object with different levels of task difficulty. Fifteen right-handed young adults participated in this study and were invited to walk at a self-selected pace on a pathway and to grasp an object as they walked through a pathway. This task was performed with different levels of difficulty. The results showed adjustments mainly in MDS for the step at the moment of object contact. MDS decreased in the ML direction and increased in the AP direction, indicating that stability impaired in the ML direction and improved in the AP direction. Moreover, MDS was most modified in the more challenging conditions. Then, the locomotor pattern is modified to accommodate the level of difficulty of the secondary task.

INTRODUCTION

The control of stability during walking is achieved by appropriate foot placement relative to center of mass in both anterior-posterior (AP) and medio-lateral (ML) directions. Stability control during gait can be captured by measuring the margin of dynamic stability (MDS) as proposed by Hof et al. [1]. However, it is not known, what are the changes that occur in dynamic stability when walking is combined with another motor task as grasping an object. Moreover, it is necessary to investigate if adjustments in dynamic stability are affected due to increase in the level of difficulty of the grasping task. The aim of this study was, therefore, to investigate the adjustments in the MDS in both AP and ML directions when walking was combined with grasping. Furthermore, it was investigated how this control was modified due to increased grasping task difficulty.

METHODS

Fifteen right-handed young adults (9 women and 6 men; age 23.9 ±2.6 years-old; height 1.70 ±0.08 m; mass 69.7 ±15.1 kg) participated in this study and were invited to walk at their self-selected pace on a pathway and to grasp an object (a wood cylinder, diameter: 4 cm, height: 10 cm) as they walked through a pathway.

The object was positioned on a support adjusted to participants' greater trochanter height. Laterally, the object was placed with a distance corresponding to 50% participants' right arm length. In all condition, the object was placed on a wood cylindrical support (diameter: 6 cm, height: 20 cm). This support was stable (wide base) or unstable (narrow base). Yet, for each type of support, there were three obstacle conditions: none, short and long distances. For the short and long distances, the object was placed between two wood obstacles (height: 20 cm, width: 6 cm). The short distance corresponded to three times the right hand thickness, whereas the long distance corresponded to five times the right hand thickness. The level of difficulty of these conditions was the distance between the obstacles and type of support. Then, the conditions performed were: stable (SS) and unstable (US) support without obstacles, stable support with obstacles at short (SSD) and long (SLD) distances, unstable support with obstacles at short (USD) and long (ULD) distances and free walking (control). SSD and USD were considered conditions with the greatest difficulty level. For each condition, 3 trials (21 trials in total) were collected. These trials were completely randomized.

Data collection was performed using a 8-camera motion analyses system (VICON-MX-T-40S) at a sampling frequency of 100 Hz. Passive reflective markers were placed on the skin at defined landmarks (head, torso, pelvis, arms, legs and foot in both sides) according to the Plug-in-Gait Full Body model (VICON). Center of mass position was calculated by NEXUS software.

The extrapolated center of mass (XCOM) was calculated according to the work of Hof et al. [1]. Based on XCOM, the margin of dynamic stability (MDS) was calculated at heel contact. Metatarsal and heel markers on both feet were used to define the extremities of the foot and to compute MDS in the AP and ML directions, respectively. MDS represents a measure of stability and it was calculated for the step at the time of contact with object (*N*), two steps before contact (*N*-2, *N*-1) and a step after contact (*N*+1). More positive values for the MDS indicate increased stability.

Three ANOVAs with repeated measures in all factors were carried out for MDS in both AP and ML directions: 1) a two-way (7 conditions [SS, US, SSD, SLD, USD, ULD, control] x 4 steps [*N*-2, *N*-1, *N*, and *N*+1]); 2) a one-way (7 conditions) just for step *N*; 3) a three-way (2 bases [stable and unstable] x 3 obstacles [none, short, and long] x 4 steps). The alpha value was set at 0.05.

RESULTS AND DISCUSSION

The first ANOVA revealed step ($F_{3,42}$=7.43, p=0.001) and interaction effects ($F_{18,252}$=2.46, p=0.001) in the AP direction. MDS in step *N*-2 was smaller than steps *N*, *N*+1. MDS in step *N*-1 was smaller than in step *N*+1. The interaction effect shows that MDS increased at step *N* for the conditions with obstacles for grasping the object (Figure 1A). For the ML direction, the interaction ($F_{18,252}$=2.07, p=0.007) showed that MDS was larger in free walking compared with all other conditions at step N. The second ANOVA revealed condition effect ($F_{6,84}$=16.34, p=0.001) for step *N*. MDS in the SS condition was smaller than SSD, SSL, USD, and USL conditions. MDS for the SSD condition was larger than US and control conditions. For USL, MDS was large as compared to US. Finally, MDS for the USD condition was larger than US, USL and control conditions. The last ANOVA revealed step ($F_{3,42}$=7.69, p=0.001) and interaction effect between obstacle and step ($F_{6,84}$=2.46, p=0.001) for the AP direction. MDS in step *N* increased for SO condition as compared to the other conditions (Figure 1B). In ML direction, ANOVA revealed only step effect ($F_{3,42}$=3.14, p=0.035). Thus, regardless of the condition, the MDS in step *N* was smaller than steps *N*-2, *N*-1 and *N*+1. These results suggest that increasing task difficulty caused changes in MDS, particularly for conditions with obstacles when grasping the object.

The results showed that, in AP direction, the MDS in step *N* increased when compared with steps before the contact with the object. Then, there was a change in walking stability at the moment of contact with object. In this situation, the increase in MDS indicates a more stable system. This increase in MDS was achieved most probably due to a decrease in center of mass velocity. These changes in MDS were observed in the most challenging condition (USD), which shows adjustments in dynamic stability control due to task difficulty. For ML direction, it was observed a decreased in body stability (decreased MDS) when grasp was added as compared to free walking. This reduction in MDS implies that the center of mass was displaced closer to the limits of the base of support in order to grasp the object, especially for conditions with obstacle. Then, for conditions without obstacles, the control of stability is similar to free walking. These findings show that dynamic stability control is affected when increasing task difficulty. We suggest that the locomotor pattern is modified to accommodate the level of difficulty of the secondary task. These results help understanding how dynamic stability control occurs when two motor tasks are combined.

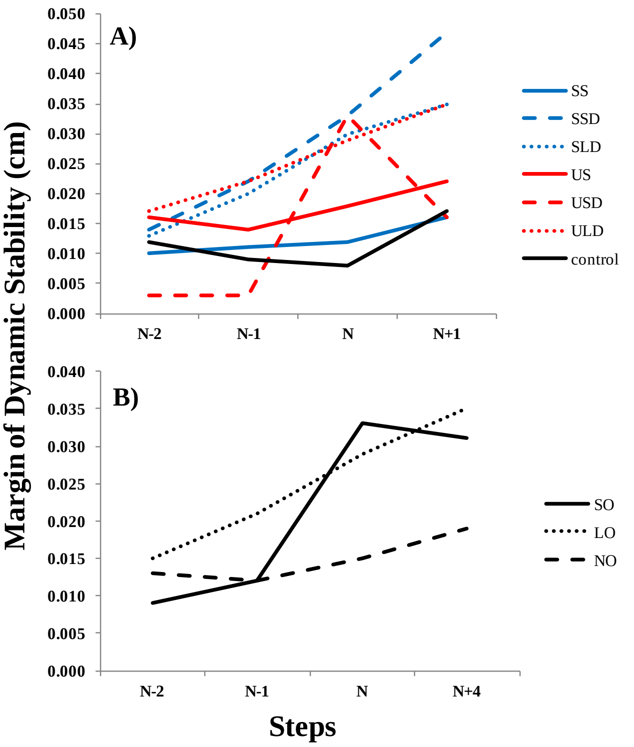

Figure 1: A) MDS for the four steps (*N*-2, *N*-1, *N*, *N*+1) in the seven experimental conditions. B) MDS for the four steps (*N*-2, *N*-1, *N*, *N*+1) in the three obstacle conditions (SO: short distance; LO: long distance; NO: no obstacle).

CONCLUSIONS

In summary, MDS was modified in the moment of object contact. In AP direction, MDS increased probably due to center of mass velocity reduction, which indicates an improvement in stability to accomplish the task more safely. However, in ML direction, it was observed a decrease in MDS, which indicates a decrease in body stability due to arm movement in the direction of the object. Finally, changes in dynamic stability control were due to an increase in task level difficulty.

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REFERENCES

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