Human leg adjustments to ground dropping perturbations during walking

Guoping Zhao, Lauflabor, TU Darmstadt
zhao@sport.tu-darmstadt.de

Extended Abstract:

Maintaining balance during bipedal walking is one of the most critical tasks for both humans and bipedal robots. In order to achieve stable walking gait, humans have to coordinate swing and stance leg to 1) keep the trunk upright and 2) prevent the falling of the centre of mass. It is more challenging if the ground drops before or during stance phase, which is also a common perturbation we encounter in the daily life. For instance, unexpectedly step off the street curb during walking.

In order to investigate how humans keep balance when there is an unexpected ground dropping during walking, we conducted perturbed walking experiment with different perturbation timing and dropping height. Specifically, we introduced the ground dropping perturbation at early stance (ES, unloading phase), late stance (LS, loading phase), and touch-down (TD). For each perturbation timing, we did 2.5cm, 5cm, and 7.5cm three different dropping heights. For the TD case, we also did 10cm dropping height. Perturbation platform acceleration and speed were set as 0.8g (7.85m/s^2) and 1.0m/s, to ensure ground contact during whole stance phase. In addition, in order to compare human behaviour between anticipated and unanticipated ground dropping, we also did the experiment which the subject knows that the ground level of perturbed step is fixed at -2.5cm, -5cm, -7.5cm, and -10cm. Twelve healthy subjects participated in the experiment. Eight repetitions were conducted for each type of the perturbation. Full body movement was captured by motion capture system. Three force plates captured the ground reaction force data of perturbed step, the step before and after the perturbed step. To investigate how leg muscles react to the perturbation, we also collected 16 leg muscles (8 muscles each leg) data from surface electromyography (sEMG). They are: gluteus maximus (GLM), rectus femoris (REF), biceps femoris (BIF), vastus (VAS), semitendinosus (SET), tibialis anterior (TIA), soleus (SOL) and gastrocnemius (GAS).

In general, we find that for all perturbations conducted in this study (both anticipated and unanticipated perturbations), leg and ankle stiffness during push-off phase remain similar to normal walking, whereas leg and ankle rest length/angle increase as the dropping height increases. This indicates human energy injection strategy in the leg direction. For ES perturbations, subjects tend to have stronger push-off if the dropping height is relatively high (5cm and 7.5cm). However, it is the opposite for LS perturbations. We also observe that comparing to the anticipated cases, leg stiffness of TD perturbations during loading phase is higher. As dropping height increases in anticipated ground drops cases, subjects switch from heel landing to forefoot landing to decrease impact force and absorb more energy by ankle joint. Those findings can help us build more robust and human-like balance controller and improve the dynamic walking behaviour of humanoids.