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Adjustment of the Whole-Body Center of Mass during Trunk-Flexed Walking across Uneven Ground

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Abstract : Despite considerable studies on the impact of imposed trunk posture on human walking, less is known about such locomotion while negotiating changes in ground level. The aim of this study was to investigate the behavior of the VBCOM in response to a two-fold expected perturbation, namely alterations in body posture and in ground level. To this end, the kinematic data and ground reaction forces of twelve able participants were collected. We analyzed the vertical position of the body center of mass (VBCOM) from the ground determined by the body segmental analysis method relative to the laboratory coordinate system at touchdown and toe-off instants during walking across uneven ground — characterized by perturbation contact (a 10-cm visible drop) and pre- and post-perturbation contacts — in comparison to unperturbed level contact while maintaining three postures (regular erect, ~30° and ~50° of trunk flexion from the vertical). The VBCOM was normalized to the distance between the greater trochanter marker and the lateral malleoli marker at the instant of TD. Moreover, we calculated the backward rotation during step-down as the difference of the maximum of the trunk angle in the pre-perturbation contact and the minimal trunk angle in the perturbation contact. Two-way repeated measures ANOVAs revealed contact-specific effects of posture on the VBCOM at touchdown ($F = 5.96$, $p = 0.00$). As indicated by the analysis of simple main effects, during unperturbed level and pre-perturbation contacts, no between-posture differences for the VBCOM at touchdown were found. In the perturbation contact, trunk-flexed gaits showed a significant increase of VBCOM as compared to the pre-perturbation contact. In the post-perturbation contact, the VBCOM demonstrated a significant decrease in all gait postures relative to the preceding corresponding contacts with no between-posture differences. Main effects of posture revealed that the VBCOM at toe-off significantly decreased in trunk-flexed gaits relative to the regular erect gait. For the main effect of contact, the VBCOM at toe-off demonstrated changes across perturbation and post-perturbation contacts as compared to the unperturbed level contact. Furthermore, participants exhibited a backward trunk rotation during step-down possibly to control the angular momentum of their whole body. A more pronounced backward trunk rotation (2- to 3-fold compared with level contacts) in trunk-flexed walking contributed to the observed elevated VBCOM during the step-down which may have facilitated drop negotiation. These results may shed light on the interaction between posture and locomotion in able gait, and specifically on the behavior of the body center of mass during perturbed locomotion.

Keywords : center of mass, perturbation, posture, uneven ground, walking
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