Stability in walking and running - biomechanical concepts and challenges

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In human walking and running, typical patterns of the ground reaction force with two humps in walking and a single hump in running are found. This behavior is widely found in nature and can be well described by assuming spring-like leg function (spring-mass model, Blickhan, 1989, extended to bipedal gaits, Geyer et al., 2006). However, systematic deviations from such a perfectly elastic leg behavior like a telescopic linear spring can be found. One reason for this is that the leg has non-elastic properties (e.g. in materials and muscles Haeufle et al., 2010). Also, the leg is landing at the ground with non-zero contact velocities leading to impact losses (De Wit et al., 2000).

The segmental design of legs with a distal foot segment and almost straight knee configurations could also contribute to deviations in the spring-like leg function (Seyfarth et al., 2001, Maykranz, 2009). In fact, elastic properties at joint level are related to spring-like leg function in a nonlinear fashion (Rummel and Seyfarth, 2008). Furthermore, hip torques joint can redirect the leg force with respect to the center of mass (Maus et al., 2008). By this, the upper body can stay in an upright position guaranteeing postural trunk stability during locomotion. Another example of extending the spring-mass model is to include lateral body movements (Seipel and Holmes, 2005, Peuker and Seyfarth, 2010). Furthermore, extensions to quadrupedal (Gross, 2009) and hexapod (Schmitt and Holmes, 2000) gait models can be considered. Interestingly, all these structural extensions of the model did preserve the previously observed self-stabilizing mechanisms found in the spring mass model (Seyfarth et al, 2001).

With this repertoire of conceptual models it becomes possible to design models of desired complexity, which could inherit features of the underlying template models (Full & Koditschek, 1999). In order to compare the model predictions with experimental data it is important to make sure that the key characteristics of human or animal gait are sufficiently represented in the biomechanical models. So far, there are fundamental differences between the predicted gait pattern and experimental data on human locomotion. For instance, it is not clear which mechanisms cause the observed step-to-step variability in kinematic and kinetic parameters. This is important as concepts on gait and gait stability often rely on the assumption of a periodic gait pattern. As such steady-state gait patterns are not present in nature, the currently used gait models need to be improved to adequately describe the observations.

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