Altered Muscle Contributions are Required to Support the Stance Limb During Voluntary Toe-Walking

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Toe-walking characterizes several neuromuscular conditions and is associated with a reduction in gait stability and efficiency, as well as in life quality. The optimal choice of treatment depends on a correct understanding of the underlying pathology and on the individual biomechanics of walking. The objective of this study was to describe gait deviations occurring in a cohort of healthy adult subjects when mimicking a unilateral toe-walking pattern compared to their normal heel-to-toe gait pattern. The focus was to characterize the functional adaptations of the major lower-limb muscles which are required in order to toe walk. Musculoskeletal modeling was used to estimate the required muscle contributions to the joint sagittal moments. The support moment, defined as the sum of the sagittal extensive moments at the ankle, knee, and hip joints, was used to evaluate the overall muscular effort necessary to maintain stance limb stability and prevent the collapse of the knee. Compared to a normal heel-to-toe gait pattern, toe-walking was characterized by significantly different lower-limb kinematics and kinetics. The altered kinetic demands at each joint translated into different necessary moment contributions from most muscles. In particular, an earlier and prolonged ankle plantarflexion contribution was required from the soleus and gastrocnemius during most of the stance phase. The hip extensors had to provide a higher extensive moment during loading response, while a significantly higher knee extension contribution from the vasti was necessary during mid-stance. Compensatory muscular activations are therefore functionally required at every joint level in order to toe walk. A higher support moment during toe-walking indicates an overall higher muscular effort necessary to maintain stance limb stability and prevent the collapse of the knee. Higher muscular demands during gait may lead to fatigue, pain, and reduced quality of life. Toe-walking is indeed associated with significantly larger muscle forces exerted by the quadriceps to the patella and prolonged force transmission through the Achilles tendon during stance phase. Optimal treatment options should therefore account for muscular demands and potential overloads associated with specific compensatory mechanisms.

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