Load on osseointegrated fixation of a transfemoral amputee during a fall: Determination of the time and duration of descent

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Abstract

Mitigation of fall-related injuries for populations of transfemoral amputees fitted with a socket or an osseointegrated fixation is challenging. Wearing a protective device fitted within the prosthesis might be a possible solution, provided that issues with automated fall detection and time of deployment of the protective mechanism are solved. The first objective of this study was to give some examples of the times and durations of descent during a real forward fall of a transfemoral amputee that occurred inadvertently while attending a gait measurement session to assess the load applied on the residuum. The second objective was to present five semi-automated methods of detection of the time of descent using the load data. The load was measured directly at 200 Hz using a six-channel transducer. The average time and duration of descent were 242+42 ms (145–310 ms) and 619+42 ms (550–715 ms), respectively. This study demonstrated that the transition between walking and falling was characterized by times of descent that occurred sequentially. The sensitivity and specificity of an automated algorithm might be improved by combining several methods of detection based on the deviation of the loads measured from their own trends and from a template previously established.

Conclusions

An insight into the determination of the time and duration of descent of a prosthetic lower limb during a real forward fall was provided for the first time. This included the presentation of five different methods of assessment of these variables as well as examples of values for an amputee fitted with an osseointegrated fixation. The fall might appear sudden with a naked eye. However, this study demonstrated that a short transition between walking and falling was characterized by times of descent of the residuum that occurred sequentially on the three forces and moments. Also, the time of deployment of a protective device should have been within approximately 575 ms to be effective in the fall analysed in this study. The sensitivity and specificity of an automated algorithm might be improved by combining several methods of detection based on the deviation of the loads measured from their own trends and from a template previously established. This work also highlighted that one of the challenges of this algorithm might be to differentiate deviations due to a real fall from those associated with normal changes of pattern between or within activities of daily living, including inactivity, stationary loading and locomotion. Finally, this work confirmed that the portable kinetic system presented here could play a role in fall detection as the core instrument of an apparatus involving other complementary sensors (e.g., foot switch, accelerometer), signal processing (e.g., recognition of falling patterns) and protective device (e.g., air bag). All together, this study provided key information to engineers and clinicians facing the challenge to design automated wearable fall protective equipment and, rehabilitation and exercise programs to restore safely the locomotion of lower limb amputees.

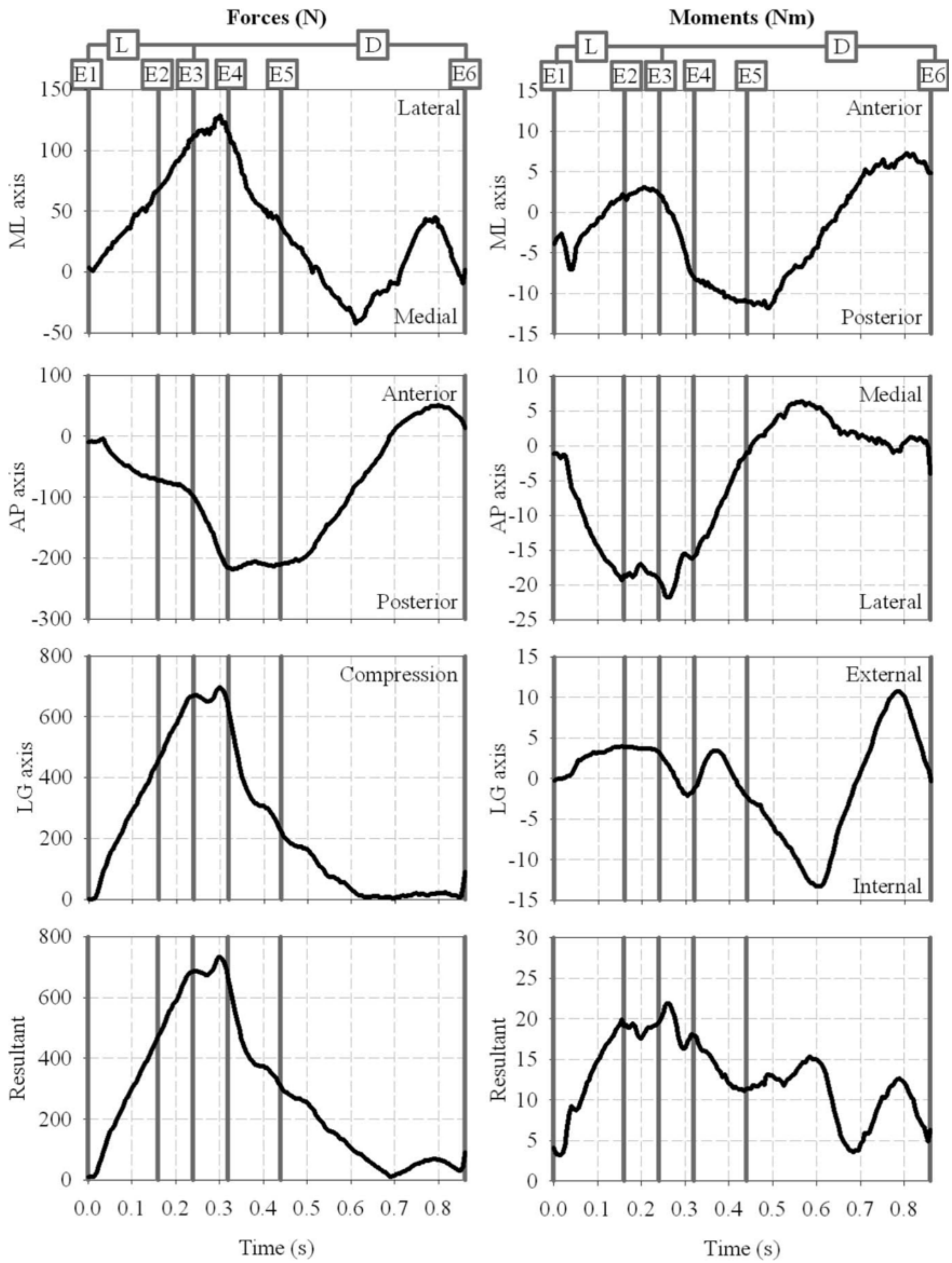

Figure 3. Overview of resultant and three components of the forces and moments on the medio-lateral (ML), anteroposterior (AP) and long (LG) axes of the fixation during the loading (L) and descent (D) phases of the forward fall as determined by the sequence of events (E1–E6). E3 corresponded to the time of descent as determined by Method 1 in Frossard et al. (2010).