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**Title**
Instrumented Motion Analysis and Trans-tibial Prosthetics: a Systematic Review

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**Summary**
A systematic review was conducted to critically evaluate methods used during three dimensional motion analysis of trans-tibial amputees. Presented is a critical review of the level of evidence, quality of research design, and summary of dependent and independent variables utilized by researchers.

**Introduction**
Joint kinematics is one of the most commonly reported outcomes from motion analysis and is often used in combination with temporospatial and kinetic variable to describe human movement. While a large number of studies have investigated kinematics of trans-tibial amputees performing a range of different activities, there appears to be a great deal of variability in the methods of data capture, the description of these methods, reporting of joint kinematics and in the interpretation of research findings.

The aim of this review was to critically examine the methods used by researchers in collecting and reporting three dimensional kinematic data related to trans-tibial amputees. We further aimed to review specific independent and dependant variables that have been investigated in studies of trans-tibial amputees and to propose recommendations relevant to future research in this area.

**Methods**
A literature search was conducted in June 2009 of the Medline, Cinahl, and Cochrane databases incorporating the search terms: “kinematic”, “biomechanics”, “amputee”, “prosthesis”, and “foot”. The search was limited to English language publications within the period spanning January 1984 to June 2009. Papers were deemed fit for inclusion in the analysis if they: utilized an experimental research design, collected three dimensional kinematic data and included...
trans-tibial amputees as experimental subjects. The literature search yielded 661 individual articles (597 Medline; 78 CINAHL; 1 Cochrane; some articles appearing in multiple databases). After an initial review 69 papers remained, each of which was reviewed and classified according to the evidence hierarchy outlined by Bhandari et al., 2006. Articles were further evaluated for methodological quality using the Critical Review Form for Quantitative Studies developed by Law et al., 1998.

Results
Of the 69 studies included in this review, 3 were classified as Level II (sub-category B; poorly designed RCT), 23 were classified as level III studies (sub-category A; case-control studies) and 43 as level IV studies (34 sub-category A, case-series studies; 9 sub-category B, case-report studies). Sample sizes in the reviewed publications ranged from a single-subject case-study design to 43 subjects. The mean number of subjects across all publications was 8.7 (SD 6.4). In articles where it was possible to determine, pooled mean age of subjects in all articles was 42.4 years (SD 13.7), with 393 males and 71 females (a proportion of 0.85 to 0.15). The methodological quality (Law et al., 1998) of the papers (maximum possible=16) showed considerable variability (mean score of 10.1; SD=2.5; range = 2-15). A review of data capture techniques used in studies involving trans-tibial amputee kinematics revealed a great deal of variation in the specific methods used. Of note are the differences in the placement of marker for capturing three dimensional motion of limb segments, the activity amputees were required to undertake and the velocity at which subjects were required to ambulate. Of the 69 studies, 33 stated that the markers were positioned on the prosthesis by estimating the location of the points from the intact limb and 36 studies did not state how they determined the positions of the markers. Sagittal plane kinematics of foot and ankle were the most documented variables.

Conclusion
A number of methodological problems were repeatedly identified in the studies reviewed. As such, the authors recommend the following practices to those intending to conduct research on trans-tibial amputees in the future.

- Clearly state the model and model number of prosthetic components used
- Clearly state how you determine the location of reflective markers on the prosthesis
• Axis of rotation for plantarflexion/dorsiflexion should be investigated for different types of prosthetic feet as this is another source of systematic variation specific only to amputee gait.
• When reporting kinematic and kinetic data be very clear whether you are presenting data from the sound or affected side.
• If reporting ankle kinematics, report both foot dorsiflexion and plantarflexion from a zero point defined as the position of the foot relative to the shank when the foot is unloaded.
• When possible use a control group.

References