Effects of prosthetic mass and mass distribution on kinematics and energetics of prosthetic gait: a systematic review

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Authors' objectives
To systematically review experimental studies on the relationship between prosthetic inertial loading and energetics and kinematics of lower-limb prosthetic gait, and to compare the review outcomes with predictions derived from theoretical models.

Searching
MEDLINE was searched from 1966 to November 1998 using the following keywords: 'prosthetic design', 'amputees', 'gait' and 'artificial limbs'. References in selected publications were examined. Studies were limited to those published in the English language in books or journals; abstracts were excluded.

Study selection
Study designs of evaluations included in the review
Inclusion criteria were not defined in terms of study design. Included studies were of the following designs: randomised controlled trials (RCTs), non-randomised controlled trials, retrospective studies (in which researchers compared patients with different prosthetic loadings) and single case studies.

Specific interventions included in the review
Techniques involving the changing of the inertial loading by changing prosthetic mass or by changing the centre of mass location were eligible. Studies investigating the influence of centre of mass location were only recognised as such when the prosthetic mass was constant. Loadings on the prosthetic mass ranged from 0 to 4.13 kg. Location of prosthetic centre of mass included 'proximal' and 'distal'; one study included variable distances both distal to the knee (17, 25 and 33 cm) and 7 cm proximal of the knee. Adjustment times, where stated, included 15 minutes, 1 week, 'allowed to practice', 'sufficient', and 'a while'.

Participants included in the review
Patients with the following types of lower-limb amputation were eligible: transtibial (TTA), through-knee (TK) and transfemoral (TF). All included patients were adult, with the exception of one child aged 13 years.

Outcomes assessed in the review
The following outcomes were assessed: effects of prosthetic mass on economy of prosthetic gait and gait pattern; and effects of prosthetic centre of mass on economy of prosthetic gait and gait pattern. Effects were assessed using self-selected walking speed (SSWS), stride frequency (SF) and stride length (SL).

How were decisions on the relevance of primary studies made?
The authors do not state how the papers were selected for the review, or how many of the reviewers performed the selection.

Assessment of study quality
The following 9 criteria were used to assess study design and methodological quality: number of patients measured; level of amputation; research design; independent variables investigated; outcome measures used; did all patients have the same prosthetic components; was the trial randomised; was a statistical analysis performed; and time patients were given to adapt to changes in the inertial loading of their prosthesis. The authors do not state how papers were assessed for quality, or how many of the reviewers performed the quality assessment.
Data extraction
Tables reported in the review included the following information, in addition to the validity criteria: author, level of amputation, number of patients, mass condition, and outcomes. Two studies used data from the same experiment and redundant data were excluded from the analysis. The authors do not state how data were extracted for the review, or how many of the reviewers performed the data extraction.

Methods of synthesis
How were the studies combined?
The studies were grouped according to outcome and combined in a narrative review.

How were differences between studies investigated?
Potential causes of differences were discussed.

Results of the review
Ten studies with 102 patients were included: 6 RCTs (57 patients), 1 non-randomised trial (4 patients), 1 retrospective study (39 patients) and 2 single case studies. TF amputees were studied in 5 experimental studies (36 patients); TTA in 2 experimental, 1 retrospective and 1 single case study (65 patients); and TK amputees studied in 1 single case study (1 patient).

The methods of most of the experimental studies were relatively poor. Of the 7 experimental studies, 5 used uniform prosthetic components in all patients and 6 performed statistical analysis. Only 4 experimental studies scored positive on all validity criteria, and most studies involved a small (10 or less) number of patients.

Effects of prosthetic mass on economy of prosthetic gait (5 studies with 76 patients, including 3 RCTs with 33 patients): 4 studies, including the 3 RCTs, reported similar non significant effects on economy after the addition of loads ranging from 0.454 to 3.5 kg, compared to the unloaded state. One non-randomised trial (4 patients) reported a significant effect of loading on economy with minimal energy use with loading of 1.70 kg, compared to heavier loads.

Effects of prosthetic mass on gait pattern (7 studies with 83 patients, including 5 RCTs with 78 patients): no significant effect of prosthetic loading was noted in any of the studies for SSWS, SL or SF.

Effects of prosthetic centre of mass on economy of prosthetic gait (2 studies with 19 patients, including 1 RCT): one RCT (15 patients) reported significant decreases in economy when the centre of mass was distal compared to proximal. The other study also found a significant effect of the location of prosthetic mass: the two intermediate mass locations, i.e. 17 and 25 cm distal to the knee, were found to be most energy efficient.

Effects of prosthetic centre of mass on gait pattern (2 studies with 16 patients, including 1 RCT with 15 patients): no significant effect was found in either study.

Authors' conclusions
The methodological quality of most of the experimental studies was limited. The review suggests that the inertial loading of the present lightweight prosthesis need not be further reduced. The discrepancy between theoretical models and experimental findings may be related to both the methodological quality of the experiments, as well as to the limited predictive value of the experimental models.

CRD commentary
The aims were stated, and inclusion criteria were defined in terms of participants, outcomes and interventions. Limiting included studies to those identified in one database and published in the English language may have omitted some relevant studies. Unpublished studies were excluded, thus raising the possibility of publication bias. Methods used to select studies were not described. Some aspects of quality were assessed and reported, but the methods used to assess quality were not described. Some relevant details of the primary studies were presented in tabular format, but no
details of patient characteristics other than level of amputation were reported, and methods used to extract data were not described. Given the heterogeneity among studies, the limited number of studies, and limited patient numbers, a narrative review was appropriate. Attention was not drawn to better sources of evidence and no comment was made on the validity and reliability of methods used to determine outcomes. The discussion included consideration of the following limitations of the review: poor methodological quality of most of the experimental research; limited statistical power of studies to detect actual differences between prosthetic configurations; inability to distinguish between different amputee patients due to limited number of studies; and the potential influence of the dynamic behaviour of the prosthetic components, such as knee and feet, on the prosthetic gait.

Given the apparently poor quality of primary studies, the limited number of studies and the small number of patients, caution must be applied when considering the results of this review.

**Implications of the review for practice and research**

Practice: The authors did not state any implications for practice.

Research: The authors state that future research should focus on testing detailed predictions derived from simulation studies, to obtain the most optimal inertial loading of prosthesis.

**Bibliographic details**


**PubMedID**

10597812

**Indexing Status**

Subject indexing assigned by NLM

**MeSH**

Amputation /rehabilitation; Artificial Limbs; Biomechanical Phenomena; Body Weight; Gait; Humans; Models, Biological; Physical Exertion; Predictive Value of Tests; Prosthesis Design; Reproducibility of Results; Research Design /standards; Walking

**AccessionNumber**

12000000071

**Date bibliographic record published**

31/10/2001

**Date abstract record published**

31/10/2001

**Record Status**

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