The Effects of Prosthesis Mechanical Properties on Balance in Unilateral Transtibial Prosthesis Users: A Literature Review

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Background

- Transtibial prosthesis users experience compromised balance and are at a higher risk of falls (1)
- Prosthesis mechanical behavior directly affects balance control of prosthesis users (2)
- Clinicians must carefully select prosthetic components according to their mechanical properties to support balance
- ***Literature studying links between prosthesis properties and user balance has not been summarized to help guide selection process***

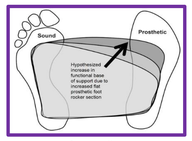


Image from Miller, 2001.

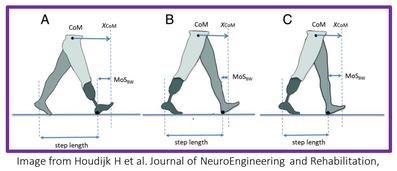


Image from Houdijk H et al. Journal of NeuroEngineering and Rehabilitation, 15. 2018.

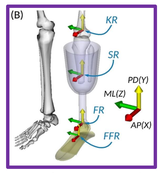


Image from LaPre AK et al. Numerical Methods in Biomedical Engineering, 34. 2018.

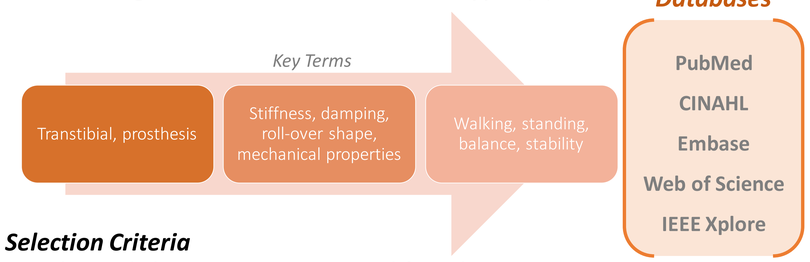
Study Objective

Review the current literature investigating the effects of prosthesis mechanical properties on standing and walking balance in unilateral transtibial prosthesis users

Methods

Search Strategy

- Search executed on October 8th, 2022
- References compiled in EndNote (3) with duplicates removed
- Remaining articles were transferred to Rayyan (4)



Selection Criteria

1. Titles and abstracts were screened for relevance
2. Inclusion and exclusion criteria applied to full text

Inclusion Criteria
- ✓ Mechanical properties bench tested and altered
- ✓ Adult unilateral transtibial prosthesis users

Exclusion Criteria
- X Balance not explicitly evaluated
- X Participants with comorbidities that affect balance

Data Analysis

Extracted data:

Title	Publication year	Authors	Study design	Sample size	Sex distribution	Age range
Time since amputation	Time using a prosthesis	Mechanical property altered	Method of alteration	Study protocol	Outcome measures	Key results

Results

Study Characteristics

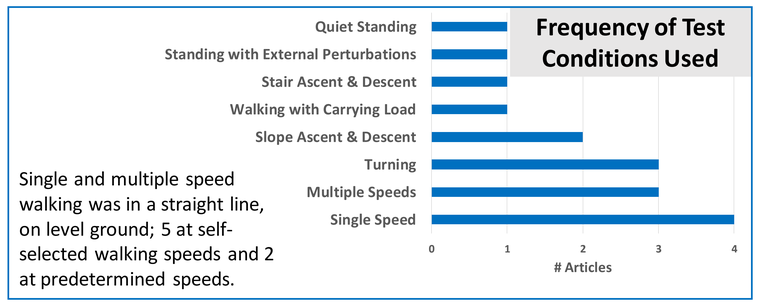
- **8 articles** included in this review
- Publication year ranged from **2010-2020**
- All cross-over repeated measures study design

Data	Range of Results	#Studies Reporting
Sample Size	3-14	8
Sex Distribution (%Male)	90-100%	7
Age Range (years)	22-78	8
Time Since Amputation (years)	0.9-53	6
Time Using a Prosthesis (hours/day)	≥ 4-8	2

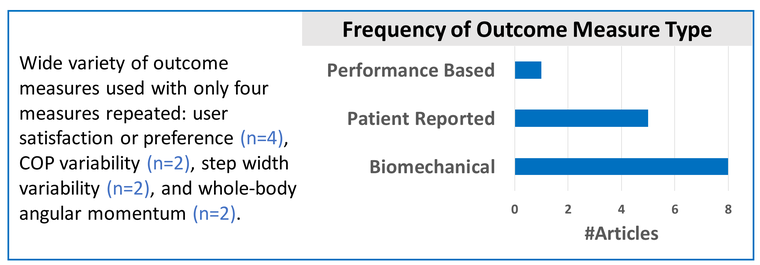
Prosthesis Adjustments

- **6 studies** used custom **experimental** components (6-7, 9-12)
- **2 studies** used **commercial** components (5, 8)

Mechanical Property Altered	#Studies
Foot sagittal plane rollover shape	1
Ankle-foot sagittal plane stiffness	2
Ankle-foot coronal plane stiffness	1
Ankle-foot transverse plane stiffness	2
Articulated ankle sagittal plane stiffness	1
Articulated ankle sagittal plane damping	1



Single and multiple speed walking was in a straight line, on level ground; 5 at self-selected walking speeds and 2 at predetermined speeds.



Wide variety of outcome measures used with only four measures repeated: user satisfaction or preference (n=4), COP variability (n=2), step width variability (n=2), and whole-body angular momentum (n=2).

Higher coronal plane stabilizing stiffness improved walking balance (9)

Articulated ankle damping control improved balance in walking, including ramps and stairs (12)

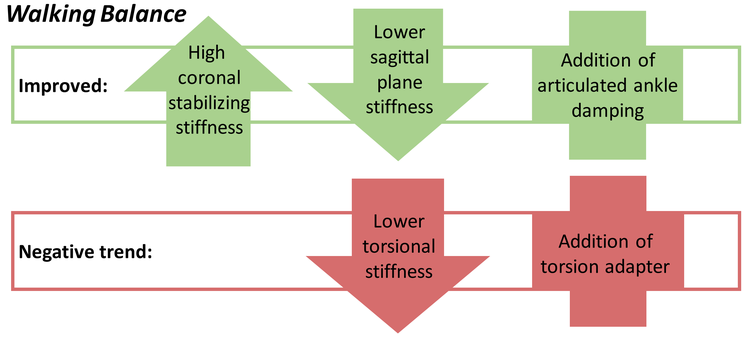
Lower sagittal plane stiffness improved walking balance, including turns, loads, ramps (5, 10, 11)

Rollover shape had no effect on standing balance with perturbations (5)

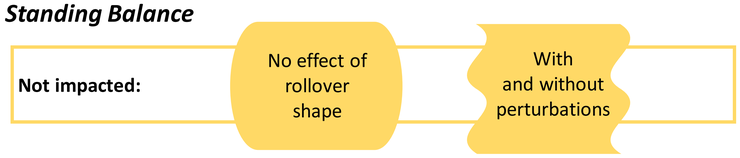
Lower ankle and pylon transverse plane stiffness had either no impact or worsened balance in walking, including turns (7, 8)

Discussion

Walking Balance



Standing Balance



Limitations

- Relatively small sample sizes (≤14 participants)
- Majority of participants were active, and many K-level 3 or above
- Considerable variability across studies in mechanical properties altered, how they were altered, and the test conditions
  - Challenging to draw conclusions based on current literature
- Outcome measures were not consistent across studies
- Some studies compared discrete stiffness levels ("high" vs. "low")
  - Higher resolution would further populate the correlation map

Conclusions

Clinical Significance

- Changes to a system's mechanical properties (stiffness, damping) can directly affect users' balance while walking
  - BUT the direction of the relationship between stiffness and walking balance performance may be *plane-specific*
  - Not all results were confirmed by more than one study

Suggestions for Future Research

- Test a wider range of prosthesis mechanical properties
- Evaluate and validate multiple test conditions, especially standing
- Standardization of outcome measures

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