Energy Storage and Return Prostheses: Does Patient Perception Correlate with Biomechanical Analysis?

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Background: The development and prescription of energy storage and return prosthetic feet in favor of conventional feet is largely based upon prosthetist and amputee experience. Regretfully, the comparative biomechanical analysis of energy storage and return and conventional prosthetic feet is rarely a motivation to either the technical development or clinical prescription of such devices. The development and prescription of prosthetic feet without supportive scientific evidence is likely due to the conflicting or non-significant results often presented in the scientific literature. Despite the sizeable history of comparative prosthetic literature and continued analysis of prosthetic components, the link between clinical experience and scientific evidence remains largely unexplored.

Objectives: A review of the comparative analysis literature evaluating energy storage and return and conventional prosthetic feet is presented to illustrate consistencies between the perceptive assessments and the objective biomechanical data.

Criteria for selecting studies for this review:

Types of studies: NA

Types of participants: NA

Types of interventions: STEN Quantum vs. Seattle/Seattle Lite Carbon vs. Copy II Flex-Foot (Table 1,2,3, Figure 5).

Types of outcome measures: Patient perceptions included descriptive dialog, functional assessment questionnaires, and numerical rating scales (Figure 6). For Biomechanical data stride characteristics, velocity, cadence stride length, temporal characteristics, kinetics, velocity force anterior-posterior force, impulse, accelerometry, moments of force, muscle power, kinematics, muscle activity, and energy expenditure were looked at (Figure 6). For Correlations and contradictions all of the following was looked at; correlations, velocity, stability, ankle motion, high activity gait, less pain, skin problems, shock at hip and knee, contradictions, endurance, downhill walking, overall gait and activity level

Search strategy for identification of studies: NA

Conclusion: The perceptive analysis literature demonstrates rather substantial evidence of the clinical support ESAR prostheses have received. Conversely, relatively few substantial conclusions can be drawn from the biomechanical data obtained through clinical gait analysis. This leads to several important conclusions. First, the distinction between clinical, scientific, and perceptive significance must be understood and addressed in the future development of comparative prosthesis analysis. Secondly, future gait analysis protocols must be limited to concentrate on specific subject populations as well as expanded to include activities where ESAR prostheses demonstrate the largest impact. Finally, future areas of research should be explored in hopes of understanding the perceptive significance illustrated by this comparison between the perceptive and biomechanical analyses conducted to date. Incorporating these elements into future planning, techniques, methodologies, and analyses will serve to better augment the evaluation of prosthetic components and provide clinicians, researchers, and designers the information required to best improve the lives of amputees.

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Perceptive Results

DESCRIPTIVE DIALOG

- Increased velocity
- Increased stability
- Poor walking at slow speeds
- Poor downhill walking

FUNCTIONAL ASSESSMENT

- Overall improved gait
- Increased activity level
- Improved ability to ambulate
- Increased endurance
- Greater ankle motion
- Increased balance
- Less pain
- Less skin problems
- Less shock at hip & knee
- Poor walking downstairs

STATISTICAL ANALYSIS

- Improved gait during upstairs, downstairs, even street, uneven ground, forest, uphill, downhill, and swift walking and running
- Improved walking at various speeds and grades

Biomechanical Results

TEMPORAL/SPATIAL

- Increased self-selected walking velocity (SSWV)
- Increased stride length at SSWV

KINETIC

- Decreased SS weight acceptance force
- Increased AS propulsive force
- Increased shock at lower walking velocity
- Decreased shock at higher walking velocity
- Increased peak ankle plantarflexion moment
- Increased ankle power generation and absorption
- Increased knee power absorption

KINEMATIC

- Increased overall range-of-motion (ROM)
- Increased late stance dorsiflexion
- Increased dorsiflexion ankle moment

ENERGETIC

- No decrease in O2 consumption

MUSCULAR

- No change in muscular timings/intensities

Fig. 6. Summary results for perceptive and objective analyses of ESAR vs. conventional prosthetic feet in transtibial amputees.

Table 1
Reported increase in S-SWV when using ESAR compared to the conventional (SACH) prosthetic foot

Foot	% increase in velocity (m/min) compared to SACH foot								
	$n = 7$ [3]	$n = 5$, $P < 0.05$ [4]	$n = 7$, $P < 0.05$ [20]	$n = 1$, $P < 0.05$ [19]	$n = 8$ [42]	$n = 10$, $P < 0.05$ [27]	$n = 9$, $P < 0.05$ [21]	$n = 10$, $P < 0.05$ [16]	$n = 7$, $P < 0.05$ [13]
STEN		5.23							
Quantum								0.64	6.95
Seattle/Seattle Lite		7.62				2.63	0.22	3.43	2.69
Carbon Copy II		9.42						2.41	2.69
Flex-Foot	8.96	3.59	6.57	1.51	5.77		0.00	5.72	13.11*

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Table 2
Reported increase in cadence at S-SWV when using ESAR compared to conventional prosthetic foot

Foot	% increase in cadence (steps/min) compared to SACH foot				
	$n = 5$, $P < 0.05$ [4]	$n = 1$, $P < 0.05$ [19]	$n = 8$ [42]	$n = 10$, $P < 0.05$ [16]	$n = 7$, $P < 0.05$ [13]
STEN	1.73				
Quantum				1.38	3.65
Seattle/Seattle Lite	2.65		3.15	2.03	1.68
Carbon Copy II	4.28*	0.34		1.47	0.30
Flex-Foot	−0.10			1.94	4.54

Table 3
Reported increase in stride length at S-SWV when using ESAR compared to conventional prosthetic foot

Foot	% increase in stride length (m) compared to SACH foot						
	$n = 5$, $P < 0.05$ [4]	$n = 7$, $P < 0.05$ [20]	$n = 1$, $P < 0.05$ [19]	$n = 8$, $P < 0.01$ [42]	$n = 9$, $P < 0.05$ [21]	$n = 10$, $P < 0.05$ [16]	$n = 7$, $P < 0.05$ [13]
STEN	4.44						
Quantum						0.00	2.40
Seattle/Seattle Lite	5.19			4.07	0.69	2.08	0.00
Carbon Copy II	5.19		1.47			1.39	1.60
Flex-Foot	3.70	3.08			−1.38	4.17*	8.00*

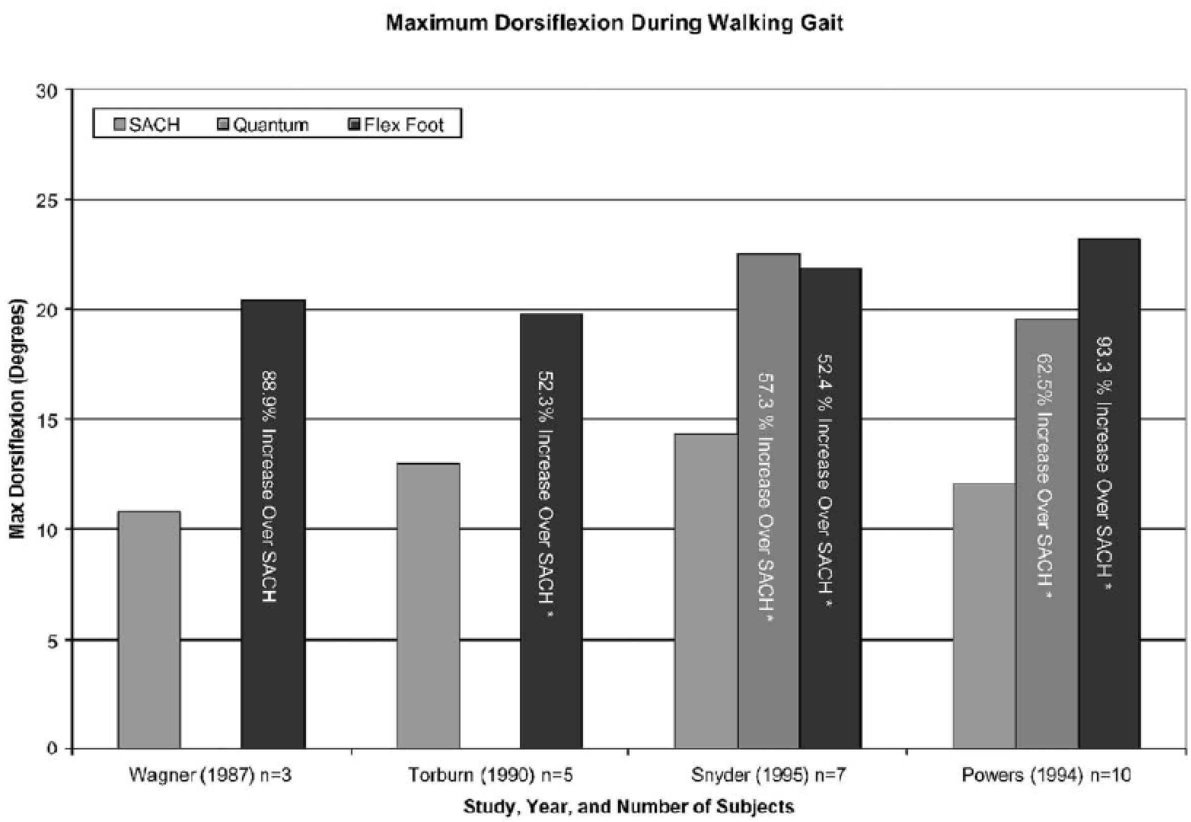

Fig. 5. Maximum dorsiflexion obtained during stance phase with various ESAR and conventional prostheses (* denotes a statistically significant increase compared to the conventional foot).