Adaptation Strategies of the Lower Extremities of Patients With a Transtibial or Transfemoral Amputation During Level Walking: A Systematic Review

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Background: Walking is highly dependent on dynamic interactions between sensory afferents and the central motor program for locomotion. Because an amputation leads to the loss of sensorimotor function of a leg, these skills are challenged. During the period of rehabilitation, a person with an amputation learns to compensate for the deterioration of these skills by adaptation strategies in both the intact leg and the remaining stump.
Objectives: To describe adaptation strategies in terms of joint power or work in the amputated and intact leg of patients with a transtibial (TT) or transfemoral (TF) amputation.
Criteria for selecting studies for this review:
Types of studies: Case control and case series (table 1).
Types of participants: TTA, TFA, cause of amputation due to trauma, vascular, and congenital (table 1).

Types of interventions: Studies were categorized into TTA or TFA, They were also divided based on outcome measures of joint power or work (table 1).

Types of outcome measures: Table 1
Search strategy for identification of studies: MEDLINE, CINAHL, Physiotherapy Evidence Database, Embase, and the Cochrane Register of Controlled Trials were searched. Studies were collected up to November 1, 2010.
Conclusion: Adaptations were seen in the amputated andintact legs. TT and TF use remarkably similar adaptation strategies at the level of the hip to compensate for the loss of plantar flexion power and facilitate forward progression. At the knee level, adaptations differed between TT and TF.

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Table 1: Characteristics of Studies of Patients With a TT Amputation

Trial, Author (Year)	Design	No. (E/C)	Age (y)	Inclusion Criteria	Reason for Amputation	Time Since Amputation	Used Foot	Outcome Measures	Walking Speed (m/s)	Methodologic Quality	
Bateni and Olney (2002)[63]	CS	E: 5 No controls	50.6±14.5	Unilateral TT amputation; prosthesis use >1y; no lesion on stump, no problem knee joint, not walking with assistive devices; good walking confirmed by prosthesist	Traumatic	≥1y	SAFE foot	Peak power K3/K4/H1/H3 (W) Work H1/H3 (J/kg) Amputated leg and intact leg	Amputated leg: 1.11±0.20 Intact leg: 1.13±0.20	Report Ext val Int val Sel bias Power Total	7/11 1/3 3/7 1/6 0/5 12
Beyaert et al (2008)[22]	CC	33 (17/15)	E: 46±16 C: 45±17	E: Unilateral TT amputation; prosthesis use >1y; not walking with assistive devices; no stump pain, tenderness; no cardiovascular, neurologic, musculoskeletal abnormalities affecting gait C: Age-matched and height-matched healthy subjects	Traumatic	16.7±17.6y	Propulsive feet (15) and SACH (2)	Work K1/K2 (J/kg) Amputated leg, intact leg, and referent leg	E: 1.36±0.20 C: 1.39±0.17	Report Ext val Int val Sel bias Power Total	8/11 1/3 5/7 1/6 0/5 15
Centomo et al (2007)[66]	CC	12 (6/6)	E: 11±5 C: 12±4	E: TT amputees using Seattle Light foot prosthesis; fully ambulatory; normally performing prosthesis C: Matched for age, height, mass, and sex; no known musculoskeletal problems affecting gait	Congenital: 4 Infection: 2	NA	Seattle Light foot	Peak power K1/K2/K3/K4 (W/kg) Amputated leg, intact leg, and referent leg	E: 1.04±0.1 C: 1.12±0.17	Report Ext val Int val Sel bias Power Total	6/11 0/3 4/7 1/6 0/5 11
Gitter et al (1991)[12]	CC	10 (5/5)	E: range 20–50 C: range 20–50	E/C: No history of lower-extremity joint dysfunction or concurrent painful conditions that might affect gait pattern	Traumatic	NA	Subjects were tested with Flex foot, SACH foot, and Seattle Light foot Acclimatization: 3wk	Work K1/K2/K3/H1/H2/H3 (J) Amputated leg and referent leg	Controlled walking speed of 1.5±10%	Report Ext val Int val Sel bias Power Total	6/11 0/3 4/7 1/6 0/5 11
Grumillier et al (2008)[69]	CC	33 (17/15)	E: 46±16 C: 45±17	E: Traumatic TT amputation; prosthesis use >1y; not walking with assistive devices; no stump pain or tenderness; no cardiovascular, neurologic, musculoskeletal abnormalities affecting gait C: Age-matched and height-matched healthy subjects	Traumatic	16.7±17.6y	Energy storage and return (15) and SACH (2)	Work H1 (J/kg) Amputated leg, intact leg, and referent leg	E: 1.36±0.20 C: 1.39±0.17	Report Ext val Int val Sel bias Power Total	8/11 1/3 5/7 1/6 0/5 15
Nolan and Lees (2000)[31]	CC	14 (4/10)	E: 41±5 C: 28.8±9.57	E: Established unilateral TT amputees regularly participating in sports C: Active in sports; no lower-leg injury or history of injury	Traumatic	7.75±2.75y	NA	Peak power (W/kg) intact leg and referent leg	Controlled walking speed of 1.3±3%	Report Ext val Int val Sel bias Power Total	5/11 0/3 4/7 1/6 0/5 10
Powers et al (1998)[56]	CC	20 (10/10)	E: 62.3±6.9 C: 50.9±8.6	E: Unilateral vascular TT amputation; independent community ambulators; no use of assistive devices C: Free of any conditions affecting gait	Vascular	>2y	Seattle Light foot	Peak positive knee power during stance (W/kg-m) Amputated and referent leg	E: 1.06±0.18 C: 1.30±0.20	Report Ext val Int val Sel bias Power Total	8/11 1/3 5/7 1/6 0/5 15

Table 1 (cont'd): Characteristics of Studies of Patients With a TT Amputation

Trial, Author (Year)	Design	No. (E/C)	Age (y)	Inclusion Criteria	Reason for Amputation	Time Since Amputation	Used Foot	Outcome Measures	Walking Speed (m/s)	Methodologic Quality	
Sadeghi et al (2001)[14]	CS	E: 5 No controls	27±12.7	Not explicitly stated; all subjects were unilateral TT amputees without stump problems	Traumatic: 3 Vascular: 2	NA	SACH	Peak power K1/K2/K3/K4/H1/H2/H3 (W/kg) Amputated and intact leg	Amputated leg: 1.27±0.22 Intact leg: 1.28±0.22	Report Ext val Int val Sel bias Power Total	8/11 1/3 4/7 2/6 0/5 15
Schneider et al (1993)[37]	CS	E: 12 No controls	10.9±3.2	Not explicitly stated; all subjects were physically active TT amputees in good health	Traumatic/disease: 3 Congenital: 9	NA	Subjects were tested with SACH and Flex foot Acclimatization: SACH >2y; Flex 2mo	Work/peak power generated and absorbed ($Js^{-1}N^{-1}$) Amputated and intact leg	Comfortable: 0.9±0.2 Fast: 1.3±0.1	Report Ext val Int val Sel bias Power Total	6/11 1/3 3/7 1/6 0/5 11
Selles et al (2003)[28]	CC	20 (10/10)	E: 38±10.4 C: 35±12.4	E: Ability to walk unassisted 5 minutes; no skin problems of stump C: Matched for age, height, sex, and body mass; subjects were free of cardiopulmonary, neurologic, or orthopedic problems that might influence walking ability	Traumatic	NA	Energy storing foot (9) SACH (1)	Peak power generated and absorbed (W) during swing Amputated and referent leg	E: 1.34±0.24 C: 1.40±0.16	Report Ext val Int val Sel bias Power Total	7/11 1/3 3/7 1/6 0/5 12
Silverman et al (2008)[13]	CC	24 (14/10)	E: 45±9 C: 33±12	E/C: Free from musculoskeletal disorders and leg pain; not requiring assistive devices; proficient walkers	Traumatic: 11 Vascular: 3	NA	Energy storing and releasing (9) SACH (5)	Concentric / eccentric work during stance and peak power K1/K2/K3/K4/H1/H2/H3 (W/kg) Amputated, intact, and referent leg	Controlled walking speed of 0.6, 0.9, 1.2, and 1.5	Report Ext val Int val Sel bias Power Total	8/11 0/3 4/7 2/6 0/5 14
Vanicek et al (2009)[21]	CC	11 (6/5)	E: 56±13 C: 57±21	E/C: Wearing prosthesis on daily basis; ability to walk 120m without walking aids and experiencing pain An additional inclusion criterion for E was a fall within the last 9mo	E: Traumatic: 4 Vascular: 2 C: Traumatic: 2 Clubfoot: 2 Vascular:1	E: 3.5±4.3 C: 10.6±12.3	E: Multiflex (4) Variflex (1) Ceterus (1) C: Multiflex (3) Variflex (1) Dynamic (1)	Peak power K1/K2/K3/K4/H1/H2/H3 (W/kg) Amputated and intact leg	E: 1.19±0.35 C: 1.07±0.20	Report Ext val Int val Sel bias Power Total	8/11 1/3 4/7 2/6 0/5 15