The effect of the C-Leg microprocessor knee on gait efficiency in unilateral transfemoral amputees

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Clinical Question: Is the C-Leg microprocessor knee bioenergetically more efficient than other prosthetic knees during gait in unilateral transfemoral amputees?

Background: Individuals with transfemoral amputation (TFA) likely utilize a prosthesis for community ambulation and many may choose to utilize a microprocessor knee(MPK).[1] Benefits associated with MPKs including the C-Leg reportedly include improved safety, cost efficacy, increased walking speed and others.[1] Evidence appears to be strongest in terms of recommending an MPK system when safety is a concern. The rapid response of MPK systems to arrest or decelerate undesired knee flexion seems to have been proven.[1,2] The ability of a microprocessor to improve gait speed also seems to be strongly supported by the evidence.[3] However, the ability of an MPK, such as the C-Leg, to improve bioenergetic efficiency during walking is far less obvious. Individual studies have yielded mixed results. For instance, Orendurff *et al*. reported a significant ($p<0.05$) increase in comfortable walking speed with C-Leg without increased oxygen cost relative to a non-MPK alternative, suggesting improved ambulatory energy efficiency.[4] Kaufman *et al*. similarly reported no difference between C-Leg and non-MPK alternatives in energy efficiency while walking, however, total daily energy expenditure was greater further suggesting increased efficiency when the MPK was used.[5] Given the small effect and inconsistent results between studies, a literature review is indicated to determine if there is a difference in ambulatory energy efficiency when persons with TFA walk with the C-Leg relative to non-MPK alternatives.

Search Strategy:
Databases Searched: PubMed, CINAHL, oandp.org
Search Terms: Combinations of the following were used: energy efficiency, gait, C-Leg, microprocessor prosthetic knee
Inclusion Criteria: 2004-current, English, Systematic Reviews or Meta-Analyses
Exclusion Criteria: Articles published prior to 2004, Non-English, Non-review articles

Synthesis of Results: The highest level of evidence included three systematic reviews (SR) (see Table). One SR specifically investigated C-Leg[1], another investigated the C-Leg predominantly[6] and the third[3] included multiple MPK systems. The SR by Highsmith *et al*. concluded that evidence supports a Grade D recommendation that compared to non-MPK systems, use of the C-Leg improved ambulatory energy efficiency across a range of gait speeds.[1] Wong et al., whose study included predominantly comparisons of C-Leg to multiple alternatives, suggested that some evidence supports improved ambulatory energy efficiency across a range of gait speeds.[6] Finally, Sawers and Hafner, whose review included multiple MPK knee systems, concluded that swing & stance MPK use results in equivalent ambulatory oxygen cost and rate compared to non-MPKs in persons with TFA. They further reported similar findings with swing only MPK systems. Low level evidence supported the conclusions regarding oxygen rate and modest level evidence supported the conclusion regarding oxygen cost.[3] All of these findings were predominantly reported in persons with traumatic, unilateral TFA who were high-functioning and in their 3rd to 5th decades of life.

Clinical Message: Low level evidence suggests that use of the C-Leg will likely result in small improvements in ambulatory energy efficiency across a range of walking speeds in those with unilateral TFA of non-vascular causes who are high-functioning. Given this, it seems that C-Leg utilization for the sole purpose of decreasing ambulatory energy cost may be minimally justifiable given the currently available literature. However, a stronger justification for C-Leg use may include other primary benefits such as safety, healthcare cost and walking speed.

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Evidence Table

	Highsmith et al, 2012[1]	*Wong et al, 2012*[6]	*Sawers and Hafner, 2013*[3]
Population	56 subjects, predominant etiologies were trauma and non-vascular causes.	58 subjects, predominant etiologies were trauma and non-vascular causes.	59 subjects, predominant etiologies were trauma and non-vascular causes.
Study Design	Systematic review of 8 studies.	Systematic review of 7 studies.	Systematic review of 8 studies.
Intervention	C-Leg	MPK	MPK
Comparison	Non-MPK	Non-MPK	Non-MPK
Methodology	Systematic review and evidence grading of comparative efficacy studies.	Systematic review and evidence grading of comparative efficacy studies.	Systematic review and evidence grading of comparative efficacy studies.
Outcomes	Evidence grading in multiple clinical outcome areas including bioenergetic efficiency. Included studies utilized numerous bioenergetics measures including oxygen uptake, heart rate, and perceived exertion.	Evidence grading in bioenergetics efficiency. Included studies utilized numerous bioenergetics measures including oxygen uptake, heart rate, and perceived exertion.	Evidence grading in multiple clinical outcome areas including bioenergetic efficiency. Included studies utilized numerous bioenergetics measures including oxygen uptake, heart rate, and perceived exertion.
Key Findings	C-Leg use for improving energy efficiency in gait supported by grade ‘‘D’’ recommendation.	Some evidence suggests MPK use may reduce energy consumption for high-functioning patients with nonvascular amputations.	S&S MPKs result in equivalent O_2 cost (SSWS, slow, & fast speeds) vs NMPKs. (Mod. level evidence) S&S MPKs decrease O_2 rate (SSWS) vs NMPKs. (low level evidence) Swing-only MPKs results in equivalent O2 rate (SSWS, slow, fast speeds) vs NMPKs (low level evidence).
Study Limitations	Many variables (i.e. accommodation, feet) were not controlled precluding meta-analyses.	Many variables (i.e. accommodation, feet) were not controlled precluding meta-analyses.	Many variables (i.e. accommodation, feet) were not controlled precluding meta-analyses.

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References:

1. Highsmith MJ, Kahle JT, Bongiorni DR, Sutton BS, Groer S, Kaufman KR. Safety, energy efficiency, and cost efficacy of the C-Leg for transfemoral amputees: A review of the literature. Prosthet Orthot Int 2010;34:362-77.
2. Blumentritt S, Schmalz T, Jarasch R. The safety of C-leg: biomechanical tests. J Prosthet Orthot 2009;21:2-17.
3. Sawers AB, Hafner BJ. Outcomes associated with the use of microprocessor-controlled prosthetic knees among individuals with unilateral transfemoral limb loss: a systematic review. J Rehabil Res Dev 2013;50:273-314.
4. Orendurff MS, Segal AD, Klute GK, McDowell ML, Pecoraro JA, Czerniecki JM. Gait efficiency using the C-Leg. J Rehabil Res Dev 2006;43:239-46.
5. Kaufman KR, Levine JA, Brey RH, McCrady SK, Padgett DJ, Joyner MJ. Energy expenditure and activity of transfemoral amputees using mechanical and microprocessor-controlled prosthetic knees. Arch Phys Med Rehabil 2008;89:1380-5.
6. Wong CK, Benoy S, Blackwell W, Jones S, Rahal R. A comparison of energy expenditure in people with transfemoral amputation using microprocessor and nonmicroprocessor knee prostheses: a systematic review. J Prosthet Orthot 2012;24:202-

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