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Microprocessor-Controlled Knee Prosthetics for Individuals With Transfemoral Amputation

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Key Messages

- One health technology assessment, 2 systematic reviews, 3 randomized controlled trials, and 9 non-randomized studies were identified regarding the clinical effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation.
- Four economic evaluations were identified regarding the cost-effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation.

Research Questions

1. What is the clinical effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation?
2. What is the cost-effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation?

Methods

Literature Search Methods

A limited literature search was conducted by an information specialist on key resources including MEDLINE, the Cochrane Database of Systematic Reviews, the international HTA database, the websites of Canadian and major international health technology agencies, as well as a focused internet search. The search strategy comprised both controlled vocabulary, such as the National Library of Medicine's MeSH (Medical Subject Headings), and keywords. The main search concepts were microprocessor and knee or transfemoral prosthetics. No filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English-language documents published between January 1, 2011 and January 27, 2021. Internet links were provided, where available.

Selection Criteria

One reviewer screened literature search results (titles and abstracts) and selected publications according to the inclusion criteria presented in Table 1. Full texts of study publications were not reviewed.

Results

One health technology assessment,[1] 2 systematic reviews,[2,3] 3 randomized controlled trials,[4-6] and 9 non-randomized studies[7-15] were identified regarding the clinical effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation. Four economic evaluations[16-19] were identified regarding the cost-effectiveness of microprocessor-controlled knee prosthetics for individuals with transfemoral amputation.

Table 1: Selection Criteria

Criteria	Description
Population	Individuals (of all ages) with transfemoral amputation
Intervention	Microprocessor-controlled knee prosthetics
Comparator	Mechanically controlled (i.e., non–microprocessor-controlled) knee prosthetics
Outcomes	Q1: Clinical effectiveness (e.g., quality of life, functionality [e.g., activities of daily living, Medicare Functional Classification Level], energy efficiency, productivity, ambulation, comfort, safety [e.g., adverse events]) Q2: Cost-effectiveness (e.g., cost per quality-adjusted life-year gained)
Study Designs	Health technology assessments, systematic reviews, randomized controlled trials, non-randomized studies, economic evaluations

Additional references of potential interest that did not meet the inclusion criteria are provided in Appendix 1.

References

Health Technology Assessments

1. Henrikson NB, Hafner BJ, Dettori JR, et al. Microprocessor-controlled lower limb prostheses: health technology assessment. Tacoma (WA): Washington State Health Care Authority; 2011: https://www.hca.wa.gov/assets/program/mc_lower_prosthetic_final_report%5B1%5D.pdf Accessed 2021 Feb 1.
   See: Summary of evidence – Microprocessor-controlled prosthetic KNEES (p.9-11)

Systematic Reviews and Meta-analyses

2. Kannenberg A, Zacharias B, Probsting E. Benefits of microprocessor-controlled prosthetic knees to limited community ambulators: systematic review. *J Rehabil Res Dev*. 2014;51(10):1469-1496. Medline

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(3):273-314. Medline

Randomized Controlled Trials

4. Cao W, Yu H, Zhao W, Meng Q, Chen W. The comparison of transfemoral amputees using mechanical and microprocessor- controlled prosthetic knee under different walking speeds: a randomized cross-over trial. *Technol Health Care*. 2018;26(4):581-592. Medline

5. Hafner BJ, Askew RL. Physical performance and self-report outcomes associated with use of passive, adaptive, and active prosthetic knees in persons with unilateral, transfemoral amputation: randomized crossover trial. *J Rehabil Res Dev*. 2015;52(6):677-700. Medline

6. Theeven P, Hemmen B, Rings F, et al. Functional added value of microprocessor-controlled knee joints in daily life performance of Medicare Functional Classification Level-2 amputees. *J Rehabil Med*. 2011 Oct;43(10):906-915. Medline

Non-Randomized Studies

7. Sen EI, Aydin T, Bugdayci D, Kesiktas FN. Effects of microprocessor-controlled prosthetic knees on self-reported mobility, quality of life, and psychological states in patients with transfemoral amputations. *Acta Orthop Traumatol Turc*. 2020 Sep;54(5):502-506. Medline

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9. Fuenzalida Squella SA, Kannenberg A, Brandao Benetti A. Enhancement of a prosthetic knee with a microprocessor-controlled gait phase switch reduces falls and improves balance confidence and gait speed in community ambulators with unilateral transfemoral amputation. *Prosthet Orthot Int*. 2018 Apr;42(2):228-235. Medline

10. Hasenoehrl T, Schmalz T, Windhager R, et al. Safety and function of a prototype microprocessor-controlled knee prosthesis for low active transfemoral amputees switching from a mechanic knee prosthesis: a pilot study. *Disabil*. 2018 02;13(2):157-165. Medline

11. Kaufman KR, Bernhardt KA, Symms K. Functional assessment and satisfaction of transfemoral amputees with low mobility (FASTK2): a clinical trial of microprocessor-controlled vs. non-microprocessor-controlled knees. *Clin Biomech*. 2018 10;58:116-122. Medline

12. Wong CK, Rheinstein J, Stern MA. Benefits for adults with transfemoral amputations and peripheral artery disease using microprocessor compared with nonmicroprocessor prosthetic knees. *Am J Phys Med Rehabil*. 2015 Oct;94(10):804-810. Medline

13. Highsmith MJ, Kahle JT, Shepard NT, Kaufman KR. The effect of the C-Leg knee prosthesis on sensory dependency and falls during sensory organization testing. *Technol*. 2014 Jan 27;2013(4):343-347. Medline

14. Highsmith MJ, Kahle JT, Miro RM, Mengelkoch LJ. Ramp descent performance with the C-Leg and interrater reliability of the Hill Assessment Index. *Prosthet Orthot Int*. 2013 Oct;37(5):362-368. Medline

15. Burnfield JM, Eberly VJ, Gronely JK, Perry J, Yule WJ, Mulroy SJ. Impact of stance phase microprocessor-controlled knee prosthesis on ramp negotiation and community walking function in K2 level transfemoral amputees. *Prosthet Orthot Int*. 2012 Mar;36(1):95-104. Medline

Economic Evaluations

16. Kuhlmann A, Kruger H, Seidinger S, Hahn A. Cost-effectiveness and budget impact of the microprocessor-controlled knee C-Leg in transfemoral amputees with and without diabetes mellitus. *Eur J Health Econ*. 2020 Apr;21(3):437-449. Medline

17. Chen C, Hanson M, Chaturvedi R, Mattke S, Hillestad R, Liu HH. Economic benefits of microprocessor controlled prosthetic knees: a modeling study. *J Neuroeng Rehabil*. 2018 09 05;15(Suppl 1):62. Medline

18. Cutti AG, Lettieri E, Del Maestro M, et al. Stratified cost-utility analysis of C-Leg versus mechanical knees: findings from an Italian sample of transfemoral amputees. *Prosthet Orthot Int*. 2017 Jun;41(3):227-236. Medline

19. Liu H, Chen C, Hanson M, et al. Economic value of advanced transfemoral prosthetics. Santa Monica (CA): RAND Corp.; 2017. Sponsored by the American Orthotic and Prosthetic Association (AOPA). https://opcanada.ca/wp-content/uploads/2019/11/RAND-Report-Economic-Value-of-Advanced-Transfemoral-Prosthetics.pdf Accessed 2021 Feb 1.
See: Summary (p.vii)

Appendix 1: References of Potential Interest

Previous CADTH Reports

20. Williams D, Farrah K. Microprocessor controlled limbs for patients with amputation: clinical effectiveness, cost effectiveness and guidelines. Ottawa: CADTH; 2019. (CADTH rapid response report: reference list). https://www.cadth.ca/microprocessor-controlled-limbs-patients-amputation-clinical-effectiveness-cost-effectiveness-and-0 Accessed 2021 Jan 29.

Systematic Reviews and Meta-analyses

Unclear Population — Transfemoral Amputation Not Specified

21. Morgan SJ, Hafner BJ, Kartin D, Kelly VE. Dual-task standing and walking in people with lower limb amputation: A structured review. *Prosthet Orthot Int*. 2018 Dec;42(6):652-666. Medline

22. Theeven PJ, Hemmen B, Brink PR, Smeets RJ, Seelen HA. Measures and procedures utilized to determine the added value of microprocessor-controlled prosthetic knee joints: a systematic review. *BMC Musculoskelet Disord*. 2013 Nov 27;14:333. Medline

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Alternative Intervention — Not Specific to Microprocessor-Powered Knee Prosthetics

24. Balk EM, Gazula A, Markozannes G, et al. Lower limb prostheses: measurement instruments, comparison of component effects by subgroups, and long-term outcomes. *(Comparative Effectiveness Review No. 213).* Prepared by the Brown Evidence-based Practice Center. AHRQ Publication No.18-EHC017-EF. Rockville (MD): Agency for Healthcare Research and Quality; 2018. https://effectivehealthcare.ahrq.gov/sites/default/files/pdf/cer-213-lower-limb-protheses-report.pdf Accessed 2021 Feb 1.
    See: Microprocessor Knees (p.153-154)

Alternative Control — Comparison Between Different Microprocessor-Powered Knee Prosthetics

25. Mileusnic MP, Rettinger L, Highsmith MJ, Hahn A. Benefits of the Genium microprocessor controlled prosthetic knee on ambulation, mobility, activities of daily living and quality of life: a systematic literature review. *Disabil*. 2019 Aug 30:1-12. Medline

Randomized Controlled Trials

Unclear Population — Transfemoral Amputation Not Specified or Not Restricted to Transfemoral Amputees

26. Lansade C, Vicaut E, Paysant J, et al. Mobility and satisfaction with a microprocessor-controlled knee in moderately active amputees: A multi-centric randomized crossover trial. *Ann Phys Rehabil Med*. 2018 Sep;61(5):278-285. Medline

27. Prinsen EC, Nederhand MJ, Olsman J, Rietman JS. Influence of a user-adaptive prosthetic knee on quality of life, balance confidence, and measures of mobility: a randomised cross-over trial. *Clin Rehabil*. 2015 Jun;29(6):581-591. Medline

28. Meier MR, Hansen AH, Gard SA, McFadyen AK. Obstacle course: users' maneuverability and movement efficiency when using Otto Bock C-Leg, Otto Bock 3R60, and CaTech SNS prosthetic knee joints. *J Rehabil Res Dev*. 2012;49(4):583-596. Medline

Alternative Control — Comparison Between Different Microprocessor-Powered Knee Prosthetics

29. Theeven PJ, Hemmen B, Geers RP, Smeets RJ, Brink PR, Seelen HA. Influence of advanced prosthetic knee joints on perceived performance and everyday life activity level of low-functional persons with a transfemoral amputation or knee disarticulation. *J Rehabil Med*. 2012 May;44(5):454-461. Medline

Non-Randomized Studies

Unclear Population — Transfemoral Amputation Not Specified or Not Restricted to Transfemoral Amputees

30. Moller S, Rusaw D, Hagberg K, Ramstrand N. Reduced cortical brain activity with the use of microprocessor-controlled prosthetic knees during walking. *Prosthet Orthot Int*. 2019 Jun;43(3):257-265. Medline

31. Moller S, Hagberg K, Samulesson K, Ramstrand N. Perceived self-efficacy and specific self-reported outcomes in persons with lower-limb amputation using a non-microprocessor-controlled versus a microprocessor-controlled prosthetic knee. *Disabil*. 2018 04;13(3):220-225. Medline

32. Onat SS, Unsal-Delialioglu S, Ozel S. The importance of orthoses on activities of daily living in patients with unilateral lower limb amputations. *J Back Musculoskelet Rehabil*. 2017;30(4):829-833. Medline

Mixed Intervention — Not Restricted to Microprocessor-Controlled Knees

33. Burcak B, Kesikburun B, Koseoglu BF, Oken O, Dogan A. Quality of life, body image, and mobility in lower-limb amputees using high-tech prostheses: A pragmatic trial. *Ann Phys Rehabil Med*. 2020 Oct 18:101405. Medline

34. Russell Esposito E, Rabago CA, Wilken J. The influence of traumatic transfemoral amputation on metabolic cost across walking speeds. *Prosthet Orthot Int*. 2018 Apr;42(2):214-222. Medline

Mixed Control — Not Restricted to Mechanical Prosthetic Knees

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Alternative Control — Comparison Between Different Microprocessor-Powered Knee Prosthetics

37. Campbell JH, Stevens PM, Wurdeman SR. OASIS 1: Retrospective analysis of four different microprocessor knee types. *J Rehabil Assist Technol Eng*. 2020 Jan-Dec;7:2055668320968476. Medline

38. Li S, Cao W, Yu H, Meng Q, Chen W. Physiological parameters analysis of transfemoral amputees with different prosthetic knees. *Acta Bioeng*. 2019;21(3):135-142. Medline

39. Thiele J, Schollig C, Bellmann M, Kraft M. Designs and performance of three new microprocessor-controlled knee joints. *Biomed Tech (Berl)*. 2019 Feb 25;64(1):119-126. Medline

40. Morgenroth DC, Roland M, Pruziner AL, Czerniecki JM. Transfemoral amputee intact limb loading and compensatory gait mechanics during down slope ambulation and the effect of prosthetic knee mechanisms. *Clin Biomech*. 2018 06;55:65-72. Medline

41. Highsmith MJ, Kahle JT, Miro RM, et al. Functional performance differences between the Genium and C-Leg prosthetic knees and intact knees. *J Rehabil Res Dev*. 2016;53(6):753-766. Medline

Alternative Control — Non-Amputee

42. Saglam Y, Gulenc B, Birisik F, Ersen A, Yilmaz Yalcinkaya E, Yazicioglu O. The quality of life analysis of knee prosthesis with complete microprocessor control in trans-femoral amputees. *Acta Orthop Traumatol Turc*. 2017 Dec;51(6):466-469. Medline

43. Morgan SJ, Hafner BJ, Kelly VE. The effects of a concurrent task on walking in persons with transfemoral amputation compared to persons without limb loss. *Prosthet Orthot Int*. 2016 Aug;40(4):490-496. Medline

Economic Evaluations

Alternative Control — Comparison Between Different Microprocessor-Controlled Knee Prosthetics

44. Highsmith MJ, Kahle JT, Wernke MM, et al. Effects of the Genium Knee System on Functional Level, Stair Ambulation, Perceptive and Economic Outcomes in Transfemoral Amputees. *Technol*. 2016 Sep;18(2-3):139-150. Medline

45. Highsmith MJ, Kahle JT, Lura DJ, et al. Short and mid-distance walking and posturography with a novel microprocessor knee. *Technol Innov.* 2014;15(4):S359-368. https://www.ingentaconnect.com/content/cog/ti/2014/00000015/00000004/art00012?crawler=true&mimetype=application/pdf Accessed 2021 Feb 1.

Alternative Outcome — Direct Medical Costs

46. Mundell B, Maradit Kremers H, Visscher S, Hoppe K, Kaufman K. Direct medical costs of accidental falls for adults with transfemoral amputations. *Prosthet Orthot Int*. 2017 Dec;41(6):564-570. Medline

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48. Kelly J, Wilson L. What is the clinical and cost effectiveness of microprocessor-controlled artificial knees compared with non-microprocessor-controlled alternatives? *(Evidence Note 44).* Glasgow: Healthcare Improvement Scotland; 2012. Structured abstract available from CRD: https://www.crd.york.ac.uk/CRDWeb/PrintPDF.php?AccessionNumber=32013000467 Accessed 2021 January 29.
See: Position Statement