

IMPACT OF MICROPROCESSOR PROSTHETIC KNEE ON MOBILITY AND QUALITY OF LIFE IN PATIENTS WITH LOWER LIMB AMPUTATION: A SYSTEMATIC REVIEW OF THE LITERATURE

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ABSTRACT

Introduction : Advanced technologies have made available the development of microprocessor prosthetic knee (MPK) to improve autonomy of patients with lower limb amputation. In the present systematic review, we aimed to evaluate the impact of the use of all types of MPK on patients' functional status and quality of life.

Evidence acquisition : We conducted this review according to the PRISMA Guidelines on Medline (via Ovid), Scopus and SportDiscuss. All identified articles were screened for their eligibility by two reviewers using Covidence software. The Cochrane Risk of Bias (RoB) or the NIH Quality Assessment Tool were used to assess the quality of the studies.

Evidence synthesis : Eighteen articles were included in the present review (7 randomized controlled trials - RCT), 6 cross-sectional and 5 follow-up studies). Number of participants included varied from 20 to 602, protocols' length varied from a single session to 12 weeks of use of MPK. Taken together, MPK users compared to NMPK users tend to present better functional status and mobility. Quality of life was also positively impacted in MPK users. On the other hand, the superiority of more advanced MPKs such as the Genium[®] is less clear, especially given the improvements over time of other MPKs such as the C-leg[®] and the Rheo knee[®].

Conclusions : Based on our results, while it is clear that MPKs outperform NMPKs both for functional status and quality of life, additional benefits of one MPK over another is less clear. Future studies are needed to clarify these aspects.

Introduction

For patients with major lower limb amputation, the impact of such an amputation on activities of daily living is often particularly challenging.¹ Indeed, transfemoral amputation (TFA) is associated with reduced mobility, restricted societal participation and an increased risk of falling. Chronic diseases, balance and stability problems are additional risk factors for amputees, especially in the elderly.¹ Patients with TFA can be prescribed a prosthesis with an exoprosthetic component to partially overcome their functional limitations. Exoprosthetic knee components can be classified into two main categories: mechanical components, *i.e.*, non-microprocessor-controlled knees (NMPK), and microprocessor-controlled knees (MPK), also called electronic or mechatronic knees. The basic function of the prosthetic knee is to provide more stability during the stance phase and more agility and flexion during the swing phase. It works with an internal computer – microprocessor – that controls the hydraulics of the prosthesis through continuous monitoring with sensors, allowing real-time adjustments. These sensors are also able to detect a pattern of movement that resemble a fall and the microprocessor will immediately react by providing a greater resistance to prevent falling.

In addition to the impact on patients' mobility, TFA is a life-altering event that has a considerable impact on their quality of life due to the physical and psychological distress that this event causes.² Many studies reported that patients with lower-limb amputation demonstrate worse quality of life than the general healthy population;³ while it has been shown that the use of a prosthesis is closely related to improved quality of life in these patients.⁴ Therefore, quality of life can also be significantly improved if patients use their prostheses effectively and correctly. Thus, the choice of an optimized and suitable prosthesis is crucial both from the point of view of mobility and quality of life of patients with TFA.

The use of a mechatronic knee for TFA patients is becoming increasingly common. The impact of this type of device on patients' mobility and quality of life has been demonstrated in several studies and reviews of the literature.⁵⁻⁷ A recent systematic review reported the beneficial effects of the Genium (Ottobock®) a specific type of MPK, but did not include studies using other types of MPKs.⁸ Therefore, the present review aims at evaluating the impact of the use of all types of MPKs on patients' mobility and quality of life.

Evidence acquisition

The protocol of the present review was registered on the Center for Open Science platform OSF (<https://osf.io/um8zg/>).

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement was followed. A review protocol was previously established and published on Open Sciences Framework.

A search on Medline (via Ovid), Scopus and SportDiscuss was conducted in February 2021 using the following search terms: Microprocessor, C-Leg®, Genium®, mechatronic, mechanic and knee. The

search strategy can be found in Table I. Additionally, a manual search within the bibliography of relevant papers was performed in order to complete the bibliographic search.

Table I. Search strategy on Medline.

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) <1946 to February 15, 2021>
1 (MPK or MPKS or NMPK or NMPKS).ti,ab,kf. (401)
2 microprocessor*.ti,ab,kf. (2777)
3 (C-Leg or Genium).ti,ab,kf. (74)
4 knee*.ti,ab,kf. (157240)
5 or/1-3 (3184)
6 5 and 4 (175)
7 ((mechatronic* or mechanic*) adj3 knee*).ti,ab,kf. (68)
8 6 or 7 (239)

The PICOT were the following:⁹

- population: patients with unilateral transfemoral limb loss;
- intervention: use of MPK;
- comparator: non-MPK;
- outcomes: gait, ambulation, mobility, ADL performance, physical performance, balance confidence, quality of life (using validated questionnaires/tests);
- type of study: original studies.

Exclusion criteria were: 1) animal studies; 2) case reports, qualitative review studies, systematic reviews, letters to the editors; 3) non-English, non-French studies; 4) no abstract available; and 5) studies including <20 participants (to report studies with a representative sample size).

All identified articles were screened for their eligibility by two reviewers first based on their title and abstract and secondly, based on their full text using Covidence software. Any discrepancies were resolved through discussion between the researchers.

The following data were extracted: authors, name of journal, year of publication, study design, type of population, sample size, intervention protocol, duration of study, all outcomes collected, main results.

The Cochrane Risk of Bias (RoB) tool was used to assess the quality of RCT,¹⁰ while for the other study designs we used the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.

Evidence synthesis

Six hundred and eighteen titles were identified and a total of 411 abstracts were screened after removing duplicates (N.=207). The full texts of 80 remaining studies were reviewed and 18 studies met the inclusion criteria (see PRISMA flowchart, Figure 1).

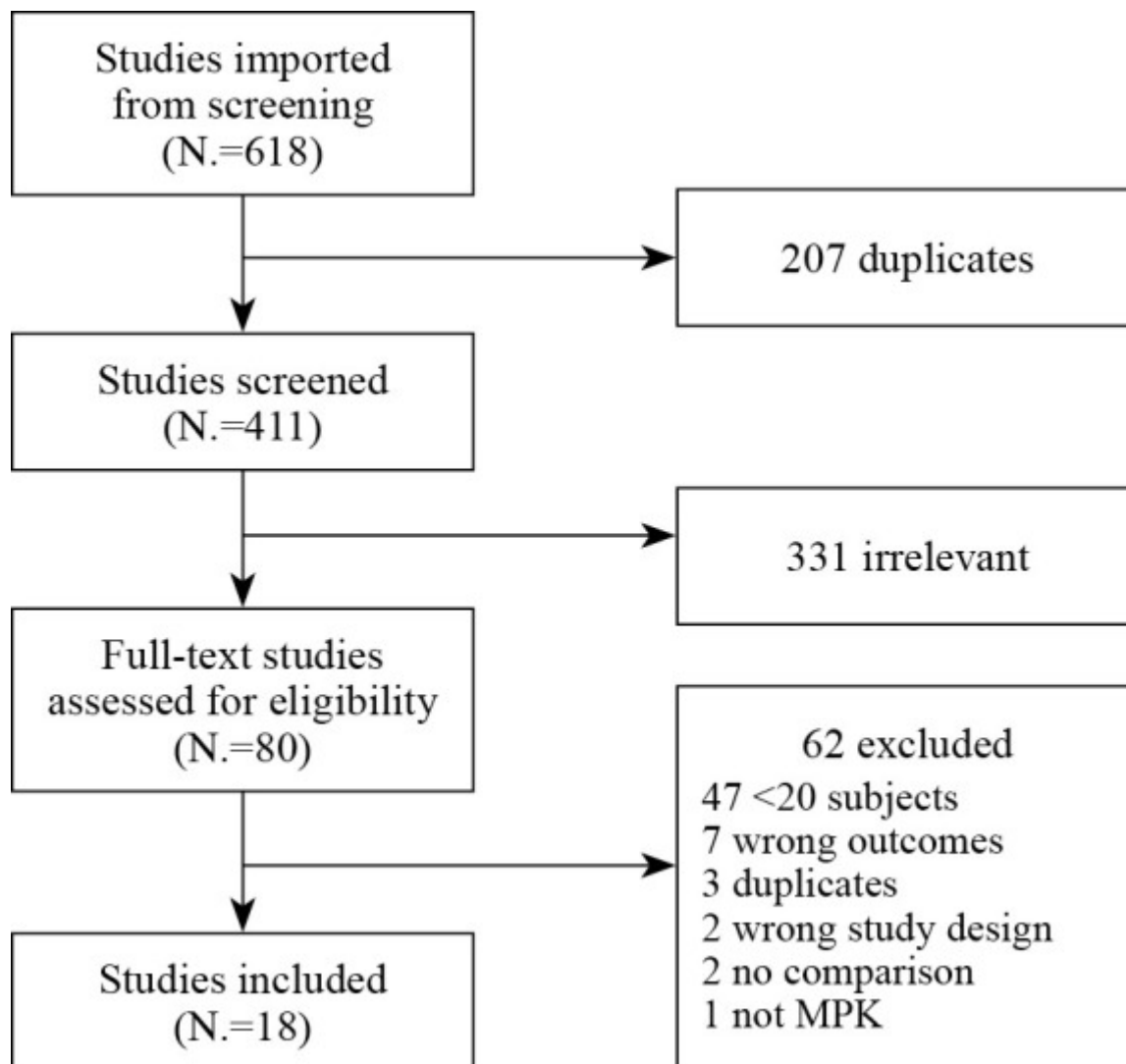


Figure 1. PRISMA flowchart.

Different study designs were included: 7 RCTs, 6 cross-sectional studies, and 5 follow-up studies. However, when extracting the data, 5 RCTs from the same team reported results from an identical sample of patients (describing different outcome measures). Therefore, the results of these 5 studies were merged into one trial, resulting in a total of 3 RCTs detailed in the present review.

Number of participants included varied from 20 to 602, protocols' length varied from a single session to 12 weeks of use of MPK. Different outcomes were investigated across studies such as 3D gait analyses, Prosthetic Limb Users' Survey of Mobility (PLUS-M), the Amputee Mobility Predictor with Prosthesis (AMPRO), walking tests, number of falls, as well as Physical quality of life or the Short-Form 36 – SF-36.

Main results of the included studies are summarized in the tables below.

RANDOMIZED CONTROLLED TRIALS

A total of three individual trials was found in the literature, all of them used a cross-over design. The first study included 30 participants classified as Medicare Functional Classification Level 2 (MFCL-2), and compared the use of a C-Leg[®] with a C-Leg compact[®] and a mechanic prosthesis for 7 days.¹¹ The authors tested the efficacy of the prostheses with the Assessment of Daily Activity Performance in Transfemoral amputees (ADAPT¹²). Participants were allocated to one of the subgroups based on their walking speed and activity level at baseline: high (>4 km/h), intermediate (3-4 km/h) and low (<3 km/h). The authors found a significant improvement when using the MPK compared to the mechanic prosthesis in the sub-groups of ‘intermediate’ and ‘high’ functional mobility levels. The subgroup classified as “low” mobility level did not show any beneficial effect of the MPK.

Another clinical trial tested the effect of a C-Leg[®] versus a Genium[®] prosthesis in 20 patients with TFA and reported the results on various metrics in five different papers.¹³⁻¹⁷ Patients used the prosthesis for a period varying from 2 weeks to three months depending on the patients’ ability to use it. Overall, the Genium[®] induced stronger improvement on different gait parameters (e.g. increased flexion in swing and stance and better symmetry) and functional outcomes (e.g., higher AMP score or increased in step activity) compared to the C-Leg[®], except for the stepping rate which was found to be better in the C-Leg[®] compared to the Genium[®].

Finally, a third RCT compared the use of a MPK compared to their regular NMPK in 35 individuals.¹⁸ The authors collected data on functional performances and quality of life before and after the use of either prosthesis for 90 days. A significant improvement in locomotor capacities (e.g., improved time to complete the TUG) and global satisfaction (e.g., better scores on the SF-36) was observed in the MPK versus the NMPK groups.

See Table II for a summary of the main findings for the RCTs.^{11, 13-18}

Table II. Randomized controlled trials.^{11, 13-18}

Author s	Design	Sample	Age (mean±SD) & gender & Etiology	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
Theeven <i>et al.</i> 2011 ¹¹	Crossover	30	59.1±13.0 22 men	23 traumatic 6 vascular	7 days of use (C-Leg, C-Leg Compact &	C-Leg & C-Leg-Compact	ADAPT circuit	1. Time to complete ADAPT shorter for “intermediate” and	Grant provided by otto Bock Healthcare GmbH, Vienna, Austria.

Author s	Design	Sampl e	Age (mean± SD) & gender & Etiology	Etiolo gy	Length	Type of MPK	Main outco mes	Main results	Finding sources & COI
				1 tumor	mecha nic)			“high” subgroups, for both MPKs 2. No difference for the group “low”	The authors had the full and unrestricted right regarding: (i) the establishing of results of the investigation leading to scientifically corroborated conclusions; and (ii) the presentation of any result or conclusion resulting from the investigation, independent of any other party or grant provider.
Lura <i>et al.</i> 2015 Highsmith <i>et al.</i> 2016a,b ,c Lura <i>et al.</i>	Crossover	20	46.5±14.2 16 men	14 traumatic tumor 4 tumor 2 vascular	2 weeks to 3 months (C-Leg & Genium)	C-Leg, Genium	3D gait analysis, CS-PFP10, SAI, FSST, AMP,	1. Genium knee increased flexion in swing and stance 2. Genium knee improved	Support from the Florida High Tech Corridor/University of Southern Florida Connect and Ottobock

Authors	Design	Sample	Age (mean±SD) & gender & Etiology	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
2017 ¹³⁻¹⁷							SAD-FL, DoA	upper-body flexibility, balance, and endurance, measured with the CS-PFP10. 3. Mean stair completion times and descent stepping rate were not different between knees. 4. Stair ascent stepping rate for C-Leg was greater compared to Genium 5. FSST was faster for Genium 6. AMP and SAD-FL increased	Healthcare. The sponsors had no role in the study design, manuscript writing, or decision to submit the manuscript for publication. The authors have declared that no competing interests exist.

Author s	Design	Sample	Age (mean± SD) & gender & Etiology	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
								for Genium 7. DoA improved for Genium	
Lansade <i>et al.</i> 2018 ¹⁸	Crossover	35	65.6±10.1 27men	20 vascular 4 diabetic 8 trauma 4 tumor 3 infection	MPK: 3m NMPK: 1m	Kenevo, OttoBock	TUG, LCI-5, falls & SF-36	1. TUG was shorter for MPK 2. LCI-5 improved for MPK 3. No difference for number of falls 4. SF-36 was better for MPK	The sponsor provided MPK devices for the study, training sessions for ortho-prosthetists and rehabilitation teams, and support to monitor the multi-centric study according to the planning defined in the protocol. The sponsor had no role in the design of this study, defined by an independent scientific advisory board, and no role in data collection, data

Author s	Design	Sampl le	Age (mean± SD) & gender & Etiology	Etiolo gy	Length	Type of MPK	Main outco mes	Main results	Finding sources & COI
									treatment and data analysis.

AMP: Amputee Mobility Predictor; ADAPT: Assessment of daily activity performance in transfemoral amputees; COI: conflict of interest; CS-PFP10: Continuous Scale of Physical Functional Performance; DoA: degree of asymmetry; FSST: Four Square Step Test; LCI: Locomotor Capability Index; MPK: microprocessor-controlled knees; NMPK: non microprocessor-controlled knees; SAI: Stair Assessment Index; SAD-FL: step activity derived functional level; SF-36: Short-Form 36; TUG: timed-up and go.

FOLLOW-UP STUDIES

Five follow-up studies were identified, including between 21 and 100 amputees. Two studies assessed the effects of MPK^{19,20} (for about three months) in a group of patients who previously used NMPK and evaluated the Stair or Hill Assessments Index (SAI, HAI), the Locomotor Capability Index (LCI-5²¹) and the SF-36.²² Both studies reported a significant improvement of motor and physical functions when patients used MPK. Regarding the SF-36, vitality and general sub-scores were improved, but there was no improvement regarding emotional role, mental health, social role, physical role or pain scores.

Two prospective clinical trials compared two samples of 50 and 57 amputees over a 4 and 10-week periods, respectively.^{23,24} They both evaluated functional changes between the use of MPK *versus* NMPK; the second study also assessed the patients' quality of life with the SF-36, with greater improvement in various motor tests in the MPK group compared to the NMPK group in both studies.

Finally, one prospective clinical trial evaluated a group of 75 previously fitted amputees and a group of 25 non-previously fitted amputees after 6 months of use of a C-Leg.²⁵ This study suggests that active TFA with a prescribed C-Leg® may show improved locomotor ability, satisfaction and physical component of quality of life as compared with the experience with a previous mechanical device.

See Table III for a summary of the main findings for the follow-up studies.^{19,20,23-25}

Table III. Follow-up studies.^{19, 20, 23-25}

Author s	Design	Sample	Age (mean±SD) & gender	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
Highsmith <i>et al.</i> 2013 ¹⁹	Single subject design clinical trial	21 (all MPK)	52.1±18.6 11 men	8 vascular 8 trauma 4 congenital 1 tumor	90 days	C-Leg	HAI	1. Higher HAI score for MPK compared to NMPK	No sponsor No COI declared.
Kaufman <i>et al.</i> 2018 ²³	Prospective non-randomized crossover trial	50 (all MPK)	69±9 28 men	25 arterial disease 13 infection 5 trauma 4 thrombosis 2 tumor 1 blood disorder	MPK: 10 weeks NMPK: 4 weeks	C-Leg Compa ct, Ossur Rheo 3, Endolit e Orion 2, Freedo m Innova tio Plié 3	Falls, % sitting, activity level, gait (entropy)	1. Reduction of falls for MPK 2. Less time sitting for MPK 3. Higher activity level for MPK 4. No difference in entropy (gait)	America n Orthotic and Prostheti c Associati on. No COI declared.
Lansade <i>et al.</i> 2020 ²⁵	Observational, longitudinal, multicenter, prospective	100 75 previously fitted 25 non-previously fitted	46 ±13.6 75 men	56 trauma 27 tumor 8 vascular 2 congenital 1	6 months	C-Leg	LCI-5, falls, SF-36 (PCS)	1. Improvement of LCI-5 for MPK 2. Reduction of falls for MPK 3. Improvement of SF-	The study was sponsored by Otto Bock France. The funder had no role in

Author s	Design	Sample	Age (mean± SD) & gender	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
				diabetic 6 others				36 (PCS) for MPK	the design of the study, collection, treatment or analysis of the data. No COI declared.
Burçak et al. 2020 ²⁴	Single subject design clinical trial	57 33 MPK 24 NMPK	39.6±11 53 men	41 trauma 8 vascular 1 tumor 7 others	4 weeks	Not reported	6-min walk test, SF-36	1. 6-min walk test faster for MPK 2. Improvement of SF-36 for MPK	No sponsor No COI declared.
Sen et al. 2020 ²⁰	Single subject design clinical trial	30 (all MPK)	38.5±10.1 28 men	20 trauma 4 congenital 3 tumor 2 vascular 1 infection	3 months	C-Leg, Plié, Rho Knee, Orion	LCI-5, SF-36	1. Improvement of LCI-5 when using the MPK 2. Improvement in physical function, vitality and general	No sponsor No COI declared.

Author s	Design	Sample	Age (mean± SD) & gender	Etiology	Length	Type of MPK	Main outcomes	Main results	Finding sources & COI
								but not on emotional role, mental health, social role, physical role or pain scores (SF-36)	

COI: conflict of interest; HAI; Hill Assessments Index; LCI-5: Locomotor Capability Index; MPK: microprocessor-controlled knees; NMPK: non microprocessor-controlled knees; SF-36: Short-From 36.

CROSS-SECTIONAL STUDIES

Six cross-sectional studies were identified with a number of participants varying from 29 to 602. The authors compared either two groups of amputees with and without a MPK or various types of MPKs.

One trial evaluated the spatiotemporal and kinematic gait parameters in a group of 29 amputees using a MPK compared to a NMPK.²⁶ The authors found an increase in gait speed in the MPK compared to the NMPK groups, while the other gait parameters were not modified with the MPK.

Four retrospective trials investigated the differences in mobility in a group of MPK compared to NMPK. One trial including 50 participants per group found a higher quality of life in the group of patients using a MPK.²⁷ On the other hand, two other studies did not identify significant differences in functionality²⁸ nor in walking ability.²⁹ However, Möller *et al.*,²⁹ found an increase in cortical brain activity, as measured with functional near infrared spectroscopy, over the prefrontal and motor cortices, for NMPK users compared to MPK users.

Another trial on 450 patients, including a third group of patients of below-knee prosthesis users (BKA), reported a greater mobility for the group of MPK compared to NMPK but less compared to the group of BKA.³⁰

Finally, a large sample (N.=602) retrospective trial compared different types of MPKs.³¹ Patients' functional mobility and satisfaction were similar among the four groups, as well as for the number of falls. A better quality of life was identified for the group using the C-Leg® compared to the Plié®. No other difference was found for any of the other variables.

See Table IV for a summary of the main findings for the transversal studies.²⁶⁻³¹

Table IV. Cross-sectional studies.²⁶⁻³¹

Authors	Sample	Age (mean±SD) & gender	Etiology	Type of MPK	Main outcomes	Main results	Finding sources & COI
Gerzeli <i>et al.</i> , 2009 ²⁷	100 - 50 MPK - 50 NMPK	45.8±11.8 MPK 45±12 NMPK 88 men	96 trauma 4 other	C-Leg	EQ5D	1. Highest EQ5D scores for C-Leg	The study was supported by a grant from Ottobock. No COI reported.
Maaref <i>et al.</i> , 2010 ²⁶	29 - 14 MPK - 15 NMPK	45±14 25 men	27 trauma 2 tumor	Not reported	3D gait analysis	1. Faster gait for MPK 2. Other parameters (stride length, stance phase duration, knee extension and latency period) were not different	No funding reported. No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.
Moller <i>et al.</i> , 2018 ²⁸	42 - 23 NMPK - 19 MPK	49±12.7 28 men	24 trauma 13 tumor 5 other	Not reported	GSE, Q-TFA	1. No difference in GSE 2. No	This research was funded in part by Ossur and TeamOlmed.

Authors	Sample	Age (mean±SD) & gender	Etiology	Type of MPK	Main outcomes	Main results	Finding sources & COI
						difference in Q-TFA	The authors report no COI. The authors alone are responsible for the content and writing of this article.
Moller <i>et al.</i> , 2019 ²⁹	29 - 15 MPK - 14 NMPK	50.4 year 23 men	13 trauma 11 tumor 4 vascular 1 infection	VGK, C-Leg, Rheo, Genium.	6-min walk, steps, 10-meter test	3. No difference in distance 4. No difference in number of steps 5. No difference in walking speed	This research was funded in part by Promobilia foundation, Össur and Team Olmed. No COI declared.
Wurdeman <i>et al.</i> , 2020 ³⁰	450 - 150 NMPK - 150 MPK - 150 BKA	NMPK: 57.6±17.2 MPK: 56.5±13.8 BKA: 58.4±12.2 346 men	167 diabetes vascular 111 trauma 40 infection 19 tumor 14 congenital 24 others 75 not reported	Not reported	PLUS-M	1. Mobility greater for MPK compared to NMKA but not compared to BKA	Support for this work was partially provided by a Small Grant Award (EB-043016) from the American Orthotics and Prosthetics Association. No COI declared.

Authors	Sample	Age (mean±SD) & gender	Etiology	Type of MPK	Main outcomes	Main results	Finding sources & COI
Campbell et al., 2020 ³¹	602 (all MPK)	C-Leg: 61.23 [48.78,68.11] Orion: 57.97 [46.15,67.74] Plie: 56.95 [46.76,65.27] Rheo: 58.63 [44.67,66.22] 448 men	177 vascular diabetes 146 non-vascular diabetes 279 unspecified	- 68 Rheo users - 178 C-Leg - 178 Orion - 178 Plié	PLUS-M, falls, PEQ	1. No difference on the PLUS-M score 2. No difference in falls 3. Nreater QOL for C-Leg	The author(s) received no financial support for the research, authorship, and/or publication of this article. No COI declared.

PLUS-M: 12-item Prosthetic Limb Users Survey of Mobility; BKA: below the knee amputation; COI: conflict of interest; GSE: general self-efficacy; MPK: microprocessor-controlled knees; NMPK: non microprocessor-controlled knees; Q-TFA: Questionnaire for Persons with a Trans-femoral Amputation; PEQ: Prosthesis Evaluation Questionnaire.

RISK OF BIAS

Regarding the RCT, Risk of Bias (RoB) for sequence generation was found to be low in two trials, while for the allocation concealment the RoB was found to be unclear, and high for the blinding of participants and assessors. The RoB for incomplete outcome data was found to be low in two studies and high in one, as for selective reporting. Regarding the follow-up and cross-sectional studies, one was considered as good and the other 9 as fair. See Supplementary Digital Material 1, Supplementary Table I for the detail of the RoB analysis.¹⁰

DISCUSSION

The main aim of the present review was to provide insight on the impact of the use of MPKs (all types combined) on patients' mobility and quality of life.

So far, only three RCTs (including one from which five manuscripts were published)^{11, 13-16, 18} evaluated the effects of MPKs on these outcomes. Taken together, our findings tend to show that the use of MPK compared to NMPK induces an improvement of walking abilities and quality of life.¹⁸ Similar findings were reported for the use of a Genium® prosthesis compared to the C-Leg®,¹³⁻¹⁷ except for stepping rate, which was higher for the C-Leg®.¹⁵

For the other study designs, overall, follow-up trials highlighted a better functional status and quality of life in patients who benefited from MPK compared to NMPK.^{19, 20, 23-25} However, the results of the cross-sectional studies were relatively mixed. Quality of life was the only outcome which

seemed to be enhanced in MPK in a reproducible manner throughout the cross-sectional studies. Regarding the trials assessing different types of MPKs, no clear and consistent difference in performance nor quality of life was found, suggesting that there is no specific type of MPK outperforming the others based on the available data published so far. Even if positive results were found in favor of MPK, the overall quality of the studies was not optimal and therefore, the above-mentioned results should be interpreted with caution.

MPK VERSUS NMPK

When looking at the mobility parameters, the tested outcomes widely varied among studies. Some authors reported specific gait parameters including 3D analysis, while others collected walking speed, risk of falls, stair or hill assessment index, the Timed-Up and Go³² or more global questionnaires taking into account different facets of the patients' mobility and autonomy such as the Prosthetic Limb Users Survey of Mobility (PLUS-M³³), Locomotor Capability Index (LCI-5) or the General Self-Efficacy (GSE). Mobility, measured with the LCI-5 or with walking speed, seems to be improved when using MPK compared to NMPK.^{18, 20, 25} On the other hand, no clear impact on the risk of falls and gait parameters was highlighted. Moreover, it should be noted that the risk of falls might be biased by the patient's functional status, as the more they engage in strenuous physical activity thanks to the MPK, the higher the risk of falling. No difference for the PLUS-M, nor the GSE was found.

Regarding the outcomes collected to evaluate patients' quality of life, most studies reported the Questionnaire for Persons with a Transfemoral Amputation (Q-TFA³⁴) or the Prosthesis Evaluation Questionnaire (PEQ³⁵). Generic quality of life questionnaires were also used such as the SF36 or the EQ5D. All studies using the SF-36 reported better results for MPK compared to NMPK. Taken together, patients locomotor functions and mobility, as well as overall quality of life seem to be improved with the use of a MPK.

One study investigated patients' brain activity while they were walking with a MPK compared to NMPK and found an increased brain activity (prefrontal and motor cortices) for NMPK users compared to MPK users.²⁹ The authors interpreted this finding by a reduction of cognitive resources required for patients walking with a MPK compared to NMPK, which could also have an impact on the risk of falls as well as the patient's fatigue or ability to walk a longer distance. Previous near infrared spectroscopy studies on patients with gait pathologies such as Parkinson or multiple sclerosis, have shown an increased brain activity over the prefrontal cortex mainly.³⁶⁻³⁸ The fact that MPK users seem to require brain activity to a lesser extent to conduct similar tasks is another advantage of the technique as their brain activity seems to be closer to what is observed in healthy individuals.

COMPARING DIFFERENT TYPES OF MPKS

Only one RCT reported a beneficial effect of Genium[®] compared to C-Leg^{®13-17} in gait parameters such as increased flexion, balance, endurance, or walking symmetry and one cross-sectional study compared the impact of different MPKs on quality of life and identified a greater quality of life for the C-Leg[®] compared to the Plié[®].³¹

A previous systematic review evaluated the benefits of the Genium[®] compared to the C-Leg[®] on patients functional status and quality of life.⁸ The authors of this review concluded that transitioning from conventional MPKs (*i.e.*, C-Leg[®]) to Genium[®] MPK resulted in more physiological gait, more equally distributed loading between the prosthetic and sound limbs, as well as reduced compensatory movements on the sound side. Genium[®] also significantly improved mobility, performance in activities of daily living, and quality of life in the patients using a conventional MPK (*i.e.*, C-Leg[®]).

It should be noted that many studies comparing different types of MPKs were carried-out with a small number of patients and, therefore, are not reported in the present systematic review as we only included trials with at least 20 participants in order to have a representative sample and avoid case-reports and case-series.

In addition, it is important to mention that the functionalities of the C-Leg[®] have been improved over time and the nowadays available C-Leg[®] MPK is more alike to the Genium[®] compared to those available five or ten years ago. Therefore, the superiority of the Genium[®] over the C-Leg[®] observed in previous studies might not be as important today.

ECONOMIC CONSIDERATIONS

Although we did not include the economic impact of MPK in the present systematic review, we believe that this aspect is worth discussing. MPKs are prescribed to active individuals with TFA with the belief that the prosthesis will improve their functional status and quality of life. However, these prostheses are expensive and the cost-effectiveness is not well determined in the TFA population, which can greatly influence health care systems' decisions. So far, only a couple of studies have evaluated the cost-effectiveness of MPK over NMPK.^{39,40} In a first study conducted in the USA, NMPK users were compared to MPK users over a 10-year period.³⁹ The authors found that for every 100 persons, MPK resulted in 82 fewer major injurious falls, 62 fewer minor injurious falls, 16 fewer incidences of osteoarthritis, and 11 lives saved. In addition, on a per person per year basis, MPK reduced direct healthcare cost by \$3676 and indirect cost by \$909, but increases device acquisition and repair cost by \$6287 and total cost by \$1702. Moreover, on a per person basis, MPK was associated with an incremental total cost of \$10,604 and increased the number of life years by 0.11 and quality adjusted life years by 0.91. Finally, the authors concluded that MPK had an incremental cost-effectiveness ratio of \$11,606 per quality adjusted life year, and the economic benefits of MPK are consistent in various sensitivity analyses. Similarly, in a second study conducted in Germany, the cost-effectiveness and budget impact of MPK in TFA with and without diabetes was compared to a population of patients using NMPK.⁴⁰ Results of the study suggest that the MPK provides substantial additional health benefits (less fall-related hospitalizations and fall-related deaths) compared to NMPK and is likely to be cost-effective in TFA, both for patients with and without diabetes at an incremental cost-effectiveness ratio threshold of 40,000€ per quality-adjusted life year gained. These two studies confirm that in addition to the effects of MPK on patients' functional status and quality of life, as shown in our review, MPK seem to be cost-effective compared to NMPK, which surpasses the initial cost of the MPK.

LIMITATIONS OF THE STUDY

It should be acknowledged that all included studies were not blinded, even for the assessors, which limit the validation and generalization of the results. The sample size in most publications was between 20 (based on our inclusion criteria) and 35 subjects with the exception of a few larger cross-sectional studies. On the other hand, we excluded a large number of studies which included less than 20 subjects and therefore, pilot and preliminary findings reported in these articles are not reported here.

Internal validity of the reviewed studies could be further improved by including information addressing fatigue and learning, as well as accommodation time, effect size calculation and reporting attrition rate as well as conflict of interest. It should also be noted that five articles were published out of the same study protocol, however, not reporting that data had already been analyzed and published elsewhere. The results of these five studies were presented as a single clinical trial; however, more transparency is recommended in the future when publishing various articles using the same protocol and dataset.

Conclusions

Taken together, the results of the present review tend to demonstrate a superiority in technical parameters and locomotor performances of patients using a MPK compared to a NMPK. Beyond functional status, the improvement reflected by the quality-of-life tests seems to represent an important dimension for the decisions to be taken in public health. From an economic standpoint, MPK seems to outperform NMPK as well. On the other hand, additional benefits of one MPK over another is less clear. Given this current gap in knowledge, future studies should be conducted to determine the possible additional benefit of one type of MPK compared to another.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions

Aurore Thibaut and Charlotte Beudart were responsible for the study protocol, study selection and data extraction, analysis and interpretation of data and drafting the article; Benoit Maertens de Noordhout was responsible for interpretation of data and drafting the article; Sybille GEERS, Jean-François Kaux and Doriane Pelzer were responsible for interpretation of data and revising the article. All authors read and approved the final version of the manuscript.

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Supplementary Digital Material

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