

Reference

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Systematic Review of the Clinical and Biomechanical Evidence for Non-Microprocessor-Controlled Knee Mechanisms and Practical Recommendations for Knee Selection

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Products

Non-microprocessor-controlled prosthetic knees (NMPK)

Major Findings

Differential effectiveness of NMPK stance mechanisms:

- **Locked knees were associated with the lowest fall risk of all types of NMPKs.**
- **Friction-brake and 4-bar knees were associated with a 52% increased fall risk compared to locked knees, and a 42% increased fall risk compared to MPKs.**
- **Multiaxial knees with ≥ 5 axes and fluid swing control and hydraulic stance control knees were associated with a 72% increased fall risk compared to friction-brake and 4-bar knees, and 244% increased fall risk compared to MPKs.**

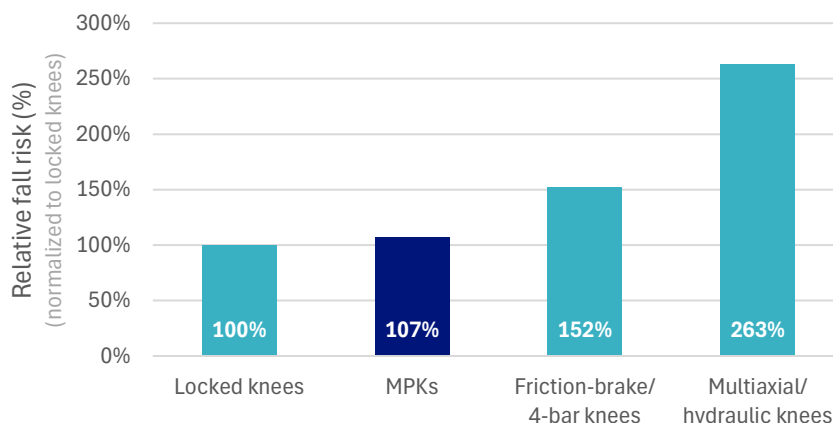


Figure1. Relative fall risk (%) for different types of NMPK stance mechanisms and MPKs, normalized to locked knees (100%).

- **Locked knees, free posterior-offset single-axis knee hinges, friction-brake knees, stance-phase lock knees, and 4-bar knees have only been studied in walking on level ground. There is no evidence for the performance of these knees on non-level surfaces.**
- **Multiaxial knees with ≥ 5 axes may outperform friction-brake knees on slopes, stairs, uneven terrain, and obstacle courses.**
- **Hydraulic stance control knees may outperform multiaxial knees on slopes, stairs, uneven terrain, and obstacle courses.**

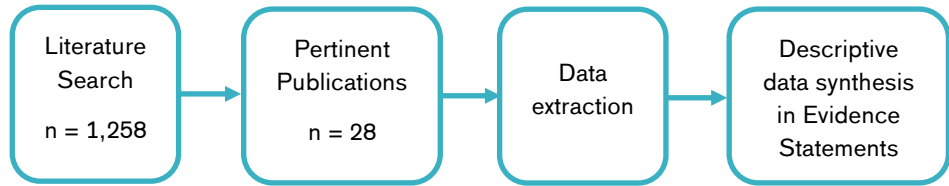
Population

Subjects: 1,048 subjects in 28 publications
(Sex not reported in all publications)

Amputation causes: 761 trauma, 163 dysvascular, 22 cancer (etiology not reported in all publications)
 MFCL: 32 MFCL-1/2, 191 MFCL-3/4 (MFCL not reported in all publications)

Study Design

Systematic review of the literature:



The publications were searched and identified through PubMed, Embase, CINAHL, OTseeker, and Google Scholar and the personal archives of the authors. Search terms used included “transfemoral amputation,” “non-microprocessor,” “mechanical,” “friction,” “polycentric,” “hydraulic,” and “prosthetic knee.” Methodological quality of the 28 pertinent studies was assessed using the State-of-the-Science Evidence Report Guidelines of the American Academy of Orthotists and Prosthetists (AAOP). Data was extracted from pertinent publications and synthesized descriptively. Statistical analyses or meta-analyses were not possible due to the heterogeneity of the data and incomplete reporting.

Results

Functions and Activities								Participation	Environment
Level walking	Stairs	Ramps, Hills	Uneven ground, Obstacles	Cognitive demand	Metabolic Energy Consumption	Safety	Activity, Mobility, ADLs	Preference, Satisfaction, QoL	Health Economics

Category	Outcomes	Results for MPK vs. NMPK	Sig. ^a
Level walking	Gait speed	K1 and low-K2 patients may walk faster and longer with a locked knee, increase prosthesis use with it, and prefer it over a friction-brake knee.	++ [1,2]
		Mid- to high-K2 patients may prefer a friction-brake knee over a locked knee, even if their walking performance is better with the locked knee.	0 [2]
		K3 patients may walk faster and consume less metabolic energy with a stance-phase lock knee compared to a friction-brake knee.	++ [8]
		K3 patients may be restricted in their walking performance by friction-brake knees and may walk faster and with more stability on level ground with a 4-bar knee.	++ [9,10]
	Biomechanics	On level ground, walking with multiaxial knees with ≥5 axes may be possible with the same or even better gait biomechanics than with hydraulic stance control knees.	0 [11]

Category	Outcomes	Results for MPK vs. NMPK	Sig. ^a
Stairs, Ramps/Hills, Uneven ground / Obstacles	Biomechanics	Locked knees, free posterior-offset single-axis knee hinges, friction-brake knees, stance-phase lock knees, and 4-bar knees have only been studied in walking on level ground. There is no evidence for the performance of these knees on non-level surfaces (exception: one study with friction-brake vs. multiaxial knees [11]).	n.a.
	Timed walk tests	Multiaxial knees with ≥ 5 axes may allow for significantly faster slope and stair ascent and stepping over obstacles than friction-brake knees.	++ [11]
		Hydraulic stance control knees may perform significantly better on slopes, stairs, and obstacle courses than multiaxial knees with ≥ 5 axes.	++ [12-14]
Metabolic energy consumption	Oxygen consumption	K3 patients may walk faster and consume less metabolic energy with a stance-phase lock knee compared to a friction-brake knee.	++ [7,8]
Safety	Fall risk	Locked knees may be associated with low fall rates in K1 and low-K2 patients.	n.a. [3]
		Free posterior-offset single-axis knee hinges may provide lower toe clearance than many polycentric knees and single-axis MPKs.	n.a. [6]
		There is no evidence on the risk of falling with free posterior-offset single-axis knee hinges.	n.a.
		Compared to locked knees, the risk of falling with a friction-brake knee may be up to 52% higher. However, compared to multiaxial knees with fluid swing control and hydraulic stance and swing control knees, the risk of falling with a friction-brake knee may be up to 72% lower.	0 [3]
		Friction-brake knees are associated with a 42% higher fall risk compared to MPKs.	0 [3]
		After longer use, K3 patients may perceive a stance-phase lock knee as safer and more stable than a friction-brake knee.	++ [8]
		There is no evidence on the risk of falling with stance-phase lock knees.	n.a.
		4-bar knees have the potential to increase toe clearance during swing, but the capability for functional shortening of the shank portion and increasing toe clearance depends on the design of the 4-bar mechanism. Many 4-bar knees may not be designed to support increase in toe clearance.	++ [6]
		Compared to locked knees, the risk of falling with a 4-bar knee may be up to 52% higher. However, compared to multiaxial knees with fluid swing control and hydraulic stance and swing control knees, the risk of falling with a 4-bar knee may be up to 72% lower.	0 [3]

Category	Outcomes	Results for MPK vs. NMPK	Sig. ^a
		4-bar knees are associated with a 42% higher fall risk than MPKs.	0 [3]
		Multiaxial knees with ≥5 axes have the potential to increase toe clearance during swing, but the capability for functional shortening of the shank portion and increasing toe clearance depends on the design of the multiaxial mechanism. Many multiaxial knees may not be designed to support increase in toe clearance.	++ [6,15]
		Compared to friction-brake and 4-bar knees, the risk of falling with a multiaxial knee may be increased by up to 72%.	0 [3]
		Multiaxial knees with ≥5 axes and fluid swing control are associated with a 244% increased fall risk compared to MPKs.	++ [3]
		Compared to friction-brake and 4-bar knees, the risk of falling with a hydraulic stance control knee may be increased by up to 72%.	0 [3]
		Hydraulic stance control knees are associated with a 244% increased fall risk compared to MPKs.	++ [3]
		There is no evidence that pneumatic or hydraulic swing controls can reduce falls. In fact, the risk of falling compared to knees with friction swing controls may be increased by up to 72%.	0 [3]
Activity, Mobility, ADLs	Walking capability	A locked knee or a manual lock in more functional prosthetic knees may provide stability and safety to start rehabilitation with the first prosthesis after TFA/KD.	n.a. [3]
		Locked knees, free posterior-offset single-axis knee hinges, friction-brake knees, stance-phase lock knees, and 4-bar knees have only been studied in walking on level ground. There is no evidence for the performance of these knees on non-level surfaces (exception: one study with friction-brake vs. multiaxial knees [11]).	n.a.
	K-level	K3 patients may be restricted in their walking performance by friction-brake knees and may walk faster and/or with lower metabolic energy consumption on level ground with stance-phase lock knees, 4-bar knees, or multiaxial knees with ≥5 axes.	++ [7-11]
		Patients ambulating at the high-K2 level with a friction-brake knee may be able to improve their overall mobility to the K3 level with a 4-bar knee.	++ [10]

^a no difference (0), positive trend (+), negative trend (-), significant (++/--), not applicable (n.a.)
significance set at p<0.05; trends set at 0.1>p>0.05

Author's Recommendation	Practical recommendations for	
	General consideration on safety and stability	There is an inverse relationship between safety and function in NMPK stance control mechanisms. Stability and safety must be traded for increased function of the knee and compensated for by increasing residual limb (RL) function of the patient. If the patient needs more function of the prosthetic knee but could not tolerate reduced stability and safety, you may want to consider an MPK.
	Locked knees and manual locking functions	<p>Locked knees are the most stable but least functional prosthetic knees. They should only be considered for K1 or low-K2 patients who are unable to consistently stabilize a more functional knee.</p> <p>For patients who receive their first prosthesis, a locked knee or a manual locking function in a more functional knee may be considered as the first step to provide high knee stability for developing confidence in the prosthesis.</p>
	Friction-brake knees, stance-phase lock knees, 4-bar knees	Friction-brake knees may be considered for K1 or K2 patients able to consistently stabilize the knee. High-K2 and K3 patients may be restricted in their mobility by a friction-brake knee and benefit more from a stance phase lock knee or 4-bar knee with higher walking speed and/or lower metabolic energy consumption. Friction-brake knees, stance phase lock knees, and four-bar knees lack the technical means to support controlled knee flexion during weight bearing, which limits their function and performance on non-level terrains. Four-bar knees have the potential to increase toe clearance, but many four-bar knees are not designed to do so. If in doubt, a trial may help guide clinical decision making.
	Multiaxial knees with ≥ 5 axes	Multiaxial knees with five or more bars/axes support limited controlled knee flexion during weight bearing and, thus, knee stance flexion during level walking and reciprocal, step-overstep ambulation on slightly uneven terrain and descent of shallow slopes. On non-level terrains, they have been shown to significantly outperform friction-brake knees. Multiaxial knees have the potential to increase toe clearance, but many multiaxial knees are not designed to do so. However, multiaxial knees with fluid swing control may be associated with a higher fall risk, so patients require moderate residual limb function typical for mid-K2 to mid-K3 mobility to adequately stabilize the knee. If in doubt, a trial may help guide clinical decision making.

Hydraulic stance control knees	Hydraulic stance control knees support unlimited controlled knee flexion during weight bearing (yielding) and, thus, knee stance flexion during level walking and reciprocal, step-overstep ambulation on uneven terrain and slope and stair descent. On non-level terrains, hydraulic stance control knees have been shown to significantly outperform multiaxial knees with five or more bars/axes. However, hydraulic stance control knees require good to excellent RL function typical for mid-K3 to K4 mobility to stabilize the knee reliably in all situations of life. If in doubt, a trial may help guide clinical decision making.
NMPK swing control mechanisms	Pneumatic and hydraulic swing controls may improve gait pattern with respect to walking speed, gait symmetry, and metabolic energy consumption compared to friction swing control in moderate (0.3–1.1 m/s, pneumatic) and active walkers (≥ 0.8 m/s, hydraulic), respectively, but there is no evidence that they may improve safety or reduce fall risk.
Note/Disclaimer	These recommendations are “guides” to inform clinical decision making and may not apply to all patients and all clinical situations. Thus, they are not intended to replace or overrule clinical judgment.

Author’s Conclusion

“Though the evidence on NMPK mechanisms is very limited, it is possible to make useful Evidence Statements and use reasonable technical and biomechanical experiences to help guide recommendations for prosthetists’ selection of NMPK stance and swing control mechanisms based on patients’ mobility level and their safety and mobility needs.” (Kannenberget al., 2025)

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