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LITERATURE REVIEW

EVIDENCE ON PROSTHETIC FEET WITH ACTIVE DORSIFLEXION FEATURE, PASSIVE MICROPROCESSOR CONTROL AND ACTIVE ANKLE POWER GENERATION: A MINI LITERATURE REVIEW.

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ABSTRACT

This paper reviewed 11 publications on non-MP controlled ankles with active dorsiflexion feature, 15 publications on passive MP controlled ankles, and 12 publications on powered MP controlled ankle-foot mechanisms. Methodological quality of publications was low to moderate. The evidence found was mostly biomechanical and generated in gait lab studies. Non-MP ankles may increase toe clearance and reduce braking forces during level walking, thus supporting propulsion with increase in walking speed. Passive MP controlled ankles may also increase toe clearance and reduce the likelihood of stumbling over an unseen obstacle. They may reduce energy expenditure during level walking and facilitate slope and stair ambulation. Non-MP and passive MP controlled ankles have been also been shown to reduce residual limb-socket interface pressures. Powered ankles may increase walking speed to the level of and decrease energy expenditure to be no longer significantly different from that of able-bodied individuals. Also, at higher walking speeds the sound knee loading may be reduced by up to 15-20%. However, it remains unclear to what extent the gait lab results for all advanced ankle-foot mechanisms can be transferred to real-life benefits in the free-living environment.

INTRODUCTION

Microprocessor technology has been adopted in prosthetic knees for almost 30 years and in prosthetic feet for about 10 years. Several systematic reviews of the literature on microprocessor-controlled knees have confirmed their benefits in safety and mobility, supporting their use in individuals with transfemoral amputation and MFCL-3 and also MFCL-2 mobility. However, microprocessor-controlled (MP) passive and powered feet are widely considered experimental, investigational and unproven by health insurances.

METHOD

The Medline and EMBASE databases as well as the online library of the Journal of Prosthetics and Orthotics were searched on January 15, 2018, for publications using search terms related to feet with non-MP hydraulic ankles/dorsiflexion feature, or passive or powered microprocessor controlled feet.

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The search terms were combined into a title, abstract, and key word search phrase using Boolean operators, resulting in the following syntax: amput* OR prosth* AND foot OR ankle OR hydraulic OR dorsiflexion OR linkage OR microprocessor OR MP* OR power*. The literature search was repeated on June 30, 2018, to identify recent publications since the original search date. Titles and abstracts of the identified publications were screened for their scope.

Technical papers and case studies were excluded. Publications on biomechanical and clinical studies were rated for methodological quality using the criteria of a Cochrane review of prosthetic foot research by Hofstad et al.1 Publications with good enough methodological quality were reviewed in full and results were extracted and summarized.

RESULTS

The literature search yielded 12 publications (reference 2-13) on biomechanical and/or clinical studies with a prosthetic foot with a non-MP controlled hydraulic ankle/dorsiflexion feature, 16 publications (reference 14-29) on passive and 17 publications (reference 30-46) on powered MP controlled prosthetic ankle-foot mechanisms. One publication on non-MP feet (12), one publication on passive MP feet (14) and 5 publications on powered ankle-foot mechanisms (35, 40, 44-46) were excluded from the review for insufficient methodological quality.

All included studies had low to moderate methodological quality and all but one were conducted with individuals with unilateral transtibial amputations. Compared to standard energy storage and return (ESAR) feet, the studies with a foot with a non-MP hydraulic ankle/dorsiflexion feature demonstrated a significantly increased toe clearance and self-selected walking speed on level ground. In addition, studies reported reduced braking forces (improved progression of the center of pressure under the foot), smoother gait and reduced perception of having to “climb over the prosthetic limb” by the patients. One study demonstrated reduced interface pressures between the socket and residual limb while walking on level and uneven terrain and ascending and descending slopes and stairs.

One study with a passive MP controlled prosthetic foot also demonstrated significantly improved toe clearance during over-ground walking, reducing the likelihood of tripping over an unseen obstacle of 0.5 cm height from 1/166 steps with an ESAR foot to 1/3,169 steps with the MP foot. Studies also found a reduction of metabolic energy consumption on level ground and a reduction in perceived energy demand for walking up slopes. One study found some improvements but also some deteriorations in biomechanical parameters during slope ambulation. Another study demonstrated that it was easier with a MP controlled than with a non-MP controlled hydraulic ankle to control the walking speed while descending a 5° slope. One study with a MP controlled foot with instant terrain adaption and a dorsiflexion stop found that it was more physiologic to stand on a 10° incline and decline with this foot than with other MP controlled feet with only gradual terrain adaption and no dorsiflexion stop. One study found some improvements in biomechanical parameters while ascending and descending stairs. Finally, one study also demonstrated significantly reduced interface stress between the socket and the residual limb when using a MP controlled foot as compared to a standard ESAR foot on varying terrains.

Studies with a MP controlled powered ankle-foot component found that subjects able to walk with at least 1.2 m/s with their regular ESAR foot have a good chance to further increase their self-selected walking speed to the level of able-bodied individuals. At higher walking speeds of 1.5 to 1.75 m/s, use of a powered foot may result in a significant 15-20% reduction of sound knee loading, which may have the potential to reduce incidence rates of sound knee osteoarthritis related to long-term prosthesis use.

Studies also found improved stability while walking on level ground and slopes. There is conflicting evidence on the reduction in metabolic energy consumption during over ground walking: One study showed a significant decrease in energy expenditure, whereas another study could only confirm that for subjects with MFCL-4 mobility. Finally, studies reported significantly improved push-off and walking speed on uneven terrain and normalized ankle power generation and increased plantarflexion during stair ascend.

DISCUSSION

A total of 38 publications on the benefits of prosthetic feet with non-MP hydraulic ankles/dorsiflexion
feature, passive or powered MP controlled ankles was reviewed. Most of the studies had been conducted in gait labs and focused on biomechanical parameters of gait.

Clinically, the most relevant finding was that non-MP and passive MP controlled ankles may have the potential to increase toe clearance and, thus, reduce the risk of tripping. However, it remains to be studied if that feature also results in reduced falls in the free-living environment. Improved passive ankle motion may result in reduced braking forces, increased self-selected walking speed, and reduced interface pressures between the residual limb and the socket on varying terrains.

Passive MP controlled feet may also improve the ability to navigate slopes and stairs. Powered feet may enable high-functioning individuals with transtibial amputation to further increase their self-selected walking speed to the level of able-bodied subjects while significantly reducing sound knee loading at higher walking speeds. Some subjects may also benefit from using a powered ankle-foot component by reducing metabolic energy consumption at faster walking speeds. However, none of studies reported any criteria for identifying patient groups who are more likely to benefit from either type of advanced foot technology than others. Thus, matching the right patient with the individually best advanced prosthetic ankle-foot mechanism remains a difficult challenge to clinicians.

CONCLUSION

Prosthetic feet with non-MP or passive MP controlled hydraulic ankles/dorsiflexion feature may be considered for transtibial amputees with compromised toe clearance and tendency to trip. These feet may also be considered for patients who experience increased residual stress while negotiating uneven terrain, slopes and stairs. Powered prosthetic feet may be considered for high-functioning individuals with transtibial amputations who want to further increase their walking capabilities and reduce their long-term risk of developing sound knee osteoarthritis.

REFERENCES


A. References for non-MP feet/ankle with ankle ROM and dorsiflexion feature (2-13)


10. De Asha AR, Johnson L, Munjal R, Kulkarni J, Buckley JG. Attenuation of centre-of-pressure trajectory fluctuations under the prosthetic foot when using an articulating hydraulic ankle attachment compared to fixed


B. References for passive MP-controlled feet/ankle (14-29)


C. References for powered feet/ankle (30–46)


DISCLOSURE

Dr. Andreas Kannenberg is a full-time employee of Otto Bock HealthCare LP, Austin, TX.