

Pedalling Optimisation and Balance Challenges in Leisure Cycling with Unilateral Transtibial Prostheses

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(片側下腿義足を装着したレジャーサイクリングにおけるペダリングの最適化とバランスの課題)

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Abstract of Dissertation

Leisure cycling is a widely practiced activity among individuals who wear unilateral transtibial prostheses and offers various physical, psychological, and social benefits. As a low-impact alternative to walking, cycling increases physical activity levels and promotes social engagement. Despite its benefits, challenges such as movement and power asymmetries can arise owing to differences between intact and amputated limbs, affecting multiple aspects of cycling. This thesis investigated equipment adjustments and situational factors that can enhance leisure cycling for individuals with unilateral transtibial amputations.

The first study focused on saddle height settings. While higher saddle heights are generally recommended to optimise joint engagement, lower saddle heights may offer advantages for leisure cycling, particularly in mitigating the effects of stiff ankle joints in prostheses. This study assessed the impact of both high and low saddle heights on reducing asymmetries. The participants wore orthoses to simulate the prosthetic conditions. The results showed that a lower saddle height, achieving a knee angle of 37–45° at maximum extension, led to joint movements more akin to intact cycling. This adjustment also resulted in improved power delivery symmetry and muscle activity, similar to those of intact cycling.

The second study explored prostheses, specifically the ankle joints. This study evaluated how the addition of ankle movement through compression springs may bring the biomechanics of the affected limb closer to those of an intact limb, improving comfort and diminishing asymmetry. Therefore, this study aimed to investigate the use of springs of varying stiffness to allow prosthetic movements at the ankle. A prototype prosthesis was tested with two participants: one with a traumatic amputation and the other with a congenital amputation. Results showed that stiffer springs improved comfort, muscle activity regularity, and power symmetry in participants with traumatic amputation. However, no significant improvements were observed in participants with congenital amputation, highlighting the need for personalised prosthetic solutions.

The final section addresses the situational challenges of balancing bicycles. Fear of falling, often present in individuals with lower limb amputations, can pose a barrier to the adoption of leisure cycling. It is generally understood that cycling speed affects cycling balance. Consequently, this study employed speed perturbations to evaluate the balancing challenges in simulated prosthetic conditions by comparing the results with those of regular, intact cycling. Prosthetic conditions caused slight instability and specific lean angles, but balance was largely unaffected within the established cycling motion. This study also found that the anticipation of speed changes possibly influenced balance and control.

In conclusion, this thesis highlights key considerations for leisure cycling among individuals with unilateral transtibial amputations. Lowering the saddle height was found to enhance symmetry between the affected and unaffected limbs while also improving manoeuvrability, as evidenced by the maintained balance. Furthermore, the observed balance improvements and heightened symmetry suggest that incorporating prosthetic ankle mobility can further increase user comfort. Overall, these findings suggest that refining prostheses and bicycles to promote natural limb symmetry and control could improve cycling accessibility, broadening their adoption as beneficial activities.