The biomechanics of cycling with a transtibial amputation: Recommendations for prosthetic design and direction for future research

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Abstract

People with amputations may find cycling advantageous for exercise, transportation and rehabilitation. The reciprocal nature of stationary cycling also makes it a viable model for research in motor control because the body is supported by the saddle allowing the researcher to focus on the cyclic movement of the legs without the confounding variable of balance. The purpose of this article is to provide an overview of the cycling task in intact cyclists and relate this information to understanding the challenges faced by cyclists with transtibial amputations (CTA). Ongoing research into the biomechanics of CTAs will be summarized to expose the differences between intact and CTA cycling mechanics, asymmetries between limbs of CTAs as well as neuromuscular adaptation following amputation. The article will include recommendations for prosthetic design and modification of the bicycle to improve cycling performance for CTA at all experience levels.

Conclusion

The cycling task provides a method for rehabilitation, exercise and investigations into motor control for people with amputation. This article provides a background in how intact persons cycle, the challenges faced by cyclists with amputation and how those challenges result in pedaling asymmetries. A change in motor control strategy is suggested as a cause of the asymmetries yet more research is warranted before a complete understanding of how this strategy differs from the sound limb or intact cyclists. This article provides recommendations on how the bicycle and the prosthesis may be adapted to improve cycling performance. These adaptations may be different for competitive and recreational cyclists. For competitive cyclists, a stiff prosthetic foot is recommended. Recreational cyclists may utilize their walking prosthesis if the pedal is moved laterally to allow clearance between the heel and the crank arm. Both groups may benefit from using a shorter crank arm on the amputated side as well as a commercially available clipless pedal system. It is recommended that the prosthetist team up with an experienced bicycle fitter to help with the complex problems of body positioning. Many questions still remain regarding the affect of different prosthetic alignment on cycling performance and will require additional research. Continuing efforts will help provide solutions to optimize prosthetic wearer outcomes for both recreation and rehabilitation.

Muscle	Corresponding abbreviation in Figure 2	Motion the muscle produces	Major function in cycling
Tibialis anterior	TA	Single joint ankle flexor (dorsiflexor)	Stabilize ankle during bottom and recovery phases
Soleus	SOL	Single joint ankle extensor (plantarflexor)	Stabilize ankle during power phase
Gastrocnemius	GAS	Two joint knee flexor and ankle extensor	Stabilize ankle and direct pedal forces during power and bottom phases
Quadriceps (Vasti)	VAS	Single joint knee extensor	Major power producing muscle group
Rectus femoris	RF	Two joint hip flexor and knee extensor	Direct force at the top of the stroke and produce power during power phase
Hamstring group	HAM	Two joint hip extensor and knee flexor	Direct forces during power and bottom phases
Iliopsoas	IL	Single joint hip flexor	Possibly aids to lift leg during recovery
Gluteus maximus	GM	Single joint hip extensor	Major power producer

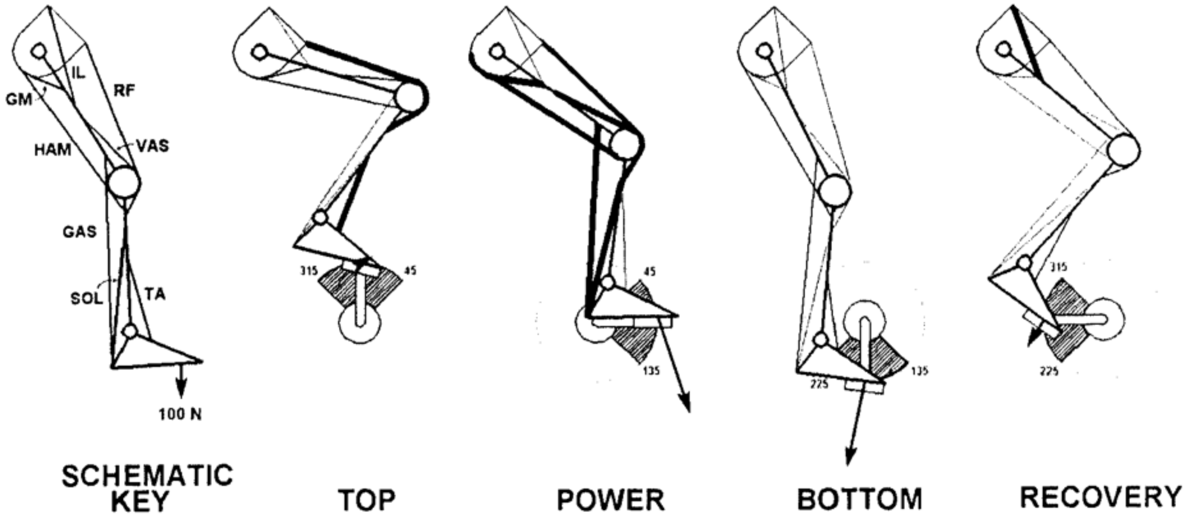

Figure 2. Schematic of the lower limb showing representative muscle activity of the lower limb, direction and magnitude of the force at the pedal, and limb positions in the four different quadrants of the pedal stroke. Muscle activity within each quadrant is indicated by the thickness and shade of the lines. Muscles may be very active (thick black), moderately active (thin black) or not active (thin grey). Numbers around the pedal arch denote the start and stop of the respective quadrant in crank degrees relative to TDC. Magnitude of the force vector corresponds to its length defined by the schematic key. Values for limb orientation, muscle activation and force production are derived from experimental data on an intact cyclist operating at 200 watts and 90 rpm. Refer to Table I for a summary of each major muscle group and their function during cycling.

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