

Application of Short and Variable-Length Pedal Cranks in Cycle Ergometry for Lower Limb Rehabilitation: A Brief Review

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Brief literature review of short and variable-length pedal crank cycle ergometry; application to early-stage postoperative rehabilitation following knee replacement and reconstruction and revision, and rehabilitation of the arthrofibrotic knee

Introduction. Cycle ergometers and stationary exercise or fitness bikes are an established component of common practice in orthopedic rehabilitation following hip and knee surgeries. These include upright (or vertical) and recumbent stationary exercise (or fitness) bikes and the SciFit Pro2® recumbent bikes.

However, the patient's access to the outpatient clinic's stationary exercise bikes is limited by their mechanical properties: first, the pedal crank length determines the minimum flexion required to complete a rotation without pain, typically 105°-110°; second, both legs must possess sufficient strength to rotate the pedals independently; and third, a vertical or recumbent fitness bike's seat and step-through space demand a certain level of core and lower limb strength, balance, and confidence to mount and ride. Only patients in more advanced stages of therapy meet these criteria.

The notion of a short pedal crank for earlier application of a cycle ergometer to lower extremity rehabilitation therapy was studied and reported over 30 years ago. A short-crank exercise bike continues to be used at the Hospital for Special Surgery (HSS) in New York City. It is listed with traditional interventions in several orthopedic rehabilitation handbooks.

A shorter pedal crank is not a new subject or novel device. It modifies a cycle ergometer to make the known benefits of cycling exercise available earlier in the rehabilitation course.

Discussion. Goodwin and Cornwall (1988) determined that patients with restricted knee ROM could use a stationary bicycle with a shorter pedal shaft (crank) because the shorter pedal cranks did not significantly affect the phasic activity of the involved lower extremity muscles or change the therapeutic characteristics of the bicycle ergometer. They made the following recommendation:

“The shortened pedal shaft used in the present study has direct application to rehabilitation. Using a shortened pedal shaft, patients with restricted ROM of their knees would be able to use a stationary bicycle. These patients would consequently be able to receive both the musculoskeletal as well as the cardiovascular conditioning available from a bicycle ergometer...The adjustable pedal shaft used in this investigation allows a versatile piece of equipment to become applicable to an even greater patient population.”

In 1991, Schwartz et al. reported on a novel short-crank cycle ergometer and a mathematical model that calculated knee flexion and extension angles from lower limb dimensions and stationary bike settings. Their commercial upright cycle ergometer was equipped with four specially machined crank sets whose pedal crank length varied from 80 mm to 170 mm (3.1 to 6.7 inches). They also showed that they could calculate the knee flexion angle and ROM for any patient at every seat height across a series of increasing pedal crank lengths. This table could guide therapists in setting goals and applying cycling therapy to a specific patient's rehabilitation.

They echoed Goodwin and Cornwall when they claimed that their custom short-crank cycle ergometer made the benefits of lower body ergometer cycling available earlier in post-operative rehabilitation:

“The...custom cycle ergometer can be used on early postoperative knee patients who are unable to ride a conventional cycle ergometer because of a lack of knee motion or on patients who require a limited arc of motion in their postoperative therapy protocol.”

These authors accepted the intrinsic value of applying the stationary exercise bike to early knee rehabilitation therapy.

John T. Cavanaugh, one of the authors on the previously cited paper, continues to employ the short-crank stationary bicycle at HSS. He specifically added it to the list of interventions following meniscal tear reconstruction surgery in a paper published in 2012:

As flexion ROM improves to greater than 85°, select OKC and CKC exercises are introduced to the therapeutic exercise program. Bilateral leg press and mini-squats are performed inside a 60°–0° arc of motion. Quadriceps isometrics are performed submaximally at 60° of flexion. *Stationary bicycling is added to the rehabilitation program by utilizing a short crank (90 mm) ergometer.* (Cavanaugh and Killian 2012, *emphasis added*)

Citing this paper, several handbooks and published guidelines for orthopedic rehabilitation therapy (see **References** for three examples) recommend the short-crank

ergometer in the treatment protocols at early stages (knee flexion 80-90°) following several specific knee reconstruction procedures.

Under the proper conditions, a 2-inch pedal crank can limit maximum knee flexion during pedal rotation to about 60°. At this maximum flexion angle the cycle ergometer is accessible to the immediate post-operative knee, substituting for the CPM machine. Indeed, it provides early motion, which, as Millet et al. (2003) stated, “is key for the successful rehabilitation of the postoperative arthrofibrotic knee.”

Adjustable-length pedal crank. Kelln et al. (2009) demonstrated promising results with the use of a bicycle ergometer fitted with variable-length pedal arms in the early post-operative rehabilitation of patients after partial meniscectomy. A built-in, easily adjustable, and rugged adjustable pedal crank system could provide a wide range of pedal crank lengths (i.e., knee flexion angles) and could meet the requirements of an outpatient therapy clinic for quick set up.

Patients suffering stiffness and decreased extension post-rehab, perhaps also patients with arthrofibrotic knees and flexion contracture, who can gain access to an adjustable-crank stationary bicycle at home or in an outpatient clinic can benefit from its extension, flexion, strengthening, and gait speed therapies. It is likely that the McKenzie Institute’s principles (McKenzie and May, 2000) for reducing articular dysfunction underlie the effectiveness of a cycle ergometer in modifying the fibrotic and shortened tissues in the stiff knee. The intrinsic cycling motion establishes a process of intermittent loading in the end range of motion of the affected joint, in the patients’ pain tolerance zone. Only a stationary bicycle equipped with a variable-length pedal crank and integrated seat can provide the incrementally progressive, long-term exercise required to remodel the target soft tissues over time.

Summary. The short crank cycle ergometer papers made substantial contributions on early lower extremity therapy to the literature. They demonstrated novel equipment and its equivalency to conventional stationary cycling, quantified the relationship between knee flexion angle and bike settings, and demonstrated early post-acute application.

The authors showed that shortened pedal cranks allowed them to apply a cycle ergometer earlier in the course of mobility rehabilitation. They stated that they believed there were benefits. The effectiveness and acceptance of the idea are demonstrated by its continued use at HSS and recommendations in physical therapy handbooks.

The variable-length pedal crank assembly makes the short-crank cycle ergometer easily available. It has been applied to accelerated rehabilitation following partial meniscectomy. In addition, local clinical and home-use experience with the OrthoBike™ OB1 has demonstrated the value of its variable-length pedal crank, integrated seat, and

dual action lever arms in acute-stage rehabilitation following TKA and ACL reconstruction surgery.

It has also helped resolve stiff and arthrofibrotic knees post-rehab and following revision surgery. The underlying principles supporting its application to fibrotic and adherent soft tissues in the knee may be described by the McKenzie Institute's MDT program for peripheral joints.

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