

Hand-Cycling: An Active Form of Wheeled Mobility, Recreation, and Sports

F.J. Hettinga, PhD^{a,*}, L. Valent, PhD^b, W. Groen, MSc^c,
S. van Drongelen, PhD^d, S. de Groot, PdD^{a,e}, L.H.V. van der Woude, PhD^a

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Given the limited work capacity of wheelchair users in general, the stress of hand-rim wheelchair mobility results in fatigue and local discomfort of the upper extremities with the possible risk of repetitive strain injuries.^{1–3} Different experiments on lever- and crank-propelled wheelchairs have shown that alternative propulsion mechanisms (levers, hub cranks) are less straining and more efficient than hand rims.^{4–8} Hand-cycling (or hand-biking) has been found to be especially efficient, as well as less straining, and has become very popular over the last decades both in industrialized^{4,5,9,10} and developing countries^{11,12} in daily life and sports. Physiologic benefits of hand-cycling have been demonstrated in people with a chronic disability and even in early rehabilitation.^{4,9,13–20}

Both in daily life and Paralympic sports performance, hand-biking is an interesting mode of training and exercise with many practical benefits. For example, hand-biking is recommended to maintain physical fitness and prevent arteriosclerotic diseases.^{9,17,18,21,22} Also, hand-bikers can easily take part in training sessions together with participants in such able-bodied cyclic sports as cycling and roller-skating. Crank-propelled tricycle wheelchairs (ie, hand cycles) have in particular demonstrated

^a Centre for Human Movement Sciences, University Medical Centre Groningen, University of Groningen, Antonius Deusinglaan 1, Sector F; Building 3215, Room 0330, 9713AV Groningen, The Netherlands

^b Heliomare Rehabilitation Research and Development, Wijk aan Zee, The Netherlands

^c Faculty of Human Movement Sciences, Research Institute MOVE, VU University, Amsterdam, The Netherlands

^d Swiss Paraplegic Research, Nottwil, Switzerland

^e Duyvensz-Nagel Research Laboratory, Rehabilitation Centre Amsterdam, The Netherlands

* Corresponding author.

E-mail address: f.j.hettinga@med.umcg.nl (F.J. Hettinga).

their important role in more extreme environmental conditions in daily life in many non-Western countries.^{8,11} Such wheelchairs enable greater physiologic responses—expressed in higher peak power production, mechanical efficiency, and, thus, endurance capacity—compared with those from hand-rim propulsion.^{4,7} Lower muscular strain in terms of muscle activation was seen²³ compared with hand-rim wheelchair propulsion. In addition, biomechanical studies—still few in number—have generated some understanding of the underlying mechanisms of the improved performance in hand-cycling, again compared with hand-rim wheelchair propulsion.^{21,24–27} Compared to hand-rim wheelchairs, hand-cycle wheelchairs enable higher velocities over a longer duration at the same or even a lower physical strain due to the following factors: (1) a natural grip of the hands to a well-formed handle bar, with the arms moving within the visual field, mostly making a fully circular motion and without the need for coupling-uncoupling actions in hand-rim propulsion; (2) the use of cranks and levers that allow the use of all flexor and extensor muscles around the arm-shoulder joints to actively contribute to external work over the full motion cycle; the latter in contrast to hand-rim propulsion where the discontinuous motion allows active work only during 30% to 40% of the cycle.^{4,7,9,13–15,20,24,27–30} The continuous power generation over the full cycle in hand-cycling is suggested to result in an increased gross mechanical efficiency for hand-cycling, which may be almost twice as high as that in hand-rim propulsion.^{31–33} This leads to a larger range of mobility, making hand-cycling a suitable mode of transportation and exercise mode at the recreational level in daily life as well as in fascinating high-level sports. Hand-cycling is interesting for persons with disabilities ranging from single-leg amputation/paralysis to complete spinal cord injuries.

HISTORY AND HAND-CYCLE TECHNOLOGY

Already in 1655, Stephen Farfler (http://de.wikipedia.org/wiki/Stephan_Farfler), a watchmaker with paraplegia, built his own, mainly wooden, self-propelled three-wheeled arm-crank wheelchair. In the 1900s and particularly halfway into the twentieth century, solid, yet large and heavy asynchronous hand bikes without gears were used in Europe as transportation modes for persons with disabilities.^{7,29,34} In the late 1980s, the first modern hand bikes for persons with lower-limb disabilities were developed for recreation and sports.^{5,35} The development of lightweight ergonomic and efficient hand cycles was motivated by the increasing popularity of using the hand bike in a sports setting. Over the last decade, hand-biking in sports gained even more popularity, and was added as an event to the World Championships for the first time in 1998. In 2004, hand-biking appeared for the first time at the Paralympics in Athens (www.paralympics.org). Nowadays, Paralympics are closely associated with the “regular” Olympics and receive the accompanying media attention. It is thus expected that hand-biking and other Paralympic sports will increase even more in popularity in the coming years.

A strong ergonomics approach and thus the use of modern technology and lightweight and innovative materials has led to the reintroduction of the synchronous hand cycle in the mid-1980s for outdoor recreational use,^{5,9,10,15,16,25} where earlier types used asynchronous propulsion.^{7,34} These early hand cycles not only followed rules of bicycle technology, but also mimicked the existing arm-crank systems that became common for upper-body exercise testing in exercise physiology and rehabilitation and showed the first physiologic benefits (higher efficiency and peak power output and lower submaximal physical strain) of full cyclic upper body exercise of asynchronous arm cranking as opposed to hand-rim propulsion.^{36–40}

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