Variations of ankle-foot orthosis-constrained movements increase ankle range of movement while maintaining power output of recumbent cycling

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Abstract: Previous research investigated recumbent cycle power output (PO) from the perspective of knee and hip joint biomechanics. However, ankle-foot biomechanics and, in particular, the effect of ankle-foot orthosis (AFO)-constrained movements on cycle PO has not been widely explored. Therefore, the purpose of this study was to determine whether AFOs of a fixed position (FP) and in dorsi-plantarflexion (DPF)-, dorsiflexion (DF)- and plantarflexion (PF)-constrained movements might influence PO during voluntary recumbent cycling exercises. Twenty-five healthy individuals participated in this study. All underwent 1-min cycling at a fixed cadence for each of the AFOs. The peak and average PO of each condition were analyzed. The peak and average PO were 27.2 ± 12.0 W (range 6–60) and 17.2 ± 9.0 W (range 2–36), respectively, during voluntary cycling. There were no significant differences in the peak PO generated by the AFOs (p = 0.083). There were also no significant differences in the average PO generated using different AFOs (p = 0.063). There were no significant differences in the changes of the hip and knee joint angles with different AFOs (p = 0.974 and p = 1.00, respectively). However, there was a significant difference in the changes of the ankle joint angle (p < 0.00). The present study observed that AFO-constrained movements did not have an influence in altering PO during voluntary recumbent cycling in healthy individuals. This finding might serve as a reference for future rehabilitative cycling protocols.

Keywords: ankle-foot orthosis; ankle movement; pedal power output; rehabilitation exercise; voluntary recumbent cycling.

Introduction
Recumbent cycling is a popular exercise modality for both healthy individuals and patients with musculoskeletal injury or neurological disability. Persons with musculoskeletal injury or neurological disability may require gait training, involving the use of a foot orthosis [15, 20] and an ankle-foot orthosis (AFO) [1, 2, 16, 17]. The prescribed AFOs may be of several types, such as solid AFO, hinged AFO, floor-reaction AFO, posterior leaf spring AFO, anterior elastic AFO, dorsi-assist/dorsi-stop AFO (DA-DS) and plantar stop/free dorsiflexion AFO (PS/DF AFO) [1, 2, 16, 17], which aim to promote recovery or improve functional outcomes. However, weight bearing may be an issue, thus requiring them to train using cycling ergometers. The general goal of recumbent cycling exercise rehabilitation is to produce the highest possible mechanical power to maximize the merit of health benefits while using the AFOs [19, 23, 24]. A fixed AFO or a fixed pedal boot is often deployed to affix the foot to the pedal, and this has been widely used to also provide shank stability, thus restricting leg movements in the sagittal plane during recumbent cycling [3, 12, 26, 28]. During electrically stimulated cycling, for example, in individuals with neurological impairments, the ankle is uncontrolled by voluntary muscle contractions due to a lack of muscle strength or ankle instability, and constraining the ankle range of motion (ROM) might produce different power output (PO) outcomes. Only a few studies have been reported focusing on the recumbent bicycle [11] and the effect of orthoses provided during cycling [31]. Therefore, comparative data from able-bodied (AB) individuals performing voluntary recumbent cycling with AFO-constrained ankle movements are needed to fairly infer its benefits for the musculoskeletal or neurologically impaired population.