

The Effect of Pedal Crank Arm Length on Lower Limb Joint Angles in an Upright Cycling Position



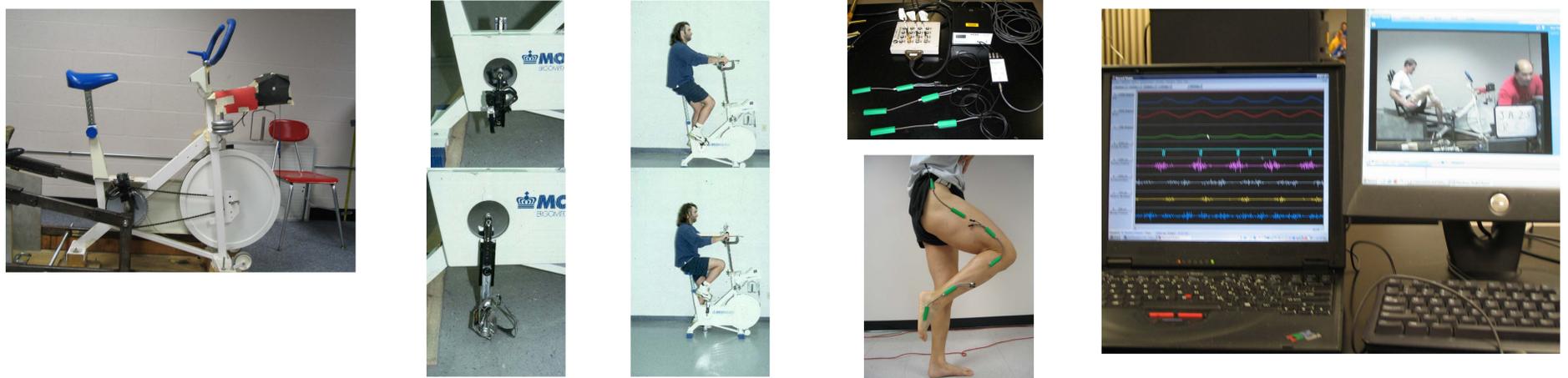
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INTRODUCTION

Previous investigations reported that changes in crank arm length (CAL) from 110-265 mm (i.e., 110, 145, 180, 230, and 265 mm) resulted in significant differences in power production and cycling duration (but not necessarily with adjacent CAL {i.e., 110 vs. 145 vs. 180 vs. 230 vs. 265 mm}) [1,2,3,4]. However, there was no information provided whether changes in CAL also resulted in significant changes in joint angles, and how changes in joint angle may affect cycling performance (based on muscle force-length relationships). Therefore, the purpose of this investigation was to determine whether changes in CAL resulted in significant changes in joint angles, and how these changes are related to changes in cycling performance.

METHODS

Seventeen males participants age 23 ± 6.74 years (mean \pm SD) were each tested on a free weight Monark cycle ergometer (Model 814E) at five pedal CAL (110, 145, 180, 215 and 250 mm) using an adjustable pedal shaft mechanism (RangeMaker™). CAL sequence was randomly determined, and seat height was set at 100% of leg length. Each participant pedaled (with pedal toe-clips) at 60 rpm (in cadence to a metronome) with a 3 kg mass applied to the ergometer. Hip, knee and ankle angles (i.e., minimum [Min], maximum [Max], and range of motion [ROM]) were recorded for 10 seconds from the right sides of the body using 3 electrogoniometers (SG150 and SG100 sensors with a K100 amplifier by Biometrics Ltd) connected to a 4 channel analog amplifier. The signal was routed to an A/D box (Noraxon NorBNC), a synchronizing unit, and to a laptop computer.



RESULTS

Nine repeated measures ANOVAs were performed to determine if there were significant differences ($p < 0.01$) in the Min, Max, and ROM of the hip, knee, and ankle. Results indicated a significant change in the Min joint angle and ROM of the hip, knee, and ankle with 35 mm increments in CAL from 110-250 mm (see Table 1). The following trends were found with incrementing CAL: (1) decreasing Min hip and knee angle; (2) increasing Min ankle angle (see Fig 1), (3) increasing ROM of the hip and knee, (4) decreasing ankle angle ROM (see Fig 2) and (5) no apparent trends in the Max hip, knee, and ankle angle (see Fig 3). Post-hoc tests revealed significant ($p < 0.05$): (1) decrements in the Min hip and knee angle for each 35 mm increment in CAL; (2) increments in the hip and knee ROM for each 35 mm increment in CAL; (3) increments in the Min ankle angle between the 145 mm and 180 mm CAL; and (4) decrements in the ankle angle ROM between the 110 mm and 145 mm CAL, and between the 145 mm and 180 mm CAL.

Table 1. Main Effect of Hip, Knee, and Ankle Joint Angles at Five Crank Arm Lengths (* $p < 0.01$)

Angle (deg)		Crank Arm Length (mm)				
		110	145	180	215	250
Hip	*Min	121.8 (3.43)	111.0 (3.97)	101.7 (4.68)	91.8 (5.67)	86.9 (6.29)
	Max	160.9 (2.09)	162.4 (2.42)	164.3 (2.17)	161.5 (2.67)	164.7 (2.64)
	*ROM	37.9 (3.61)	50.5 (2.95)	61.4 (4.22)	69.0 (4.81)	77.4 (5.63)
Knee	*Min	102.2 (4.34)	87.7 (4.78)	74.4 (4.93)	63.6 (5.22)	56.3 (5.66)
	Max	157.2 (3.84)	153.5 (3.69)	151.4 (5.41)	147.6 (5.68)	147.9 (6.95)
	*ROM	55.0 (4.28)	65.8 (4.3)	77.1 (5.73)	84.0 (5.94)	91.5 (6.62)
Ankle	*Min	84.3 (2.47)	87.8 (2.13)	91.5 (2.58)	93.2 (2.67)	93.9 (2.47)
	Max	117.2 (3.51)	115.4 (3.62)	115.9 (3.78)	116.8 (3.12)	118.3 (3.71)
	*ROM	32.9 (3.8)	27.5 (3.16)	24.3 (2.76)	23.6 (2.52)	24.4 (2.7)

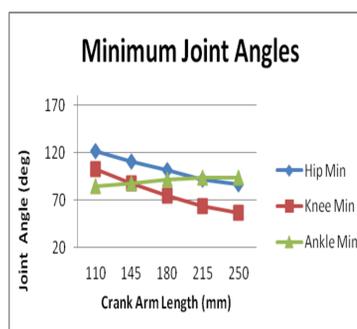


Figure 1: Minimum hip, knee, and ankle angles with changes in pedal crank arm length

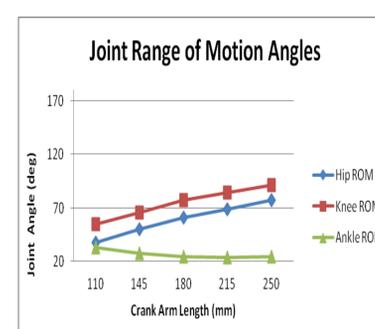


Figure 2: Hip, knee, and ankle range of motion with changes in pedal crank arm length



Figure 3: Maximum hip, knee, and ankle angles with changes in pedal crank arm length

DISCUSSION

It was expected that increments in CAL would result in decrements in Min joint angles, and increments in joint ROM (if the seat height was controlled). However, the reverse was found for the ankle angle (i.e., increment in Min and decrement in ROM) with increments in CAL. This unexpected trend, in conjunction with a significant increment in the Min ankle angle between the 145 mm and 180 mm CAL (from 87.8 deg [i.e., a dorsiflexed position] to 91.5 degrees [i.e., a plantar flexed position]) may be attributed to: (1) insufficient flexibility of the ankle and/or physical constraints/limitations to dorsiflex (due to the structure of the ankle joint) as the CAL is increased; (2) greater ankle force production potential (in a more effective portion/range of the force-length curve) as the Min ankle joint angle increases (from a dorsiflexed position to a plantar flexed one); and (3) increased ankle joint angles to a plantar flexed position (with longer CALs) which alters the joint angles to allow the larger hip and knee muscles to more effectively produce force (i.e., changes the length of the hip and knee muscles so it is in a more effective portion of the tension-length curve to produce force). This appears to be supported by the result that a systematic increase of 35 mm in CAL from 110-250 mm did not result in an equivalent systematic decrease in Min knee angle. In fact, with each change in CAL by 35 mm (from 110 to 145 to 180 to 215 to 250 mm), the minimum knee angle decreased 14.5, 13.3, 11.1, and 7.3 degrees, respectively. Further investigations in this area are required to understand the relationship between CAL, joint angles, muscle length, force/torque production and cycling performance.

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