

Effects of Asymmetric Crank Arm Shortening on Knee Biomechanics for Patients of Total Knee Arthroplasty

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Summary

Asymmetrically shortening cycling crank arm lengths for the replaced limb of early post-operative patients receiving a total knee arthroplasty (TKA) decreased knee range of motion (ROM) while maintaining knee extension joint loading. These findings have favorable implications for improving patient outcomes via cycling with asymmetrically shortened crank arms.

Introduction

Individuals receiving TKA have been shown to have unilateral kinetic deficits during cycling beyond 6 months of surgery [1]. Earlier implementation of physical activity in the rehabilitation process is important for long-term outcomes but exercise adherence can be difficult due to known differences in swelling, pain, and stiffness [2]. Asymmetrical shortening of the crank arm length of the replaced limb may help to decrease the range of motion and the physical requirements of cycling, allowing for earlier implementation of rehabilitative exercise. Therefore, the purpose of this study was to investigate the kinematic and kinetic effects of asymmetric crank arm shortening in early-stage TKA patients.

Methods

Participants (2 male, 2 female, age=65±7 yrs., BMI=35±1.16) were post-TKA patients from a local physical therapy clinic who were 1-2 months after receiving TKA surgery. Stationary cycling on an Excalibur+Sport cycle ergometer (Lode BV, Groningen, The Netherlands) was used with 3D force-sensing bike pedals (1200Hz, Kistler) with adjustable crank arm lengths. Participants performed in five separate cycling conditions with crank arm lengths (mm) adjusted for the Replaced/NonReplaced limbs: C1 (140/170), C2 (155/170), C3 (170/170), C4 (155/155), C5 (140/140). Each cycling condition was performed at 70 Watts at 70 RPM for 2 minutes. The last 10 seconds of each condition were recorded and truncated into 5 individual trials (crank cycles). A 13-camera Vicon system (240Hz) was used to record kinematic and pedal

kinetic data in Vicon Nexus. Data were imported into Visual 3D and further processed in a custom Python3 program used to identify discrete events in time series data. A 2x5 (Limb x Crank Length) ANOVA within the IBM SPSS was used to identify differences of crank length, limb, and their interactions.

Results and Discussion

A main effect of crank length was seen for sagittal knee ROM and peak knee extension angle (Table 1). A significant reduction in knee ROM was seen only in the replaced limb in C1 and C2 compared to C3. A significant increase in the peak knee extension angle was also seen in only the replaced limb between C1 and C2 compared to C3. No main effects or interactions were observed for peak knee extension moment. This preliminary evidence shows that symmetrically shortening the crank arms does not result in a significant difference from the standard crank arm lengths while asymmetrically shortening them does.

Conclusions

Asymmetrical shortening of crank arm lengths for the replaced limb of early post-operative TKA patients may be able to reduce ROM requirements accommodate their reduced ROM post TKA and allow for earlier adoption of cycling as an exercise modality. Further research should consider exercise intensity as another modifiable factor for improving post-operation patient outcomes.

Acknowledgments

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References

- [1] Hummer et al., 2021. *J Biomech* **115**, 110111.
- [2] Bakaa et al., 2022. *Disabil Rehabil* **44**, 6348-6355.

Table 1: Knee angles (°), joint range of motion (ROM) (°), and joint Moment (Nm) across crank length conditions: Mean ± STD

Variable	Limb	C1 (140/170)	C2 (155/170)	C3 (170/170)	C4 (155/155)	C5 (140/140)	Crank Length (p-val)	Limb (p-val)	Int. (p-val)
Sagittal ROM	NR	59.38° ± 6.12	62.55 ^{d,e} ± 4.26	62.97 ^{d,e} ± 4.12	57.47 ^e ± 3.35	51.90 ± 3.39	0.002	0.192	0.134
	R	53.10° ± 4.94	55.08 ^{c,e} ± 3.72	60.43 ^{d,e} ± 4.64	55.85 ^e ± 4.39	50.55 ± 2.85			
Peak Ext. Angle	NR	41.48° ± 8.05	40.03° ± 6.19	38.09 ^{d,e} ± 8.76	43.13° ± 8.71	-46.26 ± 8.48	<0.001	0.449	0.623
	R	46.52° ± 7.75	45.38 ^{c,e} ± 4.73	41.57° ± 4.39	45.27° ± 6.34	-49.62 ± 5.58			
Peak Ext. Moment	NR	26.03 ± 11.17	24.97 ± 3.90	30.91 ± 11.43	26.56 ± 9.49	29.37 ± 8.92	0.724	0.114	0.337
	R	17.88 ± 8.14	17.44 ± 7.29	16.59 ± 6.61	19.80 ± 8.47	17.36 ± 4.70			

NR: Non-Replaced limb, R: Replaced limb, ^a: significantly different from C1 within limb, ^b: significantly different from C2 within limb, ^c: significantly different from C3 within limb, ^d: significantly different from C4 within limb, ^e: significantly different from C5 within limb.