Analysis of Pedaling Power Asymmetry During Cycling

Shahram Rasoulian[1], Reza Ahmadi[2], Hamidreza Heidary[2], Samira Fazeli Veisari[3], Atousa Parsaei[3], Sierra Sweeney[1], Walter Herzog[1,2], Amin Komeili[1,2,3]

[1]Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Calgary, Canada

[2]Department of Mechanical and Manufacturing Engineering, University of Calgary, Calgary, Canada

[3]Department of Biomedical Engineering, University of Calgary, Calgary, Canada

Email: shahram.rasoulian@ucalgary.ca

Summary

This study aimed to investigate the effect of fatiguing cycling exercise on mechanical power asymmetry assessed using the Normalized Symmetry Index (NSI). No significant changes in NSI were observed from the beginning to the end of the cycling session, suggesting that fatigue does not substantially affect the symmetry of mechanical power production between the left and right limbs. The outcome of the study may provide insights into optimizing training, performance strategies, and clinical rehabilitation.

Introduction

Fatigue in cycling manifests as a reduction in mechanical power, diminished efficiency, and impaired performance due to physiological, biomechanical, environmental, and psychological factors [1]. Asymmetry, characterized by unequal force or torque production between limbs, accelerates fatigue by overloading one limb, reduces efficiency, and increases injury risk [2]. Conventional indices of asymmetry have yielded misleading results due to their sensitivity to low force values, which can create singularities when forces approach zero, highlighting the need for developing methods such as the Normalized Symmetry Index (NSI) [3]. In this study, we aimed to examine the effect of fatiguing cycling exercise on mechanical power asymmetry using an instrumented cycling ergometer to measure 3D pedal forces.

Methods

Twenty participants (8 males, 12 females; 22.8±4.5 years, 171±8 cm, 71±13 kg) with no prior injuries in lower limbs that may affect cycling performance were recruited (REB #1803). Cycling shoes with cleats were provided for participants. Saddle height was set at 109% of the inseam length, and the handlebar was adjusted for comfort. The test protocol included a step test to determine maximum power output and a constant-power test for asymmetry assessment. Both tests were conducted at 70 rpm and started with a 3-minute warm-up at 40 W. The step test power increased by 20 W every minute until task failure, whereas the constant-power test included cycling at 70% of maximum power until task failure, which was defined as either voluntarily stopping cycling or a power output declining by more than 20% for 10 seconds. 3D pedal forces were collected at 250 Hz and segmented into cycles using a custom labeling function. The first and last 30 seconds of data were excluded from the analysis. Pedal forces averaged over 5-degree intervals across the crank cycle. Power data were normalized using the cycle's minimum (P_{min}^C) and maximum (P_{max}^C) values, as described in Eq. (1). The NSI was calculated for each cycle to compare power output of dominant and non-dominant limbs (PN_D^C, PN_{ND}^C), as expressed by Eq. (2) [3,4]:

$$PN_i^C = \left(\frac{P_i^C - P_{min}^C}{P_{max}^C - P_{min}^C}\right) + 1 \qquad (1)$$

$$NSI_i\ (\%) = \left(\frac{PN_{D_i}^C - PN_{ND_i}^C}{(PN_{D_i}^C + PN_{ND_i}^C)/2}\right) \times 100 \qquad (2)$$

The NSI of cycles over the first and last minute of the test were averaged and used in a paired t-test.

Results and Discussion

Positive, large power was observed during the power phase (0-180°), while negative and small power was seen in the recovery phase (180-360°) (Fig 1 a, b). The NSI values (Fig 1 c), ranged from -6% to +3%, and are consistent with literature values [3, 4]. The initial cycles showed slightly higher NSI values than the final cycles, but the differences were marginal (1–2%) and not statistically significant (p = 0.51, Effect Size = 0.15). The small variations in NSI may be due to the inherently symmetric nature of cycling and the healthy participants. Additionally, the use of cleats likely restricted participants' ability to adjust limb repositioning as fatigue developed.

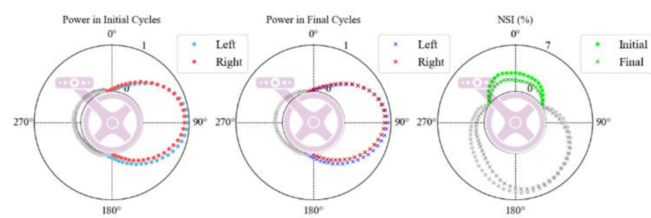

Figure 1: Normalized Power (via max) and NSI distribution for cycling across a full crank cycle for all participants: a) Normalized Power for Initial 1-minute; b) Normalized Power in Final 1-minute cycles, c) NSI (%). For better visualization of power and NSI magnitudes, negative values are shown in their absolute form and represented in gray. In parts (a) and (b), darker gray indicates negative values for the left limb (blue), while lighter gray represents the right limb (red).

Conclusions

There was no significant variation in cycling symmetry with fatigue during cycling on an ergometer.

Acknowledgments

The authors acknowledge the financial support of Alberta Innovates (#222300358) and NSERC (#401610).

References

[1] Mateo, M., et al. (2022). *Int. Phys. Perf.*, 17(6): 926-931.
[2] Lozinski, J., et al. (2023). *Sensors*, 23(5): 2846.
[3] Martín, E., et al. (2023). *Ann. Biom. Eng.*, 51(3): 618-631.
[4] Bini, R. R., et al. (2017). J. Sports Sci., 35(14): 1336-1341.