EFFECT OF PEDALLING WORKLOAD ON KNEE JOINT FORCES

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Introduction

The study of the effect of pedalling power in cycling dynamic is a widespread study in the literature. These works are usually constrained to the sagittal plane and analyse scalar variables such as ranges or maximum values. This approach can lead to loss of relevant information, regarding the 3D dynamics of the cyclist. Hence, the objective of this work is to analyse the effect of pedalling power on the 3D joint forces along the pedalling cycle using statistical parametric mapping (SPM)[3].

Methodology

The dynamic of the lower body during pedalling was analysed in 10 participants at 3 different pedalling powers (P1=170 W, P2=250 W and P3=310 W). All of them were male, had no underlying pathologies and used the bicycle as a means of transport. To solve the inverse dynamic problem, the kinematic data were obtained from the marker protocol developed by Martín-Sosa[1]. The pedal reaction force was obtained from the measurement equipment developed by the authors[2]. The tests were performed on a commercial bicycle provided by the laboratory anchored to a training roller. The dynamic problem was solved by the bottom-up method using vector dynamics and the d'Alembert principle. To analyse the effect of pedalling power on knee joint forces, a one-factor (pedalling power) statistical study with three levels (P1, P2 and P3) was carried out. The dependent variables in this study were the temporal evolution of knee joint forces. First, a MANOVA analysis was performed. If significant results were obtained ($p<0.05$), a one-way ANOVA analysis was performed for each variable. For those variables with significant results, a post-hoc study based on a two-tailed Student's t-test was performed. Finally, the effect size (Cohen's D) was calculated, defining a large effect size for a d value > 0.8, similar to that used by other authors[4].

Results and Discussion

A MANOVA analysis was performed on the joint forces and significant differences were obtained. The subsequent ANOVA analysis for each force indicated that the forces in the Cranio-Caudal (CC) and Antero-Posterior (AP) directions of the 3 joints combined with the force in the Lateral-Medial (LM) direction of the knee showed significant differences due to the use of different pedalling powers. The paired study showed significant differences in all the above force components for all 3 comparisons except for the knee AP direction force (P1-P3 and P2-P3), figure 1. In this figure the intervals in which differences occur in the AP direction are contained in the recovery phase and close to the bottom dead centre (BDC). This component has its main source in the pedal movement. The differences may be related to the fact that as power increases, participants switch from exerting forces that were opposing the pedal movement to applying forces to favour the pedal movement. In the CC direction, once the BDC is passed, the joint force tends to be positive. This behaviour may be because in the first instants of the recovery phase the lower body tractions to pull the pedal. In this case, the increase in pedalling power causes the participants to exert a greater pull on the pedal to optimise the cycling effort. The LM force component of the knee joint force is mostly located at the top dead centre (TDC) and BDC. This behaviour may be caused by a lack of control of the lower body movement in this direction.

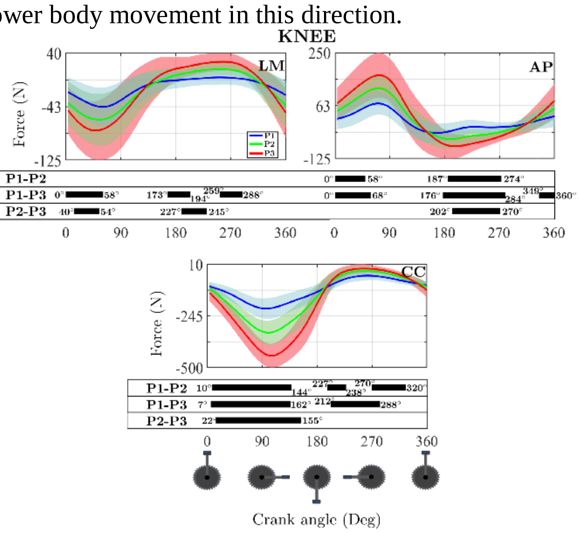

Figure 1: Mean and standard deviation of the knee joint force in AP, LM and CC direction for the three powers. Results are presented from TDC to BDC. SPM of the differences between stages is presented on the part below each graph.

All intervals with significant differences between pedalling powers showed a Cohen's D greater than 0.8. The use of the SPM can be a very useful tool to analyse different cases in the field of cycling biomechanics.

References

1. Martín-Sosa E. et al, ESB Vienna, 2019
2. Martín-Sosa E. et al, Sensors, 2021; 39(3):275-88.
3. Pataki T. C. et al. J Biomech, 2013; 46:2394-2401.
4. Bini R. et al, J. Sports Sci, 2021; 39(3):275-88.

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