ACUTE EFFECTS OF SMALL CHANGES IN BICYCLE SADDLE HEIGHT ON PEDALLING COORDINATION

Pablo Floría[1], Ventura Ferrer-Roca[2] and Juan García-López[3]

Physical Performance & Sports Research Center, Universidad Pablo de Olavide, Sevilla, Spain[1]
High Performance Center (CAR), Sant Cugat del Vallés, Barcelona, Spain[2]
Faculty of Physical Activity and Sport Sciences, Universidad de León, Spain[3]

The purpose of this study was to analyse the acute effects of small changes in bicycle saddle height on pedalling coordination, using vector coding analysis. Lower extremity kinematic data were collected from ten well-trained cyclists while they pedalled at three different saddle heights in random order: preferred, 2% higher and 2% lower than preferred position. A modified vector coding technique and circular statistics were used to quantify coordination for selected hip-knee, hip-ankle, and knee-ankle joint couplings. The results indicate that modifications in saddle height produced moderate alterations in the frequency of movement patterns, which were not enough to alter the classification of coordination. The small modifications observed were in the direction of increasing the frequency of the proximal coordinative pattern as the saddle height decreased.

KEYWORDS: vector coding, cycling, motor pattern.

INTRODUCTION: In cycling, the constant repetition of the pedalling cycle facilitates the development of neuromuscular adaptations that may result in changes in the motion pattern. It has been shown that expert cyclists have different technical pedalling characteristics than amateurs (Chapman et al., 2009; García-López et al., 2016). The coordination (i.e., angle-angle coupling) of the main joints involved in the pedalling cycle (i.e., hip, knee, and ankle) is affected by the performance level of the cyclists (Chapman et al., 2009), by the cadence (Sides & Wilson, 2012) and by the bicycle settings (Dedieu et al., 2020).
Dedieu et al. (2020) analysed the effect of saddle height on coordination in a group of experienced cyclists. The authors observed that modifications of the saddle height with respect to the usual height increased the frequency of in-phase coordination. Hip, knee, and ankle joints demonstrated that their phase angles moved in a similar fashion. The authors used a continuous relative phase technique to quantify the joint coordination. Specific literature (Van Emmerik et al., 2013; Wheat & Glazier, 2006) suggests that comparison between studies that quantify coordination using different techniques should be made with caution. Consequently, more studies are needed to corroborate the effect of saddle height on joint coordination during pedalling, using different analysis techniques.
Therefore, the purpose of this study was to analyse the acute effects of small changes in bicycle saddle height on pedalling coordination. A vector coding technique was used to assess coordination in experienced cyclists while pedalling at three different saddle heights (preferred ±2%). It was hypothesized that there would be differences in joint coordination between saddle heights. Specifically, we expected to find a greater percentage of in-phase coordination with modifications of the saddle position.

METHODS: Ten well-trained cyclists (male, age 33 ± 6 years, height 1.76 ± 0.05 m and body mass index 23 ± 2 kg·m^3) with 8 ± 5 years of experience were tested in two sessions separated by 7 days. The first session was an incremental maximal cycling test to establish the physiological profile and the intensity of pedalling during the next submaximal tests. During the second session each cyclist performed 3 sets of 6 min at 65% of maximal power output with different saddle heights in a random order: preferred, 2% higher and 2% lower than the preferred position (Dedieu et al., 2020; Ferrer-Roca et al., 2014). A rest period of 6 min was taken between sets. During each set, the lower limb kinematics of the cyclists' left sides were registered, assuming symmetry of motion between left and right sides (Ferrer-Roca et al.,

2014). A high-speed IEEEI1394 digital video camera (Basler A602fc, Basler AG, Ahrensburg, Germany) and six retro-reflective markers (greater trochanter, lateral femoral condyle, lateral malleolus, lateral aspect of the fifth metatarsal-phalangeal joint, and both crank and pedal axes of rotation) were used to collect two-dimensional kinematic data at 200 Hz (Ferrer-Roca et al., 2014). Sagittal hip, knee and ankle angles were determined following Nordeen-Snyder's convention (Nordeen-Snyder, 1977). The hip angle was calculated with respect to the horizontal. Joint kinematic data for each cycle were interpolated to 101 points representing one crank cycle from 0º to 360º, using a cubic spline. Ten cycles of data were extracted to analyse the joint coordination. A modified vector coding technique (Chang et al., 2008) was used to quantify hip-knee, hip-ankle, and knee-ankle coordination in the sagittal plane during the pedal cycle. Four unique coordination patterns were identified: Antiphase, in-phase, proximal joint phase, and distal joint phase. In-phase couples rotate in the same direction. Antiphase couples rotate in opposite directions. Proximal phase in which the proximal joint rotates exclusively. Distal phase in which the distal joint rotates exclusively (Chang et al., 2008).
A one-way repeated-measures ANOVA was used to compare coordination pattern frequency between saddle height positions. Bonferroni-adjusted pairwise comparisons were performed between the preferred and higher or lower positions. The statistical significance level was set at $P < .05$. Statistical analysis was completed by the estimation of the effect size using Cohen's d to evaluate the magnitude of the differences.

RESULTS: Figure 1 shows the frequencies of each coordination pattern during the pedalling cycle for the three saddle height conditions. Overall, the dominant coordination pattern did not change when the saddle height was modified. For the sagittal hip vs. knee joint coupling, the in-phase pattern was dominant. For the sagittal hip vs. ankle joint coupling, the hip pattern was dominant, with a decrease in ankle patterns and an increase in the hip pattern when the saddle height was lowered ($t > 2.902$, $p < 0.029$, $ES > 0.9$, Large). For the sagittal knee vs. ankle coupling, the knee pattern was dominant, with a decrease in the in-phase pattern and an increase in the knee pattern when the saddle height was lowered ($t > 3.030$; $p < 0.043$, $ES > 1.0$, Large).

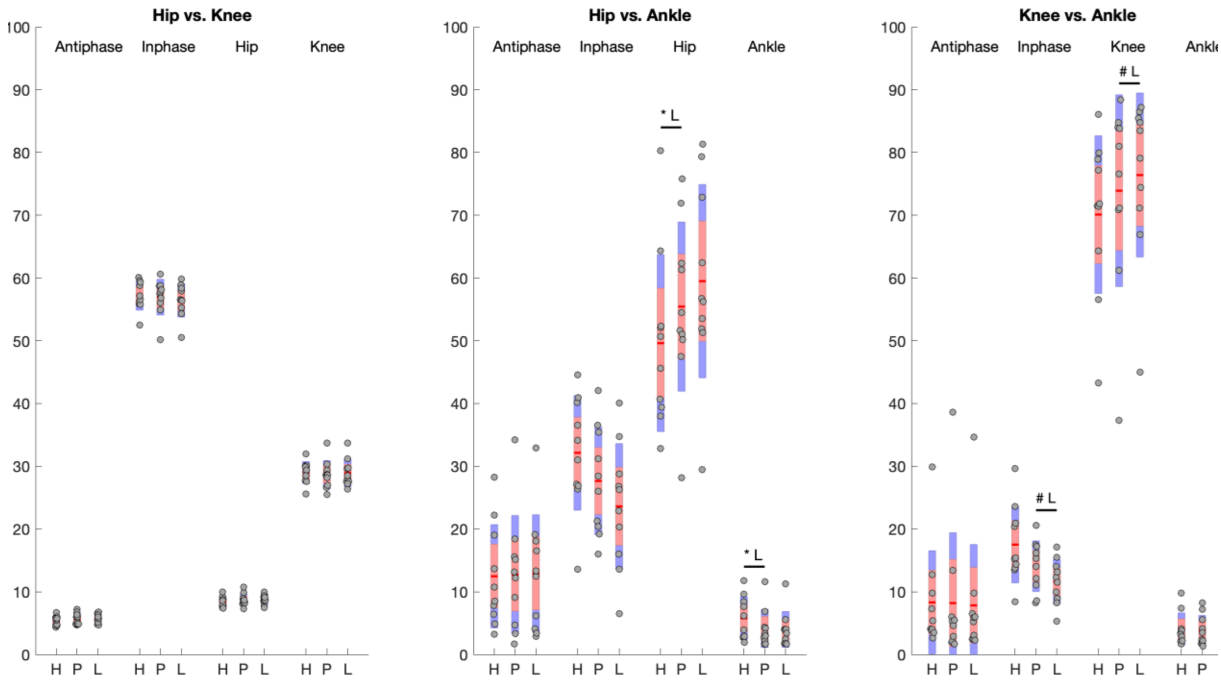

Figure 1: Saddle height comparisons (H: High, P: Preferred and L: Low) across a pedalling cycle for hip vs. knee, hip vs. ankle, and knee vs ankle joint couplings: These are represented as

binning percentages. Frequencies are laid over a 1.96 SEM (95% confidence interval) in red and a 1 SD in blue. * Statistical differences between high and preferred saddle heights. # Statistical differences between low and preferred saddle heights (P < 0.05).

DISCUSSION: In general, the dominant coordination pattern did not change in response to modifications in the saddle height (Figure 1), indicating a strong and stable coordination that can be maintained despite alterations in saddle height by ±2%. Regardless of the selected saddle height, the proximal coordinative pattern (hip and knee) was more frequent when the ankle was included in the joint couple, while an in-phase coordinative pattern was the most frequent when the hip vs. knee couple was analysed. These results suggest the relevance of the proximal joints in leading the pedalling cycle.

The results rejected the hypothesis that a modification of the saddle height in any direction, above or below the preferred height, increased the frequency of the in-phase coordination pattern. These findings are contrary to those of Dedieu et al. (2020), who reported shifts toward the in-phase coordination pattern in response to increases or decreases in saddle height. This discrepancy could be due to the use of different coordination analysis techniques, considering that the present study used a modified vector coding technique while Dedieu et al. (2020) used continuous relative phase (CRP). Previous studies have pointed out the advantages and disadvantages associated with each technique (Van Emmerik et al., 2013; Wheat & Glazier, 2006), and Miller et al. (2010) suggested that comparisons between studies that quantify coordination using different techniques should be made with caution. Modified vector coding technique facilitates spatial joint motion interpretation although it entails the loss of higher-order information compared with CRP. Further studies comparing both techniques are needed to identify which technique is more sensitive to performance changes while providing the most useful information about pedalling coordination.

When the saddle height was lowered, an increase in the frequency of both hip and knee coordination patterns was observed, which was accompanied by a decrease in the frequency of both in-phase and ankle coordination patterns. This alteration in joint coordination was accompanied by a greater proportion of the proximal coordination pattern (*i.e.,* hip and knee). These results in conjunction indicated that cyclists adapt their pedalling pattern to small changes in saddle height, which could be due to the alteration in the joint range of movement observed when the height of the saddle is changed. Previous studies have observed that a decrease in saddle height reduces the range of motion of the lower limb, but it is in the ankle where the limitation of movement and the decrease in angular velocity are more noticeable (Ferrer-Roca et al., 2014). Similarly, recent studies observed an alteration of ankle angular velocity to maintain the knee and hip kinematics during pedalling with noncircular chainring (Leong et al., 2017). Therefore, it seems that the proximal joints (*i.e.,* hip and knee) increased their contribution to the coordination pattern as the saddle height was lowered. Further studies are needed to evaluate the long-term effects of changing saddle height on pedalling coordination.

It is recognised that this study has certain limitations. The findings of the present study are limited to acute effects of saddle height on pedalling coordination, and it is unknown whether these effects persist in the long term. The motion capture was limited to two-dimensional analysis of pedalling instead of a three-dimensional one, although in the sagittal plane both analyses have an interchangeable interpretation (García-López et al., 2016).

CONCLUSION: Overall, the dominant coordination pattern in the sagittal plane during pedalling was not affected by small changes in saddle height in well-trained cyclists. However, when the saddle height was lowered, the proximal joints (*i.e.*, hip and knee) increased their contribution to the coordination pattern with respect to the distal ones (*i.e.,* ankle). Contrary to previous findings, the in-phase coordination pattern decreased when the saddle height was lowered, which could be due to the different techniques used to analyse the pedalling coordination (i.e., continuous relative phase *vs.* vector coding). Future long-term studies using vector coding are necessary to confirm these findings.

REFERENCES

Chang, R., Van Emmerik, R., & Hamill, J. (2008). Quantifying rearfoot-forefoot coordination in human walking. *Journal of Biomechanics*, *41*(14), 3101–3105. https://doi.org/10.1016/j.jbiomech.2008.07.024

Chapman, A., Vicenzino, B., Blanch, P., & Hodges, P. (2009). Do differences in muscle recruitment between novice and elite cyclists reflect different movement patterns or less skilled muscle recruitment? *Journal of Science and Medicine in Sport*, *12*(1), 31–34. https://doi.org/10.1016/j.jsams.2007.08.012

Dedieu, P., Pelaez, M., Poirier, E., & Zanone, P. G. (2020). Effects of saddle height on muscular pattern and interlimb coordination in cycling. *Journal of Physical Education and Sport*, *20*(1), 222–228. https://doi.org/10.7752/jpes.2020.01029

Ferrer-Roca, V., Bescós, R., Roig, A., Galilea, P., Valero, O., & García-López, J. (2014). Acute effects of small changes in bicycle saddle height on gross efficiency and lower limb kinematics. *Journal of Strength and Conditioning Research*, *28*(3), 784–791. https://doi.org/10.1519/JSC.0b013e3182a1f1a9

García-López, J., Díez-Leal, S., Ogueta-Alday, A., Larrazabal, J., & Rodríguez-Marroyo, J. A. (2016). Differences in pedalling technique between road cyclists of different competitive levels. *Journal of Sports Sciences*, *34*(17), 1619–1626. https://doi.org/10.1080/02640414.2015.1127987

Leong, C.-H., Elmer, S. J., & Martin, J. C. (2017). Noncircular chainrings do not influence maximum cycling power. *Journal of Applied Biomechanics*, *33*(6), 410–418. https://doi.org/10.1123/jab.2017-0035

Miller, R. H., Chang, R., Baird, J. L., Van Emmerik, R. E. A., & Hamill, J. (2010). Variability in kinematic coupling assessed by vector coding and continuous relative phase. *Journal of Biomechanics*, *43*(13), 2554–2560. https://doi.org/10.1016/j.jbiomech.2010.05.014

Nordeen-Snyder, K. S. (1977). The effect of bicycle seat height variation upon oxygen consumption and lower limb kinematics. *Medicine & Science in Sports & Exercise*, *9*(2), 113–117. https://doi.org/10.1249/00005768-197709020-00008

Sides, D., & Wilson, C. (2012). Intra-limb coordinative adaptations in cycling. *Sports Biomechanics*, *11*(1), 1–9. https://doi.org/10.1080/14763141.2011.637118

Van Emmerik, R. E. A., Miller, R. H., & Hamill, J. (2013). Dynamical systems analysis of coordination. In D. G. E. Robertson, G. E. Caldwell, J. Hamill, G. Kamen, & S. N. Whittlesey (Eds.), *Research Methods in Biomechanics* (pp. 291–315). Human Kinetics.

Wheat, J. S., & Glazier, P. S. (2006). Measuring coordination and variability in coordination. In K. Davids, S. Bennett, & K. Newell (Eds.), *Movement System Variability* (pp. 167–182). Human Kinetics. http://www.humankinetics.com/products/all-products/movement-system-variability

ACKNOWLEDGEMENTS: This study was funded by the Performance and Health Research Group for High-Level Sports (GIRSANE), High Performance Sport Centre of Sant Cugat, the Professional Sports Medicine School (University of Barcelona), and the Faculty of Physical Activity and Sports Sciences of the University of Leon (Spain).