# NO BILATERAL ASYMMETRY DURING PEDALLING IN HEALTHY CYCLISTS OF DIFFERENT PERFORMANCE LEVELS

**Juan García-López[1], Sergio Díez-Leal[1], Josu Larrazabal[2], Ana Ogueta-Alday[1,3]**

**Department of Physical Education and Sports, University or León, León, Spain[1]**
**Personal Training Coach, Trek Factory Racing, Professional Cycling Team[2]**
**Faculty of Psychology and Education, University of Deusto, Bilbao, Spain[3]**

The main purpose of this study was to analyse the pedalling force symmetry in cycling, and the possible influence of performance level and pedalling power on it; additionally, the 2D pedalling kinematics symmetry was analysed. Forty-seven road cyclists of different competitive levels (Study 1) and eighty-four club cyclists (Study 2) participated. Their bikes were replicated in a cycle ergometer with instrumented cranks, and they pedalled at 200-250-300 W (Study 1) and a self-selected power ~185 W (Study 2). In both studies 2D kinematics of the right leg was analysed, and in the Study 1 the left leg was also analysed. In conclusion, the pedalling movement could be considered symmetric from kinematic and kinetic points of view; and the slight force differences found in the dominant leg (below 2%) could be related to the chainring location and the right-dominance of general population, which constitutes further investigation.

**KEY WORDS:** biomechanics, cycling, crank kinetic.

**INTRODUCTION:** The pedalling movement could be considered symmetric from kinematic and kinetic points of view (Bini & Hume, 2004). However, some studies showed differences until 20% in pedalling force between preferred and non-preferred lower limbs (Carpes et al., 2010), and these differences could be considered abnormal (Impellizzeri et al., 2007). There is no consensus about the possible influence of pedalling intensity (i.e. power output) on force pedalling asymmetry (Carpes et al., 2007; Bini & Hume, 2014). Equally, although there is an inverse relationship between the level of performance and force bilateral asymmetry in sports in general (Bailey et al., 2013), it has not been investigated in cycling. On the other hand, only one study analysed the kinematics symmetry during pedalling (Edeline et al., 2004), concluding that pedalling kinematics in non-cyclists was asymmetric. To the best of our knowledge, no study about this topic was performed in cyclists. Therefore, the main purpose of the present study was to analyse the pedalling force symmetry in cycling, and the possible influence of performance level and pedalling power on it. Secondary, the 2D kinematics symmetry was also analysed.

**METHODS:** Forty-seven road cyclists participated in the first part of the study (Study 1): professional cyclists from a UCI ProTour Team (n= 11), elite cyclists from a UCI Continental Team (n= 13), sub-elite cyclists from a UCI under 23 Team (n=10) and club cyclists belong to different competition teams (n= 13). Eighty-four club cyclists participated in the second part of the study (Study 2). All of them participated voluntarily, being informed of the procedures and possible risks of the study, and written consent was obtained before starting the study.
Firstly, cyclists‘ bikes measurements and their own anthorpometrical characteristics were obtained. After this, the bikes´ measurements (crank inclusive) and the clipless pedals were replicated in a cycle ergometer. Simultaneous kinematic (flexion, extension and ROM of the hip, knee and ankle joints) and kinetic analyses (maximum and minimum torques, positive and negative impulses, dominant/non-dominant mean torque contribution) of pedalling were performed during three sets of 5-min with 6-min rest in between (Ferrer-Roca et al., 2014). To perform the kinematic analysis, five reflective markers of 10 mm diameter were attached to the skin of the cyclists (greater trochanter, lateral femoral epicondyle and lateral malleolus), and automatic tracking, processing and analysing data were performed by a specific software (Kinescan-IBV, Version 2001, Institute of Biomechanics of Valencia,

Valencia, Spain) (García-López et al., 2008). Kinetic analysis was performed on a validated electromagnetically braked cycle ergometer (Lode Excalibur Sport, Lode BV, Groningen, Netherlands), which allowed the measurement of the torque exerted on the left and right cranks independently every 2º of a complete revolution (Dorel et al., 2009). The cyclists of the Study 1 pedalled at 200, 250 and 300 W, while 2D kinematic analysis of the right side was performed assuming symmetry of motion. The cyclists of the Study 2 pedalled at low, medium and high subjective intensities (medium intensity was selected for further analysis), while 2D kinematic analysis was performed on both right/left sides. The cyclists received continuous feedback about their cadence and were asked to keep it constant at 90 rpm. Besides, dominant leg was considered as the preferred leg to kick a ball (Neptune and Herzog, 1999). ANOVA with repeated measures (Newman-Keuls post hoc analysis) and Cohen's *d* Effect sizes (ES) were also calculated.

**RESULTS:** In the Study 1, significant differences were found between some kinetics variables during pedalling (Figure 1). Dominant leg showed higher positive impulse (1.8%, ES= 1.0 and p<0.001) and Dominant/Non-dominant mean torque contribution (1.2%, ES= 1.1 and p<0.001). No significant differences were found in the rest of the analysed variables. The differences were independent of the pedalling power output (200, 250 *vs* 300 W) and the performance level (professional, elite, sub-elite *vs* club cyclists).

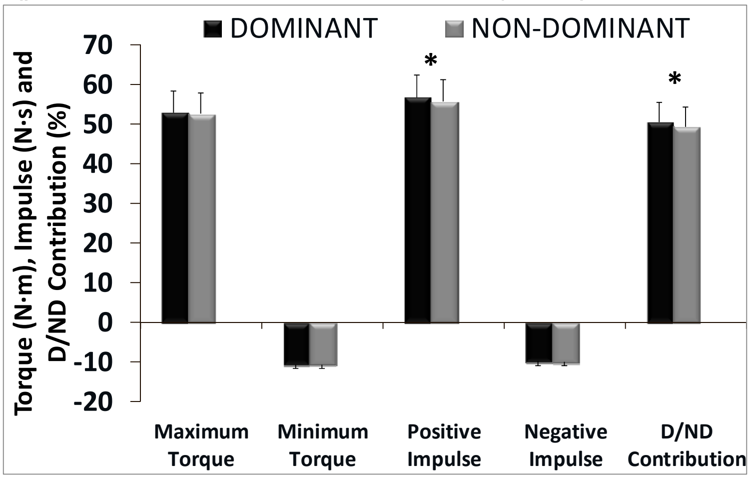


**Figure 1: Kinetics variables (Mean ± SD) analysed in the Study 1 (professional, elite, sub-elite and club cyclists). D/ND Contribution, Dominant *vs* Non-Dominant mean torque contribution.**

In the Study 2, the power at medium intensity was 186±37 W (range 100-300 W). Only the positive impulse (1.7%, ES= 1.2 and p<0.001) and Dominant *vs* Non-dominant mean torque contribution (1.8%, ES= 1.3 and p<0.001) showed significant differences. No significant differences were found in the 2D kinematics variables during pedalling (Table 1).

**Table 1: Two-dimensional kinematic analysys in the Dominant and Non-Dominant legs**

| Kinematic variables (º) | Dominant | Non-Dominant |
|---|---|---|
| Hip extension | 61.8±3.8 | 61.9±3.7 |
| Hip flexion | 16.4±3.5 | 16.5±3.5 |
| Hip ROM | 45.4±3.1 | 45.4±3.1 |
| Knee extension | 142.2±5.9 | 142.1±5.8 |
| Knee flexion | 68.7±3.4 | 68.8±3.5 |
| Knee ROM | 73.5±5.1 | 73.3±4.6 |
| Ankle extension | 137.2±6.3 | 136.0±6.2 |
| Ankle flexion | 120.5±7.4 | 120.3±6.8 |
| Ankle ROM | 16.6±5.3 | 15.7±5.7 |

Mean±SD. ROM, range of movement.

**DISCUSSION:** The main finding of the present study was to demonstrate that, even though there are some differences between dominant and non-dominant leg, these are so small (lower than 2%). Therefore, we can conclude that there is not bilateral force asymmetry during cycling, independently of the pedalling power output and the performance level of the cyclists. This is logical, because asymmetry values higher than 15% could be considered abnormal or pathological (Impellizzeri et al., 2007), and in the present study healthy cyclists and not pathological cyclists participated. However, these findings are in contrast to others which found that "cyclists present frequent asymmetry", depending it on external workload (Bini et al., 2010). In addition, in the present study, no kinematics asymmetry in the movements of flexion-extension in the lower limbs was found. This is in consonance with previous studies (Edeline et al., 2004) which showed differences in tilt and abduction/adduction movements, but not in the flexion/extension movements (with the exception of the ankle extension at low pedalling power output).

One possible explanation to the discrepancies about if there is pedalling force asymmetry during cycling could be the heterogeneous number of variables which have been used to analyse the pedalling symmetry: pedal forces (Sanderson, 1990), crank torques (Carpes et al., 2007) or pedalling power (Smak et al., 1999). In the present study, there were significant differences when comparing positive impulse and dominant/non-dominant contribution (between 1.2-1.8%); however, there were not differences when comparing other kinetics variables. These results are in consonance with other studies which observed small differences in favour of the dominant leg (0.5-2.0%) by analysing the mean torque contribution. Another possible explanation to the abovementioned discrepancies could be the utilization of commercial instrumented crank systems (e.g. SRM or PowerTap), which did not allow to measure left/right limbs separately (Bini & Hume, 2014). These devices only measure the mean torque of both legs, while the ergometer which was used in the present study measured both legs independently. From this perspective, some studies which showed differences until 20% can't be considered valid (Carpes et al. 2007), because they were performed with the SRM system. Although nowadays various commercial devices with a similar functioning (e.g. Garmin Power Vector, Pionner, Power2max, Polar Look Keo Power) claim the possibility of measuring pedalling asymmetry, they really did not.

Smak et al. (1999) obtained that non-dominant leg had more negative power that dominant leg. In the present study, there was a tendency to a higher negative impulse in the non-dominant leg when comparing to dominant leg (10.1±2.9 *vs* 9.9±3.0 and $p = 0.12$), but it was not significant. In this same line, the fact that the dominant leg must lift the negative work of the non-dominant leg doesn't justify the small differences between both legs. On the other hand, it could be possible that dominance influences slightly on the capacity of applying force to the pedals, but studies performed in the general population did not find force asymmetry in the lower limbs (Ditroilo et al., 2010). The fact that the chainring is always located at the right side of the bike and that the majority of the population is right-dominance could be considered as a factor to explain the slight differences between both legs. This should be analysed in future studies.

Finally, one limitation of the present study was to analyse the pedalling in 2D instead of 3D. The use of 3D systems is recommended to analyse pedalling movement, because the side-to-side differences could be better obtained (Edeline et al., 2004). However, from a practical point of view, dynamic analyses of the correct bike fitting are normally performed with 2D systems (Ferrer-Roca et al., 2012 and 2014). They are more cost effective, and their functioning is easier than in the 3D systems. According to the results of the present study, one-side 2D analysis system could be used to perform a correct bike fitting, assuming symmetry between both legs. Another limitation of the present study was to consider the symmetry between dominant vs non-dominant legs instead of strong vs weak legs. The present results must be analysed taking into account this consideration.

**CONCLUSION:** According to the results of the present study, the pedalling movement could be considered symmetric from kinematic and kinetic points of view. The slight force differences found in the dominant leg (below 2%) could be related to the chainring location and the right-dominance of general population, which constitutes further investigation. From a practical perspective, one-side 2D analysis system could be used to perform a correct bike fitting, assuming symmetry between both legs. However, the use of the actual devices (i.e. SRM, Garmin Power Vector, Pionner, Power2max, Polar Look Keo Power) to analyse the force asymmetry during pedalling must be avoided.

**REFERENCES:**

Bailey Ch, Sato K, Alexander R, Chiang Ch Y & Stone MH (2013). Isometric force production symmetry and jumping performance in collegiate athletes. *Journal of Trainology*, 2, 1-5.

Bini RR & Hume PA (2014). Assessment of bilateral asymmetry in cycling using a commercial instrumented crank system and instrumented pedals. *International Journal of Sports Physiology and Performance*, 9, 876-81.

Carpes FP, Mota CB & Faria IE (2010). On the bilateral asymmetry during running and cycling - a review considering leg preference. *Physical Therapy in Sport*, 11, 136-42.

Carpes FP, Rossato M, Faria IE & Mota CB (2007). Bilateral pedaling asymmetry during a simulated 40-km cycling time-trial. *Journal of Sports Medicine and Physical Fitness*, 47, 51-7.

Ditroilo M, Forte R, Benelli P, Gambarara D & De Vito G (2010). Effects of age and limb dominance on upper and lower limb muscle function in healthy males and females aged 40–80 years. *Journal of Sports Sciences*, 28, 667–77.

Dorel S, Couturier A & Hug F (2009). Influence of different racing positions on mechanical and electromyographic patterns during pedalling. *Scandinavian Journal of Medicine and Science in Sports,* 19, 44-54.

Edeline O, Polin D, Tourny-Chollet C & Weber J (2004). Effect of workload on bilateral pedalling kinematics in non-trained cyclists. *Journal of Human Movement Studies*, 46, 493-517.

Ferrer-Roca V, Rivero Palomo V, Ogueta-Alday A, Rodríguez-Marroyo JA & García-López J (2014). Acute effects of small changes in crank length on gross efficiency and pedalling technique during submaximal cycling. *Journal of Science in Cycling*, 3, 16.

Ferrer-Roca V, Roig A, Galilea P & García-López J (2012). Influence of saddle height on lower limb kinematics in welltrained cyclists: Static vs. dynamic evaluation in bike fitting. *J Strength Cond Res,* 26, 3025-29.

García-López J, Rodríguez-Marroyo JA, Juneau CE, Peleteiro J, Martínez AC & Villa JG (2008). Reference values and improvement of aerodynamic drag in professional cyclists. *Journal of Sports Sciences*, 26, 277-286.

Impellizzeri FM, Rampinini E, Maffiuletti N & Marcora SM (2007). A Vertical Jump Force Test for Assessing Bilateral Strength Asymmetry in Athletes. *Medicine and Science in Sports and Exercise*, 39, 2044-50.

Sanderson D. (1990). The influence of cadence and power output on asymmetry of force application during steady-state cycling. *Journal of Human Movement Studies*, 19, 1-9.

Smak W, Neptune RR & Hull ML (1999). The influence of pedaling rate on bilateral asymmetry in cycling. *Journal of Biomechanics*, 32, 899-906.

*Acknowledgement*

The authors thank the cyclists who participated in this study and the Euskaltel-Euskadi Cycling Team for its collaboration during the study, and for its authorization to communicate the results. This work has been supported by the Spanish Council of Sports (CSD) (12/UPB10/07), Spain. Thanks also to the Basque Government for supporting this research project with a predoctoral grant (2011–14). The authors have no conflicts of interest to disclose.