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RELATIONSHIP BETWEEN DISSYMMETRY IN LOWER LIMBS AND PEDALING FORCE DISTRIBUTION WITH NO PROFESSIONAL CYCLISTS

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Abstract. In this work we had the objective to relate the dissymmetry of the lower limbs with the asymmetry index. 23 no professional cycling subjects participated. It was done a dissymmetry test with the direct method, in which we measured from the anterior superior iliac spine to the tibial malleolus and we compared the results with the other leg, so before to do this test we proceed to the Weber-Barstow maneuver, which began in supine position on the litter with the legs in parallel and flexed, it was performed an hip extension, the subject returned to the initial position and the examiner stretched the legs, and for last a test of distribution of power was done on the Wattbike, with a duration of 10 minutes and an intensity of 5 over 10 in the range of perceived exertion. To reach a correct cycling position, we used a goniometer to measure the knee angle and then we continued with previous published guidelines. The statistical analysis was done with JASP, in which we first performed a descriptive study and then a correlation test according to its normality. The asymmetry index was 4,086 %, with a slight bigger force distribution in favor of the right leg versus the left leg (50,56 % - 49,44 %). It had a slight positive tend in the relation of the dissymmetry and the power distribution in pedaling, but without significance data.

Keywords: dissymmetry, cycling, lower limbs, pedaling, dominant leg.

RELACIÓN ENTRE LA DISMETRÍA DE LOS MIEMBROS INFERIORES Y EL ÍNDICE DE ASIMETRÍA EN EL PEDALEO EN CICLISTAS NO PROFESIONALES

Resumen. Este estudio tiene como objetivo relacionar la dismetría de los miembros inferiores y el índice de asimetría en el pedaleo. 23 sujetos no profesionales del ciclismo participaron en el estudio. Se realizó un test de dismetría mediante el método directo, que consiste en la medición desde la espina ilíaca anterosuperior hasta el maléolo tibial y la comparación de los resultados con la otra pierna. Antes de realizar esta prueba se realizó la maniobra Weber Barstow, la cual consiste una extensión de cadera partiendo de decúbito supino en la camilla con las piernas en paralelo y flexionadas, para después volver a la posición inicial. Por último, se realizó un test de efectividad de pedaleo sobre la Wattbike de 10 minutos, a una intensidad de 5 sobre 10 del rango de esfuerzo percibido. Para conseguir una posición correcta de los participantes se usó un goniómetro para medir el ángulo de rodilla y se siguieron las pautas de protocolos preestablecidos. El análisis estadístico fue realizado con JASP. Se realizó un estudio descriptivo y posteriormente un test de correlación acorde a su normalidad. El índice de asimetría fue del 4,086 %, con una ligera mayor distribución de fuerza de la pierna derecha sobre la izquierda (50.56 % - 49.44 %). Se encontró una tendencia positiva en la relación entre mayor magnitud de dismetría y el índice de asimetría, pero sin significancia estadística.

Palabras clave: dismetría, ciclismo, miembros inferiores, pedaleo, pierna dominante

Introduction

Bilateral symmetry in humans is considered a genetic sign of health (Fink et al., 2019) and is considered a basic requirement for efficient movement (Kendall et al., 2005). Many human parts develop with bilateral symmetry. This implies that the right and left parts of the human being can be divided into identical parts. However, because of biological factors related to human development or environmental and environmental factors, bilateral symmetry is rarely found in humans (Lindhauer, 1998). This bilateral symmetry is affected by external factors such as gravity and by internal factors such as the sensory system and the musculoskeletal system (Siegler et al., 2019). In turn, structural and functional asymmetry can cause poor posture and impair motor patterning (Picelli et al., 2016). In contrast, greater bilateral knee symmetry in 8-year-old Jamaican subjects shows improved sprinting ability after 14 years in 100- to 200-meter events, while ankle symmetry also shows a small positive effect on this ability (Trivers et al., 2013). This is because symmetry is more efficient in running, so less energy expenditure is made (Trivers et al., 2014). Therefore, sports science highlights the importance of maintaining a symmetrical body to improve athletic performance and to prevent injuries (Hinton et al., 2017). Meanwhile, human beings have a lateral preference, also called dominance or laterality, in which when performing any voluntary motor action, the dominant laterality is always chosen (Carpes et al., 2010). Since in several sports there are repeated technical actions, asymmetry ends up occurring as in soccer with the throwing leg and the stability leg (DeLang et al., 2017).

In relation to cycling, a cyclic sport and apparently symmetrical in pedaling, it seems that pedaling speed and external load influence bilateral pedaling asymmetry, although there is great variability in the rate of asymmetry among the participating subjects and among the different evaluation protocols of each study (Carpes et al., 2010). On this, many studies have examined bilateral pedaling and demonstrated a certain degree of asymmetry in different variables such as strength, force moment, workload, and power or intensity generated during pedaling (Carpes et al., 2010). Likewise, the asymmetry index in the different studies on asymmetric pedaling shows very varied values. Both a very high asymmetry index and a very low index have been found, as in the case of the relationship between pedaling cadence and asymmetry index, in which no firm evidence has been found on how the influence of cadence on asymmetry index is (Carpes et al., 2010). In contrast, subjects who are more trained or experienced in the discipline present smaller asymmetries than those subjects who are not so trained in the discipline (Carpes et al., 2008). It should be noted that the relationships between asymmetry, injury risk, and performance are only theoretical aspects in cycling, without reaching a clear answer of what actually happens practically (Bini et al., 2017).

On the other hand, there is proven evidence that bilateral lower limb differences in relation to power and workload generated in uninjured cyclists are from 5% to 20% (Carpes et al., 2007a), but in cyclists with an anterior cruciate ligament deficiency or previous injury, it can grow up to 400% (Hunt et al., 2003). In turn, there is much controversy about the relationship between asymmetry and pedaling intensity. On the one hand, it has been shown that asymmetry increases if work intensity increases (Bini and Hume, 2014). On the other hand, it has been indicated that asymmetry is reduced if work intensity is reduced (Carpes et al., 2007b). Other studies have indicated that there is no variation in asymmetry at different work intensities (Bini et al., 2007; Garcia Lopez et al., 2015). With respect to the asymmetry index in peak force moments in pedaling, it was found at low to moderate work intensities (Carpes et al., 2007b), while in other researches they were found at high intensities (Trecroci et al., 2018), so there is no clear evidence of how is the correlation of peak force moments in pedaling and different pedaling intensities. Meanwhile, the scientific literature agrees that feedback training can reduce pedaling asymmetry (Bini et al., 2017). Furthermore, a variation in saddle height has no effect on pedaling asymmetry at the moment of force in the different tests that were performed, which were the Wingate test, a maximal incremental test, and a constant load test (Diefenthaeler et al., 2016). The technical retraining in subjects with asymmetries of more than 20% has a positive effect, so it reduces the asymmetry in the pedaling force and this can reach an index very similar to subjects with a very symmetrical pedaling, so it can be qualified that it is very important the feedback to improve the asymmetry index (Bini et al., 2017).

About the pedaling cadence and its relationship with asymmetry there is no clear conclusion, but it was shown that increasing the cadence from 60 revolutions per minute (rpm) to 120 rpm, at the same work intensity, reduces the asymmetry index from 29% to 10% (Smak et al., 1999). It was also observed that increasing pedaling cadence training presented a reduction in asymmetry (Maloney, 2019). In an evaluation on pedaling asymmetry in which the force produced during the propulsive phase and its relationship to different pedaling cadences was considered, consisting of 60, 80, and 100 pedal strokes per minute and with two different intensity levels, at 100 and 235 watts, no direct relationship was found (Daly and Cavanagh, 1976).

Some of the studies cited differentiate between the dominant leg and the non-dominant leg. Consequently, a study on the degree of functional asymmetry of the lower limbs and the consequence on pedaling effectiveness is of some practical interest. This is because 70% of the world's population suffers from lower limb dysmetria (Valverde Tarazona et al., 2017), which is unknown how it affects pedaling. Therefore, the overall objective of the study was to analyze whether there is any correlation between lower limb dysmetria and pedaling asymmetry index. The proposed hypothesis is that functional dysmetria has no correlation with pedaling effectiveness.

Method

Participants

A total of 23 non-professional cycling subjects were selected as a sample for the study, of which 5 were discarded for not having a dysmetria of more than 0.5cm.18 subjects finally participated, of which 15 are male and 3 are female: (µ age 23.09 ± 6.3 years), (µ weight 69.87 ± 7.5kgs), and (µ height 176.87 ± 9.3cms). All participants gave their consent to participate in the study, which was previously approved by the ethical committee.

The sample was chosen by convenience and non-probabilistic sampling, with the approach that the sample chosen was greater than 20 subjects. The recruitment of volunteer participants was done through social networks and in different classes of a university, commenting on the details of the inclusion and exclusion criteria and certain details of the test to be performed. The inclusion criterion was to perform physical exercise at least 30 minutes a week and a frequency of 3 days a week. The exclusion criterion was to have any injury, to have undergone an operation that could interfere with the test or their dysmetria measurements, or to have a professional or semi-professional cycling license. It was taken into account that, of the subjects, several of them might not have dysmetria, so these were discarded for the experimental study because they did not meet the requirements of the study.

Material

The instruments used were the Wattbike to perform the asymmetry test. The Wattbike is an exercise bike with included software of power generated by the cyclist and the distribution of forces of each leg to measure the asymmetry. The Wattbike was chosen because it is a validated and reliable tool to measure the variable of the distribution of forces in pedaling (Hopker et al., 2010). For the pedaling test, the weight data were entered and the subject was allowed to pedal 5 minutes at the standardized intensity. After that, a 10-minute Wattbike test was created, following the indications mentioned in the study procedure. Another instrument used was the goniometer to measure the biomechanically correct angles of the participants. The goniometer was chosen because it is a reliable instrument for measuring joint mobility of the knee and ankle (Gil Fernández and Zuli Escobar, 2011). It was used at maximum pedaling extension for both legs to measure that the subjects were in the correct angle ranges to perform the test. The range of perceived exertion (RPE) was used to calculate the exercise intensity of the participants. The scale used was zero to ten (1 is the low value and a very mild form exercise, while 10 is a maximum effort such as a sprint). This tool is validated to calculate exercise intensity in cycling and with high correlation with lactate and heart rate (Zinoubi et al., 2018). As a last tool, Excel was used as a database to perform the subsequent statistical analysis. In the Excel database, the different variables to be analyzed were entered.

Variables

The variables analyzed in the study were the characteristic data of the subjects such as age in years, height in centimeters, weight in kilograms, cycling experience stipulated in years of practice, length of right leg, and left leg in centimeters. With these last measurements, the dysmetria in centimeters was calculated, which is a main variable of this research, resulting from leg of greater length - leg of lesser length. If the result showed 0.5 cm or more, and according to the inclusion criteria, the subject was included as a participant in the study. With these variables, a descriptive study was subsequently carried out. On the other hand, the knee angle at the maximum extension of the pedaling cycle was calculated, which was stipulated at about 145º, and the average watts of the test performed, which were collected at the end of the test from the Wattbike. Finally, the force distribution in percentage of the left leg and right leg was obtained, with which the corresponding asymmetry index formula ((Dominant leg - Non-dominant leg) / (Dominant leg + Non-dominant leg / 2) x 100) could be performed (Bini and Hume, 2014) (Bini and Hume, 2014).

Procedure

The participants were summoned to the biomechanics laboratory of the Universidad Europea del Atlántico to perform the different tests for data collection.

The first test performed was a test to check for dysmetria, in which the subjects had to pass a dysmetria of 0.5 mm (Valverde Tarazona et al., 2017). This test was the direct method that has been proposed as a protocol for the assessment of lower limb length differences (Jamaluddin et al., 2011). The direct method consisted of measuring with a tape measure the lower limb from the anterosuperior iliac spine to the tibial malleolus, and the results were compared with the other leg. Before performing this test, the Weber Barstow maneuver was performed. It starts in the supine position on the couch with the legs parallel and flexed, and a hip extension is performed. After that, the subject returns to the initial position and the examiner stretches the legs. In case the test was positive (+ 0.5 mm of dysmetria), the following test was performed.

The second test consisted of adjusting the rider properly on the Wattbike with the correct knee and ankle angles in the pedal cycle with maximum knee extension. The recommended and biomechanically proven angles were followed (Garcia Lopez et al., 2009). These angles were checked using a goniometer. The participants had to pedal with normal footwear or boots with mountain bike clipless pedals, with the requirement of not being able to wear lifts or wedges in the boots or cleats. After the correct fit, they performed a 5-minute warm-up on the Wattbike at a range of perceived exertion (RPE) of three out of ten. Once the warm-up was completed, they began the pedaling effectiveness test at a medium intensity, a cadence greater than eighty pedal strokes per minute and lasting ten minutes, following a previously described protocol (Kell and Greer, 2017). The intensity chosen was a five out of ten RPE, the subjective intensity was previously explained to the subject. During the force distribution test, having a conversation with the subject was avoided in order to have their concentration on the test. It was also placed in front of the subject so that the subject would not divert his or her attention to one side, and this would allow an asymmetry by modifying the posture of the participant. Because the Wattbike monitor displays different values for the percentage of pedaling force, it was tilted until the subject could not see the monitor and thus not get feedback from it. Finally, the subject was encouraged to pedal in a seated position for the entire ten minutes of the test. Once the pedaling force distribution test was completed, the data were recorded in the database created in Excel in which the average watts of the test, and the force distribution of each leg were recorded as a percentage.

Statistical analysis

Statistical analysis was performed with JASP software. The statistical tests performed were first a descriptive study in which the mean, minimum, maximum, and standard deviation were measured. This was followed by the Shapiro-Wilks test for normality, which was chosen because it is the test to be used if the sample is less than 50 subjects. The result, with a chosen significance level of $p < 0.05$, determined that Spearman's correlation test was necessary.

Results

The descriptive data collected on the characteristics of the subjects show that the participants were almost 25 years old, 1.76 m tall, 71.2 kg in weight, and a length in cm of the right leg of 91.74 cm and 91.8 cm of the left leg.

Table 1
Descriptive data of the participating subjects

	Age	Height	Weight	Right leg	Left leg
Mean	24.8	176.667	71.222	91.744	91.8
Standard deviation	6.902	8.423	10.435	5.462	5.208

Regarding the dysmetria test performed, a dysmetria of 0.87 cm on average was first found in the subjects, assuming this later in an asymmetry index of 4.086 in the force distribution test in the pedaling performed. More force applied with the right leg was also observed. An average of 139.722 W was collected and a slight superiority of the power of the right leg 70.762 W versus 68.961 W of the left leg.

Table 2
Descriptive data of the study variables

	% Asymmetry Index	Dysmetria in cm	% Right l.	% Left l.
Mean	4.086	0.872	50.556	49.444
Standard deviation	2.851	0.455	1.854	1.854
Minimum	0.000	0.500	48.000	46.000
Maximum	10.390	2.000	54.000	52.000

Note: This table shows the asymmetry index obtained in the test, the dysmetria in centimeters of the participating subjects, and the percentage of total forces of each lower extremity, where righ l. = right leg, and left l. = left leg.

Table 3
Force results collected during the test at Wattbike

	Ave. watts	L.L. watts	R.L. watts
Mean	139.722	68.961	70.762
Standard deviation	47.524	23.105	24.754
Minimum	65.000	30.550	34.300
Maximum	209.000	100.000	112.860

Note: This table shows the power data collected during the test, both from the average total and unilaterally according to the force distribution of each leg mentioned in the table above. Ave. watts = average watts, L.L. watts = left leg watts, and R.L. watts = right leg watts.

In the Spearman correlation performed between the dysmetria variables and the asymmetry index, it was observed that there is no correlation between both variables, with a result of $p = 0.182$.

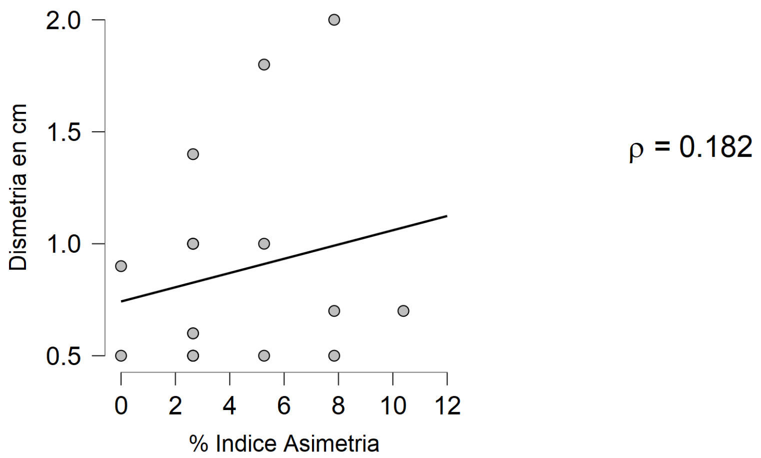

Figure 1. The relationship between dysmetria and asymmetry index.

Discussion and conclusions

It is observed that the asymmetry index obtained in the pedaling force distribution test was 4.086%. This difference is greater than the 2 % of dysmetria in pedaling force found in the study conducted with experienced cyclists, with a protocol of 3 series of 5 minutes at different pedaling intensities (Garcia Lopez et al., 2015). However, it is closer to the asymmetry rate between 3 and 5 % shown in the study conducted with trained cyclists on the Wattbike (Kell and Greer, 2017), although there are certain differences in these asymmetry rates. It also coincides, in part, with the study conducted with a sample of 10 cyclists and/or triathletes with competitive experience in which it was observed that there is from 5 to 11 % of asymmetry in pedaling (Bini, and Hume. 2014). In another study with another 10 cyclists and triathletes with competitive experience, a similar asymmetry rate was also found, consisting of 3 to 10 % in a 4 km time trial (Bini and Carpes, 2013). On the other hand, in another 4 km time trial with 10 experienced cyclists and triathletes, asymmetry results of 8 to 22 % in effective force, 5 to 10 % in resultant force, and 1 to 3 % in pedaling efficiency were obtained (Bini and Hume, 2015). All these studies show that the rate of asymmetry ranges from 2 % to 11 %. It should be noted that it is a wide range, but if the asymmetry index is less than 10 %, this is optimal, while if it is higher, it is usually an injury risk factor and proceeds to lower sports performance due to lower efficiency. In the study that had as objective the effect of cadence on asymmetry maintaining the same intensity, ranges of asymmetry index ranging from 10 to 29 % were found (Smak et al., 1999), so in this case it widely exceeds the asymmetry index that we obtained in the study.

It should be noted that, when studying the magnitude of dysmetria and its relationship with pedaling effectiveness, a slight positive trend was obtained, but it cannot be compared with other studies since the scientific literature has not taken into account the dysmetria of the participants, but rather the predominance of laterality. This small tendency for the asymmetry index to increase as dysmetria increases cannot be answered by the results of this study.

The intensity of the test is another factor to take into account when interpreting the results of previous studies in relation to those obtained in this one. This can lead to increases in the asymmetry index (Bini and Carpes, 2013), which can be from 4 % to 11

% (Bini and Hume, 2014). However, in another study, no differences were found at different intensities, which were 200, 250, and 300 watts (Garcia Lopez et al., 2015). In another study, it was observed that the asymmetry is reduced with lower intensity (Carpes et al., 2007b), and it was also observed that at the lower intensity and higher cadence there is the highest asymmetry index (Sanderson et al., 1991). In this study, participants were asked to pedal at an average intensity of 5 out of 10 of the RPE. Therefore, the test was executed at the same intensity for all subjects, making comparison with previous studies impossible. In any case, this fact, in terms of power generated, may be due to the different level of the participating subjects and to the variability of the subjective intensity of the RPE.

Conclusion

The results of this study indicate that the asymmetry index is 4.086 % in the distribution of forces in pedaling or pedaling effectiveness, being the correlation of this asymmetry index and the magnitudes of dysmetria of p = 0.182. That is, there is no significance or correlation between these variables, although there is a slight positive trend between the asymmetry index in pedaling and the greater magnitude of dysmetria of the lower limbs. This responds positively to the initial hypothesis that there was no correlation between the functional dysmetria of the subjects and the asymmetry index in the distribution of forces in pedaling.

Future studies are recommended to identify if, from more than 1 cm of dysmetria, there is more asymmetry in pedaling, as there were not too many participants who had that magnitude of dysmetria. Another recommendation is to replicate the study with cyclists with their own bike fit and trained with this posture in order to be able to simply adjust the Wattbike; or alternatively to put the bike on a roller to run a pedaling effectiveness test, taking into account only functional dysmetria in trained subjects and a correct and trained posture.

Despite the findings obtained, it is necessary to point out some limitations. There were inexperienced subjects who had no background using the subjective RPE scale, so the perceived exertion of 5 out of 10 could have been different. In addition, the biomechanical fit on the bicycle was performed simply with maximum knee extension in the pedaling cycle, measuring the ankle and knee. This is a basic way of adjusting the most inexperienced subjects to be within an optimal range but not the most correct one according to the characteristics of each subject.

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