A Preliminary Study of the Cycling Kinematics Before and After Dimensional Adjustments

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Abstract

Cycling has become one of the most popular sports in the world in recent years. But its growing popularity has also resulted in an increasing number of injuries and the subsequent need to better understand the relationship between bicycle dimensions, forces, and the athlete's anthropometry. The objective of this research was to evaluate the kinematics of the cycling before and after making some adjustments in the dimensions of the bicycle. One healthy subject participated in the study, the kinematics was measured with seven infrared cameras (vicon) and reflective markers. The results found in the study show that there was an increment in the range of motion of the knee and hip joints after the adjustment of the dimensions of the bicycle. The mean range of motion of the left knee was 65.3 and 70.3 degrees before and after the adjustments respectively. For the right knee, it was 68.1 and 74.8 degrees before and after the adjustments respectively. Moreover, it was found an irregular pattern in the range of motion of the ankle joint before making the adjustment to the bicycle. The main contribution of this work is the development of a protocol to measure the range of motion of the knee, hip and ankle joint. This will help to identify irregular patterns in the range of motion and prevent injuries in the athletes.

Keywords: Biomechanics, Cycling, Motion analysis.

1. Introduction

The practice of sports and physical exercise are widely recommended for a good state of physical and mental health. However, in most cases it is carried out without having knowledge of the anthropometry and physical capacity of individuals, which is why it is counterproductive and generates a negative impact on athletes . Alterations in the musculoskeletal system are very common nowadays [2], they can be congenital or in some cases they result from the wrong practice of physical and sports activities. Cycling has become one of the most popular sports in the world in recent years. But its growing popularity has also resulted in an increasing number of injuries and the subsequent need to better understand the relationship between bicycle dimensions, forces, and the athlete's anthropometry. So the scientific studies related to the biomechanics of sports cycling is relatively important compared to that developed in other sports activities, possibly due to three main aspects: the first one related to the importance of the bicycle has had and continues to have as therapy and rehabilitation, the second due to the traditional use of the cycle ergometer for the functional assessment of the athlete and the third, due to the growth of socioeconomic interests that surround professional cycling [3].

Although cycling is generally a movement of the leg in a predefined circular path [4], it is far from being a simple movement, since it can be influenced by small geometric and geographical changes and by other factors that may have a greater or lesser impact on biomechanical parameters of cycling.

dx.doi.org/10.24254/CNIB.20.34

Knowledge about some of these factors can be used to achieve benefits, either for rehabilitation or skills [5], [6]. In cycling, technique, performance and comfort are directly related to the structure and materials of the bicycle. You cannot pedal, or pretend to perform well without having your body's anthropometry perfectly adapted to the different components of the bicycle. Therefore, each cyclist needs a personalized adaptation of his bicycle and must consider that, even if it is his size, it does not mean that it is perfectly adapted to it, and that it is necessary to adjust the height, inclination, setback and angle of the seat, and handlebars [7]. Therefore, it is extremely important to adapt the bicycle to the biotype and pedaling style of the athlete and even to the circumstances of the terrain where they have to compete.

Once the adjustments to the dimensions of the bicycle are made, the rider must adapt to the new position and this cannot be done in a single day, especially when the rider has spent long periods of time in a certain position. The adaptation process must be gradual, so that the body and motor coordination adapt to the new corrected position. On the other hand, there is the idea of thinking that we should visit a specialist in the area of biomechanics when problems, pain or injuries appear. However, this should not happen, it is very important to carry out a biomechanical study as a preventive measure before starting to ride a bicycle for hundreds of kilometers. An analysis of the movement of cyclists can provide very important information about their pedaling skill and technique. Changes in the position of the body on the bicycle have a great impact on the angles of the joints of the lower extremities [1].

Analysis of the biomechanics of cycling can provide very important information on pedaling and skills of cyclists. Furthermore, it can provide physical performance of an athlete and detect abnormal patterns which could produce a musculoskeletal disorder in a short or long term. Few studies have assessed 3D motion analysis of cycling; therefore, further research is needed in these areas [1], [8], [9]. The objective of this research work was to evaluate the kinematics of cycling in an athlete before and after some adjustments in the dimensions of the stationary bike using infrared cameras and reflective markers. This with the aim of understanding the effect of these changes in the range of motion of the knee, hip and ankle joints, which could produce a musculoskeletal disorder in the short or long term.

2. Methodology

In order to evaluate the kinematics of the cycling before and after performing some changes in the dimensions of a stationary bicycle, the tridimensional movement (xyz) of some reflective markers was measured. The tridimensional location of each marker was recorded with the vicon system (Nexus version 2.8.1.111866h x86, Vicon Motion System Ltd. Oxford UK). The calculation of the range of motion of each joint (knee, hip and ankle) was done in Matlab R2015a (version 8.5.0.197613, The MathWorks Inc., Natick, Massachusetts, USA).

2.1 Experimental protocol

One male volunteer, age 30 years old, and mass 70 kilograms participated in the study. The participant was able to perform the trials without any problem and did not present musculoskeletal disorders. The participant was informed prior to the tests, the use of comfortable clothes so as not to interfere with the execution of the exercises and the duration of the trials. Once in the laboratory, the participant was informed about the operation and main parts of the motion caption system (VICON).

He was allowed to perform exercises prior to the experimental tests to familiarize himself with the equipment and protocol. The procedures, risks and benefits were explained in order to obtain the informed consent for voluntary participation, in accordance with the General Health Law of Mexico, and taking care of the principles of the Declaration of Helsinki.

The experimental protocol consists of two stages. First, it was asked to the participant to adjust the dimensions of the bicycle (adjust the height, inclination, setback, and angle of the seat) until he felt comfortable. Then, the kinematics of the cycling was measured with seven infrared cameras at the sampling frequency of 100Hz. Second, some anthropometric measurements of the participant were taken in order to adjust the bicycle for the second time. Then, the kinematics of the cycling was measured again. Finally, a comparison of the range of motion of the knee, hip and ankle joint was done before and after the adjustment of the bicycle.

2.2 Subject preparation

First, the setup of the infrared cameras of the Vicon System was performed. Then, 39 markers (10 mm of diameter) were located on anatomical bony landmarks of the participant, as shown in Fig. 1. The markers were attached to the skin of the participant with double-sided tape. The placement of the markers was carried out according to the Vicon manual. Furthermore, the markers were labeled on the software Nexus using the names of the PlugInGait FullBody template, Table 1.

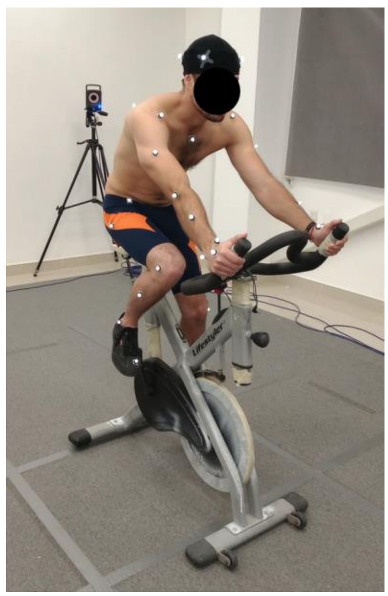

Fig. 1. Subject preparation, placement of the markers on the participant.

Table 1: Name and label of each reflective marker.

No	Name of marker	No	Name of marker
1	RFHD Right forehead	21	LASI Left anterior superior iliac
2	LFHD Left forehead	22	RASI Right anterior superior iliac
3	LBHD Left back of head	23	C7 7° Cervical vertebra
4	RBHD Right Back of head	24	RBAK Right back
5	RSHO Right shoulder	25	T10 10° thoracic vertebra
6	RUPA Right upper arm	26	RPSI Right posterior superior iliac
7	RELB Right elbow	27	LPSI Left posterior superior iliac
8	RFRM Right forearm	28	RTHI Right thigh
9	RWRB Wrist marker B	29	RKNE Right knee
10	RWRA Wrist marker A	30	RTIB Right tibia
11	RFIN Right finger	31	RANK Right ankle
12	LSHO Left shoulder	32	RTOE Right toe
13	LUPA Left upper arm	33	RHEE Right heel
14	LELB Left elbow	34	LTHI Left thigh
15	LFRM Left forearm	35	LKNE Left knee
16	LWRB Wrist marker B	36	LTIB Left tibia
17	LWRA Wrist marker A	37	LANK Left ankle
18	LFIN Left finger	38	LTOE Left toe
19	CLAV Clavicle	39	LHEE Left heel
20	STRN Sternum		

2.3 Equipment

Vicon system is a set of motion capture cameras that provide digital-optical data in real time. The basic principle of operation of the system is to locate the XYZ position of the reflective markers that are placed on the subject to be studied, with the information, the biomechanics or kinematics of the subject can be analyzed. VICON was initially created for the production of video games and science fiction movies. However, their applications in the health sector have been expanded. The system allows analyzing the kinematics of the human body and detecting pathologies that are not visible to the naked eye. Nowadays, VICON is considered as the gold standard for the analysis of the movement of the human body [10], [11].

The stationary bike technical features were 104 cm large, 52 cm wide, 119 cm high, adjustable seat high 76-90 cm, adjustable distance between the seat and the handlebar 68-83 cm, bike weight 43 kg, maximum body weight supported 105 kg and 20 kg of the inertial wheel.

2.4 Data processing

Once the experimental procedure was performed, the postprocessing of the data in the software Vicon Nexus 2.5 was done. The unlabeled markers were relabeled and lost information was recovered using the Gap Filling tools of the software (Vicon Nexus 2.5). The sampling frequency during the trials was 100 Hz. Then, the location of the markers in a 3D coordinate system (xyz) was exported in txt file.

Fig. 2 shows different views of the reconstruction of the human body with the 39 markers in the Matlab software. The range of motion of both knee joints was calculated with three markers (LKNE, LTHI, LANK, for left side) in the sagittal plane. The range of motion of the hip joint was calculated with the markers of the thigh and knee, using the direction angle with respect to the horizontal plane. Finally, the range of motion of the ankle joint was measure with the markers of the tibia, ankle and toe.

All the cycles were averaged and then the mean and standard deviation was calculated.

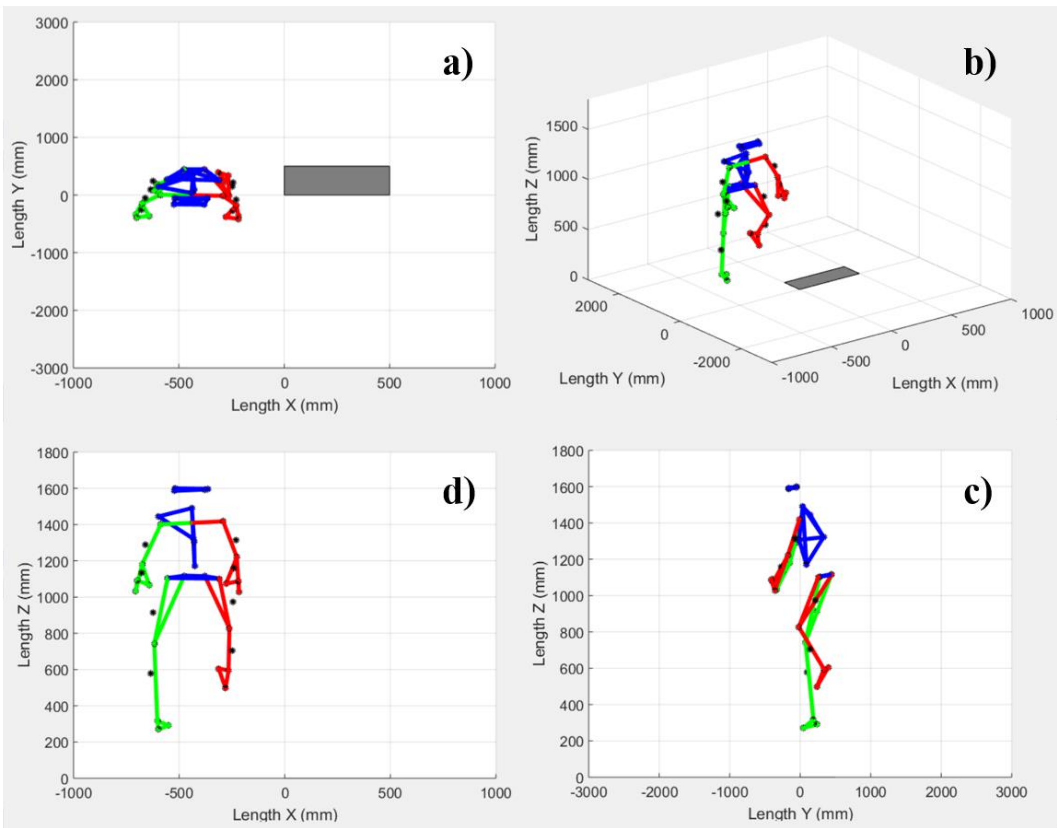

Fig. 2. Three-dimensional model of the human body, green color for the right side and red color for the left side: a) Top view, b) Isometric view on the bike, c) Lateral left view and d) Frontal view.

3. Results and discussion

Fig. 3 shows the mean and standard deviation of the range of motion of the left and right knee joint before and after the adjustments of the bicycle. The mean range of motion of the left knee was 65.3 and 70.3 degrees before and after the adjustments respectively. From this information, it is clear how the adjustment in the dimensions of the bicycle affect the range of motion of the knee joint.

Similarly, the range of motion of the right knee followed a similar pattern, it was 68.1 and 74.8 degrees before and after the adjustments respectively. Moreover, it is evident from the results that the extension and flexion angles of both knees increases after the adjustments. The range of motion of the knee after the adjustments is similar to the results found by Bini *et al.*, [8] in athletes and non-athletes.

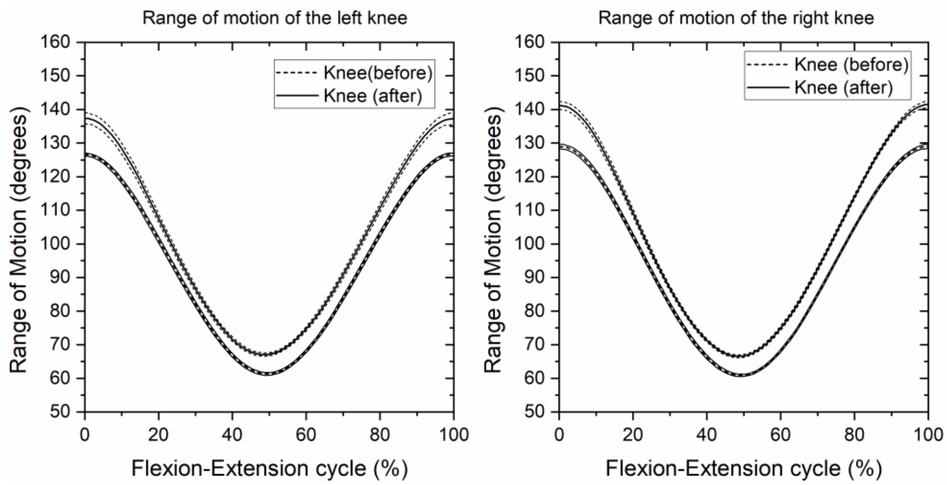

Fig. 3. Mean and standard deviation of the left and right knee before and after the adjustment of the bicycle.

The range of motion of the left and right hip is shown in Fig. 4. The mean range of motion of the hip was measured considering the longitudinal axis of the thigh and the horizontal plane. Therefore, the mean range of motion of the left thigh was 40.6 and 42.5 degrees before and after the adjustments respectively. The range of motion of the right thigh was 44.1 and 46.3 degrees before and after the adjustments. The results show an increment in the flexion and extension angles of the hip after the adjustment of the bicycle. The results of the range of motion of the hip after the adjustments agree with the results found by Bini *et al.*, [8].

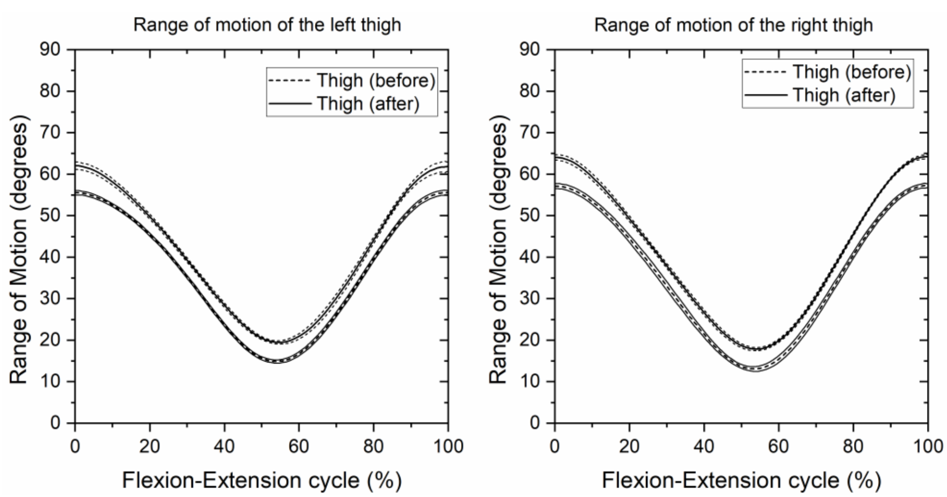

Fig. 4. Mean and standard deviation of the left and right thigh before and after the adjustment of the bicycle.

From Fig. 5, it was found that the range of motion of the ankle joint before the adjustments is more irregular. This effect could be produced by the bike fitting procedure performed by the participant. The range of motion of the ankle becomes more regular after the bike fitting procedure performed in relation to the anthropometric measurements. The ankle was the joint with less amplitude of the range of motion. Irregular patterns could produce an unstable joint and begin the initial stage of a musculoskeletal disorder in the future. Therefore, it is very important to continue developing more research in this area. The results of the range of motion of the ankle joint are similar to those found by Bini *et al.*, [8].

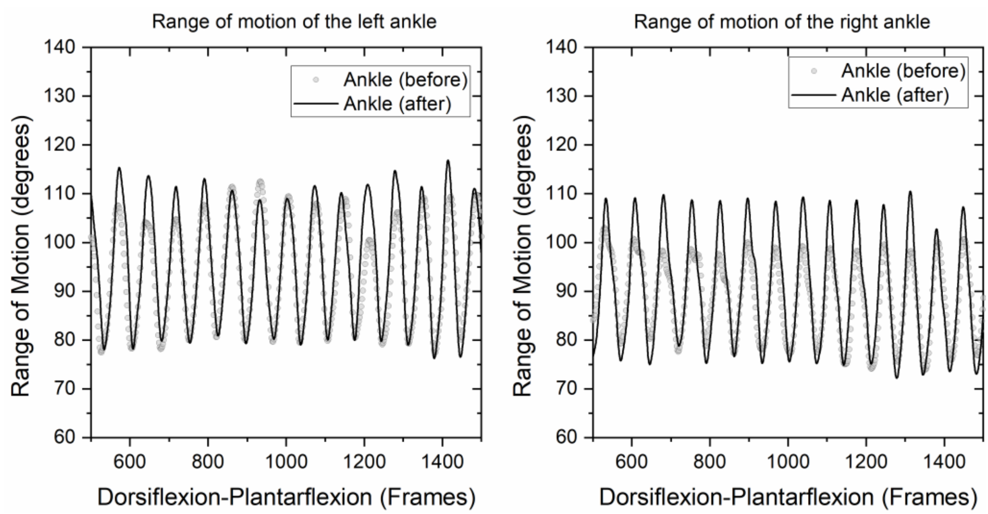

Fig. 5. Range of motion of the left and right ankle before and after the adjustment of the bicycle.

The current research presents some limitations. First, the results cannot be generalized due to just one participant being studied. Second, the results found in this study could be different to those studies developed in mountain and road bikes, as it has been found differences between road and mountain bikes, those differences could be related to the configurations of the bicycle or its structure [12]. However, although there are some limitations in the study, the results of the range of motions of the upper limbs agrees with those found by Bini *et al.*, [8]. Further work needs to be done increasing the sample of participants and considering high performance cyclists. Moreover, other parts and joints of the human body, such as, shoulder, elbow, wrist, neck and spine need to be studied.

4. Conclusions

The main contribution of this work is the development of a protocol to measure the range of motion of the knee, hip and ankle joint. This will help to identify irregular patterns in the range of motion of the athletes. Furthermore, it will be possible to compare the kinematics before and after any adjustment to the bicycle. This study also contributes to identifying any asymmetry in the range of motion between the left and right sides of the athletes.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

The authors would like to thank the Centro de Innovación Aplicada en Tecnologías Competitivas, CIATEC, A.C. for supporting the development of the research.

References

[1] R. R. Bini and F. P. Carpes, Biomechanics of cycling. Porto Alegre - Brazil: Adis-Springer, 2014.

[2] I. Miguel-Andrés, A. E. Rivera-Cisneros, J. J. Mayagoitia-Vázquez, S. L. Orozco-Villaseñor, and A. Rosas-Flores, “Flatfoot index and areas with the highest prevalence of musculoskeletal disorders in young athletes,” *Fisioterapia*, vol. 42, no. 1, pp. 17–23, 2020.

[3] M. Gutierrez, “Biomecánica y ciclismo,” *Rev. Motrocidad*, vol. 1, no. 1, pp. 77–99, 1994.

[4] F. Hug and S. Dorel, “Electromyographic analysis of pedaling: A review,” *J Electromyogr Kinesiol*, vol. 19, no. 2. Elsevier, pp. 182–198, 2009.

[5] B. Fonda and N. Sarabon, “Biomechanics of cycling (Literature review),” *Sport Sci. Rev.*, vol. 19, no. 1, pp. 187–210, 2010.

[6] C. A. Wozniak Timmer, “Cycling Biomechanics: A Literature Review,” *J. Orthop. Sport. Phys. Ther.*, vol. 14, no. 3, pp. 106–113, 1991.

[7] C. J. Márquez Torres, L. Pérez Jambrina, and D. Tocino Estrada, “Análisis biomecánico para ciclistas,”. Trabajo de fin de grado en Ingeniería Informática. Universidad Complutense de Madrid, España, 2017.

[8] R. R. Bini, D. Senger, F. Lanferdini, and A. L. Lopes, “Joint kinematics assessment during cycling incremental test to exhaustion,” *Isokinet. Exerc. Sci.*, vol. 20, no. 2, pp. 99–105, 2012.

[9] B. R. Umberger and P. E. Martin, “Testing the planar assumption during ergometer cycling,” *J. Appl. Biomech.*, vol. 17, no. 1, pp. 55–62, 2001.

[10] D. Beckwée, M. Degelaen, M. Eggermont, M. Gonzalez-Rodriguez, N. Lefeber, *et al.*, “Validity and test-retest reliability of the Stride Analyzer in people with knee osteoarthritis,” *Gait Posture*, vol. 49, pp. 155–158, 2016.

[11] S. Lorenzetti, T. Lamparter, and F. Lüthy, “Validity and reliability of simple measurement device to assess the velocity of the barbell during squats,” *BMC Res. Notes*, vol. 10, no. 1, p. 707, 2017.

[12] R. R. Bini, P. A. Hume, and J. Croft, “Cyclists and triathletes have different body positions on the bicycle,” *Eur. J. Sport Sci.*, vol. 14, no. SUPPL.1, pp. S109–S115, 2014.