ORIGINAL ARTICLE

A biomechanical analysis of differences between natural and clinical angle degrees and correlations to performance in road cycling

Aliye Büyükergün[1ABD], Milaim Berisha[1,2ACDE]

[1]*Istanbul Gelisim University, School of Physical Education and Sport, Turkey*
[2]*Istanbul Gelisim University, School of Physical Education and Sport, Turkey*
[2]*UBT College, Faculty of Sports and Movement Sciences, Kosovo*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim The study aims to determine differences between natural and clinical angle degrees in hips and shoulders, and determination of the correlations between angle degrees and functional threshold power (FTP) in road cycling athletes.

Material and Methods The study includes 11 male road cycling athletes aged 14-16 years old. The volunteer's body weight average was determined as 68.5±14.58, body height average was 175.4±6.98, and body mass index average 21.8±3.87. Volunteers are active athletes in "Büyükçekmece Road Cycling Team". To measure the performance of the cyclists clinical hip angle, clinical shoulder angle, hip angle degree, shoulder angle, functional threshold power (FTP) tests were used. The Kinovea 0.8.15 program was used in the data analysis of the variables in the study. Analyzes were performed using SPSS 26 analysis program. The analyses of the Shapiro Wilks test resulted in the normal distribution of the variables included in the study. Correlations between FTP test parameters and angle degrees, the correlation of a continued variable were calculated with Pearson correlation.

Results A statistically significant correlation between functional threshold power parameters such as distance, power avarege, total energy, cadance avarege, speed avarege, functional threshold power, and hip angle degree parameter ($p<0.05$). Similarly, correlations between functional threshold power, parameters such as power avarege and back curve resulted to be statistically significant ($p<0.05$). Also, like an functional threshold power parameter, speed avarege resulted to be in a significant correlation with the clinical shoulders angle degree.

Conclusions Based on these results, increases in the FTP parameters may affect positively the cyclist's performance helping to avoid undesirable hip angles, which may lead to back pain. Similarly, power average and back curve degree resulted to be in a correlation. Therefore, the back curve degree may be increased or decreased by the changes in the power average parameter. In addition, during the high intensity of training and fatigue levels increased, the clinical hip and shoulder angles were also increased.

Keywords: back curve, functional threshold power, natural angle, clinical angle, cyclist

Introduction

The harmony of the posture positions of the body on the bicycle according to the joint positions of the human body is important in terms of performance [1]. The literature has shown that hip and shoulder angle degree is a determinant factor in road cycling performance. It is important to analyze the difference between natural and clinical angles measured during cycling, as changes in the kinematic chain may have an effect on performance, technique efficiency, and injury risk [2]. For more, high clinical angle degrees on the back, and lack back curve may cause lower and upper back pain and decreases in performance. However, most common cycling injuries to the lower extremity are preventable [3]. In this context, up to 60% of cyclists suffer from persistent pain especially in the neck and back [4]. This issue usually results from a prolonged extension of the cervical spine and a hyper-flexed lumbar spine that induce potentially high loads and compression at the intervertebral discs during increased forward-leaning [5]. Based on the fact that the body works better in anatomical positions it can be thought that a high clinical angle degree is undesirable in road cycling. Therefore, the similarity of natural angle degrees and clinical angle degrees may avoid injuries and back pains of athletes. There are studies in the literature about riding upright, raising the body height, shortening the body length can solve back discomfort. However, the elasticity of the body tissues may allow a significant clinical angle degree, which is related to the hips, hamstrings, and shoulders muscles [6]. Also, the elasticity of the body tissues may be affected by the active flexibility [7] and mobility [4;8]. Literature has shown that more flexibility and mobility mean better dynamics in road cycling [9]. Also, low back pain may occur in riders who are overstretched on the bike. Most common cycling injuries to the

doi:10.15561/26649837.2022.0301

lower extremity are preventable [10]. Some studies have reported that posture affects performance in cyclists. Recently, reported that lower torso angles attenuate performance in well-trained male cyclists [11]. For this reason, it has been observed that studies on this subject have increased rapidly in the literature in recent years.

Based on the current literature it can be seen that there is a lack of research that directly addresses the issue of the clinical angle degree effect on performance and back pain. In addition, it seems that current literature failed to determine the difference between clinical angle degrees (increases in the back curve caused by loads and fatigue), and natural angle degrees (back position while athletes are not loaded or fatigue level is low). Therefore, addressing this issue may be beneficial in cyclist training programs creating, setting training sessions, and determining the muscle groups needed to be improved. Similarly, the results of the study may help to clarify the motor abilities needed to be improved to decrease clinical angle degree, respectively back curve caused by the increase of training intensity and fatigue level of the athletes. Thus may be beneficial to decrease the back pain of the cyclist and increase the performance during competition. In the light of the previous information, it needs to determine differences between natural and clinical angle degrees during cycling, and the effects of the angle degrees on performance in road cycling.

The study aims to determine differences between natural and clinical angle degrees in hips and shoulders. Besides this, the study aims to determine the correlations between angle degrees and performance (functional threshold power FTP) in road cycling performance. In addition, by the determination of the differences between natural and clinical angle degrees, it will be determined the role of the flexibility and mobility on hips and shoulders positions during cycling.

Material and Methods

Participants

The study was included 11 male road cycling athletes aged 14-16 years old. The volunteer's body weight average was 68.5±14.58, body height average was 175.4±6.98, and body mass index average 21.8±3.87 volunteers are active athletes in "Büyükçekmece Road Cycling Team".

Research Design

To determine the differences between clinical and natural angle degrees, which occur during cycling, a causal relational research model was used [12]. Athletes were informed about the activities and tests, which were made for the study. Besides this, athletes, parents, and coaches of the team were informed about the benefits and risks (even there was not predicted any risk) of the applied activities and tests. The study was made according to the Helsinki declaration. The ethical approval of the study was taken from the Istanbul Gelisim University.

Testing Procedures

Clinical hip angle

Clinical hip angle tests reference is lumbar spine (L5) when is located me measurement tool. The angle is created by the line, which starts from the lumbar spine and continues to the greater trochanter of the femur. Similarly, the second line of the angle starts from the lumbar spine (L1-L5) and continues to the thoracic spine (T1-T12) imaginary straight line. It means that the curve of the spine is not considered in angle degree determination [13]

Clinical shoulder angle

The clinical shoulder angle test includes an imaginary line across the thoracic spine and the second line across the acromion and lateral epicondyle of the humerus. The angle degree created by the imaginary line across the thoracic spine and line across the acromion and lateral epicondyle of the humerus is named the clinical shoulder angle degree. It means that the curve of the spine is not considered in angle degree determination. It may help to determine the curve degree of the spine during cycling [13].

Hip angle degree

Hip angle degree measurements reference is greater trochanter of the femur, which is the center of the angle. The first line of the angle starts from the greater trochanter to the lateral epicondyle of the femur. The second line of the angle degree starts from the greater trochanter to the acromion [13].

Shoulder angle

Shoulder angle degree measurements reference is acromion, which is the center of the angle. The first line of the angle starts from the acromion and continues to the lateral epicondyle of the humerus. The second line of the angle degree starts from the acromion and continues to the greater trochanter [13].

Note: To determine the differences of the back curve during the FTP test execution in the testing process of the angle degree, the athlete was photographed in 1st, 5th, 10th, 15th, and 20th minutes (every 5 mins). The angle degree that occurred in each position were compared to each other. Measurements were made when the leg was completely straight which means that the pedal was at 5 o'clock.

Functional threshold power (FTP) test

The FTP test is defined as the uppermost power sustainable for 60-min in a quasi-steady state [13]. The intensity setting of the FTP test is created to be third degree and is determined as a standard for all athletes. A 30-minute warm-up protocol was applied before the 20-minute FTP test. The air resistance level in the control group was 1, while in the experimental group, it was 3. For this test, we suggested 95 rpm as a good benchmark cadence, but it was not limited to this. Because the literature has shown that the preferred cadences should be determined based on the cyclist's requirements (80-100 rev. min^{-1}) [14]. The implementation of the FTP test was done on the Wattbike Pro/Trainer device [15].

Statistical Analysis

For the data analysis of the variables the Kinovea 0.8.15 program, which is a video player for sports analysis and provides a set of tools to capture, slow down, study, compare, annotate and measure technical performances (16), was used. To mark the location, measure distance, and determine the angle degree of the videos, tools of the program such as a line, circle, cross marker, angle, etc. were used. The videos were recorded with a Galaxy S10, which has three cameras on the back: a main 12-megapixel with an aperture that shifts between f/1.5 and f/2.4 depending on light, an ultra-wide 16-megapixel unit, and a telephoto 12-megapixel for zooming.

Analyzes were performed using SPSS 26 analysis program. To determine the normality of the data, the Shapiro Wilks test was used. The analyses of the Shapiro Wilks test resulted in the normal distribution of the variables included in the study. To determine the general values of the variables descriptive statistics were applied. Correlations between FTP test parameters and angle degrees, the correlation of a continued variable were calculated with Pearson correlation. Differences between Hip angle degree (natural and clinical angles), and shoulder angle degree (natural and clinical angles) were calculated by using Independent T-test statistics. The difference percentage between natural and clinical angle degrees was calculated by using the formula "%Δ = (x natural angle – x clinical angle) / clinical angle".

Results

In table 1, where the average values were given, has been determined the normality of the FTP test and its parameters which seem to be normal (mesocortical) expecting the CPrpm which the kurtosis value resulted to be leptokurtic. Besides this, results were divided into three categories (25th, 50th, and 75th) as percentile values to be used as determinants for cyclists' level on the FTP test and its parameters.

In table 2, where the average values were given, has been determined the normality of the angle degree parameters which seem to be normal (mesocortical) expecting the BC° which the kurtosis value resulted to be leptokurtic. Besides this, results were divided into three categories (25th, 50th, and 75th) as percentile values to be used as determinants for cyclists' level on angle degrees and back curve which occur during the cyclist's performance.

Results of table 4 have determined statistically significant differences between hip angle degree ($\bar{X}$=106.6) and clinical hip angle degree ($\bar{X}$=120.3),

Table 1. Descriptive statistics and level of the FTP and its parameters

Parameters		DKm	PAwat	ET	CArpm	PPwat	PMwat	CPrpm	SAkmh	HRa	HRp	FTP
$\bar{X}$		12.17	203.0	305.6	90.64	715.5	3.1664	130.8	36.7	188.60	207.0	192.7
SD		1.04	43.6	49.8	8.016	212.0	.72362	20.4	3.0	6.5	7.9	41.6
	25th	11.31	173.0	271.0	85.0	540.0	2.95	122.0	34.0	183.7	199.2	164.0
%	50th	11.89	187.0	287.0	88.0	726.0	3.15	133.0	36.0	188.5	209.0	177.0
	75th	12.99	223.0	329.0	96.0	938.0	3.79	150.0	38.0	194.5	214.2	212.0

Distance (km): Dkm, PAwat: Power Avg (wat), ET: Total energy, CArpm: Average cadance (rpm), PPwat: Peak Power (wat), PM_wat: Power/Mass (wat), CPrpm: Peak cadance (rpm), SAkmh: Average speed (km/h), HRa: Average heart rate, HRp: Peak heart rate, FTP: Functional threeshold power; Skewness: > 1 - positive skew, ± 0 - normal, < - 1 - negative skew; Kurtosis: > +2 leptokurtic distribution, ± 2 normal (mesokurtic) distribution, < -2 platokurtic distribution.

Table 2. Descriptive statistics and level of the angle degree and back curve during cycling

Parameters		HAo	CHAo	SHAo	CSHAo	BCo
$\bar{X}$		106.6	120.3	86.2	106.2	145.322
SD		3.5	4.2	4.6	6.0	9.5542
	25th	103.3	119.0	84.0	101.1	136.3
%	50th	107.1	120.7	87.5	106.1	143.4
	75th	110.2	122.6	88.6	109.9	151.4

Had: Hip angleo, CHAo: Clinical hip angle degree, SHAo: Shoulders angle degree, CSHAo: Clinical shoulders angle degree, BCo: Back cureve degree; Skewness: > 1 - positive skew, ± 0 - normal, < - 1 - negative skew; Kurtosis: > +2 leptokurtic distribution, ± 2 normal (mesokurtic) distribution, < -2 platokurtic distribution.

where is seen that clinical hip angle is higher than natural angle degree during cycling ($p<0.05$). Similarly, statistically significant differences between shoulders angle degree ($\bar{X}$=86.2) and clinical shoulders angle degree ($\bar{X}$=106.2) were determined, where is seen that clinical shoulders angle is higher than natural shoulders degree during cycling ($p<0.05$). While the differences between hip angle and clinical hip angle degrees were determined as 13%, differences between shoulders angle and clinical shoulders angle degrees result to be 23%.

Discussion

As a result of the study differences between natural and clinical angle degrees in hips and shoulders have been determined. Besides this, the correlations between angle degrees and performance (functional threshold power FTP) have been determined. Determination of the differences between natural and clinical angle degrees determined the role of the flexibility and mobility on hips and shoulders positions during cycling.

To be more specific, a statistically significant

Table 3. Correlations between FTP test parameters and angle degrees that occur during cycling

Parameters		HAo	CHAo	SHAo	CSHAo	BCo
DKm	r	-.703	.436	-.480	.130	-.590
	p	.023	.208	.160	.720	.072
PAwat	r	-.704	.412	-.326	.212	-.624
	p	.016	.208	.327	.532	.040
ET	r	-.707	.410	-.328	.216	-.628
	p	.015	.211	.325	.524	.039
CArpm	r	-.676	.491	-.326	.217	-.658
	p	.023	.125	.327	.521	.028
PPwat	r	-.551	.225	-.356	.587	-.774
	p	.079	.506	.283	.058	.005
PMwat	r	-.385	.132	-.043	-.078	-.035
	p	.243	.698	.899	.819	.918
CPrpm	r	-.554	.533	-.197	.701	-.896
	p	.077	.092	.562	.016	.000
SAkmh	r	-.658	.434	-.305	.165	-.568
	p	.028	.183	.363	.628	.068
HRa	r	-.488	.481	.111	.743	-.617
	p	.152	.159	.761	.014	.058
HRp	r	-.213	.431	.064	.527	-.459
	p	.554	.213	.860	.118	.182
FTP	r	-.707	.411	-.326	.212	-.625
	p	.015	.209	.329	.531	.040

Distance (km): Dkm, PAwat: Power Avg (wat), ET: Total energy, CArpm: Average cadance (rpm), PPwat: Peak Power (wat), PM_wat: Power/Mass (wat), CPrpm: Peak cadance (rpm), SAkmh: Average speed (km/h), HRa: Average heart rate, HRp: Peak heart rate, FTP: Functional threeshold power; HAO: Hip angleo, CHAo: Clinical hip angle degree, SHAo: Shoulders angle degree, CSHAo: Clinical shoulders angle degree, BCo: Back curve degree.

Table 4. Differences between natural angle degrees and clinical angle degrees that occur during cycling

Parameters	$\bar{X}$	SD	%	p
HAo	106.6	3.56	13	0.000*
CHAo	120.3	4.24		
SHAo	86.2	4.67	23	0.000*
CSHAo	106.2	6.09		

HAo: Hip angleo, CHAo: Clinical hip angle degree, SHAo: Shoulders angle degree, CSHAo: Clinical shoulders angle degree.

correlation has been determined between FTP parameters such as distance, power average, total energy, average cadence, average speed, FTP, and back curve tests such as hip angle degree parameter. The degree of hip angle increases as distance, average power, total energy expenditure, average cadence, and average speed increase; It gives the result that the curvature of the back increases with fatigue, which is not a desirable situation for athlete performance. Based on this, studies are showing that increased hip angle is also associated with insufficient back strength. In addition, the insufficiency of lumbar and hamstring flexibility can be seen as the most important reason for the increase in the degree of hip angle [17]. Similarly, it is seen that there is a strong positive relationship between clinical shoulders angle degree and peak cadence. As the cadence increased, the clinical shoulder angle also increased. It can be said that one of the most important consequences of unnatural (clinic) positions is the imbalance in muscle activation of spinal flexors and extensors, which causes may be muscle fatigue [18].

In addition, a statistically significant differences between hip angle degree and clinical hip angle degree, where is seen that clinical hip angle is higher than natural angle degree during cycling. Previous studies have shown that a reduction in the back curve can improve performance and minimize the risk of injury [19]. In this study by Moshe Salai et al. [18] from the fluoroscopic/biomechanical study of cyclists, it appears that low back pain can be attributed, in part, to the anatomical extension between the pelvis and the spine. This results in tensile forces along the anterior longitudinal ligament of the lumbar spine, which increase as the result of sitting on the saddle and reclining on the handlebar, as has been shown in this work. Based on the fluoroscopic/biomechanical studies of cyclists made by Salai et al., [18] low back pain can be partially attributed to the anatomical extension between the pelvis and spine. As seen in Table 4, there is a significant difference between hip angle and unnatural (clinical) angle degree.

Schulz and Gordon's [11] pilot study of recreational cyclists found that in 95% of trials, lumbar spine flexion increased when participants cycled for 10 minutes which as the effect of gravity made an increase in spine extension more likely. They noted that the adoption of greater flexion may be a mechanism for reducing the end gap position of the lumbar facet joints and joint compression in an extended position. Considering that Schulz and Gordon's [4] study reached this conclusion even though the 10-minute cycling maintenance was quite short. Anyway, the 10 minutes' time may not be valid to get a conclusion on the matter. Therefore, using the 20-minute high-intensity FTP test would be more appropriate to get more valid results.

Conclusions

As the conclusion of the study, hip angle degree resulted to be correlated with FTP parameters such as distance, power average, total energy, average cadence, and average speed. Therefore, hip angle degree can be changed positively or negatively by the increases or decreases of the FTP parameters, especially distance, power average, total energy, average cadence, and average speed. Based on these results, increases in the FTP parameters may affect positively the cyclist's performance and help to avoid undesirable hip angles, which may lead to back pain. Similarly, power average and back curve degree resulted to be in a correlation. Therefore, the Back curve degree may be increased or decreased by the changes in the power average parameter.

When angle degrees of hips and shoulders have been compared to the clinical angles has been shown that clinical hip and shoulders degrees are higher than natural angles. This means that during the high intensity of training and fatigue levels increased, the clinical hip and shoulder angles also increased.

Acknowledgments

The authors acknowledge the collaboration and supporting assistance from the "Büyükçekmece Belediye Bisiklet Kulübü and Ümraniye Belediye Bisiklet Kulübü".

Conflict of interests

The authors reported no potential conflict of interest.

References

1. Kılınç F, Aksoy I. Milli Yol Bisikletçisinin Bikefit (Bisiklet Ile Fiziksel Uyumluluk) Analizinin Mekanik Ve Appa Bikefit Programiyla Karşilaştirmali Incelenmesi [A Comparative Analysis of National Road Cyclist's Bike Fit (Physical Compatibility with Bicycle) Analysis with Mechanics and Appa Bikefit Program]. *Sivas Cumhuriyet* Üniversitesi *Spor Bilimleri Dergisi*, 2017; 2 (2): 76-86. (In Turkish).
2. Holliday W, Fisher J, Theo R, Swart J. Static versus dynamic kinematics in cyclists: A comparison of goniometer, inclinometer and 3D motion capture, European Journal of Sport Science, 17:9, 1129-1142. https://doi.org/10.1080/17461391.2017.1351580
3. Syahrul M, Nizam M. Anterior Knee Pain (Patellar Tendonitis) Management And Modification In Bike Fitting For A Track Cyclist. *Proceedings of the 30th Annual Conference of Biomechanics in Sports*, Melbourne; 2012; (203):290–93.
4. Schulz SJ, Gordon SJ. Riding position and lumbar spine angle in recreational cyclists: A pilot study. *Int J Exerc Sci,* 2010; 3(4):174-181.
5. Dettori NJ, Norvell DC. Non-traumatic bicycle injuries: A review of the literature. *Sports Medicine,* 2006; 36(1): 7–18. https://doi.org/10.2165/00007256-200636010-00002
6. Süzen LB. *Hareket sistemi anatomisi ve kinesiyoloji* [Movement system anatomy and kinesiology]. Istanbul: Nobel Medical Bookstores; 2017. (In Turkish).
7. Mellion MB. Common cycling injuries: Management and prevention. *Sports Medicine,* 1991;11:52-70. https://doi.org/10.2165/00007256-199111010-00004
8. Jeffreys I. Warm-up revisited: The ramp method of optimizing warm-ups. *Prof Strength Cond,* 2007; (6):12.
9. Clarsen BR, Bahr MW, Heymans M, Engedahl G, Midtsundstad L, Rosenlund, G. Thorsen, and G. Myklebust. "The Prevalence and Impact of Overuse Injuries in Five Norwegian Sports: Application of a New Surveillance Method." *Scandinavian Journal of Medicine and Science in Sports,* 2015; 25(3):323–30. https://doi.org/10.1111/sms.12223
10. Streisfeld GM, Bartoszek C, Creran E, Inge B, McShane MD, Johnston T. Relationship between body positioning, muscle activity, and spinal kinematics in cyclists with and without low back pain: A systematic review. *Sports Health,* 2017; 9(1): 75–79. https://doi.org/10.1177/1941738116676260
11. Muyor JM., Zabala M. Road Cycling and Mountain Biking Produces Adaptations on the Spine and Hamstring Extensibility. *International Journal of Sports Medicine,* 2015; 37(1):43–49. https://doi.org/10.1055/s-0035-1555861
12. Karasar N. Bilimsel araştırma yöntemi [Scientific research method]. Ankara: Nobel Publishing; 2012. https://doi.org/10.17121/ressjournal.705
13. Swart J, Holliday W. Cycling Biomechanics Optimization - The (R) Evolution of Bicycle Fitting. *Current Sports Medicine Reports,* 2019; 18(12):490–96. https://doi.org/10.1249/JSR.0000000000000665
14. Ansley L, Patrick C. Determinants of 'Optimal' Cadence during Cycling. *European Journal of Sport Science*. 2009; 9 (2):61–85. https://doi.org/10.1080/17461390802684325
15. Wilson IJ. *Wattbike*. [Internet]. 2007. [updated 2022; cited 2022 Jan 20]. Available from: https://wattbike.com/
16. *Kinovea 0.8.15. 2006-2011*. [Internet]. 2021. [updated 2021 Apr 15; cited 2021 Feb 5]. Available from: https://www.kinovea.org/
17. Hoof WV, Volkaerts K, O'Sullivan K, Verschueren S, Dankaerts W. Comparing lower lumbar kinematics in cyclists with low back pain (flexion pattern) versus asymptomatic controls – field study using a wireless posture monitoring system, *Manual Therapy*, 2012;17(4):312-317. https://doi.org/10.1016/j.math.2012.02.012
18. Salai M, Brosh T, Blankstein A, Oran A, Chechik A. Effect of changing the saddle angle on the incidence of low back pain in recreational bicyclists. *British Journal of Sports Medicine,* 1999;33(6):398-400. https://doi.org/10.1136/bjsm.33.6.398
19. Kotler DH, Babu A, Robidoux G. Prevention, Evaluation, and Rehabilitation of Cycling-Related Injury, *Current Sports Medicine Report,* 2016; 15(3):199-206. https://doi.org/10.1249/JSR.0000000000000262

Information about the authors:

Aliye Büyükergün: (Corresponding Author); https://orcid.org/0000-0003-0096-5673; abuyukergun@gelisim.edu.tr; Coaching Department, School of Physical Education and Sport, Istanbul Gelisim University, Istanbul, Turkey.

Milaim Berisha; (Corresponding author); https://orcid.org/0000-0002-0353-7247; mbeisha@gelisim.edu.tr dr.milaimberisha@gmail.com; Coaching Department, School of Physical Education and Sport, Istanbul Gelisim University, Istanbul, Turkey.

Cite this article as:
Büyükergün A, , Milaim Berisha M. A biomechanical analysis of differences between natural and clinical angle degrees and correlations to performance in road cycling. *Pedagogy of Physical Culture and Sports,* 2022;26(3):144–150.
https://doi.org/10.15561/26649837.2022.0301

Received: 20.02.2022
Accepted: 11.05.2022; Published: 30.06.2022