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Original Article

Biomechanical analysis of clinical angle degrees of the lower and upper back at different stages of the functional threshold power (FTP) test in mountain cyclists

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Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): The aim of the study was a biomechanical analysis of the angular degrees of the hip angle, shoulder angle, clinical hip angle, and clinical shoulder angle at five stages of the FTP test.
Methods: The study includes 8 male mountain cycling athletes aged 14-16 years old. Sample size sufficiency was tested using the G*Power program. Performance measure and evaluation tests; clinical hip angle, clinical shoulder angle, hip angle degree, shoulder angle, and the FTP test-were applied. For the data analysis of the variables, the Kinovea-0.9.4-x64.exe program was used. Repeated Measure ANOVA and Pairwise Comparison Analysis were used.
Results: Differences of the back curves and clinical hip and shoulder angle degrees in different stages of the FTP test were found to be statistically significant between and within groups ($p<0.05$). However, there were no statistically significant changes in clinical shoulder angle degrees during the different stages of the FTP test or between groups ($p>0.05$).
Conclusion: During the execution of the FTP test, clinical hip and shoulder angles increased, and it was accompanied by back curve increases. To avoid injury risk, back pain, and delayed fatigue, it is necessary to develop flexibility and mobility of the hips and force of the erector muscles.

Keywords: Back Curve Changes, Natural Angle, Clinical Angle, Cyclist, Fatigue.

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INTRODUCTION

Cycling is a sport that is characterized by the relationship between the cyclist and the bicycle [1]. As there are many different categories (road bike, bicycle track, mountain bike, cyclo-cross, BMX, etc.) in cycling, there are also different types of handlebar grips (tops, hoods, ramps, drops), which cause changes in body positions during cycling. Body positions during cycling are related to aerodynamics and may affect the athlete's performance [2]. Besides this, when body positions such as a back curve, hip angle, shoulder angle, etc. take the wrong position, it causes decreased performance, back pain, etc. Low back pain (LBP) is a common complaint among mountain bikers, with a prevalence of 24% to 41% [3,4].

Many studies have reported back pain at various levels of the spine among cyclists at rates of 30-70% in recreational people who use bikes as a transport tool [5]. There is significant literature that proves injury levels in mountain bikers [6].

Therefore, according to the previous information, the back curve during cycling should be similar to hip-shoulder angle degrees in order to avoid injury risk and improve performance. Otherwise, high clinical hip and shoulder angles may cause back pain and decrease the performance of athletes. Sufficient flexibility and mobility in the hip and shoulder joints may decrease the risk of injury and delay the fatigue of athletes. But a deficit of flexibility and mobility in the hip and shoulder joints causes a clinical hip and angle curve in the back, which is an undesirable back curve that may result in back pain and decreased performance [7]. The back curve may also differ during cycling, parallel to the intensity and time of cycling. Also, the changes on the back curve during cycling should be monitored and determined to improve the bike-fit characteristics for each athlete. Based on the literature, it seems that the biggest culprit is not knee pain in cyclists; it is lower back pain [7]. To avoid undesirable back pain and decreased performance, we should monitor the changes in the back curve during cycling [5]. To realize the performance measurement in the study, the FTP was used as the test, which is one of the best indicators of cycling performance. Due to the arduous nature of the 60-minute FTP test, a shorter, less arduous test was developed. The FTP20 test is a 20-minute effort, and on completion, the maximal power output (MPO) is scaled by 95% to represent a 60-minute equivalent FTP [8]. Based on the above data, the necessity emerged to investigate how the clinical hip and shoulder angles change at different stages of the FTP test.

In light of the previous information, the aim of the study is a biomechanical analysis of angular degrees of the hip angle, shoulder angle, clinical hip angle, and clinical shoulder angle at different stages (1st, 5th, 10th, 15th, and 20th minutes) in the functional threshold power (FTP) test in mountain cyclists. Besides this, the study also aims to determine the correlations between the FTP test and the hip angle, shoulder angle, clinical hip angle, and clinical shoulder angle.

METHODS

Research design

The study is experimental and consists of a control and an experimental group. In both groups, five repeated measures were applied. The control group measurements were applied with minimal effort, while the experimental group measurements were applied with maximal effort.

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In the study, eight male road cycling athletes aged 14-16 years old were included. The volunteers' body weight average was 65.4, their body height average was 172.6, and their body mass index average was 21.7. Volunteers were active athletes on the "Ümraniye Cycling Team". In the present study, the G*Power 3.1.9.4 program was used to determine the adequacy of the sampling size, which consisted of 8 people. For the in-group test, the "MANOVA: Repeated Measures within Factors" test was chosen from the F tests group by using the "Direct" method, and the partial η2 value was found to be 0.5, the effect size value was found to be 1.000, the α error probability value was found to be 0.05, and the power (1-ß err probe) value was determined to be 0.82. For the tests between the groups, the "effect size from means" method was chosen by using the "MANOVA: Repeated Measures Test"; and the effect size-f value was found to be 12.500, the α error probability value was found to be 0.05, and the power (1-ß err probe) was found to be (0.98).

The study was made according to the Helsinki Declaration, which protects the privacy of the volunteers. The study received approval from the Ethics Committee of Istanbul Gelisim University under the protocol number 2021-28.

Performance measures and evaluation tests:

Clinical hip angle

The clinical hip angle test reference is the lumbar spine (L5), where the measurement tool is also located. 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) as an imaginary straight line. This means that the curve of the spine is not considered in angle degree determination [9].

Clinical shoulder angle

The clinical shoulder angle test includes an imaginary line across the thoracic spine and a second line across the acromion and lateral epicondyle of the humerus. The angle degree created by the imaginary line across the thoracic spine and the 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 [10].

Hip angle degree

The hip angle degree measurement reference is the 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 [11].

Shoulder angle

The shoulder angle degree measurement reference is the 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 [12].

Functional threshold power (FTP) test

The FTP test is defined as the uppermost power sustainable for 60-minutes in a quasi-steady state [10, 11, 12]. 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

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determined based on the cyclist's requirements (80-100 rev. min-1) [13]. The implementation of the FTP test was done on the Wattbike Pro/Trainer device [14].

Note: To determine the differences in the back curve during the FTP test execution, the athlete was photographed in the 1st, 5th, 10th, 15th, and 20th minutes (every 5 minutes). The angles 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 in the 5 o'clock position.

Data Analysis

For the data analysis of the variables, the Kinovea-0.9.4-x64.exe program, which is a valid and reliable kinematics analysis software [15] and provides a set of tools to capture, slow down, study, compare, annotate, and measure technical performances (Kinovea-0.9.4-x64.exe), was used [16]. To mark the location, measure the 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 made by a Galaxy S10, which had 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.

To determine the normality of the data, the Kolmogorov-Smirnov test was used. Besides this, to measure the normality of variables, skewness and kurtosis values were used. Based on the normality of the data, a repeated measure ANOVA and pairwise comparison analysis were used.

RESULTS

Table 1. Differences in back curve angle degree during different stages of the FTP test

V	FTPS	G	X̄±SD	*Sig	*η2	**Diff	**Sig	***η2
BCA[0]	1st min of FTP[1]	1	155.6±4.26	FTPS: .003	FTPS: .749	1>5	TWSE: .001	TWSE: .384
		2	161.6±4.26			2>5		
	5th min of FTP[2]	1	146.8±4.18	FTPS*G: .247	FTPS*G: .365	4>5	TWSE*G: .030	TWSE*G: .215
		2	162.9±4.18					
	10th min of FTP[3]	1	144.1±3.66				TBSE: .012	TBSE: .371
		2	160.2±3.66					
	15th min of FTP[4]	1	152.1±2.71					
		2	143.3±3.84					
	20th min of FTP[5]	1	147.6±3.25					
		2	137.5±4.60					

*Note: V: Variables, BCA0: Back Curve Angle Degree, G: Group (1=experimental, 2=control), *Multivariate test (Wilks' Lambda, Partial eta squared), Mauchly's test of sphericity (***Green house geisser: .543), **Pairwise comparison (differences). TWSE: Test of Within-Subject Effects; TBSE: Test of Between-Subject Effects*

Table 1 has shown that differences in the back curves in different stages of the FTP test resulted to be statistically significant between ($p<0.05$) and within groups ($p<0.05$). Based on the results of the study, the back curve increased significantly from the 1st minute of FTP to the 20th minute of the FTP test.

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Table 2. Differences in Clinical Hip Angle Degrees during different stages of the FTP test

V	FTPS	G	$\bar{X}$±SD	*Sig	*η2	Diff	**Sig	**η2
CHA[0]	1st min of FTP[1]	1	7.05±1.78	FTPS: .000 FTPS*G: .017	FTPS: .826 FTPS*G: .640	1>5 4>5	TWSE: .001 TWSE*G: .003 TBSE: .008	TWSE: .349 TWSE*G: .290 TBSE: .408
		2	5.41±1.78					
	5th min of FTP[2]	1	12.63±2.58					
		2	5.33±2.58					
	10th min of FTP[3]	1	13.27±2.22					
		2	4.83±2.22					
	15th min of FTP[4]	1	13.65±2.12					
		2	3.28±2.12					
	20th min of FTP[5]	1	18.73±1.68					
		2	6.52±1.68					

*Note: V: Variables, BCA0: Clinical Hip Angle Degree, G: Group (1=experimental, 2=control), *Multivariate test (Wilks' Lambda, Partial eta squared), Mauchly's test of sphericity (**Green house geisser: .580), Pairwise comparison (differences). TWSE: Test of Within-Subject Effects; TBSE: Test of Between-Subject Effects*

Table 2 shows that differences in the clinical hip angle degree in different stages of the FTP test resulted in being statistically significant between (p<0.05) and within groups (p<0.05). Based on the results of the study, clinical hip angle degree increased significantly from the 1st minute of the FTP to the 20th minute of the FTP test.

Table 3. Differences in Clinical Shoulder Angle Degrees during different stages of the FTP test.

V	FTPS	G	$\bar{X}$±SD	*Sig	*η2	Diff	**Sig	**η2
CSHA[0]	1st min of FTP[1]	1	13.8±9.4	FTPS: .080 FTPS*G: .083	FTPS: .504 FTPS*G: .500	-	TWSE: .007 TWSE*G: .067 TBSE: .440	TWSE: .278 TWSE*G: .168 TBSE: .043
		2	17.9±5.6					
	5th min of FTP[2]	1	21.2±7.6					
		2	15.9±4.8					
	10th min of FTP[3]	1	21.7±4.5					
		2	17.6±9.3					
	15th min of FTP[4]	1	22.7±5.3					
		2	16.1±7.5					
	20th min of FTP[5]	1	24.4±6.8					
		2	24.0±12.2					

*Note: V: Variables, BCA0: Clinical Shoulders Angle Degree, G: Group (1=experimental, 2=control), *Multivariate test (Wilks' Lambda, Partial eta squared), Mauchly's test of sphericity (**Green house geisser: .580), Pairwise comparison (differences). TWSE: Test of Within-Subject Effects; TBSE: Test of Between-Subject Effects*

Table 3 showed that there are no statistically significant changes in clinical shoulder angle degree during the different stages of the FTP test (p>0.05) or between groups (p>0.05). However, based on the averages, the clinical shoulder angle degree increased from the first to the last stage of the FTP test. Therefore, based on these results, increases in the back curve during the different FTP stages were less related to the clinical shoulder degree and more related to the clinical hip angle degree.

DISCUSSION

Based on its purposes, the study determined changes in the back curve caused by the inefficiency of the hip (gluteus maximus, gluteus medius, tensor fasciae letae, etc.,) and shoulders (deltoid, infraspinatus, teres major, teres minor, etc.) muscles in terms of flexibility and mobility. In order to monitor mechanical changes of the back curve, clinical hip and shoulder angle measurements were applied five times (1st, 5th, 10th, 15th, and 20th minutes) during the Functional Threshold Power (FTP) test.

Therefore, analysis of the back curves in different stages of the FTP test resulted in statistically significant differences between and within groups. Based on the results of the study, the back curve increased significantly from the 1st minute of the FTP to the 20th minute of the FTP test. As the FTP test is one of the best indicators of cyclist performance and fatigue, it can be concluded that increases in back curve were caused by the lack of performance of the erector muscles such as the iliocostalis, longissimus, and spinalis [17]. A direct link was detected between the changes in muscle fatigue state and subsequent changes in movement kinematics during cycling [18]. It means that changes in back curve angle degrees are accompanied by performance decreases and increases. According to the fact that the predominant body position in cycling is seated on the bicycle with an anterior inclination of the trunk and lumbar flexion to reach the handlebars with the hands [2], increasing the back curve may cause back pain. However, even if erector muscles are insufficient, the back curves may not occur dramatically if the flexibility and mobility of hip muscles such as the hip extensor, gluteus maximus, hamstrings, and erector muscles such as the iliocostalis, longissimus, and spinalis, etc. are sufficient. But inefficiency in hip muscles during cycling causes back flexion in hip muscles (hips fall back), which is named the clinical hip angle [9]. In this respect, the insufficiency in hip muscles reveals erector spinal muscle inefficiency, which is accompanied by increases in the back curve, causing decreased performance and back pain. In order to determine the effects of the clinical hip angle degree on the back curve and thus decrease performance and back pain, clinical hip angle degrees were also analyzed in the study.

The clinical hip angle degree in different stages of the FTP test was found to be statistically significant between and within groups. Based on the results of the study, clinical hip angle degree increased significantly from the 1st minute of the FTP to the 20th minute of the FTP test. In addition, as time passed (i.e., fatigue increased), the clinical hip angle degree also increased. As it can be seen, the clinical hip angle may cause a back curve as well. Mechanical and anatomical analyses explain that clinical hip angle is caused by the inefficiency of the flexibility and mobility of hip muscles such as the hip extensor, gluteus maximus, hamstrings, and erector muscles such as the iliocostalis, longissimus, and spinalis, etc. [17, 19]. Despite its high prevalence, there is a paucity of high-quality research on the precipitating factors of lower back pain in mountain bikers [20]. According to Lebec et al.'s studies, hamstring shortness, anterior pelvic tilt, hip flexor hyperactivity [4], and deficiency of lumbo-sacral core stabilizers [2], also contribute to chronic lower back pain.

As increases in clinical angle degree cause an increased back curve, they also cause changes in body position and other joint positions. Based on the results of the study, increases in clinical hip angle degree were accompanied by increases in the angle between upper body and arms, which is named clinical shoulder angle degree in the literature [9].

Clinical shoulder angle degree was included in the study analysis, which showed that there were no statistically significant changes in clinical shoulder angle degrees during the different stages of the FTP test ($p>0.05$) or between groups ($p>0.05$). Based on these results, increases in the back curve during the different FTP stages were not related to the clinical shoulder degree. Therefore, it can be concluded that increases in the back curve during the different FTP stages are related to clinical hip angle degree.

According to the study results and parallel to the literature data, in our study, it was concluded that the back curve increases during different stages (1st, 5th, 10th, 15th, and 20th minute of the FTP), which may be related to the clinical hip angle degree. Also, the average of the clinical hip angle degree, back curve, and clinical shoulders angle degree showed more dramatic increases in the back curve in the first five and last minutes of the FTP test. However, there was no significant increase or decrease in the back curve or clinical angles between five to fifteen minutes of the FTP test. Besides this, in parallel with the increases in fatigue, the differences between the control and experimental groups became clear.

To be clearer, the increased back curve is undesirable for the cyclist. Normally, the lower back has a lordotic curve that causes the lumbar spine to bike, and this curve is flattened. Cyclists prefer to ride with a “flat back” because it improves aerodynamics. However, the flattening of the lordotic curve, especially when it becomes the opposite of lordosis, can place increased pressure on the anterior aspect of the lumbar vertebrae, and intervertebral disc herniation can result [17].

All previous information leads us to understand that, during cycling, low back curve, low clinical hip, and shoulder angle degree may improve cyclists' performance, avoid injury risk, and decrease back pain.

CONCLUSION

Cyclists tend to develop back problems because the riding position places anatomical stressors on the curved spine. Instead of holding a lordotic curve, cyclists like to ride with a “flat back” because it improves aerodynamics. However, when the lordotic curve is flattened, it can place increased pressure on the anterior aspect of the lumbar vertebrae, and intervertebral disc herniation can result. Especially if the back curve increases contrary to the lordotic curve, it causes undesirable aerodynamics, which leads to decreased performance and back pain.

The increased back curve occurs through increases in clinical hip and shoulder degrees. Therefore, the inefficiency of hip muscles' flexibility and mobility stimulates a back curve, which in fact occurs when the force of the erector spinal muscles such as the iliocostalis, longissimus, and spinalis, and the latissimus dorsi, rhomboid major, teres major, teres minor, infraspinatus, and trapezius is insufficient.

To avoid the risk of injury, back pain, undesirable aerodynamics, and performance decreases, besides force and endurance, the development of flexibility and mobility is unavoidable. Besides this, the development of the erector muscles such as the iliocostalis, longissimus, and spinalis may avoid increases in the back curve as an undesirable aerodynamic and anatomic position.

SUGGESTIONS

The bike-fit of the athletes will correct the posture disorders on the bike and prevent overuse injuries that they will experience in the future.

Cycling goes beyond the body's proper posture, in the gym, you should focus on developing these back muscles to avoid future aggravation. While flexibility exercises to be done 1-2 days a week should not be missing from the training of cyclists, post-training stretching exercises are also important.

CONFLICT OF INTEREST

The authors reported no potential conflict of interest.

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