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Original Article

Effect of cycling exercise on lumbopelvic control performance in elite female cyclists

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Abstract

Objectives: The purpose of the present study is to assess the effects of an intense cycling training session on the stability of the lumbopelvic-hip complex through two dynamic exercise tests - the single-leg-deadlift (SLD) and a variation of the bird-modified dog (BD), via the OCTOcore application. **Methods**: Thirty-one elite female road cyclists were self-evaluated with their own smartphones, before and immediately after finishing their training sessions. Right, left and composite were measured for each exercise test. **Results**: There was a significant time effect on performance for both the SLB and BD tests (p<0.05; η^2=0.137), and the SLD and BD tests were increased with respect to the pre-test at 15% and 17%, respectively. **Conclusion**: An intense cycling training session produced significant alterations in lumbopelvic behavior in the elite female cyclists. The OCTOcore application demonstrated that it was a sensitive tool in detecting these changes and it could easily be used by the cyclists themselves.

Keywords: Assessment, Mobile Technology, Core Stability, Session Intensive, Dynamic Test

Introduction

Lumbopelvic hip complex stability aims to maintain the spine within its physiological limits, preserving structural integrity against external and internal disturbances. Moreover, this complex involves the basis of the kinetic chain from which force is transferred to the distal segments, playing a key role in the joint load supported[1,2]. In this sense, the pedaling action in cycling represents a paradigm, due to the mechanical force transmission to the feet, accompanied by the lumbar and thoracic flexion positions[3,4].

Several studies have shown that the stability and resistance of this complex can lead to greater performance of the torso on the saddle, which contributes to the optimizing of lower extremities' mechanics during pedaling[5,6]. Fatigue alters lumbopelvic-hip stability in high intensity cycling[6,7], and this can lead to poor lumbopelvic-hip complex stability, and thereby to poor alignment of lower extremities during pedaling or a deficit in the transfer or force applied to pedals[5].

Several authors have remarked upon the importance of assessing the cyclist's musculoskeletal status to predict possible compensatory movements that may occur during pedaling to alter performance[5], causing discomfort or overuse injury[7-10]. Disorders from movement patterns of the lumbopelvic-hip complex in cycling have been mainly analyzed during pedaling assessing the electromyographic activity (EMG) of the main muscles involved[8]. Kinematic evaluation has been implemented as well, through biomechanical motion capture systems, showing high reliability values (ICC=0.84–0.96)[5,11,12]. Finally, the ROM has been analyzed through different electronic devices such as the Spinal Mouse (ICC=0.84–0.97)[4], 13 or BodyGuard (ICC≥0.97)[13] used by Hoof et al.[14].

Lumbopelvic complex stability has been successfully evaluated in the active population[15-17]. In this sense, mobile technology allowing evaluations of dynamic stability through its accelerometers, and the study by Guillén-Rogel et al., (2019) have shown the high reliability of the OctoCore system to assess lumbopelvic complex stability in two dynamic exercises[16].

Unfortunately, scientific evidence on musculoskeletal

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assessment in cycling is limited. Furthermore, there is some controversy regarding the validity of the tools applied for the lumbopelvic stability analysis[18]. The Functional Movement Screen (FMS) battery, which requires high experience of the evaluator[19], as well as the front plank test[20], the seat and reach, assessment of the hip ROM through a goniometer in supine position[10], or the assessment of the anterior pelvic tilt in a sitting position, with knees extended through the SmartLevels device[21], are tests that have not demonstrated a clear validity to assess lumbopelvic stability.

To our knowledge, there are no previous studies evaluating the effects of intense cycling training on lumbopelvic stability in female cyclists. Therefore, the present study aims to assess the following: (1) The effects of an intense cycling training session on lumbopelvic-hip complex stability for two dynamic exercise tests (SLD and the variation on BD) via the OCTOcore app; (2) Whether there are differences between the SLD test and the modified BD variations in assessing stability in female cyclists after high intensity exercise.

Materials and Methods

Experimental Design

Prior to the assessments all participants provided written informed consent for the use of their data in this study. In the case of the under the age of 18 years, written informed consent was obtained from each subject's parent(s) or legal guardian(s). The research project was conducted according to the Declaration of Helsinki and was approved by the CyMO Research Institute granted Ethical approval to carry out the study (1.200.538).

Participants

Thirty-one elite female road cyclists (age: 19.8±5.3 years; body weight: 53.6±2.8 kg; height: 164.8±3.4 cm) volunteered to participate in this study. All subjects were classified as post-puberal. Only experienced cyclists were involved in this study. They were members of a national club that participate in the road competitions of the national and international calendar, with a training routine based on six weekly sessions during the regular season. All participants were injury-free from three months ago, especially in terms of ankle joints and feet. The exclusion criteria were as follows: (1) Any cardiovascular, respiratory, abdominal, neurological, musculoskeletal, or other chronic disease; (2) any symptoms that could affect the musculoskeletal system; (3) self-reported regular menstrual cycles and not use oral contraceptives; (4) be in between the late follicular and early luteal phase.

Procedures

The cyclists completed two testing sessions at intervals of 24 hours. In the first session, each cyclist used her smartphone to test the reliability of the OCTOcore app for the two test modalities (partial range SLD and BD variation). The administration order of the tests were randomized among the cyclists, with five minutes of recovery between each test, as outlined by Guillén-Rogel et al.[16] (2019). In the second session, each cyclist performed the same two tests (SLD and BD) before and after the indoor training session, using their own bike rollers. The order of exercises of the core stability tests were randomized among the cyclists again.

Measurements

OCTOcore App

The core stability was assessed following the protocol, previously described by Guillén-Rogel et al.[16] (2019). The OCTOcore app (Check your MOtion, Albacete, Spain) was used to collect data, that presented high intraclass correlation coefficient (ICC) values (0.73-0.96) with low coefficient of variation (0.9% to 4.8%)[16]. The values of the standard error of measurement and the minimum detectable difference were 0.6 to 1.5 mm/s^{-2} and 2.1 to 3.5 mm/s^{-2}, respectively[16].To do this, the application was installed on the cyclists' smartphones and used by them to self-evaluate their lumbopelvic-hip complex stability. The mobile phone was placed through a belt on the midline of the subject's back, at the level of the iliac crests at the fourth lumbar vertebra. This application produced three measures for each exercise test:

I. Right ($mm·s^{-2}$)
II. Left ($mm·s^{-2}$)
III. Composite ($mm·s^{-2}$)

Single-Leg Deadlift (SLD)

The cyclists began the test standing with their backs to the wall, at a distance of two feet from the wall, with their feet positioned at the width of their hips, parallel to each other, and their arms crossed over their chests. During the entire test, each subject was asked to look forward. Following the indication of the mobile application, "left" or "right," the subject was instructed to touch the wall with the indicated heel, keeping the trunk and leg straight and slightly leaning the trunk forward. Afterwards, they returned to the starting position, both feet parallel and resting on the ground, waiting for the next instruction of the application. Each exercise (left or right) was performed for 30 repetitions as a familiarization trial. After a three-minute break, participants performed 50 repetitions.

Bird-dog (BD) Variation

According to Guillén-Rogel et al., (2019) in the "bird" or quadruped exercise, the contralateral upper and lower extremities are raised horizontally from the initial quadruped position. The lumbar spine and pelvis have to be kept in a neutral position, and the trunk kept as still as possible. The knees should be bent at 90°, and the toes on the ground facing forward. The cyclists performed repetitions, according to the random order marked by the application "left" or "right" stretching the selected leg with dorsiflexion of the ankle, lifting the opposite arm, parallel to the ground, with a

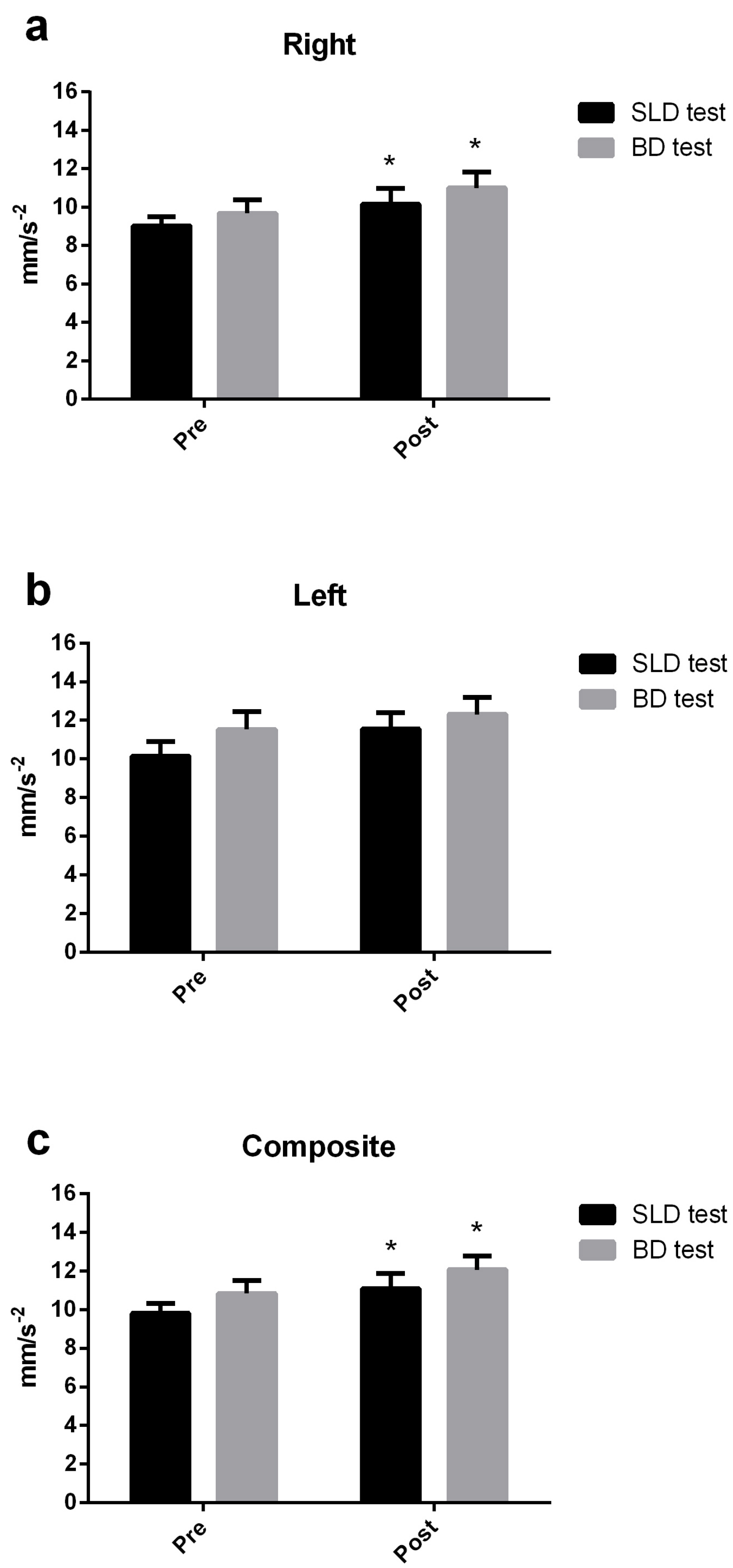

Figure 1. Effects of an intense training session on the lumbopelvic complex during the dynamic stabilometric tests: Single-leg deadlift (SLD), and bird-modified dog (BD) variation. (a) right side; (b) left side; (c) composite side. (*) Statistical difference from to pre-session ($p \leq 0.05$).

90° shoulder abduction and external rotation (thumb facing the ceiling)[16]. Each exercise (left or right) was performed for 30 repetitions as a familiarization trial. After a three-minute break, participants performed 50 repetitions.

Indoor Training Session

Each cyclist performed the training session on their own bike that was situated on bike rollers indoor trainers (RooDol). The session was according to the British Cycling Digital Training Plans and consisted of a 20-minute warm-up. The main part consisted of seven blocks of six-minute ramped intervals, which started with two minutes in the sweet-spot [88-93% of functional threshold power (FTP)], then two minutes in the 94-106% of FTP, and the last two minutes in the 106-120% of FTP, followed by easy recoveries for five minutes (spin easy against minimal resistance). The cool down included 10 minutes of spin easy. Each subject used a medium gear that allowed her to maintain 90 rpm during the efforts. The subject used her power training zones adjusted to functional threshold power, as described by Allen et al.[22], (2014) using visual feedback from a monitor on the handlebars.

Internal Workload

The heartrate [beats per minute (bpm)] was continually monitored using the heartrate monitor to supplement the powermeter. The subjective internal load of the session was measured using the session rating of perceived exertion method, as established by Borg's category-ratio (Borg CR10), at the end of the session[23]. This method has been previously validated in cycling for use in the prescription of training for continuous- and alternated-intensity exercises, and it has shown a good correlation between Borg CR10 and Borg RPE[24,25].

Statistical Analyses

Data was analyzed using the PASW/SPSS Statistics 20 (SPSS Inc, Chicago, IL), and the significance level was set at $p \leq 0.05$. The normality of the data was checked and subsequently confirmed via the Shapiro-Wilk test. Dependent variables (right, left, and composite) were evaluated with a two-way repeated measures analysis of variance (ANOVA) on a time x test. When a significant F-value was achieved, pairwise comparisons were performed using the Bonferroni post hoc procedure. Dependent variables of each test were re-measured on a different day to determine the test-retest repeatability of such measurements, by calculating the intraclass correlation coefficient ($ICC_{3,1}$)[26]. The effect size statistic (η^2) was analyzed to determine the magnitude of the effect, independent of sample size; values are presented as mean ± SEM. The level of significance was fixed at $p \leq 0.05$.

Results

The ICCs were greater than 0.84, indicating a high level of reproducibility in assessing the dependent variables - the SLD test (right: 0.87; left: 0.84; composite: 0.90) and BD test (right: 0.86; left: 0.85; composite: 0.90).

For right side, a time effect was observed ($p<0.05$; $\eta^2=0.191$), and poor performance was registered for both tests after the indoor training session. The SLD and BD were increased with respect to the pre-tests at 16% and 23%, respectively (Figure 1a). There were significant differences between the SLD and BD tests ($p<0.05$; $\eta^2=0.145$). No time x test interaction effect was detected for the right side values ($p>0.05$; $\eta^2=0.094$).

To the left side, there were no significant time effects for the SLD and BD tests ($p>0.05$; $\eta^2=0.070$), and both had increased with respect to the pre-test at 21% and 15%, respectively (Figure 1b). There were no significant differences between SLD and BD tests ($p>0.05$; $\eta^2=0.172$). No time x test interaction effect was detected for the composite values ($p>0.05$; $\eta^2=0.001$) or the left side values ($p>0.05$; $\eta^2=0.010$).

For composite, a time effect was observed ($p<0.05$; $\eta^2=0.137$), and the SLD and BD tests were increased with respect to the pre-test at 15% and 17%, respectively (Figure 1c). There were significant differences between the SLD and BD tests ($p<0.05$; $\eta^2=0.103$). No time x test interaction effect was detected for composite values ($p>0.05$; $\eta^2=0.001$).

Discussion

Our findings showed that an intense training session in experienced cyclists produced alterations on the lumbopelvic complex. Specifically, it was evidenced that after the cycling session, the athletes obtained a worse performance during the dynamic stabilometric assessment (SLD and BD), performed via the OCTOcore application. This tool was sensitive when objectifying the modifications induced as consequence of the moderate-high fatigue (RPE=8.6±0.6), because of a strenuous workout session. This was based on the findings of Arney et al. (2019) who found the following values in response to different intensities in interval exercise sessions, using the Borg CR10 to correlate with the Borg RPE, % heart rate reserve, and blood lactate (easy exertion=3.1±7.3; moderate exertion=6.5±1.2; hard exertion=8.9±1.1)[24].

The SLD and BD tests analyze lumbopelvic stability with greater intervention of the foot or shoulder girdle, respectively. Thus, the results of the present study show that the effects of intensity cycling affect the lumbopelvic complex stability both in movements involving the foot and shoulder girdle. To our knowledge, this is the first study to analyze the effect of an intense cycling session on these variables in trained cyclists. However, there is evidence on possible associations between the stability of the lumbopelvic complex and its effects on cycling performance.

Rannama et al. (2017) related body control measured through the FMS test of the cyclist with central stability during pedaling, at different intensities, showing that cyclists with a lower score (≤14 points) in the test moved their bodies more on the saddle, due to low central stability and ability to control their body movements[7]. Along the same lines, the existence of muscular synergies between the upper extremities and the trunk, as well as the influence that the stability of the latter may have on the increase of the articular moments of the upper extremities[27,28] or in lumbar flexion[6,8], has been previously indicated by the scientific literature. Finally, it is important to note that it has been previously shown that fatigue of the lumbopelvic complex causes alterations in kinematic variables during pedaling, so its stability represents a key factor from the biomechanical perspective of cycling[5].

The results of our study demonstrated that both SLD and BD tests were sensitive to high intensity interval training. This reinforces ideas from previous studies on the relationship between central stability and lower and upper extremity mechanics during cycling[5,7]. The previous findings showed after-core fatigue protocol increased the total frontal plan knee motion and total sagittal plane knee and ankle motion values by 13.4-54.3%, during the incremental test in cycling protocol[5]. This could be because the cyclist, when they need to increase the power on the pedals, moves towards the tip of the saddle, which requires a greater stabilization of the trunk muscles to control the force from the upper to the lower extremities[7]. In this sense, our tool allows to monitor the intensity of the session by detecting the appearance of possible compensations that may cause a deficiency in pedaling mechanics, although its potential to quantify the load of the session must be explored in future studies.

Conclusion

In conclusion, the current study shows that an intense training session can produce significant alterations in lumbopelvic behavior in elite female cyclists. Furthermore, the OCTOcore app was sensitive in detecting these changes and could easily be used by the cyclists themselves. This makes it a useful and promising tool in the future for daily training routines.

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References

1. Kibler W Ben, Press J, Sciascia A. The Role of Core Stability in Athletic Function. Sports Medicine 2006; 36(3):189-198.
2. Sulowska I, Mika A, Oleksy Ł, Stolarczyk A. The Influence of Plantar Short Foot Muscle Exercises on the Lower Extremity Muscle Strength and Power in Proximal Segments of the Kinematic Chain in Long-Distance Runners. BioMed Research International 2019;2019.
3. FitzGibbon S, Vicenzino B, Sisto SA. Intervention at the foot-shoe-pedal interface in competitive cyclists. International Journal of Sports Physical Therapy 2016; 11(4):637-650.
4. Muyor JM, López-Miñarro PA, Alacid F. Spinal posture of thoracic and lumbar spine and pelvic tilt in highly trained cyclists. Journal of Sports Science and Medicine 2011;10(2):355-361.
5. Abt JP, Smoliga JM, Brick MJ, Jolly JT, Lephart SM, Fu F. Relationship between cycling mechanics and core stability. Journal of Strength and Conditioning Research 2007;21(4):1300-1304.
6. Wiest M, Diefenthaeler F, Mota C, Carpes F. Changes in postural stability following strenuous running and cycling. Journal of Physical Education and Sport 2011;11(4):406-413.
7. Rannama I, Pedak K, Bazanov B, Port K. Cycling specific postural stability during incremental exercise: The relationship with cyclists functional movement screen score. Journal of human sport & Exercise 2017;12:83-95.
8. Burnett AF, Cornelius MW, Dankaerts W, O'Sullivan PB. Spinal kinematics and trunk muscle activity in cyclists: A comparison between healthy controls and non-specific chronic low back pain subjects - A pilot investigation. Manual Therapy 2004;9(4):211-219.
9. Hadala M, de Bernardo N, Vera P, Laiz C, Barrios C. Pre-season screening of core muscle balance and control tests in the lumbar spine in professional road cyclists can we prevent uncontrolled movement? British Journal of Sports Medicine 2011;45(4):351-351.
10. Wadsworth DJS, Weinrauch P. The role of a bike fit in cyclists with hip pain. A clinical commentary. International Journal of Sports Physical Therapy 2019; 14(3):468-486.
11. Sayers MGL, Tweddle AL. Thorax and pelvis kinematics change during sustained cycling. International Journal of Sports Medicine 2012;33(4):314-319.
12. Bourdon E, Mavor M, Hay DC. Assessment of Three-Dimensional Trunk Kinematics and Muscle Activation during Cycling with Independent Cranks. Journal of Sports Science and Medicine 2017;16(4):536-542.
13. O'Sullivan K, Verschueren S, Pans S, Smets D, Dekelver K, Dankaerts W. Validation of a novel spinal posture monitor: Comparison with digital videofluoroscopy. European Spine Journal 2012;21(12):2633-2639.
14. Van Hoof W, 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.
15. Butowicz CM, Ebaugh DD, Noehren B, Silfies SP. Validation of two clinical measures of core stability. International journal of sports physical therapy 2016;11(1):15-23.
16. Guillén-Rogel P, Franco-Escudero C, Marín PJ. Test-retest reliability of a smartphone app for measuring core stability for two dynamic exercises. Peer J 2019;2019(8).
17. Perrott MA, Pizzari T, Opar M, Cook J. Development of Clinical Rating Criteria for Tests of Lumbopelvic Stability.

Rehabilitation Research and Practice 2012;2012:1-7.
18. Okada T, Huxel KC, Nesser TW. Relationship Between Core Stability, Functional Movement, and Performance. Journal of Strength and Conditioning Research 2011;25(1):252-261.
19. Kraus K, Schütz E, Taylor WR, Doyscher R. Efficacy of the functional movement screen: A review. Journal of Strength and Conditioning Research 2014; 28(12):3571-3584.
20. Asplund C, Ross M. Core stability and bicycling. Current Sports Medicine Reports 2010;9(3):155-160.
21. McEvoy M, Wilkie K, Williams M. Anterior pelvic tilt in elite cyclists - A comparative matched pairs study. Physical Therapy in Sport. Published online 2007:22-29.
22. Allen H, Goggan A. Entrenar y Correr Con Potenciómetro. 1a. (Paidotribo, ed.).; 2014.
23. Jameson C, Ring C. Contributions of local and central sensations to the perception of exertion during cycling: Effects of work rate and cadence. Journal of Sports Sciences 2000;18(4):291-298.
24. Arney BE, Glover R, Fusco A, et al. Comparison of RPE (rating of perceived exertion) scales for session RPE. International Journal of Sports Physiology and Performance 2019;14(7):994-996.
25. Zinoubi B, Zbidi S, Vandewalle H, Chamari K, Driss T. Relationships between rating of perceived exertion, heart rate and blood lactate during continuous and alternated-intensity cycling exercises. Biology of Sport 2018;35(1):29-37.
26. Weir JP. Quantifying test-retest reliability using the intraclass correlation and the SEM. Journal of Strength and Conditioning Research 2005;19(1):231-240.
27. Costes A, Turpin NA, Villeger D, Moretto P, Watier B. Influence of position and power output on upper limb kinetics in cycling. Journal of Applied Biomechanics 2016;32(2):140-149.
28. Turpin NA, Costes A, Moretto P, Watier B. Upper limb and trunk muscle activity patterns during seated and standing cycling. Journal of Sports Sciences 2017;35(6):557-564.