

Original Article

Short-term effects of lumbopelvic complex stability training in elite female road cyclists

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Abstract

Objectives: The purpose of this study was to determine the effects of short-term lumbopelvic stability training on muscular endurance and stability in elite female cyclists. **Methods:** Twenty-four female road cyclists were randomly allocated to a core training group (CTG, n=12) or control group (CG, n=12). In addition to their scheduled training the CTG performed a core training program, that consisted of 6 core exercises performed in a session every other day until a total of 8 training sessions were completed. The CG did not receive the core training program and completed their scheduled training. The lumbopelvic-hip complex was assessed pre- and post-core program included the following exercises: single leg deadlift (SLD), bird-dog (BD), plank test (PT), and side-bridge plank test (SPT). **Results:** In comparison to CG, CTG significantly improved the time to failure in PT, SPT-Left, and SPT-Right ($p<0.05$). Further, CTG resulted in a significant decrease in SLD ($p<0.05$) compared to CG for the three accelerometry measures. **Conclusion:** The present results indicate that following 8 sessions of lumbopelvic stability training muscular endurance and core stability were enhanced.

Keywords: Core Endurance, Core Program, Core Stability, Dynamic Exercise, Mobile Technology

Introduction

In recent times, it has been shown that sports practice requires greater strength and lumbopelvic-hip complex stability to preserve the structural integrity of the spine during sports movements compared to daily activities¹⁻³. Trunk control on the pelvis favors to the distal segments, playing a key role in the joint load supported^{2,4,5}. Cycling is a sport in which the athlete transmits force to the pedals, while maintaining a position of lumbar and thoracic flexion⁶. Several studies have shown that the lumbopelvic complex stability and strength lead to greater control of trunk on the saddle, which optimizes the mechanics of the

lower extremities and the control of the transfer of the force applied to the pedals^{7,8}.

Maintaining good stability of this complex depends mainly on an adequate interaction between the passive, active and neural subsystems^{3,9,10}. In this sense, exercise programs focused on improving core stability should be composed of processes aimed at muscle strengthening and neuromuscular control of this complex¹¹⁻¹⁴.

Previous research has demonstrated that training programs aimed at the neuromuscular control of the trunk and hip, increased the control of alignment of the lower extremities and reduced the risk of injury^{15,16}. Although there is a lack of consensus on the duration of these programs, the recommendations of the scientific literature suggest that a program focused on training the lumbopelvic complex should establish a frequency of 2 to 4 sessions over a period of 4 to 8 weeks^{14,17,18}. However, the selection of the exercises to be applied in these programs generates greater controversy in the literature, without clarifying which exercises are most effective for improving the endurance, stability or strength of this complex^{9,10,19-22}.

To our knowledge, there are no previous studies evaluating the effects of a training program for the lumbo-pelvic hip

Pedro J. Marín is the designer of the OCTOcore application. The remaining authors have nothing to declare.

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complex on the stability and endurance of this complex in female cyclists. Therefore, the aims of the present study was to determine the effects of a short-term lumbopelvic-hip complex stability training on adaptations in core stability and endurance. We hypothesized that short-term lumbopelvic – hip complex stability training program would improve core stability and endurance.

Materials and methods

Experimental Design

The core stability and trunk muscle endurance of each cyclist were assessed on two sessions, before and after an 8-session training period according to previous study¹⁴. The initial session (pre-test) was one day before starting the training program and the second (post – test) was one day after the training program finished, respectively. All subjects provided written informed consent for the use of their data in this study. The research project was conducted according to the Declaration of Helsinki and was approved by the Research Institute granted Ethical approval to carry out the study (1.200.546).

Participants

Twenty-four female road cyclists volunteered to participate in this study. They were members of a national club that participated in the road competitions of the national and international calendar with a training routine based on six sessions weekly during the regular season. Subjects were randomly allocated into two groups, the core training group (CTG) (n=12, age: 18.83±3.87 years, body weight: 52.04±2.11 kg, height: 163.59±2.37 cm) and control group (CG) (n=12, age: 17.50±2.84 years, body weight: 55.75±2.80 kg, height: 165.92±3.90 cm).

All subjects were injury-free from 3 months ago. Exclusion criteria were: (1) any cardiovascular, respiratory, abdominal, neurological, musculoskeletal, or other chronic disease and (2) any symptoms that could affect the musculoskeletal system.

Procedures

During the session test, each subject performed the Single Leg Deadlift (SLD), the Variation of bird – dog (BD), the Plank test (PT) and the Side-bridge plank test (SPT) with each side randomly, resting for 3 minutes between exercises core stability test and for 5 minutes between exercises trunk muscle endurance.

Core stability assessment

OCTOcore App

Core stability was assessed following a previously protocol described by Guillén-Rogel et al. (2019)²³. 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%)²³. To do this, this application was installed on the cyclists' smartphones to self – evaluate lumbopelvic –hip complex stability. The mobile phone was placed, through a belt, on the midline of the cyclist's back at the level of the iliac crests at the level of the fourth lumbar vertebra. This application produced three accelerometry measures in each exercise test²³:

- I. Right (mm•s⁻²)
- II. Left (mm•s⁻²)
- III. Composite (mm•s⁻²)

Single Leg Deadlift (SLD)

Cyclist 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 (Figure 1). 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 with slightly leaning the trunk forward. Afterwards, the subject returned to the starting position, both feet parallel and resting on the ground, to wait for the next indication of the application.

Variation of bird – dog (BD)

According to Guillén - Rogel et al. (2019)²³ 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 had 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 (Figure 1). The cyclists performed repetitions according to the random order marked by the application, “left” or “right”, the subjects stretching the selected leg with dorsiflexion of the ankle, with lifting the opposite arm remains parallel to the ground, with 90-degree shoulder abduction and external rotation (thumb facing the ceiling)²³.

Trunk muscle endurance assessment

The trunk muscle endurance was assessed by plank test and side-bridge plank test described by several authors²⁴⁻²⁶. Both tests are reliable methods for assessing core endurance, high values ICC (0.97 and 0.99, respectively)^{25,26}.

Plank test (PT)

The subject maintained a plank position, an upside-down bridge supporting their own body weight on the forearms and feet. Subjects were instructed to keep ankles in plantar flexion, legs extended and together, back straight, elbows shoulder-width apart, hands together extended forward, and head in a neutral position (Figure 1). The recording of time stopped when some segment of the body of the subjects did not remain parallel to the ground. The maximum time (seconds, s) that the subject was able to hold the correct test position was recorded²⁴.

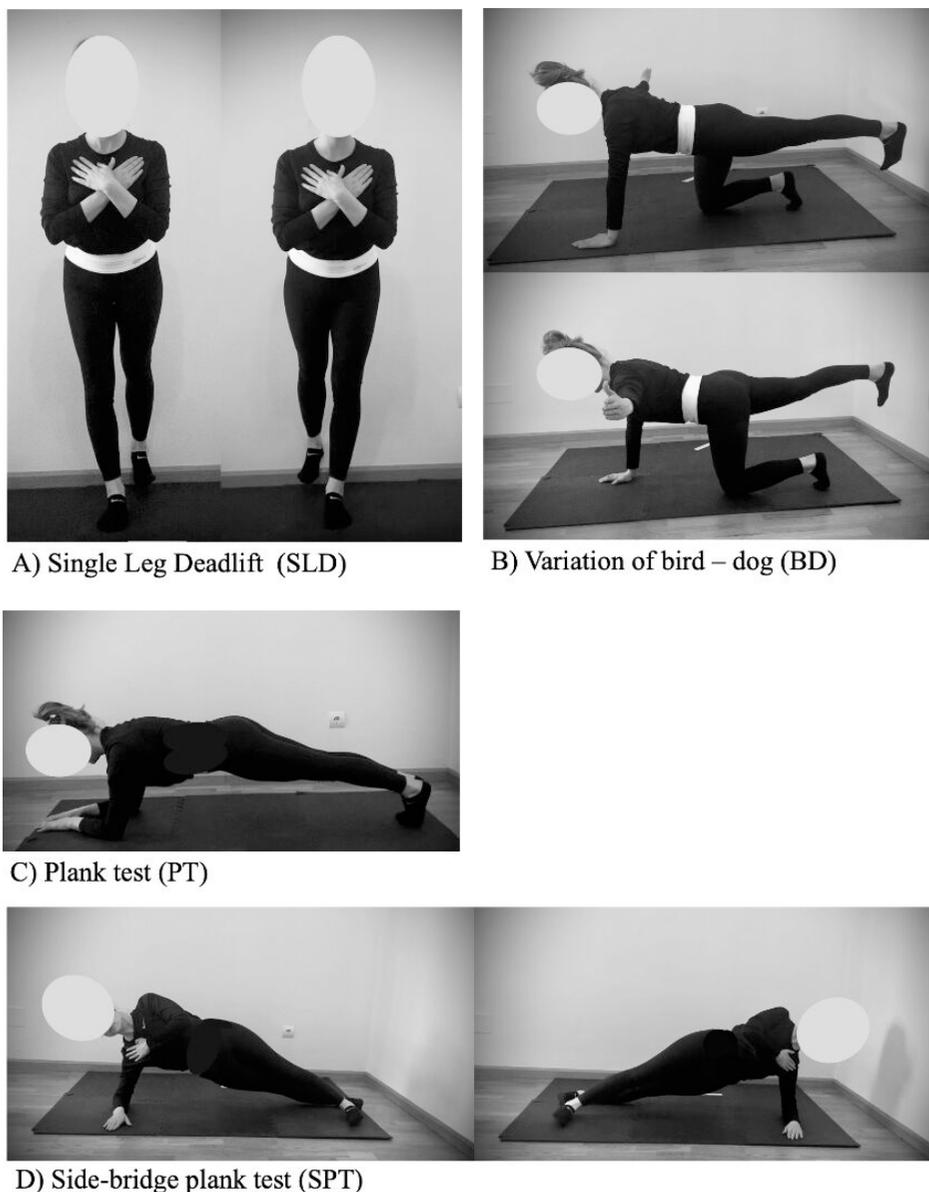


Figure 1. (A), (B): Core stability tests and (C), (D): Trunk muscle endurance tests.

Side-bridge plank test (SPT)

The subject started from a lateral lying position and was asked to raise their hips to zero degrees to maintain a straight lateral bridge position supporting her body weight on the forearm, elbow and foot on the same side. The foot on the opposite side rested on the ground in front of the lower foot and the arm from the opposite side was held on the chest with the hand touching the opposite shoulder²⁶ (Figure 1). The maximum time (seconds, s) that the subject was able to hold the correct test position was recorded. The sides were randomized between cyclists.

Core Training Program

The CTG performed a core training program, that consisted of 6 core exercises performed in a session every other day until completing a total of 8 training sessions of 20 minutes long in addition to their scheduled training. (Figure 2). The following 6 exercises were visually demonstrated and verbally instructed by the investigator after the first session (A) short foot exercise in rotation, (B) balance, (C) anterior plank with leg raises, (D) dead bug, (E) bird – dog, (F) bridge single leg. These exercises have been used in previous studies to determine the effects of core stability^{18,27-33}. The training

	SESSION 1	SESSION 2	SESSION 3	SESSION 4	SESSION 5	SESSION 6	SESSION 7	SESSION 8
 <p>A) Short foot exercise in rotation</p>	3 Reprs. R30s	3 Reprs. R30s	3 Reprs. R30s	4 Reprs. R30s	4 Reprs. R30s	4 Reprs. R30s	5 Reprs. R30s	5 Reprs. R30s
 <p>B) Balance</p>	2 Sets x 10 Reprs. R30s	2 Sets x 10 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 16 Reprs. R30s	2 Sets x 16 Reprs. R30s
 <p>C) Anterior plank with leg raises</p>	2 Sets x 10 Reprs. R30s	2 Sets x 10 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 16 Reprs. R30s	2 Sets x 16 Reprs. R30s
 <p>D) Dead bug</p>	2 Sets x 10 Reprs. R30s	2 Sets x 10 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 16 Reprs. R30s	2 Sets x 16 Reprs. R30s
 <p>E) Bird - dog</p>	2 Sets x 10 Reprs. R30s	2 Sets x 10 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 16 Reprs. R30s	2 Sets x 16 Reprs. R30s
 <p>F) Bridge single leg</p>	2 Sets x 10 Reprs. R30s	2 Sets x 10 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 12 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 14 Reprs. R30s	2 Sets x 16 Reprs. R30s	2 Sets x 16 Reprs. R30s

Figure 2. Description of the core program and its progression along the 8 sessions.

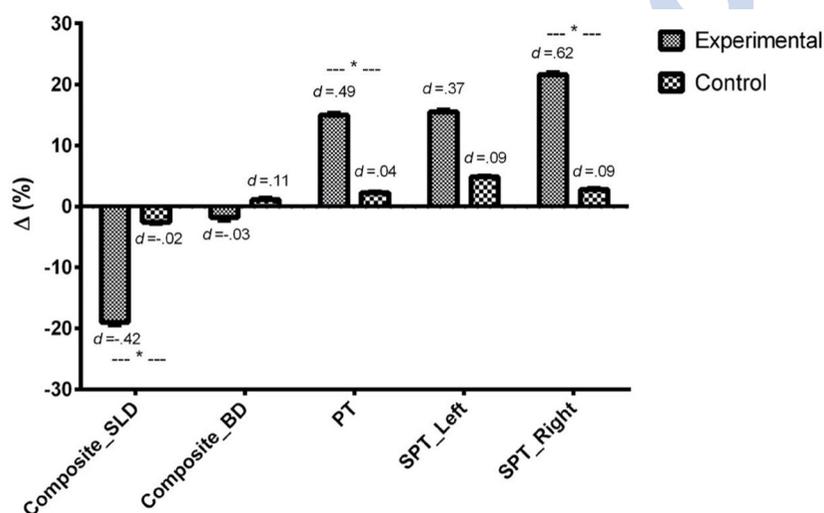
focused on stabilizing the core and the body. In addition to keeping the trunk as stable as possible, the subject used the OCTOcore app to randomly mobilize the right or left limb in all exercises, except exercise A) short foot rotation exercise. The level of load was increased every second session. Except for exercise (A) that its load was increased

every third session. The exercises are relatively well balanced, targeting the core muscles (abdominals, hip flexor/extensor muscles, and back extensor muscles). All exercises were fully instructed and demonstrated to ensure understanding of proper mechanics after the pre-workout test. The CG did not receive the core training program.

Table 1. Effects of core training program in the endurance and the stability core test for experimental (CTG) and control (CG). The values are expressed as mean \pm SD.

	Experimental (CTG) (n=12)				Control (CG) (n=12)			
	Pre Mean \pm SD	Post Mean \pm SD	<i>p</i>	Effect size (<i>d</i>)	Pre Mean \pm SD	Post Mean \pm SD	<i>p</i>	Effect size (<i>d</i>)
Composite_BD (mm*s ⁻²)	9.94 \pm 2.74	10.02 \pm 2.54	0.930	0.03	9.59 \pm 2.93	9.90 \pm 2.57	0.710	0.11
Composite_SLD (mm*s ⁻²)	9.18 \pm 2.46	8.05 \pm 2.91	0.035	-0.42	8.28 \pm 0.97	8.26 \pm 1.41	0.947	-0.02
PT (s)	116.27 \pm 39.74	134.88 \pm 36.08	0.000	0.49	74.62 \pm 32.09	75.72 \pm 29.54	0.519	0.04
SPT_Left (s)	59.07 \pm 27.73	68.15 \pm 21.28	0.021	0.37	50.88 \pm 25.34	53.20 \pm 24.07	0.202	0.09
SPT_Right (s)	62.52 \pm 25.21	80.71 \pm 33.66	0.010	0.62	50.32 \pm 21.69	52.30 \pm 21.73	0.318	0.09

Notes. BD (Bird-dog); SLD (Single leg deadlift); PT (Plank test); SPT (Side-bridge plank test); Effect size (*d*). Statistical difference from to pre - session ($p \leq 0.05$).

**Figure 3.** Percentage change between pre- and post core training program in the endurance and the stability core test for experimental (CTG) and control (CG) group in Plank test (PT) (s); Side-bridge plank test (SPT_Left; SPT_Right) (s); Variation of bird - dog (BD) (mm*s⁻²); Single Leg Deadlift (SLD) (mm*s⁻²). The values are expressed as percentage \pm SD. Effect size (*d*). (*) Statistical difference from control group ($p \leq 0.05$).

They followed their scheduled training and were instructed to report any changes to the investigator. Additionally, the CTG received a copy and video of the exercise instructions.

Statistical Analyses

Data were analyzed using PASW/SPSS Statistics 20 (SPSS Inc, Chicago, IL). The normality of the data was analyzed through the Shapiro-Wilk test. Comparisons of dependent variables between treatment conditions (i.e. Experimental vs. Control) were analyzed by Student's paired t-test. Dependent variables (pre-test and post-test) were analyzed using repeated-measures of variance analysis with two-factor ANOVA (group x time). When a significance F-value was achieved, pairwise comparisons were performed using

the Bonferroni post hoc procedure. Values are shown as mean \pm SD. Additionally, effect size statistic, *d*, was analyzed to determine the magnitude of the effect independent of sample size. Effect sizes (ES) were analyzed to determine the magnitude of an effect independent of sample size (the difference between the means divided by the pooled SD). ES of 0.5 and below was considered *low*, 0.51-0.8 considered a *medium* ES, and 0.81 and above a *large* ES. The level of significance was set at $p \leq 0.05$.

Results

In the core stability assessment, for the CTG there was no significant change in mm*s⁻² for BD ($p > 0.05$; $d = 0.03$). However, there was a significant decrease in mm*s⁻² for

SLD ($p < 0.05$; $d = -0.45$) (Table 1). For the CG there was no significant changes in $\text{mm} \cdot \text{s}^{-2}$ for BD ($p > 0.05$; $d = 0.11$), and SLD ($p > 0.05$; $d = -0.02$) (Table 1), (Figure 3).

In the trunk muscle endurance assessment, for the CTG there was significant increase in time for all dependent variables, PT ($p < 0.05$; $d = 0.49$), SPT - Left ($p < 0.05$; $d = 0.37$), SPT - Right ($p < 0.05$; $d = 0.62$) (Table 1). For the CG there was no significant increase for any of variables, PT ($p > 0.05$; $d = 0.04$), SPT - Left ($p < 0.05$; $d = 0.09$), SPT - Right ($p > 0.05$; $d = 0.09$) (Table 1), (Figure 3).

Discussion

The purpose of our study was to investigate the effects of short-term lumbopelvic stability training on muscular endurance and stability of this complex in elite female cyclists. The results of our study demonstrated that the muscular endurance (PT and SPT) and the core stability in SLD exercise for three accelerometry measures were improved after 8 lumbopelvic stability training sessions.

Lack of consensus on the methods for assessment lumbopelvic endurance and stability limits the discussion of our results with previous studies. However, based on scientific evidence, the intensity, the focus of the exercises applied, and the duration of the program could be decisive in the effects on core endurance and stability^{14,18,34}.

Previous studies indicated that cyclist with low central stability in Functional Movement Screen (FMS) test moved their bodies more on the saddle³⁵, and that could affect the optimizing of lower extremities' mechanics during pedaling^{7,8}. Moreover, the fatigue of the lumbopelvic complex causes alterations in kinematic variables during pedaling⁷. Previously, strength training improved fatigue resistance³⁶ and it may be feasible that a 'core' program also has the ability to resist fatigue or reduce the decline of fatigue. Additionally, the current 'core' exercises are likely to promote spine stiffness/stability to enhance distal mobility, by stiffening the core it allows the proximal components of the hip muscles to produce more muscular force in the lower extremities³⁷ during pedaling.

The intensity of the exercises could produce adaptations of core endurance and/or stability. High-intensity exercises challenge postural control to a greater extent and thus, could favor a greater adaptation of core stability, while longer low-moderate intensity exercises mainly challenge trunk muscle endurance³⁸. According to Vezina et al. (2000), load exercises below 60% MVIC contribute to improving core endurance as a component associated with stability in dynamic exercises³⁴. Ebert et al. (2017)²⁰, classified bridge exercises and unilateral quadrupeds with contralateral movement, as moderate-high load exercises (21-60% MVIC). In our study, CTG showed a significant improvement for all core endurance tests (PT and SPT) and the SLD stability test, but not for the BD test. These adaptations could be due to the fact that the exercises in our study consisted of bridge and quadruped positions (i.e., anterior plank with leg raises, bird - dog, bridge single

leg) may have contributed a greater effect on trunk muscle endurance. In contrast the exercises applied in a single-leg position (i.e., short foot exercise in rotation and balance) may have provided greater intensity to improve the stability of the lumbopelvic complex in a single-leg position.

Szafraniec et al. (2020)¹⁴, examined lumbopelvic complex stability training for 8 sessions on weightlifters and reported significant improvements in dynamic balance and endurance of the trunk muscles in novice weightlifters. This is consistent with our findings in endurance tests and the SLD test for the CTG group and allows us to consider that possibly 8 core training sessions are insufficient to improve stability in the BD test. Further, not only does BD target the internal oblique on the side of the elevated arm, but the erector spinae is known to elicit the highest muscle activity of the contralateral limb³⁹. Thus, BD may not solely target one specific muscle and relies on the integration of various muscles to increase spine stability⁴⁰.

For cyclists and trainers including a 20-minute core program will not interfere and have any adverse effects with the concurrent cycling training. The advantages of the core program are that it does not require gym equipment, it can be performed in a small space and is time efficient for a cyclist that has a busy training schedule. The current results demonstrated improved core stability and endurance and that could contribute to maintaining lower-limb alignment to apply greater force production during pedaling that ultimately may enhance performance.

This study has certain limitations that must be acknowledged. First, the data from this study cannot be extrapolated to the general population, as the present study was conducted with a specific sample of female road cyclists. Moreover, this study determined the effects of short-term lumbopelvic-hip complex stability training on adaptations in core stability and endurance. However, the cycling performance enhancement after core training program must be explored in future studies.

Future research should focus on the role that lumbopelvic stability training has on cycling performance to promoting greater stability thereby maintaining lower-limb alignment to apply greater force production. Determining cycling-specific lumbopelvic training would also be advantageous.

Conclusion

The results of this study suggest that short-term lumbopelvic stability training of six exercises for eight sessions was effective in enhancing muscular endurance and core stability in female elite cyclists.

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