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Body balance in a free-standing position in road and off-road cyclists

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Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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Key words: *body balance, vestibular system, cycling*

Abstract

Background: *The purpose of this study was to compare body balance in road and off-road cyclists, immediately before and after the racing season.*

Material/Methods: *Twenty individuals participated in the study and they were divided into two groups: specialists in road-cycling (n = 10) and in off-road cycling (n = 10). Immediately before and after the five-month racing season stabilographic trials were carried out (at rest and after progressive exercise). In assessing body balance the distance and velocity of the centre shifts (in the anterior-posterior and left-right direction) were analysed. The tests were performed with the cyclists' eyes open, eyes closed, and in feedback.*

Results: *After the racing season, in the off-road cyclists' group, distance and velocity of the centre of pressure shifts increased after a progressive exercise.*

Conclusions: *In the off-road cyclists' group the balance of the body in the sagittal plane deteriorated after the racing season. Moreover, after the racing season off-road cyclists were characterized by a worse balance of the body, compared to road cyclists.*

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Introduction

The efficiency of movement in sport may depend, among others, on the ability to maintain balance in static and dynamic conditions [1]. Body posture is the position of the body's segments in relation to the forces of gravity [2]. Sport disciplines that require one to maintain balance in static (shooting) and dynamic (soccer, gymnastics) conditions are characterized by a small pathway and amplitude of the centre of pressure movement, especially in the sagittal plane [1]. Due to the potential impact of the body balance on sports performance, some authors proposed specific training that would improve body balance [1, 3]. As a result of exercise, an increase in muscle strength of the lower limbs helps to improve posture stabilization [4, 5]. Regular exercise is also considered as a factor compensating for balance disorders [6].

Body balance is disrupted by effort [7]. The greatest changes are observed in running, mainly due to a disruption in the integration of visual and vestibular reception [8, 9]. Researchers have observed a smaller range of imbalances in other types of isokinetic movement, such as cycling [9] or concentric and eccentric exercise on a dynamometer [10]. This effect is attributed to impaired proprioreception in terms of local fatigue of muscles serving the hip, knee and ankle joints [8, 10]. Erkmen et al. [11] showed that impaired balance control might be exacerbated by the lack of adequate hydration during exercise. Likewise, the intensity of work, and so – perhaps – a mechanism of local fatigue, affects the magnitude of these changes. The results of Mello et al. [12] suggest that the rocking of the body is more reduced after a long-term effort than after a maximum continuous progressive test. Regardless of the reasons, effective postural control returns to the resting state within a few quarters of an hour [8].

The results of Bressel et al. [13] and Matsuda et al. [14] demonstrated that specialisation in different sport affects the static and dynamic balance of the body. Therefore, specific training in road and off-road cycling may influence differences in the body balance. During road cycling stimulation of the vestibular system is particularly associated with the reception of motion, acceleration and braking [6]. Similarly, in off-road cycling vibrations and vertical movements appear due to the nature of the ground one rides on.

The aim of this study was to compare stabilographic changes in two specific cycling groups (road and off-road) immediately before and after racing season. We have assumed that all cyclists, after the racing season, would improve their static body balance in a free-standing position. We are expecting a greater scope of changes in the off-road cycling group on account of more stimuli having an impact on the vestibular system during mountain biking.

Material and Methods

Participants

Two groups of 10 cyclists each took part in the study: road (RC, n = 10) and off-road (ORC, n = 10). They were members of the Polish National Team, participants and medallists in European and World Championships. Prior to the study the groups did not significantly differ as regards body composition and aerobic efficiency (Table 1).

Table 1 Selected parameters characterising the RC and ORC groups before the experiment.

Group		Age	High [cm]	Weight [kg]	VO_{2max} [ml·kg^{-1}·min^{-1}]	W [kJ]
RC	$\bar{x}$	24.4	176.2	68.2	60.85	274.8
	SD	3.4	15.3	6.8	9.56	76.8
ORC	$\bar{x}$	23.2	172.1	66.8	64.6	266.8
	SD	4.1	8.5	3.6	9.02	72.7

VO_{2max}, maximal oxygen uptake in the progressive test; W, total work in the progressive test ; SD, standard deviation; $\bar{x}$ arithmetic mean; RC, road cyclists; ORC, off-road cyclists.

The study was approved by the Ethics Committee of University School of Physical Education in Wroclaw and was carried out in accordance with the Declaration of Helsinki. Athletes gave their written informed consent before participating.

The racing season that was considered in the study lasted five months, from April until August. During the racing season RC participated in 15-21 races (at least two were multistage); ORC competed in a cross-country Olympic race format (17-21 races) and cross-country marathon (5-8 races). The total duration of the races in the racing season: 102.1 h (± 34.2) for RC and 55.1 h (± 18.5) for ORC was calculated for each athlete as the sum of the rivalry in all races of the season and presented as the mean value for groups RC and ORC. (After each race, there is a classification showing each participant's place and the achieved time).

Procedures. Each of the participants underwent two physiological tests immediately before and after the racing season (lasting five months). The first test was performed at an individually (for each cyclist) chosen time, 10-14 days before the first race of the season. The second test was performed 8-10 days after the last race of the season. The study was conducted at the Laboratory of Exercise Research at the University School of Physical Education in Wroclaw (Certificate PN – EN ISO 9001:2001).

Participants performed:

- a progressive cycloergometer test,
- a stabilographic test (immediately before and after the progressive test).

The progressive test. The test was conducted on an Excalibur Sport cycloergometer (Lode BV, Holland, Groningen) calibrated, prior to testing, via a computer programme supplied by the manufacturer. The test began with a load of 50 W. The load was increased by 50 W every 3 minutes and the effort continued to exhaustion. The cycloergometer was controlled by a computer that recorded real power, work time, and the frequency of rotations. On this basis the total work done during the test was calculated.

A Breath by Breath Register – oxygen uptake (VO2) and carbon dioxide excretion (VCO_2) – began 3 minutes before the exercise and ended 5 minutes after its completion. The participants breathed through a mask, while the breathed air was analysed by the Quark telemetry measurement system (Cosmed, Italy, Milan). The apparatus was calibrated to atmospheric air and gas mixture composition of: CO_2 – 5%, O_2 – 16% and N_2 – 79%. In the analysis of respiratory parameters (VO_2, VCO_2) results averaged at intervals of 30 seconds were employed.

Stabilographic test. The study was performed using a dynamometric platform (Olton, Poland) that recorded the value of ground reaction forces. Participants stood on a platform (without shoes), on both feet, in a free-standing position with upper limbs along the trunk.

The stabilographic test was performed immediately before (BE) and after (AE) the progressive test. During the stabilographic test the centre of pressure (COP) movement was measured and recorded at a frequency of 100 Hz by a measurement platform. This test consisted of three parts: 1) with eyes open (EO), 2) with eyes closed (EC) and 3) with feedback (FB) where the subjects followed the direction of COP movement relative to the optimum vertical posture on a computer screen. Each part lasted 32 seconds, the rest between parts lasted 60 seconds. The stabilographic results achieved before or after the progressive test were compared separately.

The computer programme recorded the following: distance [mm] of COP shifts in the anterior-posterior direction (DAP) and the left-right direction (DLR), the average velocity [$m \cdot s^{-1}$] of COP shifts in the anterior-posterior direction (VAP) and the left-right direction (VLR) with reference to the optimal vertical posture, and the surface area [mm^2] of COP shifts (VCOP).

Statistical analysis. A STATISTICA 9 programme was used to develop statistical data. The arithmetic mean and standard deviation were calculated. The ANOVA variant analysis was used for repeated measurements and the post hoc Duncan test to identify significant differences between groups and before vs. after the racing season. A level of statistically significant $P < 0.05$ was adopted.

Results

After the racing season the results of the stabilographic test, in rest conditions, showed a significant increase in the surface area of the centre of pressure shifts (VCOP) with eyes closed in the off-road cyclists group. In the group of road cyclists the above parameter was significantly lower compared to off-road cyclists, after the racing season (Table 2).

In the ORC group after the racing season, a significant increase in the velocity and the distance of COP shifts in the sagittal plane after exercise with eyes closed were observed (Table 3-4). In the road cyclists' group, compared to the off-road cyclists, after the racing season a lower velocity of COP shifts in the sagittal plane (in the stabilographic test performed at rest with feedback) and a lower distance of COP shifts in the sagittal plane (in the stabilographic test performed at rest with eyes closed and feedback and after exercise with eyes closed) were observed (Table 3-4). No significant changes in the velocity and distance of COP shifts along the transverse axis (left-right direction) were observed (Table 5-6).

The standard deviation assumes particularly high values in the results in Table 2. This was due to several times larger amplitude changes of one cyclist. When the changes were statistically significant, the direction of change in all cyclists was the same.

Table 2. Surface area [mm^2] of COP shifts

Parameter	ORC				RC			
	trial I		trial II		trial I		trial II	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
EO-BE [mm^2]	165.3	61.9	201.4	122.6	170.6	81.6	160.7	102.3
EC-BE [mm^2]	296.3	172.2	450.1*	345.8	242.2	135.3	174.7†	71.2
FB-BE [mm^2]	154	60.5	164	47.3	184.3	86.3	145	61.1
EO-AE [mm^2]	237.6	92.8	449.6	402.7	284	142.2	295.8	193.3
EC-AE [mm^2]	369	192.4	607.4	409.2	348.9	245.9	322.2	336.3
FB-AE [mm^2]	219.3	89.5	664.4	1204	221.7	139.5	206.6	138.1

Legend Tables 2-6: Trial I, before the competition period; trial II, after the competition period; EO, eyes open; EC, eyes closed; FB, feedback; BE, before exercise (progressive test); AE, after exercise (progressive test); ORC, off-road cyclists; RC, road cyclists; $\bar{x}$ arithmetic mean; SD, standard deviation; *$P < 0.05$, significant difference between before vs. after; †$P < 0.05$ significant difference between ORC vs. RC.

Table 3. Average velocity [$m \cdot s^{-1}$] of COP shifts in the anterior-posterior direction

Parameter	ORC				RC			
	trial I		trial II		trial I		trial II	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
EO-BE [$m \cdot s^{-1}$]	4.25	0.71	4.5	0.93	3.89	1.62	3.67	1.22
EO-AE [$m \cdot s^{-1}$]	5.25	1.16	7.37	4.1	5.89	2.26	5.11	1.27
EC-BE [$m \cdot s^{-1}$]	6.75	2.43	7.87	2.8	5.56	2.19	4.89	1.45
EC-AE [$m \cdot s^{-1}$]	7	2.56	9.12*	4.19	6.56	2.24	6.33	2.6
FB-BE [$m \cdot s^{-1}$]	5.37	1.19	6	1.31	4.78	1.79	4.56†	0.73
FB-AE [$m \cdot s^{-1}$]	6.37	1.92	8.37	5.42	6.44	3.09	6.56	2.13

Table 4. Distance [mm] of COP shifts in the anterior-posterior direction

Parameter	ORC				RC			
	trial I		trial II		trial I		trial II	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
EO-BE [mm]	142.5	22	143.6	29.3	124.8	48.8	115.8	35
EO-AE [mm]	173	36.6	235.1	129.9	185.2	72.5	159.9	36.8
EC-BE [mm]	217.2	72.9	252.5	88.4	177.7	65	156.2†	45.3
EC-AE [mm]	231.6	82.8	297.5*	132.2	209.6	72.3	202.6†	81.9
FB-BE [mm]	170.7	39.1	192.5	46.1	155	59	143.4†	21.5
FB-AE [mm]	207.6	60.5	272.5	166.9	209.4	95.6	204.6	66.9

Table 5. Distance [mm] of COP shifts in the left-right direction

Parameter	ORC				RC			
	trial I		trial II		trial I		trial II	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
EO-BE [mm]	119.4	39.8	111.9	40.3	97.6	17.1	96.7	22
EO-AE [mm]	129.6	36.8	189.9	186.6	125.7	36.7	129.2	40.6
EC-BE [mm]	155.1	73.4	151.4	62.2	128.2	45.2	123.6	39.5
EC-AE [mm]	151	53.9	186.4	128.7	139.3	41.1	139.1	56.7
FB-BE [mm]	131.1	30.3	113.9	42.6	115	30.1	108.8	23.4
FB-AE [mm]	146.7	53.3	223	289.3	135.3	74.4	141.2	44.2

Table 6. Average velocity [$m \cdot s^{-1}$] of COP shifts in the left-right direction

Parameter	ORC				RC			
	trial I		trial II		trial I		trial II	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
EO-BE [$m \cdot s^{-1}$]	3.75	1.28	3.62	1.41	3.11	0.6	3	0.7
EO-AE [$m \cdot s^{-1}$]	4.12	1.13	5.87	5.79	3.89	1.05	4.11	1.27
EC-BE [$m \cdot s^{-1}$]	5	2.39	4.75	1.12	4	1.32	3.89	1.27
EC-AE [$m \cdot s^{-1}$]	4.75	1.67	5.75	3.99	4.33	1.32	4.44	1.81
FB-BE [$m \cdot s^{-1}$]	4	1.07	3.62	1.3	3.66	1	3.33	0.71
FB-AE [$m \cdot s^{-1}$]	4.62	1.77	6.75	9.1	4	2.24	4.67	1.41

Discussion

Changes in the surface area of COP shifts indicate a reduction in the ability to maintain a stable posture only by off-road cyclists after the racing season. Similarly, Lion et al. [15] demonstrated, in comparative studies, that off-road cyclists are characterized by lower levels of balance while standing with eyes open and in disturbed somatosensory information conditions than road cyclists. To identify the mechanism of changes among ORC, movement analysis was performed to measure the centre of pressure in the sagittal and frontal planes. The obtained data shows that the change of mechanisms to maintain balance in the ORC group was in the anterior-posterior direction, in the trials after exercise, and at rest with eyes closed.

In the group of off-road cyclists, increased velocity and distance of COP shifts in anterior-posterior direction were observed after exercise. Several authors demonstrated a temporary deterioration of body balance during exercise involving vertical movements. It results from a modified stimulation of the visual receptors and the vestibular system, for example while running [8, 9, 10]. Such movements also occur during off-road cycling in rugged terrain. When cycling, a cyclist absorbs vibrations through limb and trunk work. Frequent overlapping of these stimuli may well provoke long-lasting modifications of the vestibular and somatosensory system reception or an adaptation of the vestibular center within the central nervous system. A greater distance and movement velocity may make it easier to cycle over rugged terrain. The absence of feedback modification shows that the visual apparatus may compensate for the modification of the vestibular and somatosensory system reception.

In tests carried out after the racing season body balance deteriorated in the ORC group following exercise with eyes closed. According to several authors, fatigue provokes temporary balance disruption [12, 16], when receptor activity – muscle spindles and Golgi-Mazzoni corpuscles – is reduced [8, 16, 17, 18, 19]. Mountain cycling may in fact involve exertion fatigue processes different from those occurring in road cycling. The intensity, volume and the nature of movement induce other mechanisms reducing work capacity, which influences the extent and duration of body balance modifications [8, 12, 16]. Mountain cycling involves shorter and more intensive exercise than road cycling. In addition, struggling for the best position right after the race begins and cycling over sharp ascents engages predominantly anaerobic metabolism [20, 21]. Research by Weber and Schneider [22] has demonstrated that intensive interval training provokes an increase in the maximum oxygen deficit. Having said that, during the progressive test the ORC subjects may have relied more on anaerobic metabolism. Animal tests have shown that lactate acidosis reduces the receptivity of type III and IV nerve endings [23]. On the other hand, however, Surenkok et al. [24, 25] have not found any correlation between lactate blood concentration and body balance. In addition, our previous research did not evidence any difference in acid-base blood balance between mountain and road cyclists before and after the racing season [26]. However, as a result of intensive training, highly efficient athletes may expand their muscle-buffer capacity as well as the processes of gluconeogenesis and lactate oxygenase [27]. The acid-base blood balance does not fully reflect the muscle environment. Therefore, modifications of post-effort body balance in the ORC subjects may result from a greater disruption of the acid-base balance. The absence of post-effort feedback modifications in ORC group shows that the visual apparatus compensates for the modifications of vestibular and sematosensory reception.

Conclusions

In the off-road cyclists group the balance of the body in the sagittal plane deteriorated after the racing season. Greater velocity and the displacement range of the sagittal center of pressure make it easier for a mountain cyclist to cycle over rugged terrain while managing to maintain body balance. Moreover, after the racing season off-road cyclists were characterized by a worse balance of the body, compared to road cyclists. The character of the efforts performed during the racing season by road cyclists did not affect the stabliographic changes.

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