Original Article

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Compensatory exercises for young cyclists in the pubescents

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Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract: The aim of the study was to evaluate the state of the musculoskeletal system of selected cyclists and to propose appropriate compensatory exercises, the effects of which were verified in practice. Twenty-eight MTB cyclists (men) participated in the study. They were divided into experimental (EXP) and control (CONT) groups. The Janda test, including the scaling method, was used to diagnose the condition of the cyclists' musculoskeletal system. The cyclists were tested twice after six weeks, when the experimental group was doing compensatory exercises twice a week. The results of the first and second tests were compared. The results showed a reduction in muscle mass in the arcuate neck flexion and trunk flexion tests. The results of the shortened muscle group tests showed shortening of the neck muscles and the upper part of the trapezius muscle in all the cyclists. The paravertebral back muscles and the pectoralis major muscle were shortened in 93% of the cyclists. 86% of the cyclists had shortened knee flexors and hip flexors. In the EXP, there was a significant improvement in the strength of the weakened muscle groups ($p<0.001$) and a significant increase in the extent of the shortened muscle groups ($p=0.001$) after the intervention. No significant changes were found in the CONT. After the intervention programme, movement stereotypes improved significantly in the EXP group compared to the CONT group. Cyclists should regularly incorporate compensatory exercises into their current training in order to prevent overuse injuries, correct posture and eliminate back pain.

Keywords: musculoskeletal system; muscle; strength; flexion; prevention; testing

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INTRODUCTION

Cycling is one of the most common forms of exercise. It is characterised by the cyclical movement of the lower limbs. Only certain muscle groups are activated, and these are often overloaded by incorrect technique, while other muscle groups are used less frequently. From the point of view of the harmonious development of the organism, it is advisable to take care of the development of all the main muscle groups so as to avoid uneven muscle development or muscular imbalances [1]. The muscles of the lower limbs are among the most activated muscles.

Conversely, the upper body muscles can often be weakened in cyclists. During the pressure phase of the pedal stroke (propulsion phase), there is extension of the hip joint (gluteus maximus and hamstrings), extension of the knee joint (quadriceps femoris) and plantar flexion of the ankle joint (triceps surae). The pedal stroke (pull-up phase) is performed by the hip flexors (iliopsoas, rectus femoris), knee flexors (biceps femoris, semitendinosus and semimembranosus) and ankle dorsiflexors (tibialis anterior). The correct position of the cyclist is ensured by the trunk, abdominal and back muscles (m. erector spinae), which play the role of fixators in the movement chain. They stabilise the position of the segments so that the other segments (mainly the lower limbs) can move. The core plays an important role when core fatigue leads to altered cycling mechanics that can increase the risk of knee injury [2]. The typical cyclist, with an average cadence of 90 revolutions per minute, will pedal between 16,000 and 21,000 revolutions during a typical 3-4 hour ride and over 33,000 revolutions during a 6 hour ride. This repetitive motion requires efficient movement patterns [3]. These data are based on adult cyclists. According to Henke [4], the annual mileage of a 14-year-old MTB rider is 5,500 km, with 350 hours of training on the bike, 125 hours of regeneration and a total of 170 hours of general preparation. For 15-year-olds it is 6500 km (450 hours) with a total volume of regeneration of 150 hours and a total volume of general preparation of 110 hours. Sigmundova et al [5] recommend the development of general movement skills in children.

The period of puberty (11-15 years) is when basic and specific movement skills develop in addition to fundamental somatic changes. Significant physical and motor changes also occur at this time. In some people, after the onset of accelerated growth and a change in proportions, we can observe a deterioration in movement coordination, a disturbance in movement dynamics with a reduction in its economy and a stagnation in the development of skills [6].

In cycling, diagnostic methods are most commonly used to assess current performance. These tests mainly include exercise tests, which aim to diagnose the individual's aerobic capacity. Less attention is paid to the functional diagnosis of the musculoskeletal system, as described by Tichy [7]. Auxiliary examination methods used to diagnose the musculoskeletal system include the muscle test and the test of shortened muscle groups [8]. It helps to analyse simple motor stereotypes and is the basis for analytical, therapeutic physical education procedures to re-educate weakened muscles. The individual tests assess the strength of the primary muscle or muscle group and examine and analyse the qualitative performance of the whole movement and the activation of individual muscles. Janda's muscle test uses six levels to determine muscle strength (0-5) and three levels (0-2) to determine muscle shortening [8].

There are a number of compensatory exercises generally recommended for athletes in the literature. However, we did not find more detailed recommendations for cyclists in the available literature. In general, much emphasis is placed on core strengthening in sport. It is crucial as a tool for injury prevention and also as a tool for performance enhancement [9]. The core provides stability to the spine while controlling trunk movement and influencing upper and lower extremity movement and power development [10,11]. As each musculoskeletal system has its own specificities, it is always necessary to look for compensatory exercises that respect the individual's current condition, eliminate muscle imbalances and lead to the optimal condition of the musculoskeletal system of a person practising a particular sport or discipline. Compensatory exercises contribute to muscular harmony - to the harmonious development of the organism. They include stretching exercises for muscles that tend to shorten, strengthening exercises for muscles that tend to weaken, breathing, relaxation and restorative exercises, and additional sports activities [1]. However, not enough attention is always paid to these exercises. Young athletes often do not even have enough knowledge, so they need to be taught compensatory and relaxation exercises as part of long-term sports training, and offered a variety of physical activities that they can do on their own. In our study, we focused on the monitoring of young cyclists who, due to the characteristics of their performance, should regularly include compensatory exercises in their training plan.

The main objective of the present study was to evaluate the musculoskeletal condition of selected older school-aged cyclists and to propose suitable compensatory exercises, the effect of which will be verified in practice.

MATERIAL AND METHODS

Participants

Twenty-eight MTB cyclists (men) participated in the study. They were similar in terms of athletic performance. They had been cycling at a competitive level for at least 4 years. Although they had done some compensatory exercises during their organised training before the test, nobody checked the correctness of the exercises they had done and the effect of these exercises was questionable. They were randomly divided into two groups: experimental (EXP; n = 14, age = 14.6 ± 1.42 years, weight = 55.82 ± 7.32 kg, height = 169.1 ± 8.89 cm) and control (CONT; n = 14, age = 14.4 ± 1.17 years, weight = 54.62 ± 6.22 kg, height = 168.3 ± 7.01 cm). The total annual mileage of these cyclists is 5,500 km. All participants gave written informed consent.

Ethics committee statement

The study was conducted in accordance with the tenets of the Declaration of Helsinki of 1975, as revised in 2008. The experimental procedures were approved by the Ethics Committee of Charles University in Prague, Faculty of Education, Department of Physical Education (approved in January 2021; No. 2021/DP_00100).

Experimental protocol

The Janda test [8], including the scaling method, was used to diagnose the condition of the musculoskeletal system of the cyclists. The experimental and control groups of cyclists were tested twice with the same set of tests. The first test took place during the first week of the preparation period (the second week of November), and between the first and second tests (the third week of December) there were six weeks in which the experimental group practised compensatory exercises twice a week according to the methodological material we created. The control group did not perform any specific compensatory exercises during these six weeks. The tests were carried out by an experienced physiotherapist who carries out this type of test on a daily basis. Twenty-four tests were used to diagnose cyclists' movement stereotypes. Thirteen tests from the set of functional muscle tests (Figures 1, 2) and eleven tests to diagnose shortened muscle groups (Figure 3). It took about 25 minutes to test one athlete. Two types of scales according to Janda [8] were used for further data processing:

- for the functional muscle test, 0-3 points (5 = 3 points; 5 - = 2 points; 4+ = 1 point and 4 = 0 points) a maximum of 39 points. However, the decrease in muscle strength on a functional basis rarely reaches a decrease in strength of grade 3 according to the muscle test, but is in the range of grade 4. Therefore, the tests focused primarily on techniques that detect values around the so-called norm, i.e. grades 4 and 5. A plus or minus sign was added to the test grade if it showed a transient muscle value;

- for the diagnosis of shortened muscle groups 0-2 points (0 = 2 points; 1 = 1 point and 2 = 0 points) out of a maximum of 22 points. Shortened muscle groups are scored on a scale divided into three grades. Grade 0 if there is no shortening. Grade 1 if there is a slight shortening and grade 2 if there is a significant shortening.

Figure1. Muscle test according to Janda [8] – part I. Where: a - arcuate neck flexion; b - trunk flexion; c - scapular adduction; d - scapular abduction with rotation; e - shoulder flexion; f - shoulder extension; g - shoulder abduction.

Figure 2. Muscle test according to Janda [8] – part II. Where: h - shoulder external rotation; i - shoulder internal rotation; j - hip extension - gluteus maximus muscle test; k - hip abduction; l - knee extension; m - ankle supination with dorsiflexion.

Figure 3. Diagnosis of shortened muscles according to Janda [8]. Where: a - neck muscles; b - m. levator scapulae; c - upper part of the trapezius muscle; d - m. pectoralis major; e - paravertebral back muscles; f - m. quadratus lumborum; g - hip joint adductors; h - flexors of the knee joint; i - hip flexors; j - m. gastrocnemius; to - m. soleus

Intervention programme used

The compensatory exercises were divided into two groups according to their nature, i.e. relaxation and activation exercises. The exercises take into account the characteristics of the sport and are based on the results of the functional tests. As we found weakness in cyclists mainly in the arcuate flexion of the neck and trunk flexion tests, as well as in the area of the shoulder joint and scapula, and in the abduction of the hip joint, and further shortening of the neck muscles, as well as the upper part of the trapezius muscle, the paravertebral back muscles and the pectoralis major muscle, knee flexors and hip flexors, we prepared a series of compensatory exercises, which were mainly focused on the problematic parts of the musculoskeletal system of cyclists. The nineteen relaxation exercises included cervical spine flexion stretch, cervical spine flexion stretch, levator scapulae stretch, pectoral muscles and shoulder internal rotator stretch, biceps and shoulder external rotator stretch, triceps stretch, forearm flexor stretch, forearm extensor stretch, back muscle stretch, Abdominal and Hip Flexor Stretch, Lumbar Muscle Stretch, Lumbar Muscle Rotation Stretch, Hip Flexor and Buttock Stretch, Hip Flexor Stretch, Knee Extensor Stretch, Knee Flexor Stretch, Hip Adductor Stretch, Hip Adductor Stretch, Gastrocintestinal Stretch. Gastrocnemius stretching and Soleus stretching. Examples of exercises to strengthen the most commonly weakened muscles in cyclists and to stretch the most commonly shortened muscles are shown in Figure 4 and have been demonstrated to cyclists by one of the authors, including a detailed photographic guide. To minimise errors in performance, the compensatory exercises were taught in the presence of a physiotherapist and a coach who is one of the authors of this study. The athletes were given precise instructions on how to carry out the recommended exercises, in order to avoid the possible failure of the expected effect of the intervention. They were also corrected during the exercises. The eight activation exercises included those listed in Figure 5. Only the EXP group completed the intervention programme for six weeks. The exercises were performed twice a week for 20 minutes under the supervision of an experienced physiotherapist.

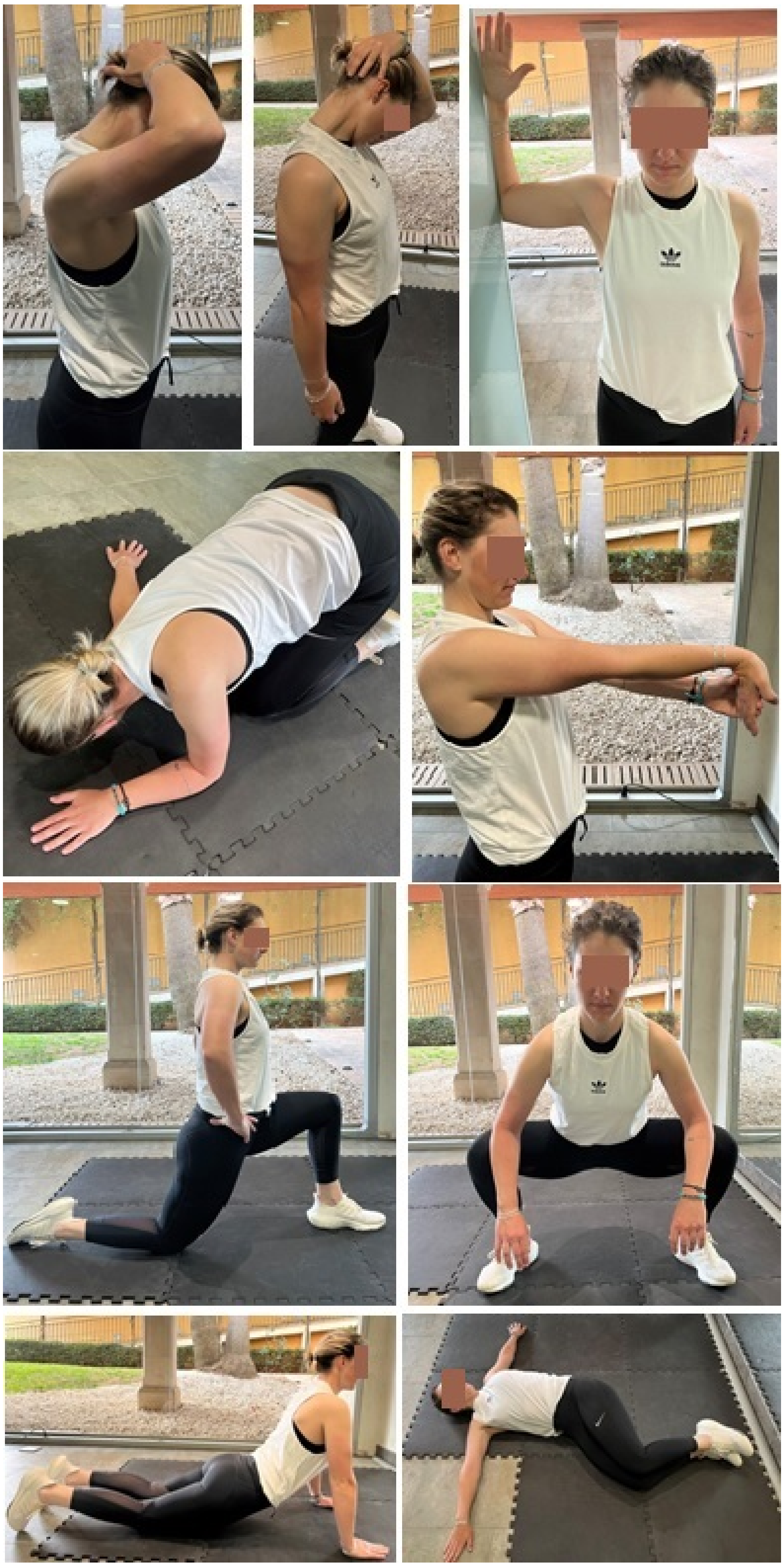

Figure 4. Selected stretching exercises of the proposed intervention.

Figure 5. Strengthening exercises in the proposed intervention program.

Statistical analysis

The scales mentioned above [8] were used for the assessment. The first and second test scores were compared for the EXP and CONT groups. The normality of the data was demonstrated for both groups, and a two-sample paired t-test (α= 5%) was used to assess statistical significance. We used Cohen's d [12] to calculate effect size. We used the extended scaling of results according to Sawilowsky [13]. The values of the coefficient d according to this method indicate the following effect sizes: d = 0.1 (very small), d = 0.2 (small), d = 0.5 (medium), d = 0.8 (large), d = 1.2 (very large), d = 2.0 (large).

RESULTS

The results of the first test showed a mass weakness in the arcuate neck flexion and trunk flexion tests. Weakness was present in all subjects in the CONT group, whereas in the EXP group only one subject had no weakness at baseline. Weakness was also common in the scapula adduction and scapula abduction with rotation tests, shoulder internal rotation and hip abduction.

The results of the shortened muscle group tests showed shortening of the neck muscles and the upper part of the trapezius muscle in all cyclists. The paravertebral back muscles and the pectoralis major muscle were shortened in 93% of the cyclists (only two were not). 86% of the cyclists had shortened knee flexors and hip flexors.

The intervention programme, which included targeted stretching exercises for selected muscles and exercises to strengthen weak muscles, had a positive effect on the control group after six weeks of preparation (twice a week in November and December). At the end of this period, both groups were tested again. The results of the second CONT test did not change significantly after six weeks. Due to changes such as training during the annual training cycle, we did not carry out later tests outside the preparation period. In the results of the second EXP tests, there were statistically significant changes in the overall parameters of the muscle test and the test of shortened muscle groups compared to the first test. There was a significant improvement in the strength of the weakened muscle groups ($p < 0.001$) and a significant increase in the extent of the shortened muscle groups ($p = 0.001$). We recommend that the proposed intervention programme be regularly incorporated into the training of young cyclists.

The result of Cohen's test for effect size (Table 1) also shows that there was a significant improvement in the monitored parameters in EXP as a result of the intervention programme. In the case of muscle test results, the effect size between the first and second test for EXP was large ($d = 1.19$). For the diagnosis of shortened muscle groups, the effect size was also large ($d = 0.92$). In the case of the CONT group, there were only small changes between the first and second measurements and no effect size could be demonstrated ($d < 0.1$).

Table 1. Comparison of the results of the muscle test and the test of shortened muscle groups at the first and second test with an interval of 6 weeks.

Test	Measurement	Group	Mean [points]	SD	d	p-values
1	Muscle	CONT	33.3	2.9	-0.05	0.5
		EXP	31.4	3.0		
	Flexe	CONT	18.0	1.8	1.19	<0.001*
		EXP	18.2	2.5		
2 (after 6 weeks)	Muscle	CONT	33.1	2.9	0.04	0.72
		EXP	34.9	2.2		
	Flexe	CONT	18.1	1.8	0.92	0.001*
		EXP	20.5	1.2		

CONT: control group; EXP: experimental group; SD: standard deviation; *d*: Cohen´s effect size; p-values *: significance level 5 %.

DISCUSSION

The aim of this study was to assess the condition of the musculoskeletal system in selected older school-aged cyclists and, based on the data obtained, to propose appropriate compensatory exercises and to verify their effect in practice. Performing an individual functional muscle test and a shortened muscle test is time-consuming. They can be carried out by a physiotherapist, specialist or trained coach. For this reason, we tried to find a universal intervention programme that would prevent the problem of musculoskeletal overload in young cyclists. The results of this study supported our hypothesis that some inappropriate movement stereotypes are already manifested in adolescent cyclists. Using the Janda test [8], we identified the most common problem areas in cyclists of this age group. These are mainly shortened muscle groups in the neck, lumbar spine, hip and knee joints. At the same time, muscle groups in the trunk and neck are weak. The intervention programme, including compensatory exercises, was carried out for six weeks in the EXP group. The effect of the proposed intervention programme was demonstrated. The EXP cyclists showed a significant improvement in musculoskeletal function, particularly in functional muscle tests ($p < 0.001$; $d = 1.19$), which indicates high significance). There was even a complete recovery of shortened muscle groups in three cyclists. The effect size was statistically significant and large ($p = 0.001$; $d = 0.92$). In the control subjects who did not participate in the intervention programme, the changes in the musculoskeletal system were minimal and their significance was not confirmed ($p > 0.05$; $d < 0.1$). In both CONT and EXP subjects, the most common problem was external rotation of the shoulder joint, which improved significantly in the EXP group after the intervention programme (10 out of 14 cyclists improved by one degree). In addition, cyclists in both groups achieved the best results in the shoulder abduction and ankle supination with dorsiflexion tests. The results corresponded to the maximum strength in both tests according to the Janda scale [8]. In terms of muscle group shortening, the worst results were obtained in the neck and knee flexor tests, while the best results were obtained in the gastrocnemius test. It was also found that some of the expected muscle imbalances did not yet occur in this age group (e.g. gastrocnemius shortening only occurred in 3 of the total number of cyclists monitored). This can be explained by the choice of age category, as these cyclists are not yet so one-sided in their sporting orientation. At the same time, it can be assumed that these individuals also participate in other sports that have a compensatory function. However, this argument needs to be verified and is only based on Henke's [4] recommendation for this age group. Based on the results of previous studies, core straightening also plays an important role in cyclists when core stability contributes to lower extremity cycling mechanics [2]. Improvements in core strength could promote greater trunk stability in the saddle and maintenance of lower extremity alignment for greater power transmission to the pedals. The lack of core stability could exacerbate the influence of the other factors (strength imbalances, flexibility deficits, heavy gear selection, high mileage accumulation) known to contribute to knee pathology [14].

The proposed intervention programme was compiled from stretching and strengthening exercises based on the research and cycling characteristics. The strengthening exercises included mainly core strengthening exercises as recommended in the literature for cyclists [9,15]. According to a study by Wilson et al [9], core stability is related to lower extremity function and injuries, and a relationship between core stability and back injuries in cyclists has been found [15]. In line with our intervention programme, we believe that it is necessary to address the correct movement pattern in young cyclists so that the whole musculoskeletal system is in harmony. It has been shown that even a relatively short intervention programme (six weeks, twice a week) can produce significant measurable changes. The tests were carried out during the preparation period, which is limited in time, so it was not appropriate to extend the interval between the two measurements. We explain this by the fact that the musculoskeletal system of young cyclists is not yet burdened with specific movement stereotypes, so their correction is not as time-consuming and systematic. Progress is visible after a short period of time, which is confirmed by the study by Yahata et al [16]. At the same time, we believe that young cyclists include other sports activities in their training. Therefore, we can state that in this age group, if methodological guidelines are followed, some stereotypes are quickly improved or corrected. In the long term, we recommend regular compensatory exercises to stretch shortened muscles and strengthen selected muscles. We consider core strengthening to be essential, in line with previous studies [2,9,14]. However, we are also aware that compensation or correction of existing movement stereotypes for some muscle groups would require longer-term and more systematic work. Their identification would require the involvement of a team of specialists. The athletes' self-discipline would be a decisive factor in influencing these stereotypes. It should also be noted that long-term physical activity can be used as an active intervention in the rehabilitation of various diseases [17] and to promote rehabilitation and physical function [18]. However, it is important to note that the activity of these young athletes should not be focused on one sport only [19]. A more varied sporting activity can prevent some musculoskeletal problems [1].

Cyclists are advised to perform complementary exercise, relaxation and stretching exercises, as well as well-defined specific exercise and rehabilitation regimes that target specific muscle groups. Suitable targets for strengthening are the upper limbs, shoulder girdle, interscapular muscles and scapular fixators. Weakness in the muscles of the thoracic spine is manifested by an increase in the kyphotic posture of the spine and the protrusion of the shoulder blades [20]. It is therefore advisable to combine exercises to train the spinal erector apparatus with exercises to strengthen the interscapular and scapular muscles. We must not neglect the back muscles, which are essential for the stability of the spine, for straightening the thoracic spine, for protecting the spine and for fixing the shoulder blades. When weakened, they cause poor posture and pain throughout the spine, including the head. A very unpopular but important exercise is to strengthen the abdominal muscles. The abdominal and pelvic floor muscles are fundamental to the body [9]. They weaken relatively quickly and become functionally old if left inactive for long periods of time. Some cyclists devote all their training to the lower limbs because they are essential for riding. Professional cyclists not only focus on developing the strength and power of their legs in the gym, but also take care to ensure proper recovery. Stretching, compression hosiery, massage and elevation of the lower extremities prevent injury [21]. According to the studies mentioned above [2,9,14], it is important to pay attention to parts of the body other than the lower extremities. As the weakening and shortening of the musculature is one of the consequences of prolonged monotonous physical activity, it would be appropriate to modify the training of a young cyclist. Coaches could consider whether, for example, endurance skills could be developed outside the saddle. Although it is difficult for coaches to change their training beliefs, we will be happy if they modify their training and enrich it with the compensatory exercises we have designed.

In addition, it is advisable to choose sports that work the muscular system symmetrically and support performance, regeneration and mobility. The all-round development of the body is essential, so it is possible to include running, cross-country skiing, swimming, yoga, Pilates or rock climbing in order to avoid premature specialisation, which does not increase the risk of injury [22].

Another sport highly recommended for cyclists is Pilates. In winter, when temperature conditions are not always ideal for cycling, it is desirable to include various forms of cross-country skiing in training. In addition to its compensatory potential, cross-country skiing or ski alpinism has the potential to develop the endurance skills needed for cycling. Downhill skiing improves coordination balance and develops the habit of cycling at high speeds [23]. At the same time, alpine skiing teaches cyclists to make quick decisions and react to external objects, including the terrain.

There are several limitations to this study. We did not prospectively record hours/week or months/year of sport participation (except cycling - they have been cycling at a competitive level for at least 4 years), so this may have influenced our results. Another limitation is that the athletes were only recruited from the boys' group, and data from the girls are missing. Although we tried to select individuals of similar performance, it was impossible to ensure a completely homogeneous group, as the differences in performance between individuals in this category are still quite noticeable. Future research should look at a wider age range of cyclists, including a group of girls. We hope to encourage informed discussions with young cyclists, parents and coaches about the potential risks of specialising in youth sport, including the possibility of preventing them. In our opinion, it is advisable to carry out a kinesiological analysis of cyclists at least twice a year. We strongly recommend that this be done during the preparation period to prevent muscular imbalances, and also during the main season to prevent possible muscular overload. However, more research is needed on this subject.

CONCLUSION

The lower limbs are particularly overloaded during competitive cycling, which in adolescent cyclists leads to certain movement stereotypes that are not conducive to the correct development of the individual. On the basis of the functional muscular test carried out, the following muscular imbalances were mainly observed in the group of young cyclists:

1. Weakness in the following tests: arcuate flexion of the neck and flexion of the trunk in the scapular adduction and scapular abduction with rotation tests; in the shoulder internal rotation and hip abduction tests;
2. Shortening of the neck muscles and the upper part of the trapezius muscle. Shortening of the paravertebral back muscles, the pectoralis major muscle and shortening of the knee and hip flexors.
3. On the basis of our 6-week intervention programme, we recommend that young cyclists carry out specific compensatory exercises for 20 minutes at least twice a week for a long-term effect.

After inclusion of the proposed intervention programme, which consisted mainly of strengthening and stretching exercises, movement stereotypes improved significantly in the EXP group compared to the CONT group; cyclists should incorporate regular compensatory exercises into their current training to prevent injuries due to overuse, correct posture and eliminate back pain, which is very common in cyclists. Core strengthening should be an integral part of training. The intervention programme has been developed specifically for the needs of cyclists and its positive results in practice have been confirmed by repeated testing. In practice, we recommend that an intervention programme be incorporated into the annual training cycle, starting with the youth categories. Cyclists can perform the exercises after training, and the exercises can also be used in group training sessions.

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