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Qualitative evaluation of FMS movement patterns in the course of femoroacetabular impingement in people practising recreational long-distance running

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Abstract

Purpose

The aim of this work was to evaluate the effect of a conservative therapeutic intervention on functional changes in the motor system assessed qualitatively with FMS motion patterns in people with femoroacetabular impingement practising long-distance recreational running.

Methods

The study involved 44 men, regularly practising recreational long-distance running. Two runs of tests were conducted in the Laboratory of Biokinetics of the AWF in Cracow. The first measurements were carried out in January 2020, and the second ones - after a 6-month therapeutic intervention in July 2020. A qualitative assessment of movement patterns was made using five tests of the Functional Movement Screen (FMS).

Results

The highest statistically significant gains in FMS scores were obtained in the total of the FMS score (FMST) and in the active straight-leg raise, FMS5. The greatest improvement was noted in the experimental group in the measurement for the affected lower limb. After the intervention, the results obtained in the tests of deep squat (FMS1) and in-line lunge (FMS3) improved significantly only in the experimental group and were approaching the values observed in the control group.

Conclusions

Observations made in this work, documented by the results of the conducted analyses, allow for practical use of the proposed proprietary, 6-month rehabilitation protocol and of a comprehensive, objective protocol for functional changes monitoring by means of qualitative assessment of FMS movement patterns in the conservative treatment of people with femoroacetabular impingement.

Keywords

conservative treatment, Femoroacetabular impingement, Functional Movement Screen, long-distance running

1. Introduction

Femoroacetabular impingement is a disturbance of the balance of the hip joint deep structures. It concerns morphological abnormalities in the femoral neck-head junction (cam-FAI) or in the acetabulum of the hip joint (pincer-FAI). Properly selected exercises aimed at mobilisation and centering of the femoral head in the acetabulum may help to improve the balance of the soft tissue tone in this articular area, thus allowing for restoration of the proper mechanics of the entire lower limb. Optimal kinematics of the lower extremity joints can be an important factor enabling running training for many years and can significantly affect performance while reducing the risk of injuries [34].

Biomechanical analysis of the run seems to be crucial – it allows for an accurate assessment of the running technique, for example. Such an assessment should include body posture, joint motion ranges, and muscle elasticity and tone. Possible dysfunctions may be caused by injuries or an improper running technique. They usually involve changes in muscles, ligaments and muscle fascia. They usually manifest as excessive muscle tone or muscle weakness, or deterioration of neuromuscular coordination. Such conditions can be corrected before their consequences occur [4].

Three functional tasks are usually analysed in the course of FAI: walking on a flat surface, climbing stairs and squat. Gait observation is based on the assessment of the hip and pelvis kinematics. The researchers point to reduced hip mobility during a walk, in the sagittal [19, 31], frontal [6, 33] and transverse [19] planes. Kennedy et al. [20] showed reduced pelvic mobility in the frontal plane during a walk in people with *cam*-FAI. However, they did not notice any changes in pelvic mobility in the sagittal and transverse planes. Rylander et al. [31] did not show any differences in pelvic mobility during a walk in people with a structural change in the hip joint, as compared to healthy people. Geoffrey et al. [15] showed an increase in the hip joint reaction forces in FAI patients.

Femoral impingement can be diagnosed using a variety of methods, including the FMS test, which helps assess the overall body function and detect potential limitations in mobility and asymmetries that may be related to FAI. The FMS can identify issues that may not be diagnosed during a regular visit to an orthopedist or physical therapist. These issues include muscle flexibility, strength imbalances, or compensation from a previous injury. These are the recognized risk factors for potential future injuries. The analysis of squat or climbing stairs ~~seems~~ to be of great importance in the context of the FMS tests carried out in this work, especially the tests of the deep squat pattern (FMS1) and the hurdle step pattern (FMS2). Flexion in the hip joint affected by FAI brings degenerated parts of the joint closer to each other, which increases pain and restricts motor functions. Rylander et al. [31] showed a reduction in mobility in the hip joint in the sagittal plane and reaching the peak value of the internal rotation range when climbing stairs in people with *cam*-FAI. Moreover, these researchers indicated an increase in the anterior pelvic tilt and an increase in the range of pelvic mobility in the transverse plane when climbing stairs, as a result of *cam*-FAI. Hammond et al. [17] suggest however that there are many similarities in the mechanics of the locomotor system presented when climbing stairs in people presenting structural changes in the hip joints and in healthy people. These researchers only indicate that there are inter-group differences in the position of the torso while climbing the stairs.

In people with structural hip joint changes in the course of FAI, most reports analyse locomotor system kinematics during a squat [17,24,30,35]. Lamontagne et al. [24] proved more shallow descent to squat in a group of people with the femoroacetabular impingement, as compared to the control group. Diamond et al. [11] pointed out the possibility of a deeper squat in people with *cam*-FAI if knees are spread wider than the beam during this activity. Increased anterior pelvic tilt observed in people with *cam*-FAI, occurring in the final phase of squatting with the maximum hip joint flexion is a trend confirmed by several publications [17]. The authors explain this fact by a reduced torque of hip extensors [3].

To date, the effect of surgical treatment on changes in the mobility and mechanics of the hip joints has most frequently been assessed in runners with FAI, predominantly with X-rays [4]. Therefore, it was important to evaluate the impact of a conservative 6-month therapeutic intervention on functional changes by qualitative assessment of FMS movement patterns in the course of femoroacetabular impingement in people practising recreational long-distance running. The control group included runners with no pathology in their hip joints. It was hypothesized that the applied therapeutic intervention would improve FMS results in the tests related to hip joint biomechanics, i.e.: deep squat, hurdle crossing, lunge in line, active lower limb extension, and thus the global result. It should be noted, however, that to date, no longitudinal study using FMS patterns has assessed the effect of conservative multi-month therapy in the form of, among others, hip joint mobilization centering the femoral head in the hip joint socket in long-distance runners. In the previous literature, there has been no thorough assessment of the effect of conservative therapeutic plan in the course of FAI on the hypothetical improvement of the biomechanics of the musculoskeletal system in runners. This was not possible due to the lack of a unified proposal for conservative treatment.

2. Materials and methods

2.1. Participants

The study involved 44 men, aged 30 to 50, regularly practising recreational long-distance running in the southern part of Poland (Table 1). The weekly distance covered by the subjects ranged from 20 to 100 kilometres (47.7 ± 26.9 km, on average). The research project gained approval of the Bioethics Committee of the Regional Medical Chamber in Cracow (Opinion No. 175/KBL/OIL/2020 of July 14, 2020). The criterion for inclusion in the femoroacetabular impingement (FAI) group was the alpha angle of >55° (*cam*-FAI) and/or the beta angle of <30° (*pincer*-FAI), as determined based on an X-ray examination, in one or both hip joints. The inclusion criterion for the non-FAI group (n-FAI) was the alpha angle of <55° and/or the beta angle of >30° and <70° in at least one hip joint [28]. The exclusion criteria included a hip injury and a diagnosis of osteoarthrosis grade >1 according to the Tönnis scale or a reduction in the upper joint space dimension below 2 mm in the A-P projection [32]. The selection for each of the two groups was made without informing the subjects to which group they had been qualified (blind trial).

Table 1. Subject characteristics

Group / Variable	**The FAI Group n=22**	**The n-FAI Group n=22**
Age [years]	38.55 ± 7.45	36.36 ± 6.31
Body weight [kg]	79.69 ± 11.81	74.84 ± 9.23
Body height [m]	1.78 ± 0.05	1.76 ± 0.05
BMI [kgm^{-2}]	22.38 ± 2.85	21.23 ± 2.21
Number of kilometres per week [km]	49.21 ± 28.44	46.26 ± 26.28
Max training run speed [ms^{-1}]	3.54 ± 0.21	3.82 ± 0.26
Min training run speed [ms^{-1}]	2.86 ± 0.16	3.08 ± 0.19

2.2. Measures

A qualitative assessment of movement patterns was made with the use of the Functional Movement Screen (FMS). The FMS assessed hip mobility, muscle elasticity, stability, coordination, and ability to maintain balance [22]. Five tests directly related to hip mechanics were performed and the total FMS score (FMST) was calculated: deep squat (FMS1), hurdle step (FMS2), in-line lunge (FMS3), active straight-leg raise (FMS5), and rotational stability (FMS7).

A special standardized measuring instrument was used for the test, consisting of a base (5 × 15 × 150 cm), a rod, two cross bars and a rubber band. The best result of three repetitions of each test was selected for analysis. Observations of the movement of the subject were made in the sagittal and coronal planes, and the performance of each of the above tests was assessed on a scale from 0 to 3, where [9]:

- 3 points mean a correctly performed test without compensation patterns,
- 2 points mean a correctly performed test, but with visible compensation patterns,
- 1 point means that the subject is unable to perform the test,

- 0 points mean that pain occurred during the test that prevented test continuation.

All FMS measurements were performed by one person, namely by a qualified physiotherapist with 15 years of clinical and research experience. This person did not know which runners had been assigned to which of the two parallel treatment groups. It was assessed whether the person being tested performed the movements correctly, without compensations or limitations.

2.3. Examination of somatic features

Body height was measured with an anthropometer with an accuracy of 0.01 m and body weight – with an electronic scale with an accuracy of 0.01 kg.

2.4.Therapeutic intervention

The original protocol of the exercises was created on the basis of principles presented in the works of Hernandez-Molina et al. [18], Loudon and Reiman [26], Griffin et al. [16], Drouin et al. [12]. These included:

- mobilisation of the hip joint in all physiological planes over a painless and safe range of motion,
- improvement of the slide of the articular surface of the femoral head in relation to the acetabulum in the posterior direction,
- centering of the femoral head in the acetabulum by means of active-passive work with use of some aids (belt, blanket),
- active correction of the position of the pelvis in relation to the lower limbs,
- enhancement of the tonic muscle strength by long static, isometric 3-minute active persistence in the corrected position. The process involved the iliopsoas, gluteus maximus and hamstring muscles. These muscles are most likely to lengthen and weaken in the case of FAI. Fulfilling the above assumptions was possible thanks to the focusing on the active work of conscious and precise correction of body position, especially of the lower limbs in relation to the pelvis and torso in static positions.

The subjects were obliged to perform subsequent exercises for 3 minutes (active work in a given position) so that the full training unit lasted no less than 30 minutes, and this was repeated 3 times per week, every other day. All the subjects whose results were included in the statistical analysis fully completed the assigned 6-month exercise programme.

2.5.Statistical methods

Statistical analysis was performed using STATISTICA v.12 software. To assess the significance of intergroup differences in the variables studied in the first and second study, the nonparametric Kruskal-Wallis test and the post-hoc Dunn test (Bonferroni test) were used. In cases where some significant differences were found between medians ($p \leq 0.05$), in multiple comparison tests, each time the results were verified, based on the comparisons of the 6 pairs of variables.

To assess the significance of differences in the studied variables measured in the first and second examination, the nonparametric Wilcoxon test was used. The differences were considered statistically significant if the level of test probability was lower than the assumed significance level ($p \leq 0.05$).

3. Results

3.1. Basic statistical measures of qualitative evaluation of FMS patterns in the experimental and control groups before and after intervention

In Table 2, the arithmetic mean, standard deviation, maximum and minimum values ($\bar{x}$, SD, Min., Max.), median value, quartile deviation (Me;Q) and coefficient of variation (V) of the studied variables are presented.

Table 2. Basic statistical measures of the results of qualitative assessment of FMS movement patterns [pts] before and after intervention

Variable Group	$\bar{x}$ [pts]	SD [pts]	Me [pts]	Q [pts]	Min [pts]	Max [pts]	V [%]
FMS1 E1F	2	0.8	2	0.9	1	3	38
FMS1 E2F	3	0.5	3	0.5	2	3	38
FMS1 E1NF	2	0.8	2	0.9	2	3	38
FMS1 E2NF	3	0.5	3	0.5	2	3	20
FMS1 C1R	2	0.6	2	0.5	1	3	27
FMS1 C2R	3	0.5	3	0.5	2	3	19
FMS1 C1L	2	0.6	2	0.5	1	3	27
FMS1 C2L	3	0.5	3	0.5	2	3	19
FMS2 E1F	2	0.6	2	0.5	1	3	24
FMS2 E2F	3	0.5	3	0.5	2	3	20
FMS2 E1NF	2	0.6	2	0.5	2	3	27
FMS2 E2NF	3	0.6	3	0.5	1	3	23
FMS2 C1R	3	0.5	3	0.5	2	3	20

FMS2 C2R	3	0.4	3	0	2	3	15
FMS2 C1L	2	0.6	2	0.5	1	3	24
FMS2 C2L	3	0.5	3	0.5	2	3	17
FMS3 E1F	2	0.9	2	1.0	1	3	43
FMS3 E2F	2	0.6	3	0.5	1	3	24
FMS3 E1NF	2	0.8	2	1.0	2	3	40
FMS3 E2NF	2	0.6	3	0.5	1	3	24
FMS3 C1R	3	0.6	3	0.5	1	3	22
FMS3 C2R	3	0.4	3	0	2	3	15
FMS3 C1L	3	0.6	3	0.5	1	3	22
FMS3 C2L	3	0.4	3	0	2	3	15
FMS5 E1F	2	0.7	2	0.4	1	3	36
FMS5 E2F	3	0.5	3	0.5	2	3	20
FMS5 E1NF	2	0.7	2	0.4	2	3	34
FMS5 E2NF	3	0.5	3	0.5	2	3	20
FMS5 C1R	2	0.8	2	0.9	1	3	42
FMS5 C2R	3	0.5	3	0.5	2	3	20
FMS5 C1L	2	0.7	2	0.4	1	3	34
FMS5 C2L	3	0.6	3	0.5	1	3	23
FMS7 E1F	2	0.6	3	0.5	1	3	24
FMS7 E2F	3	0.5	3	0.5	2	3	17
FMS7 E1NF	3	0.6	3	0.5	1	3	23
FMS7 E2NF	3	0.4	3	0.4	2	3	16
FMS7 C1R	3	0.5	3	0.5	2	3	17
FMS7 C2R	3	0.3	3	0	2	3	12
FMS7 C1L	3	0.5	3	0.5	2	3	18
FMS7 C2L	3	0.4	3	0	2	3	14
FMST E1F	16	2.7	16	1.9	10	20	17
FMST E2F	18	1.7	18	1.3	14	21	9
FMST E1NF	16	2.7	16	1.5	9	9	17
FMST E2NF	18	1.7	18	1.4	15	21	9
FMST C1R	17	2.0	17	1.9	14	21	12
FMT C2R	19	1.2	19	0.5	16	21	6
FMST C1L	17	2.0	17	1.5	13	21	12
FMST C2L	19	1.3	19	1	17	21	7

Legend:

FMS1 – the result of the Functional Movement Screen for deep squat, expressed in [pts]
FMS2 – the result of the Functional Movement Screen for hurdle step, expressed in [pts]
FMS3 – the result of the Functional Movement Screen for in-line lunge, expressed in [pts]
FMS5 – the result of the Functional Movement Screen for active straight leg rise, expressed in [pts]
FMS7 – the result of the Functional Movement Screen for rotational stability, expressed in [pts]
FMST – the total score of the Functional Movement Screen, expressed in [pts]
E1F – the affected lower limb in the FAI experimental group before the intervention

E1NF – the non-affected lower limb in the FAI experimental group before the intervention
E2F – the affected lower limb in the FAI experimental group after the intervention
E2NF – the non-affected lower limb in the FAI experimental group after the intervention
C1R – the right lower limb in the n-FAI control group before the intervention
C1L – the left lower limb in the n-FAI control group before the intervention
C2R – the right lower limb in the n-FAI control group after the intervention
C2L – the left lower limb in the n-FAI control group after the intervention

3.2. The results of the analysis of intergroup difference significance for median values in the FMS tests before and after intervention

Table 3.Results of the analysis of intergroup differences carried out using the Kruskal-Willis Anova variance for median values of FMS test results, before and after intervention

Variable/ Group	FMS1 [pts]	FMS2 [pts]	FMS3 [pts]	FMS5 [pts]	FMS7 [pts]	FMST [pts]
E1F - E1NF	0.7951 D	0.6428 D	1.0000 D	0.9022 D	0.5281 D	0.4224 D
E1F - C1R			0.3330 D			
E1F - C1L			0.2018 D			
E1NF - C1R			0.2727 D			
E1NF - C1L			0.1627 D			
C1R - C1L			1.0000 D			
E2F - E2NF	0.8673 D	0.3899 D	1.0000 D	0.9893 D	0.4648 D	0.1706 D
E2F - C2R			0.3659 D			
E2F - C2L			0.3659 D			
E2NF - C2R			0.6316 D			
E2NF - C2L			0.6316 D			
C2R - C2L			1.0000 D			

D - assessment of the significance of differences performed using a post-hoc Dunn test

The analysis of variance conducted with the Kruskal-Willis test showed a possibility of statistically significant intergroup differences in the median values of FMS3 test results, both before and after the intervention. The post-hoc multiple comparison test performed each time within the six pairs of variables did not reveal any significant differences between the median results of the qualitative assessment of the excursion pattern in the FMS3 line, before and after the intervention.

The median FMS3 score (in-line lunge) in the control group for both lower limbs (C1R and C1L) before the intervention was the maximum score of 3 points. The median score of this test in the experimental group was lower by 1 point both for the affected lower limb (E1F) and for the non-affected one (E1NF). After the intervention, the FMS3 variable for both limbs (C2R and C2L) remained unchanged in the control group; the same result was also obtained for the non-affected limb in the experimental group (E2NF). A lower median value (2 points) was observed for the affected limb in the experimental group (E2F). In both examinations, these differences were found to be statistically insignificant ($p<0.05$).

3.3. The results of the analysis of the significance of differences of median values of the FMS test measured before and after the intervention in the experimental and control groups

Table 4. The results of Wilcoxon's analysis of the significance of differences between the median values of the FMS test measured before and after the intervention in the experimental and control groups

Variable/Group	FMS1 [pts]	FMS2 [pts]	FMS3 [pts]	FMS5 [pts]	FMS7 [pts]	FMST [pts]
E1F vs E2F	0.0218*^{W}	0.1823^{W}	0.0249*^{W}	0.0022***^{W}	0.2213^{W}	0.0001****^{W}
E1NF vs. E2NF	0.0218*^{W}	0.1424^{W}	0.0218*^{W}	0.0051**^{W}	0.1823^{W}	0.0001****^{W}
C1R vs. C2R	0.0745^{W}	0.0926^{W}	0.2863^{W}	0.0077**^{W}	0.2076^{W}	0.0003****^{W}
C1L vs. C2L	0.0745^{W}	0.0450*^{W}	0.4008^{W}	0.0117*^{W}	0.2076^{W}	0.0002****^{W}

*statistically significant differences at the level $p < 0.05$, **statistically significant differences at the level $p < 0.01$, ***statistically significant differences at the level $p < 0.005$, ****statistically significant differences at the level $p < 0.001$, W - statistically significant differences, calculated using the Wilcoxon test

More than half of the FMS results noted in the second examination differed statistically significantly from the results achieved in the first examination, both in the experimental and control groups. The highest statistically significant score increments were obtained in the total test result, FMST ($p<0.001$). In each group, in this post-intervention examination, median scores increased by 2 points as compared to the pre-intervention examination, corresponding to an increase of 13% in the EF and ENF groups and of 12% in the CR and CL groups.

There was also a high significance of result differences in the active straight-leg raise pattern (FMS5). The results of this test improved in the measurements after the intervention in each of the studied groups – the greatest improvement was observed in the experimental group in the measurement for the affected lower limb ($p<0.005$). An improvement was also observed in the measurement results for the non-affected limb ($p<0.01$) and for the right ($p<0.01$) and left ($p<0.05$) limbs in the control group. In each group, the median score after the intervention was higher by 1 point as compared to the pre-intervention score.

As far as the results achieved in the deep squat (FMS1) and in-line lunge (FMS3) are concerned, statistically significant differences were observed in the results for both limbs in the experimental group ($p<0.05$) – median values improved from 2 points in the first measurement to 3 points in the second measurement.

There was a statistically significant improvement ($p<0.05$) of hurdle step (FMS2) score only for the left limb in the control group. There were no statistically significant differences between the two measurements in the rotary stability (FMS7) in each of the studied groups.

4. Discussion

Recent studies suggest that on the one hand the FMS may be useful in assessing the functional movement patterns of physically active people and thus may assess their risk of injury, but on the other hand, they also show some limitations of this test, especially in the result interpretation [5,23]. It should be noted that this test was designed as a universal tool that can be used in people practising various sports. The results obtained in this test may depend on the specific nature of a given sports discipline or injuries specific for this discipline [2,8,21]. FMS may have some limitations in terms of its reliability and accuracy. Some studies have shown that FMS results may vary over time and also be quite dependent on the person performing the test. It was also indicated that FMS results may be poorly associated with other indicators of functional movement patterns [5].

A study conducted by Loudon and Reiman [26] on a group of 103 runners of varying levels of proficiency showed that the higher their FMS score, the lower their risk of injury. Runners with a total FMS score above 14 points had a lower risk of injury than those with a score below 14 points. Runners with lower FMS scores also had greater balance problems, lower muscle strength in the lower extremities, and were more likely to experience overload injuries such as shin splints. They were also often suffering from ankle pain. The authors of this study suggest that the FMS may be a useful tool for functional diagnosis, although they note that it should be treated as part of a more comprehensive biomechanical evaluation of a runner [29].

Agresta et al. [1] conducted a normative analysis of FMS results in healthy long-distance runners. They found that this group achieved higher FMS scores than other people in the population. This may suggest that the specific running training requirements may affect test results in the studied group. The researchers also found that runners with greater running experience had better FMS scores than novice runners, and that men tended to have higher scores than women [13].

Results of a study conducted on 37 people by De Oliveira et al. [10] showed that there were no statistically significant differences in the biomechanical parameters of the run between runners who achieved different results in the FMS testing. The authors noted that the FMS measures range of motion and balance, but does not take into account movement dynamics and muscle strength that are so important during a run. For this reason, FMS test results do not always reflect a complete picture of the biomechanical characteristics of the runner.

In the literature, there are studies assessing movement patterns similar to those found in the FMS battery. However, the assessment of movement patterns in these projects is based on the assessment of hip and pelvis kinematics rather than the quality of movements using a scoring system [15,19,20,31]. The authors of these papers focus on the analysis of movement in two FAI-related movement acts, namely climbing stairs and squat. Both of these motor acts seem to be of great importance to people with FAI, as flexion in the hip joint can cause pain. Studies show that people with FAI have less hip mobility in the sagittal plane, and they reach the peak range of internal rotation when climbing stairs. During squat, people with *cam*-FAI tend to have increased anterior pelvic tilt achieved in the final phase of the squat at the maximum hip joint flexion [15,19,20,31].

This study is probably the first one to present in detail a qualitative assessment of movement patterns in runners with FAI. It was shown that the results obtained in the FMS testing by the runners from the experimental group did not differ significantly from the results obtained by the runners from the control group, both during the first and during the second examination. The biggest difference was noted in the in-line lunge test (FMS3). The FAI group achieved a median of two points in this test, both in the affected and in the non-affected limb, and the n-FAI group achieved a median of three points for both lower limbs. People with FAI had also lower values of the total FMS score (FMST). On a 21-point scale, runners with FAI reached 16 points for each leg, on average, and n-FAI runners – 17 points. The differences between these variables, despite the lack of statistical significance, indicate a certain favourable trend. Among all FMS tests, the in-line lunge test (FMS3) is the one most engaging hip joint flexion with concurrent adduction and internal rotation. This movement is known to be limited in the course of FAI [14]. Therefore, the in-line lunge test puts the highest stress on the structures of the hip joint. Interestingly, the results achieved in the deep squat test (FMS1) did not differ between groups. It is possible that due to the component of significant external rotation in the hip joint in this pattern, the structures of the hip joint have been relieved.

The lack of significant differences in the quality of presented movement patterns between the results of FAI and n-FAI runners stands in opposition to observations of other authors who found errors in the patterns of squat and climbing stairs in people with FAI. Their analyses during these motor acts were based on examination of hip joint kinematics. In the context of the limitations of the FMS in the assessment of movement patterns[16], it is possible that measuring lower limb and pelvis kinematics is a more objective diagnostic choice than testing with FMS. Only Brown-Taylor et al. [7] noted that FMS may be useful in evaluation of movement disorders and in planning treatment for people with FAI.

An important part of this work was, first of all, the attempt to assess the effects of therapeutic intervention introduced into the treatment of femoroacetabular impingement. All results of the second examination were higher than or equal to the results of the first examination. The highest statistically significant score increments were obtained in the total FMS result (FMST). Both FAI and n-FAI groups also showed significant improvement in the patterns of active straight-leg raise (FMS5). This means that after the intervention both subjects with FAI and those from the control group showed better flexion in the hip joint with extended knee joint. This improvement is important in the context of proper function of the hip joint in the course of FAI. The greater range of flexion reflects both the elasticity of the muscles of the back side of the lower limb and the mobility of joint structures. The improvement in the FMST result demonstrates a comprehensive increase in mobility across all assessed functional patterns and thus may provide potential for avoiding more serious injuries [23].

After the intervention, there was also an improvement in the results achieved for deep squat (FMS1) and in-line lunge (FMS3) for both lower limbs in the experimental group. This improvement was not noted for any limb in the control group. This fact may suggest a favourable effect of the applied exercise program on squat and in-line lunge that are key patterns in the FAI course. The improvement in these tests indicates an increase in the functional range of flexion, internal and external rotation, and possibly also adduction and abduction in the hip joint. The increase in mobility may result from an increase in the elasticity of the soft tissues of the pelvis, torso and lower limbs, as well as from a direct increase in the mobility of bone elements of the hip joint, as a result of correction of the position of the femoral head in the acetabulum.

Similar conclusions were reached by Laws et al. [25] who assessed the impact of a 6-week Pilates program on FMS test scores and run quality in people practising recreational running. The results showed that after completion of the exercise cycle, runners achieved significantly higher FMS scores – this suggests an improvement in the presented movement patterns. Additionally, participants reported run quality improvement after study completion, including reduced muscle pain and stiffness, improved posture and stability, as well as increased running efficiency. So it may seem that, like our 6-month exercise protocol, Pilates can also be an effective tool to prevent injuries and improve running comfort during workouts and competitions. However, Laws et al. [25] examined only healthy runners. Therefore, it can be concluded that this study sheds new light on an effective impact on improvement of movement patterns in runners with changes in the hip joint structure in the form of femoroacetabular impingement.

5. Conclusions

Both before and after the therapeutic intervention, no statistically significant differences were found in the values measured with the FMS test between the FAI and n-FAI runners. After the intervention, the values of the analysed variables in runners from both studied groups have improved and in the majority of cases they were significantly higher than those obtained before the intervention. The highest statistically significant score increments in the FMS test were obtained for the FMST result. In each group in this test, a median score higher by 2 points was obtained during the second examination, as compared to the first examination. After the intervention, there was also a significant and substantial improvement of the results for active straight-leg raise (FMS5). The greatest improvement was noted in the experimental group in the measurement for the affected lower limb. After the intervention, the results obtained in the tests of deep squat (FMS1) and in-line lunge (FMS3) improved significantly only in the experimental group and were approaching the values observed in the control group. The only test in which there were no statistically significant differences between the two measurements among all subjects was rotary stability (FMS7). Observations made in this work, documented by the results of the conducted analyses, allow for practical use of the proposed proprietary, 6-month rehabilitation protocol and of a comprehensive, objective protocol for functional changes monitoring by means of qualitative assessment of FMS movement patterns in the conservative treatment of people with femoroacetabular impingement practising recreational long-distance running.

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