Original paper

Radiographic parameters of hip joints in the course of femoroacetabular impingement in people practising recreational long-distance running

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Abstract

Introduction: Changes in hip joint morphology include distortions, deformities, or abnormalities in the anatomy that can affect its function and cause pain. Femoroacetabular impingement is one of them. Frequent running may increase the risk of this condition; regular feet hitting against the ground at each running step can lead to significant strain on hip joints.
Aim of the research: The aim of the study was to assess the effect of a conservative 6-month therapeutic intervention on changes in the values of selected radiographic parameters of hip joints in people practising recreational long-distance running.
Material and methods: The study included 44 men, aged 30 to 50 years, who regularly practised recreational long-distance running. Diagnosis of femoroacetabular impingement was made based on X-ray examination of hip joints in A-P and axial views with measurements of the width of the hip joint space laterally (JSW_L) and centrally (JSW_C), of the OS INSPACE distance, and of the alpha, beta, and Wiberg angles.
Results and conclusions: Analysis of variables showed statistically significant intergroup differences in values of the central joint space width (JSW_C), OS INSPACE distance, and alpha (A_ANG) and beta (B_ANG) angles in the measurements both before and after the intervention. Statistically significant differences in the measured values of X-ray parameters between the two examinations were noted only in the affected limb in the experimental group. An increase in the OS INSPACE distance ($p < 0.05$), a decrease in the alpha angle (A_ANG) ($p < 0.001$), and an increase in the beta angle (B_ANG) ($p < 0.05$) were shown.

Introduction

Changes in hip joint morphology include various distortions, deformities, or abnormalities in the anatomy that can affect its function and cause pain. These changes may be congenital or may result from an injury [1].

Ganz *et al.* [2] were the first to focus in their research on an anomaly showing in the abnormal shape of the head and neck of the femoral bone and of the acetabulum. This abnormality can cause collisions of the femoral head and acetabulum during movements of the hip joint. They called this type of pathology "femoroacetabular impingement" (FAI). There are studies that confirm the relationship between femoroacetabular impingement and development of degenerative changes in the hip joint [3].

Overload-induced changes in hip joint morphology are often diagnosed in runners. Frequently occurring pain may cause irregular pace of running steps, which can make running difficult and increase the risk of serious injuries [4].

A review by Dempster *et al.* [5] showed that 21% of runners experienced hip joint pain, and a review by Lopes *et al.* [6] reported that this value is 10%. There are no exact statistics on the incidence of FAI among runners because it is rarely diagnosed and confused with other conditions. Frequent running may increase the risk of these changes – regular impact of feet against the ground with each running step can lead to significant strain on hip joints [7].

Therefore, it seems important to conduct research aimed at defining both the diagnosis and the treatment of FAI. It is also important to determine the direction of changes occurring in the entire musculoskeletal system in people with this condition. Due to the possibility of significant damage resulting from this pathology and due to additional training loads occurring in recreational runners, it is worth checking what radiological consequences result from this hip disorder and whether the prescribed conservative treatment will improve the biomechanics of this joint and the function of the runner's motor system. Access to modern diagnostics and awareness of the problem

Table 1. Subjects' characteristics

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 [kg/m^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

of FAI occurrence among amateur runners are reduced, as compared to the situation of professional athletes. This raises a suspicion of increased exposure to motor system overload in these amateur runners, related to their running activity. Non-detected and untreated femoroacetabular impingement may promote development of adverse compensations in adjacent segments of the musculoskeletal system.

To date, the effect of surgical treatment on changes in the radiographic image of hip joints in the course of FAI has been evaluated in runners [8]. Therefore, it was important to assess also the impact of a conservative 6-month therapeutic intervention on changes in the values of selected radiographic parameters of hip joints in people practising recreational long-distance running, as compared to a group recruited from runners with no pathological changes in hip joints. It should be noted that, to date, no longitudinal study using X-ray imaging has been performed that would evaluate the effect of conservative therapy of several months' duration, involving mobilisation of the hip joint, in long-distance runners. To date, in the available literature, there are no publications trying to precisely assess the effect of a conservative therapeutic plan in the course of FAI on the improvement of biomechanics of hip joints in runners. This was not possible because of the lack of any proposed standardised conservative approach.

Material and methods

The study included 44 men, aged 30 to 50 years, regularly practising recreational long-distance running in the southern part of Poland. X-ray diagnosis of the femoroacetabular impingement was performed in the iMED24 Medical Centre in Krakow, in the A-P and axial views, with determination of the joint space width laterally (JSW_L) and centrally (JSW_C) with an accuracy of 0.5 mm, of the OS INSPACE distance with an accuracy of 0.5 mm, and of the alpha, beta, and Wiberg angles in the hip joint with an accuracy of 1°. The criterion for inclusion into the 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 n-FAI group was the alpha angle of < 55° and/or the beta angle of > 30° and < 70° in at least one hip joint (Table 1) [9]. The first measurements were carried out in January 2020, and the second ones were performed after a 6-month therapeutic intervention, in July 2020. The research project gained the approval of the Bioethics Committee of the Regional Medical Chamber in Cracow (Opinion No. 175/KBL/OIL/2020 of 14 July 2020).

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.

Therapeutic intervention

The original protocol of the exercises was created on the basis of principles presented in the works of Hernandez-Molina *et al.* [10], Loudon *et al.* [11], Griffin *et al.* [12], Drouin *et al.* [13], Emara *et al.* [14], and Xu *et al.* [15]. These included the following:
- mobilisation of the hip joint in all physiological planes in 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,
- centring 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.

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 second day.

Statistical analysis

Statistical analysis was performed with use of the Statistica v.12 software. Normality of variable distribution was checked with the Shapiro-Wilk test. To assess the significance of intergroup differences in the studied variables in the first and second examina-

Table 2. The results of testing of normality of distribution (Shapiro–Wilk test) of the joint space lateral (JSW_L [mm]) and central (JSW_C [mm]) width, OS INSPACE [mm] distance, and alpha (A_ANG [°]), beta (B_ANG[°]), and Wiberg (W_ANG [°]) angles in the experimental and control groups

Group/variable	JSW_L [mm]	JSW_C [mm]	OS INSPACE [mm]	A_ANG [°]	B_ANG [°]	W_ANG [°]
E1F	0.0101*	0.0067*	0.0054*	0.3333	0.2058	0.6776
E1NF	0.0167*	0.0049*	0.1240	0.7777	0.1455	0.8075
E2F	0.0078*	0.0019*	0.4979	0.4242	0.8490	0.8009
E2NF	0.0183*	0.0053*	0.4146	0.1997	0.7203	0.5629
C1R	0.0003*	0.0000*	0.2063	0.5282	0.9865	0.0533
C1L	0.0125*	0.0049*	0.2715	0.1670	0.8159	0.5043
C2R	0.0007*	0.0000*	0.2054	0.1105	0.1710	0.1603
C2L	0.0082*	0.0147*	0.3914	0.5609	0.8710	0.5823

$p < 0.05$, 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.

tions, in the case of normal distributions, univariate analysis of variance ANOVA (test F) was used with *post-hoc* Tukey test verification. If a non-normal distribution was found, the non-parametric Kruskal-Wallis test and *post-hoc* Dunn test (Bonferroni test) were used.

To assess the significance of differences in the studied variables measured during the first and second run of tests, the *t*-test for the dependent variables was used. The non-parametric Wilcoxon test was used if there was a non-normal distribution of the results. The differences were considered statistically significant if the level of test probability was lower than the assumed significance level ($p \leq 0.05$).

Results

Testing normality of distribution of mean values of radiographic hip joint parameters before and after intervention in the experimental and control groups

The results of measurements of lateral (JSW_L) and central (JSW_C) joint space width in all groups and of the OS INSPACE distance in group E1F showed non-normal distribution ($p < 0.05$). For the other variables in all groups the distribution was normal (Table 2).

Results of the analysis of intergroup difference significance for mean values of radiographic parameters of hip joints before and after intervention

The analysis of variance showed statistically significant intergroup differences in values of the central joint space width (JSW_C), OS INSPACE distance and alpha (A_ANG) and beta (B_ANG) angles in the measurements both before and after the intervention (Table 3).

The post hoc testing showed that the values of the JSW_C variable for the affected and non-affected limb in the experimental group prior to intervention were significantly higher ($p < 0.05$) than the values measured for the left limb in the control group. After the intervention, the values of the joint space central width (JSW_C) in each group increased.

Prior to the intervention, there were lower values of the OS INSPACE distance in the measurements for limbs from the experimental group, as compared to the control group. After the intervention, the OS INSPACE distance values increased in the limbs in the experimental group, but no such increase was observed in the control group.

The alpha (A_ANG) and beta (B_ANG) angle values were the eligibility criteria for participation in the project; therefore, the intergroup differences in the measurements before the intervention are obvious. After the intervention, there was a marked decrease in the alpha angle (A_ANG) value and a marked increase in the beta angle (B_ANG) value in the assessment of the affected limb.

Results of analysis of the significance of differences of mean values of radiographic hip joint parameters measured before and after intervention in the experimental and control groups

X-ray variables determining the anatomy of hip joints were noted between the pre- and post-intervention examination only for the affected limb in the experimental group. An increase in the OS INSPACE distance of 1% ($p < 0.05$), a decrease in the alpha angle (A_ANG) value of 7% ($p < 0.001$), and an increase in the beta angle (B_ANG) value of 23% ($p < 0.05$) were shown (Table 4).

Table 3. Results of the analysis of intergroup differences carried out using ANOVA and Kruskal–Willis ANOVA variance for mean values of lateral (JSW_L) and central (JSW_C) joint space width, OS INSPACE distance, and alpha (A_ANG), beta (B_ANG) and Wiberg (W_ANG) angles before and after intervention

Group/variable	JSW_L [mm]	JSW_C [mm]	OS INSPACE [mm]	A_ANG [°]	B_ANG [°]	W_ANG [°]
E1F – E1NF	0.2755^{D}	1.0000^{D}	0.3241^{D}	0.0094^{**T}	0.0210^{*T}	0.1836^{T}
E1F – C1R		0.2652^{D}	0.0041^{***D}	0.0001^{****T}	0.0001^{****T}	
E1F – C1L		0.0133^{*D}	0.0000^{****D}	0.0001^{****T}	0.0002^{****T}	
E1NF – C1R		0.6470^{D}	0.8504^{D}	0.0036^{***T}	0.0064^{**T}	
E1NF – C1L		0.0475^{*D}	0.0192^{*D}	0.0067^{**T}	0.2195^{T}	
C1R – C1L		1.0000^{D}	0.8361^{D}	0.9970^{T}	0.4895^{T}	
E2F – E2NF	0.1926^{D}	1.0000^{D}	0.2088^{T}	0.4464^{T}	0.6091	0.4192^{T}
E2F – C2R		0.4313^{D}	0.0074^{**T}	0.0002^{****T}	0.0002^{****T}	
E2F – C2L		0.0037^{***D}	0.0002^{****T}	0.0002^{****T}	0.0005^{****T}	
E2NF – C2R		0.8361^{D}	0.5375^{T}	0.0039^{***T}	0.0008^{****T}	
E2NF – C2L		0.0115^{*D}	0.0204^{*T}	0.0045^{***T}	0.0204^{*T}	
C2R – C2L		0.6240^{D}	0.3739^{T}	1.0000^{T}	0.7095^{T}	

Statistically significant differences, calculated by post-hoc test ($p < 0.05$), **statistically significant differences, calculated by post-hoc test ($p < 0.01$), ***statistically significant differences, calculated by post-hoc test ($p < 0.005$), ** statistically significant differences, calculated by post-hoc test ($p < 0.001$), TEvaluation difference significance carried out by the post-hoc Tukey test, DEvaluation of difference significance carried out by the post-hoc Dunn test.*

Table 4. Results of analysis of the significance of differences between mean values of the width of the joint space laterally (JSW_L) and centrally (JSW_C), OS INSPACE distance, and alpha (A_ANG), beta (B_ANG), and Wiberg (W_ANG) angles measured before and after intervention in both study groups

Variable/group	JSW_L [mm]	JSW_C [mm]	OS INSPACE [mm]	A_ANG [°]	B_ANG [°]	W_ANG [°]
E1F vs. E2F	0.3105^{W}	0.5930^{W}	0.0125^{*W}	0.0021$^{***\ t}$	0.0357^{*t}	0.3952^{t}
E1NF vs. E2NF	0.1730^{W}	0.3613^{W}	0.1397^{t}	0.8747^{t}	0.7946^{t}	0.0948^{t}
C1R vs. C2R	0.7893^{W}	0.2249^{W}	0.8330^{t}	0.5873^{t}	0.9493^{t}	0.1260^{t}
C1L vs. C2L	1.0000^{W}	1.0000^{W}	0.2037^{t}	0.9415^{t}	0.2263^{t}	0.162^{1t}

**$p < 0.05$; ***$p < 0.001$, tEvaluation of difference significance according to the t-test, WEvaluation of difference significance according to the Wilcoxon test.*

Discussion

After hip arthroscopy in people with femoroacetabular impingement, adverse changes in hip anatomy frequently improve [16, 17]. The alpha angle decreases, and the beta angle and width of the joint space increase. These changes may indicate an improvement in hip joint function and a reduction in the risk of complications resulting from FAI, such as articular cartilage injury [18, 19]. A decrease in the alpha angle indicates a reduction of the impingement, and an increase in the beta angle indicates a change in the orientation of the acetabulum in relation to the femoral head [20, 21].

Harris *et al.* [22] evaluated the effectiveness of treatments for femoroacetabular impingement aimed at symptom relief and structural change reduction. The authors analysed the results of 26 scientific publications in which FAI treatments such as manual therapy, kinesiotherapy, steroid injections, and arthroscopy were presented. The conclusion of this review is that FAI treatment should be individualised and tailored to individual patient's health condition.

Fairley *et al.* came to similar conclusions [23]. They analysed 18 studies in which they assessed the effectiveness of FAI treatment. They concluded that conservative treatments, such as manual therapy or exercise therapy, could be effective in symptom elimination in patients at an early stage of FAI.

Bastos *et al.* [16] found that hip surgery did not bring greater improvement as compared to conservative treatment in the context of pain, motion range, and quality of life of FAI patients. These results suggest that conservative treatment may be an effective treatment tool for FAI and should be considered as the first stage of therapy before surgery is decided.

In the work by Griffin *et al.* [12] it was found that physical exercise improved hip joint function, reducing pain and improving the quality of life of patients. The exercise protocol proposed by Griffin *et al.* [12] included exercises that improve hip joint stability and strengthen thigh and buttock muscles [24].

The above-mentioned issues leave no doubt that conservative treatment in people diagnosed with FAI is justified.

Due to the lack of X-ray evaluation of the effectiveness of FAI conservative treatment in the literature, observations from our analysis can only be related to the effects of surgical procedures used so far. The X-ray assessment was performed primarily to qualify the subjects to two groups. Therefore, the intergroup differences before the intervention should not be particularly surprising. It transpired that the introduced exercise protocol had a positive effect on the size of the OS INSPACE distance and the value of alpha and beta angles in the hip joint affected by femoroacetabular impingement. The OS INSPACE distance increased on average from 3.8 mm to 4.5 mm, the alpha angle decreased on average from 57° to 53°, and the beta angle increased from 21° to 27°. All these differences were statistically significant. The OS INSPACE distance both before and after the intervention was below the normative values given in scientific publications, but the upward trend was favourable for hip joint anatomy. There was a highly significant change in the alpha angle value. Its value in the hip joint affected by FAI decreased after the intervention below the upper limit of the normal values of this parameter. The results for the beta angle values were also satisfactory – the observed increase of this angle brought the level of this parameter closer to the normal range.

The exercise protocol of several months' duration resulted in positive changes in the image of hip joint anatomy in people with FAI, and these changes were comparable to the effects of hip arthroscopy. The use of X-ray imaging has brought some benefits in the form of interesting conclusions. It seems that it was a good idea to include people practising long runs recreationally, due to the additional systematic load on the structures of the hip joint. The unique value of the work was separate analysis of the affected and non-affected limbs in the FAI group and of the right and left limbs in the n-FAI group. This fact allowed us to obtain a clear and reliable picture of the functionality of the motor system in the examined persons. Due to the innovative nature of the proposed exercise program and its proven effectiveness, this paper introduces a fresh view on conservative treatment of the femoroacetabular conflict in people practising recreational long-distance running. It is also a starting point for further research, with particular emphasis on experiments in athletes practising other sports that place strong loads on the hip joints.

Conclusions

Analysis of the X-ray variables showed statistically significant intergroup differences in values of the central joint space width (JSW_C), OS INSPACE distance, and alpha (A_ANG) and beta (B_ANG) angles in the measurements both before and after the intervention.

Statistically significant differences in the measured values of X-ray parameters between the two tests were noted only in the affected limb in the experimental group. An increase in the OS INSPACE distance a decrease in the alpha angle (A_ANG) value and an increase in the beta angle (B_ANG) value were shown.

The values of selected variables characterising hip morphology in X-ray assessment in the evaluation after the intervention in the FAI group showed greater improvement than in the n-FAI group. This demonstrates a favourable effect of the rehabilitation procedure in people with FAI.

The observations made in this paper, documented by the results of the examinations performed, allow for practical use of the proposed proprietary, 6-month physiotherapy protocol and a comprehensive, objective protocol for the monitoring of changes in the motor system, in the conservative treatment of physically active people with FAI.

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Ethical approval

Opinion No. 175/KBL/OIL/2020 of July 14, 2020, Opinion of the Regional Bioethics Commission in Krakow.

Conflict of interest

The authors declare no conflict of interest.

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