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Original Article

A Low Pelvic Incidence Angle May Not Place Young Athletes at Risk of Developing Cam Morphological Changes in The Hip Joint

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Abstract

Introduction: Femoroacetabular impingement syndrome has been shown to be common in young athletes. It has been hypothesized that the spino-pelvic complex may lead to the development of Femoroacetabular impingement syndrome.

Purpose: To investigate the relationship between the Pelvic Incidence angle and the cam morphology (α-angle >55°) in young elite alpine skiers compared with a non-athletic control group.

Methods: The sample group (n=102), mean age 18 (±1.5) years, consisted of elite alpine skiers (n=75) and non-athletes (n=27). Hip joints were examined for the cam morphology, (α-angle >55°) with Magnetic Resonance Imaging and Pelvic Incidence angle measured from standing lateral plain Radiographs.

Results: No correlation was shown between a low Pelvic Incidence and an α-angle >55° across all clock positions in both groups. Skiers had a significant greater prevalence of the cam morphology (49%, n=31) compared to the controls (19%, n=5, P=0.009). Greatest frequency of the cam morphology was shown at 1 o´clock for skiers' right (30%) and left (35%) hip compared to the controls (right: 8%; left: 4%). Mean values of α-angle at 1 o'clock for the skiers were 52° (±6.1) compared with the controls 48° (±4.6, P<0.001). There was no difference in mean Pelvic Incidence angle between skiers (51±12.3°) and controls (50±9.8°).

Conclusion: A low Pelvic Incidence may not be correlated with a cam abnormal morphology defined as α-angle >55°. Moreover, this study may question the significance of a low Pelvic Incidence angle as a risk factor associated with the predisposition of hip joint to cam morphological changes in young elite alpine skiers.

Keywords: Femoroacetabular Impingement Syndrome; Hip Joint Deformity; Pelvic Incidence; Skiers; Athletes.

Abbreviations:

FAIS Femoroacetabular impingement syndrome
PI Pelvic Incidence
PT Pelvic Tilt
SS Sacral Slope

Introduction

Femoroacetabular Impingement Syndrome (FAIS) has been described as a motion- or positional-related pain in the groin or hips [1]. FAIS (Figure 1) can be divided into two types, cam (abnormal morphology at the femur) and pincer (abnormal morphology at the acetabulum) or by a combination of both [2-4]. The cam morphology has been shown to be common in young athletes, with the etiology being linked to possible growth disturbances developing during adolescence as a response to vigorous sporting activities [5,6]. It has been suggested that other risk factors associated with the predisposition for FAIS may be related to increased morphological femoral anteversion and acetabular retroversion [7,8]. Moreover, it has recently been hypothesized that the spino-pelvic complex may lead to the development of cam FAIS and that an increased acetabular over-coverage due to a low Pelvic Incidence (PI) may influence hip joint range of motion (ROM) [9].

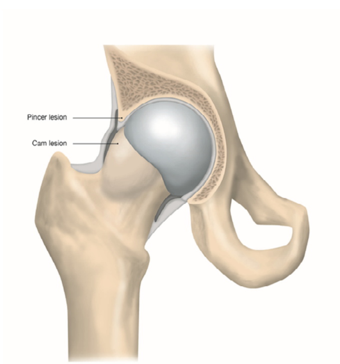

Figure 1. Pincer and CAM changes.

A well-balanced spino-pelvic-hip complex assists humans to maintain an upright posture, forward gaze and to minimize energy expenditure [10,11]. Such a relationship allows for sagittal balance of the trunk that is positioned upon the femoral heads in relation to the pelvic girdle. The pelvic girdle acts as a mobile platform that is governed by both morphological and functional pelvic parameters [12]. The PI angle has been shown to provide the most substantial information for understanding the possible adaptations relating to pelvic compensation. Previous studies have proposed the PI angle to be a fixed entity that remains constant after skeletal maturity, while PT and SS are functional adaptions as a result of the fixed PI angle. A correlation between the PI angle and lumbar lordosis (LL) has been highlighted in standing position [13,14].

Individuals with a low PI, will compensate with increased anterior PT around the axis of the femoral heads to maintain spinal sagittal balance [12]. However, this may increase anterior acetabular over-coverage making it more difficult for individuals to cope with extreme levels of hip flexion and increase the risk of premature hip impingement and the subsequent development of the cam morphology. Previous studies have used a conceptual model and cadavers to show that an anterior PT may increase acetabular over-coverage and reduce hip joint ROM in flexion and internal rotation [9,15]. Additionally, patients with bilateral cam morphology have shown to have a lower PI angle compared with controls [16]. This suggests that a correlation may exist between these variables, i.e. a cam morphology may be related to a low PI or vice-versa. Young elite alpine skiers have shown higher prevalence of the cam morphology and a different spinal sagittal alignment compared to non-athletes [17,18]. Therefore, it would appear reasonable to investigate further if a low PI correlates with the cam morphology within this sporting discipline.

The purpose of this study is to investigate the relationship between the PI angle and the prevalence of cam morphology in young elite alpine skiers and to compare them to non-athletic age-matched controls. The hypothesis of this study is that young elite alpine skiers have a low PI angle that correlates with a cam morphology compared with a non-athletic age-matched control group.

Materials and Methods

Study subjects

The sample group (n=102) consisted of young elite alpine skiers (n=75) between 16-20 years of age and a non-athletic population (n=27) 16-17 years of age. The inclusion criteria for the skiers group were training and competing at elite level within the high school competitions. Inclusion criteria for the control group were no previous nor present participation in any organized sport activities, neither any physical activity more than 2 hours per week. Participants, skiers and non-athletes, were excluded if they had had an episode of traumatic injury of the thoraco-lumbar spine or a history of previous surgery on the spine, pelvis, or hip joints. In addition, the exclusion criteria included pregnancy and any history of systemic disease including inflammatory arthritis or pelvic inflammatory disorders.

The radiographic and MRI examinations were taken at the Radiographic Department, Östersund Hospital, Sweden. All participants and their parents received both written and oral information about the study. The present study was approved by the Regional Ethical Review Board in Gothenburg, Gothenburg University, Gothenburg, Sweden (ID number: 692-13).

Testing procedure

Plain radiographic examination

For Plain radiographic examinations, a standardized protocol was used for all participants [19]. Participants were instructed to stand with the feet together in a natural upright posture, without spinal rotation, with arms hanging by their side for frontal views and arms horizontal resting on supports for sagittal views. The total measurement time was approximately 10 minutes. Automatic Exposure Control (AEC) was completed using a low dose and the edges of the images were enhanced to clearly distinguish vertebral bodies and endplates.

Pelvic parameters

Geometrical measurements relating to the pelvic parameters (Figure 2) were measured and recorded in degrees from the following; PI, a morphological parameter, is the angle measured from a perpendicular line to the mid-point of the sacral plate and extended to the center of the femoral head. PT, a positional parameter, is the angle measured from a perpendicular line starting at the center of the femoral head and extended to the mid-point of the sacral plate. SS, a positional parameter, is the angle measured from the superior endplate of S1 and a horizontal axis (13, 20). A geometrical relationship exists between the morphological (PI) and functional parameters (PT, SS) resulting in the equation PI=PT+SS [20].

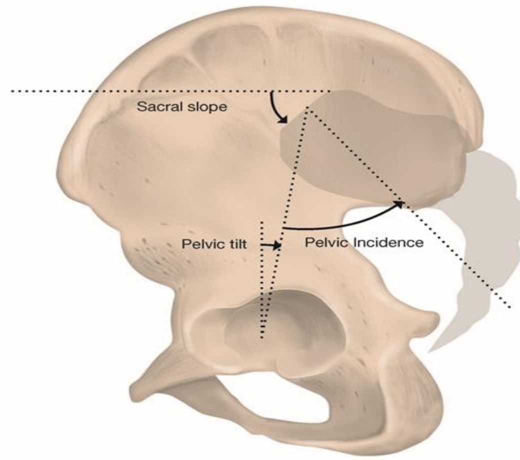

Figure 2. Pelvic balance measurements including Pelvic Incidence, Pelvic Tilt and Sacral Slope.

Magnetic Resonance Imaging (MRI) examination

MRI scan protocols were performed on both hips for all participants. The MRI machine GE Optima 450 Wide 1.5T was used for all examinations; a coil surface HD 8 channel Cardiac Array by GE was used. The total time for examination of two hips was approximately 40 minutes. The protocol was repeated twice, first for the right hip and then the left hip. The coil surface was shifted at each hip for maximum signal. Similar to previously performed studies, seven 1 mm thick radial reformats spaced clockwise in 30°-intervals around and perpendicular to the femoral neck axis were measured (Figure 3) [21]. These positions are anterior, anterior-superior, superior-anterior, superior, superior-posterior, posterior-superior and posterior and are represented by the clock positions (9, 10, 11, 12, 1, 2, 3). The clock positions are generated from the 3-D data set by using multiplane reconstruction software [22]. The alpha (α) angle is used to quantify the shape of the femoral head (Figure 3), and was measured according to Nötzil et al. [21]. This is the angle between a line drawn along the axis of the femoral neck and a line drawn from the femoral head center to the point where the head extends beyond the margin of a best-fit circle. The α-angle was measured in all planes from 9 to 3 o'clock. In the present study, the α-angle was set as greater than 55° for showing a cam morphology in the hip joint [21,22].

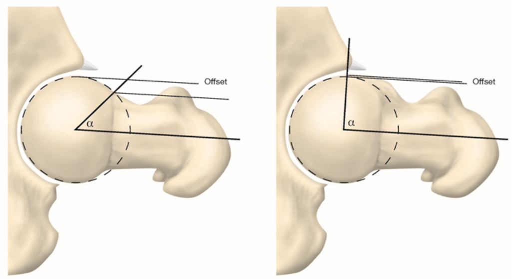

Figure 3. Measurement of the α-angle, between the femoral neck axis and a line from the center of the femoral head to a point where the contour of the femoral head-neck junction exceeds the radius of the femoral head.

Statistical analysis

Data was analyzed using IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. The description of data was expressed in terms of the mean and standard deviation (SD), including frequencies and percentages. An independent t-test and Pearson Chi-Square test were performed to compare variables. Intra-class correlation coefficients (ICC) were performed to compare variables (α-angle clock positions and PI, PT and SS). The statistical significance for all tests was set as $p<0.05$.

Results

Table 1. summarizes the demographic characteristics of the sample. Total 87 pelvises and 174 hips in eighty-seven participants (61 skiers and 26 controls) were available for the final analysis. Reasons given for dropout were difficulties with timings for radiology and MRI appointments due to traveling abroad and failure to attend appointments. The mean age of the enrolled population was 18 (⍰1.5) years. Gender highlighted fewer females in the skiers group (48%) compared with the control group (65%).

	All (n=87)	Skiers (n=61)	Controls (n=26)
Age, years	18 (1.5)	18 (1.5)	16 (1.3)
Gender %	Female 53%	Female 48%	Female 65%
BMI, km/m^2	23 (3.4)	23 (2.9)	23 (5.3)
α-angle, °	44° (5.4)	45° (5.6)	43° (3.9)
Pelvic Incidence, °	51° (11.6)	51° (12.3)	50° (9.8)
[a]Values are presented as mean (SD) except Gender that shows female percentage			

Table 1. Demographics for All Participants and Stratified by Groupa

Skiers had a higher prevalence of the cam morphology (α-angle >55 °) in the right (38%, n=23) and left (39%, n=24) hip and for bilateral (28%, n=17) compared with the controls (right: 12%, n=3, P=0.015; left: 12%, n=3, P=0.010; bilateral: 4%, n=1, P=0.011). It was also significant at the individual level with 49% of the skiers were shown to have the cam morphology compared to 19% of the controls (P=0.009). The PI angle for participants with a bilateral cam morphology (n=18) was 52.2°(±9.1) and 49.9°(±11.1) in participants without cam morphological changes (n=50). This was not significant.

Table 3 shows mean α-angle across all clock positions. There were statistical differences between skiers and controls at every clock position. The 1 o´clock position showed the largest difference with a mean α-angle for the skiers 52° (±6.1) and 48° (±4.6, P=0.001) for the controls, followed by the 11 o´clock (skiers: 45±3.9°; controls: 42±3.2°, P<0.001) and 3 o´clock (skiers: 43±5.1°; controls: 40±4.1°,P<0.001) positions. The greatest frequency of α-angle >55° occurred at the 1 o' clock position for the skiers' right hip (30%) and left hip (34%) compared to the controls right hip (8%) and left hip (4%) (Table 2).

Clock Position	All (n=87)	Skiers (n=61)	Controls (n=26)	P value*
9	38° (4.1)	39° (4.1)	37° (3.4)	0.001
10	42° (4.7)	43° (5.1)	41° (3.5)	0.050
11	44° (3.9)	45° (3.9)	42° (3.2)	<0.001
12	48° (4.8)	49° (4.9)	46° (4.3)	0.003
1	51° (5.9)	52° (6.1)	48° (4.6)	<0.001
2	46° (5.8)	47° (5.5)	45° (6.3)	0.029
3	42° (5.1)	43° (5.1)	40° (4.1)	<0.001

[a]Values are presented in degrees as mean (SD). *Independent T-Test between skiers and controls

Table 2. Mean α angle in both hips across clock positions for All Participants and Stratified by Group[a]

	All (n=87)	Skiers (n=61)	Controls (n=26)
9 R	0%	0%	0%
9 L	0%	0%	0%
10 R	1%	0%	4%
10 L	2%	3%	0%
11 R	1%	2%	0%
11 L	0%	0%	0%
12 R	9%	11%	4%
12 L	9%	11%	4%
1 R	23%	30%	8%
1 L	25%	34%	4%
2 R	9%	11%	4%
2 L	8%	10%	4%
3 R	1%	0%	4%
3 L	2%	3%	0%

[a]Values presented in percentage. R: right, L: left

Table 3. Proportion of α-angle >55° across all clock position for All Participants and Stratified by Gorupa

There was no difference in the mean value of the α-angle in both hips as total for skiers (45±5.6°) compared with controls (43±3.9°). Similarly, mean value of the PI angle was shown to be 51° (±12.3) for the skiers compared with the controls 50° (±9.8) (Table 1).

No significant correlation was shown between a low PI angle and increased α-angle measurements across all clock positions in either group. Similar results were shown for the PT and SS variables.

Discussion

The most important findings from this study highlights that no correlation was shown between a low PI angle and an increased α-angle in young elite alpine skiers compared with controls. A cam morphology was more prevalent in the skiers (49% vs controls 19%, P=0.009), especially at the 1 o'clock position. However, the skiers were also shown to have a higher mean PI angle compared to the controls (51° vs. 50°). This suggests that the cam morphology in part may be a response to the high level loading from skiing, but questions the significance of a low PI angle as a risk factor in this particular age-group and sporting discipline.

Previous studies have proposed that individuals with a low PI angle may compensate with an anterior PT and increase the risk of mechanical hip joint impingement, which may lead to the development of the cam morphology [9,16,17,28]. The present study was unable to substantiate this. One explanation may relate to the different methodology, In the present study, young asymptomatic adolescents (18 years) were tested compared to the study of Hellman et al. [23] (symptomatic adults, 33 years). It is important to highlight that an increased α-angle provides only information on size and does not necessarily mean a decrease in clearance between the femoral head and the acetabular rim [23]. Therefore, in the absence of clinical signs and symptoms such as pain, a cam morphology may not affect the spino-pelvic complex in standing position. Moreover, the outcome may also be affected by the late fusion of the pelvic bones. Partial fusion of the iliac crest occurs from 15-22 years with complete union around 23 years [24]. The ischial epiphysis is noticeable on imaging around 13 to 16 years with complete union occurring around 20 to 21 years [24]. It could be suggested that late fusion of the acetabulum may influence acetabular version and with such a young cohort in the present study, this may give rise to the high PI angle values. Furthermore, by using young adolescent athletes, one must also consider the effect of soft tissue myofascial restrictions; stiffness and capsular tension that may influence joint position and limit the accuracy of measurements [28].

Another explanation could be related to the methods of imaging. Hellman et al. [23] measured the PI angle on a scout lateral radiograph, while the present study used a standing lateral Radiograph. The standing lateral Radiograph provides a more detailed and accurate image and may have made it easier to interpret and measure PI angles. Moreover, position changes (standing vs. supine) may have influenced the outcome. PI angle in the present study was measured from radiological investigations taken in standing rather than supine. The standing position requires postural muscle activity compared to the supine position, where postural muscle activity may be more relaxed [24].

The more common cam morphology in skiers compared to controls (49% vs 19%, P=0.009) appears to be conducive with published literature [25]. Inspite of this, there was no correlation shown between a low PI values and increased α-angle measurements at any clock position. Moreover, the PI angle values were within normal parameters for a healthy population for both skiers and controls [13,26,27]. Perhaps this suggests that in the absence of clinical signs and symptoms such as pain, imaging findings alone may not be such an appropriate method to investigate relationships between these anatomical regions.

Limitations

The sample size of the cohort and the lack of power calculations limit the study. It is possible that such small numbers especially in the control group may have impacted statistical analysis and therefore, the significance of any results may have been purely due to an error in measurement. Likewise, accuracy and interpretation of the radiological measurements may have biased the outcome of the study. It could be suggested that errors may have occurred due to postural variances, biomechanical lower limb asymmetries and fatigue from prolonged standing. The exclusion of clinical signs and symptoms such as pain and using the imaging findings alone may have vied as a study limitation. Another limitation is that the subjects in the present study are too young and therefore have not developed permanent spino-pelvic and hip alignment. This may be due to the non-fusion of the pelvic bones at this age.

Clinical relevance

The clinical relevance of this study highlights that in this particular age group and sport, a low PI angle may not be a risk factor associated with the development of the cam morphology that may subsequently progress to FAI. Therefore, it is suggested that further large-scale studies are needed to determine if pelvic morphology is an important factor affecting hip morphology or vice-versa.

Conclusion

A low Pelvic Incidence angle may not be correlated with increased cam morphological changes. This study may question the significance of a low Pelvic Incidence angle as a risk factor associated with the predisposition to cam morphology in young elite alpine skiers.

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