Hip and groin pain in athletes

Morphology, function and injury from a clinical perspective

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Citation for published version (APA):
CHAPTER 7

Relationship between the frequency of football practice during skeletal growth and the presence of a cam deformity in adult elite footballers

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*Br J Sports Med. 2015 May;49(9):630-4*
Abstract

Background / aim: Cam deformity (CD) is likely a bony adaptation in response to high impact sports practice during skeletal growth. The aims of this study were to ascertain whether a dose-response relationship exists between the frequency of football practice during skeletal growth and the presence of a CD in adulthood and if the age at which a football player starts playing football is associated with the presence of a CD in adulthood.

Methods: Prevalence of a CD (alpha angle>60°) and a pathological CD (alpha angle>78°) was studied using standardized anteroposterior (AP) and frog-leg lateral (FLL) radiographs that were obtained during seasonal screening. The age of starting playing football with a low (LF; ≤3 times/week) and high (HF; ≥4 times/week) frequency was retrospectively assessed. The differences in prevalence of a CD per hip in either view between groups were calculated by logistic regression with generalized estimating equations.

Results: Sixty-three players (mean(±sd) age 23.1(±4.2) years) participated, yielding 126 hips for analysis. The prevalence of a CD on the FLL was 40% (n=82) in players that started playing HF football from the age of 12 years or older and 64% (n=44) in those playing HF before the age of 12 years (p=0.042). This was also true for a pathological CD (12% vs. 30%, p=0.038). The AP views revealed no difference.

Conclusion: Our results indicate a probable dose response relationship between the frequency of football practice during skeletal growth and the development of a cam deformity, which should be confirmed in future prospective studies.
Introduction

A cam deformity is present when there is extra bone formation at the anterolateral head neck junction. This cam deformity can be forced into the acetabulum particularly during flexion and internal rotation of the hip, a situation referred to as cam impingement\(^{72,103}\). Cam impingement is associated with decreased internal hip rotation\(^{15,120,269}\), groin pain\(^{116,216}\) and ultimately osteoarthritis of the hip\(^{115}\).

A cam deformity becomes radiographically visible during early adolescence around the age of 12 to 13 years\(^2\). The deformity is more prevalent in males than in females\(^{76,80,132}\) as well as in athletes practicing high impact sports than in non-athletic controls\(^{2,215}\). Interestingly, it was recently found that a cam deformity in football players probably only develops during skeletal maturation of the hip, when the proximal femoral growth plate is open\(^4\). This strongly suggests that most cam deformities are a result of a structural bony adaptation to high impact sports.

Prevention of the formation of a cam deformity might be possible by adjusting the type, duration or frequency of loads that are applied to the hip during skeletal growth\(^5\). However, it is unknown in which specific age range during adolescence high impact loading patterns on the hip lead to this adaptation. It is also unknown whether the frequency or duration of playing football in young football players affects the prevalence of a cam deformity.

The first aim of this study was to ascertain whether there is a dose-response relationship between the frequency of playing football during skeletal growth and the presence of a cam deformity in adult elite football players. The second aim was to investigate if the age at which a player starts playing football is associated with the presence of a cam deformity in adulthood.

Methods

Subjects

Professional elite football players from two Dutch football clubs in the highest national league were studied. All these footballers played in the first team. Standardized radiographs were obtained during the seasonal screening. The radiographs were retrieved from the medical files of the footballers, anonymized and dates of birth were erased and replaced by the age of the players. All variables needed for this study were taken from the personal files of the football players by the medical staff, anonymized by numerically coding and used for analysis.

This study complied with the requirements of the declaration of Helsinki. As this was a retrospective study with anonymized data, the Dutch Central Committee on Research
on Human Subjects (CCMO) confirmed that no ethical approval was needed according to the Dutch Medical Research Involving Human Subjects Act (WMO). Written informed consent was obtained from all participants.

Radiographs
As cam deformities are not more frequently found in the left or right hip or in the leg of dominance 4, all participants had weight bearing anteroposterior (AP) pelvic radiographs and frog-leg lateral radiographs obtained of both hips. The radiographs were obtained according to a standardized protocol. For the AP pelvic radiograph, participants were in the standing position with their feet in a frame to ensure 15° of internal rotation. The tube to film distance was 130 cm, and the beam was centred 5 cm above the pubic symphysis. The frog-leg lateral radiographs were performed with the participant in supine position. The hip and knee were flexed so that the heel was at the level of the joint line of the contralateral knee. The hip was then abducted and externally rotated, using a standard 45° wedge that was placed under the upper leg against the greater trochanter (Figure 1A). The tube to film distance was 115 cm, and the beam was centred in the middle of the groin on the femoral head. Gonadal shields were applied.

This protocol has been tested for accuracy to visualize the presence of a cam deformity and has been used before in other studies 42. An ICC of 0.82 for intra observer reliability was then established 4.

Figure 1. (A) Frog-leg lateral radiographs of each hip were obtained. Note the 45° wedge under the upper leg to standardize the participant position. (B) A frog-leg lateral view of a 25-year-old footballer with a cam deformity (white arrow). (C) The α angle (99°) was automatically calculated from the points set (white dots) along the contour of the bone.

Cam deformity
The outcome measure was the presence of a cam deformity. A cam deformity was quantified by the alpha angle on both the AP and frog-leg lateral views. The alpha angle measures the extent to which the femoral head deviates from being spherical. From a points set that was positioned in a standardized way along the surface of the bone by one
investigator (RA) using statistical shape modelling software (ASM toolkit, Manchester University, Manchester, United Kingdom), the alpha angle was automatically calculated using Matlab (v. 7.1.0) (MathWorks Inc, Natick, Massachusetts, USA) to ensure an unbiased accurate measurement.

The alpha angle is determined by drawing a best fitting circle around the femoral head. Then a line is drawn from the centre of the femoral head through the centre of the femoral neck, and a second line is drawn from the centre of the femoral head to that point where the surface of the head-neck junction first departs from the circle. The angle between these two lines is the alpha angle (Figure 1C) [69].

The presence of a cam deformity was defined by a recently validated alpha angle threshold value of >60° [6]. The presence of a pathological cam deformity was defined by an alpha angle >78°, which has previously been shown to be the threshold most discriminative for those at highest risk for developing osteoarthritis of the hip [6]. Results are presented for the presence of a cam deformity (>60°) and the presence of a pathological cam deformity (>78°) in the AP and frog-leg lateral view separately as well as their presence in either view.

Athletic activity
Data on the frequency of football practice during adolescence, the age at which they started playing football and the leg of dominance were obtained by questionnaires. These were obtained during the pre-seasonal screening procedure.

In the Netherlands, adolescents at amateur clubs usually play at a maximal frequency of 3 times a week whereas adolescents at a professional football club play at a frequency of at least 4 times a week including the match. All participants were asked in retrospect at which age they started playing at a professional football club. For the age at which they started playing football at a football club, the question posed was: ‘At what age did you start playing football at a club? This is with a highest possible frequency of 3x/week’. For the higher frequency the question was; ‘At what age did you start playing for a professional football club and/or with a minimal frequency of 4x/week?’. From these questions two dichotomous variables were extracted indicating whether or not a participant was playing low (≤3x/week) or high (≥4x/week) frequency football before the age of 12. A threshold of 12 years was applied as from this age a cam deformity can become visible on radiographs [2]. With respect to possible variations the results for a threshold of 11 and 13 years are presented as well.

Statistical analysis
Reliability of the alpha angle measurement was assessed using intra-class correlation coefficient (ICC). One investigator performed the positioning of the points set from which the alpha angle was automatically calculated. To examine intra-observer reliability,
the points set was positioned twice in 25 randomly selected AP radiographs and 25 randomly selected frog-leg lateral radiographs with an interval of 2 months. Differences in prevalence of a cam deformity between groups (defined as low and high frequent training) and association with leg dominance were calculated using logistic regression with generalized estimating equations (GEE). By using GEE, the correlation between left and right hips was modelled. Data were processed using SPSS 20 (Statistical Package for the Social Sciences, Chicago, US). The α-level for statistical significance was set at 0.05.

Results

Participant characteristics
Data of 63 footballers resulting in 126 hips were available for analysis. Their characteristics are presented in Table 1.

Table 1. Data of the players presented as mean (±SD, range).

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.1 (4.2, 18.2-38.4)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>182.3 (7.3, 167-197)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>78.2 (7.9, 62-108)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.4 (1.8, 18.7-28.1)</td>
</tr>
<tr>
<td>Dominance n (%)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>43 (69)</td>
</tr>
<tr>
<td>Left</td>
<td>18 (28)</td>
</tr>
<tr>
<td>Both</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Age at start of football (years)</td>
<td></td>
</tr>
<tr>
<td>At amateur football club</td>
<td>6.4 (2.4, 4-16)</td>
</tr>
<tr>
<td>At professional football club</td>
<td>12.5 (2.9, 5-20)</td>
</tr>
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</table>

Findings of cam deformity and pathological cam deformity in all subjects
All participants had closed growth plates on the radiographs and were thus considered skeletally mature. The ICC for intra observer variability of the alpha angle was 0.81 (95% CI 0.62-0.91) for the AP view and 0.92 (95% CI 0.83-0.96) for the frog-leg lateral view. The prevalence numbers of cam deformity for all subjects are displayed in Table 2. The prevalence of a cam deformity and a pathological cam deformity in all hips is given for the AP, the frog-leg lateral and either view. The prevalence per person is also provided and shows the presence of a cam deformity and pathological cam deformity on either view in either hip. On the AP and frog-leg lateral 2/126 and 33/126 cam deformities (>60°)
were found in the dominant and 3/126 and 29/126 in the non-dominant leg respectively. Cam deformities were not more prevalent in the dominant than in the non-dominant leg (p=0.64). In 18/63 players a cam was unilateral and in 22/63 players this was bilateral.

**Table 2.** The prevalence of a cam deformity in all hips and all footballers.

<table>
<thead>
<tr>
<th>Prevalence per hip (n=126)</th>
<th>Alpha angle &gt;60°</th>
<th>Alpha angle &gt;78°</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>4% (n=5)</td>
<td>0% (n=0)</td>
</tr>
<tr>
<td>Frog-leg lateral</td>
<td>48% (n=61)</td>
<td>18% (n=23)</td>
</tr>
<tr>
<td>Either view</td>
<td>49% (n=62)</td>
<td>18% (n=23)</td>
</tr>
<tr>
<td>Prevalence per person (n=63)</td>
<td>64% (n=40)</td>
<td>29% (n=18)</td>
</tr>
</tbody>
</table>

Table 3. Difference in prevalence of a cam deformity in adult elite football players with respect to frequency of football practice during adolescence.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Cam deformity (AA&gt;60°) in either view</th>
<th>Cam deformity (AA&gt;60°) in frog-leg lateral view</th>
<th>Pathologic cam deformity (AA&gt;78°) in either view</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 years</td>
<td>Low frequency (n=96)</td>
<td>49% (n=47)</td>
<td>48% (n=46)</td>
</tr>
<tr>
<td></td>
<td>High frequency (n=30)</td>
<td>50% (n=15)</td>
<td>50% (n=15)</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.94</td>
<td>0.87</td>
</tr>
<tr>
<td>12 years</td>
<td>Low frequency (n=82)</td>
<td>42% (n=34)</td>
<td>40% (n=33)</td>
</tr>
<tr>
<td></td>
<td>High frequency (n=44)</td>
<td>64% (n=28)</td>
<td>64% (n=28)</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.055</td>
<td><strong>0.042</strong></td>
</tr>
<tr>
<td>13 years</td>
<td>Low frequency (n=62)</td>
<td>40% (n=25)</td>
<td>40% (n=25)</td>
</tr>
<tr>
<td></td>
<td>High frequency (n=64)</td>
<td>58% (n=37)</td>
<td>56% (n=36)</td>
</tr>
<tr>
<td></td>
<td>p-value</td>
<td>0.099</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Abbreviation: AA=alpha angle.
Association between frequency of football practice during adolescence and the presence of a cam deformity

Considering the low prevalence of a cam deformity on the AP view, we only present the results for the presence of a cam deformity in the frog-leg lateral view and for the presence of a cam deformity in either the AP view or frog-leg lateral view. The prevalence of a cam deformity on the frog-leg lateral view was significantly lower in footballers that were playing football at an amateur football club (frequency ≤3 times/week) from the age of 12 years or older (40.2%, n=82) than in footballers who started playing football at a professional football club before the age of 12 years (63.6%, n=44, Odds Ratio (OR)= 0.39, 95% CI 0.15-0.97, p=0.042). When comparing the same groups the respective difference in prevalence of a cam deformity in either the AP or frog-leg lateral view (alpha angle >60°) was not statistically significant but showed a strong trend (41.5% vs. 63.6%, OR= 0.41, 95%CI 0.16-1.02, p=0.055) while there was a significant difference in the prevalence of a pathological cam deformity (alpha angle >78°) in either view (12% vs. 30%, OR= 0.33, 95%CI 0.12-0.94, p=0.038). These results and those for threshold values of 11 years and 13 years are presented in Table 3.

Association between age starting playing football and the presence of a cam deformity

All but 2 players started football at an amateur club. Only 3 footballers (6 hips) started playing football at a club from the age of 12 years or older, all others started when they were younger. The prevalence of a cam deformity per hip in either view in those that started playing football from the age of 12 years was lower (17%) than those that started before the age of 12 years (51%, n=120), though this was not statistically significant (OR=0.19, 95% CI 0.03-1.38, p=0.10). No pathological cam deformities were found in those that started playing football from the age of 12 years while the prevalence was 19% in those that started playing football before the age of 12 years.

Discussion

In footballers, a cam deformity is probably a structural bony adaptation resulting from high impact hip loading while the proximal femoral growth plate is open 4. The results of this study suggest a dose response relationship between the frequency of football practice during skeletal maturation and the presence of a cam deformity in adulthood, as a cam deformity was less likely to develop when adolescents started to play frequently (≥4 times/week) from the age of 12 years as compared with those who started playing frequently before the age of 12 years. Adjusting high impact loading patterns during skeletal maturation might thus prevent the formation of a cam deformity in some cases 5,
thereby possibly lowering the incidence of future groin pain, limited hip function and osteoarthritis.

Several quantitative and semi-quantitative measures to define the presence of a cam deformity have been proposed such as the alpha angle, (modified) triangular index and head-neck ratio, including various threshold values for each measure. The most commonly used measure is the alpha angle, which defines the extent to which the femoral head deviates from being spherical. Higher alpha angles, which often imply more severe cam deformities, confer a higher risk of limited internal rotation and osteoarthritis. We used the recently validated alpha angle threshold of 60° to define the presence of a cam deformity and 78° for a pathological cam deformity, to allow comparison with other (future) studies. We chose to use only one measure to define the presence of a cam deformity in order to decrease the chance of falsely positive classified cam deformities, as a wide reliability range has been reported for those measures.

The prevalence of cam deformities in the adult elite football players in this study are in line with previously reported prevalence numbers in male athletes. Although we studied the presence of a cam deformity per hip, the prevalence per person in the total group of elite football players was 64%, which equals previously reported prevalence numbers in male football players and other high impact sports such as American football, ice hockey and basketball, which all range between 60% and 89%. The wide range of reported prevalence of cam deformities in athletes is partly due to different definitions of what a cam deformity is, but differences in sporting frequency (from amateur to elite athletes) between studies are probably also of influence, as supported by our data. Despite this wide range these are still significantly higher than those reported in the general male population (17-20%). Interestingly, the prevalence of cam deformity in football players who started playing frequently only from the age of 12 years or later (prevalence around 40%) was between the reported prevalence of the general population and the athletic population. Additionally Gosvig et al. found that working loads during a professional occupation later in life do not relate to the presence of a cam.

Taken together, these findings support the hypothesis of the effect of hip loading during bone growth on the formation of a cam deformity. This was confirmed by two other studies that directly compared athletes with non-athletic controls. These showed a significantly higher prevalence of cam deformities in young athletes (footballers and basketball players) than in non-athletic controls. This difference in prevalence was as large as 80%, with a 9% prevalence in non-athletic controls and an 89% prevalence in basketball players who had a closed growth plate. This suggests that adjusting the loads on the hip during skeletal growth may be a way to prevent the formation of a cam deformity.

As the data of the current study show a dose response relationship between the frequency of playing football and the formation of a cam deformity, preventive strategies...
might be implemented. Our data suggest that playing high frequency especially around the age of 12 to 13 years is of influence on the development of a cam deformity. Our data support this, as the accumulated years of football practice before this age were not associated with the presence of a cam deformity (p=0.58). When regarding a cam deformity as an adaptive phenomenon of bone growth in response to high loading, a parallel can be drawn with studies investigating the effect of exercise on bone mineral density. Multiple (prospective) studies investigating the effect of exercise on bone mineral accrual in the hip have been performed in children and adolescents. These studies also suggest the existence of a period in which bone is most responsive to exercise, for boys between the age of 12 and 14 years. Besides mechanical components, bone growth is also dependent on biological components, such as genetic factors, nutrients, and hormonal regulation. Interestingly, in boys around the age of 12 to 14 years, there is a peak in circulating growth hormone and insulin growth factor-1, possibly making bone more responsive to hip loading during this stage of skeletal development.

A slightly lower frequency or duration of playing football or another type of loading during the age of 12 to 13 years might already prevent a cam deformity developing in some cases. Regarding the potential modifiable dose-response character of a cam deformity, our results legitimise future prospective studies in adolescents. These studies should focus on the effects of adjusted training frequency, intensity and duration, aiming to reduce the loads on the hip on the prevalence of a cam deformity and subsequent pathology in a certain period of growth. The degree and timing of any activity modification should be advised based on newly acquired data. Due to ethical reasons with respect to burden of the young patients and radiography radiation load, one should be careful when exposing adolescents to research but confirming the findings of our study in larger prospective studies in adolescents seems warranted as it is a relevant topic in current clinical practice. We suggest frequent evaluation of hip morphology during the period of closure of growth plates with no radiation load (MRI) and monitoring loading variables also during the years before this closure.

Several limitations of this study need to be acknowledged. The retrospective nature by which football frequency during adolescence was obtained by questionnaires might have influenced the results. This recall bias might influence the accuracy of frequency specification of playing in youth. We chose to express playing load as the frequency of playing football. As loading seems the most important variable, parameters that express the different aspects of loading need a clearer specification. Besides frequency these are duration (time) and intensity (low or high impact). This information is generally available in professional adult elites, but was not available for the adolescent years of these players. However, it is unlikely that 12-year-old players at an amateur level, when playing three times a week, exceed loading times of those playing at a professional club.
at the same age with 4 times a week or more. Besides that, the time that adolescents were playing football or sports in non-organized situations like on the street or football grounds could not be controlled for in a retrospective way. With respect to the radiographs there might have been minimal differences in players position possibly affecting the alpha angle measurements. However, this chance was minimised by using a standardized protocol and visual inspection of the radiographs that did not show obvious differences.

There were no radiographs available taken at a young age, so we could neither screen for pre-existent hip deformities at the time before 11/12 years of age nor did we know at what age growth plates have closed in individual players as there might be a discrepancy between biological age and chronological age17. Furthermore this cohort exists of a small number of participants. Nonetheless clear trends can be observed. Taking these limitations into account, some caution is required when interpreting the results.

The strengths of this study are the use of a standardized radiographic protocol and the homogenous group with respect to sport type and levels. All subjects were footballers and were thus likely exposed to the same movement patterns. Furthermore they all played at a professional football club under comparable conditions during adulthood. This decreases the chance of difference in prevalence with respect to loading in this period of their life. Also the use of software to calculate alpha angles leads to high test-retest reliability and guarantees an unbiased measurement, as the researcher is not influenced by the visual appearance of the femoral head-neck junction.

**Conclusion**

A higher prevalence of cam deformities was found in players who report starting high frequency football training before 12 years of age. This suggests a dose response relationship of football during skeletal growth, which should be investigated further with the ultimate aim to develop strategies to prevent the formation of cam deformities.

**Acknowledgement**

The authors like to thank Simon Goedegebuure and Sjoerd-Jan de Vries (physicians) and Mark Rekers and Han Tijssen, (physical therapists) for their help in data acquisition.

**Competing interests and funding**

None