



Research article

Radiographic assessment of the pubic symphysis in elite male adolescent football players: Development and reliability of the Maturing Adolescent Pubic Symphysis (MAPS) classification

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ABSTRACT

Introduction: The pubic symphysis is susceptible to growth related injuries long after the adolescent growth spurt. Our study describes the radiographic maturation of the pubic symphysis on pelvic radiographs in adolescent football players and introduces the Maturing Adolescent Pubic Symphysis classification (MAPS classification). **Methods:** Anteroposterior pelvic radiographs of 105 healthy adolescent male football players between 12 and 24 years old were used to develop the classification system. The radiological scoring of the symphyseal joint was developed over five rounds. The final MAPS classification items were scored in random order by two experienced readers, blinded to the age of the participant and to each other's scoring. The inter- and intra-rater reliability were examined using weighted kappa (κ).

Results: We developed a classification system with descriptive definitions and an accompanying pictorial atlas. The symphyseal joint was divided into three regions: the superior corners, and the upper and lower regions of the joint line. Inter-rater reliability was substantial to almost perfect: superior region: $\kappa = 0.70$ (95% CI 0.60–0.79), upper region of the joint line: $\kappa = 0.89$ (95% CI 0.86–0.92), lower region of the joint line: $\kappa = 0.65$ (95% CI 0.55–0.75). The intra-observer reliability showed similar results.

Conclusion: The Maturing Adolescent Pubic Symphysis classification (MAPS classification) is a reliable descriptive classification of the radiographic maturation of the pubic symphysis joint in athletic males. The stages can provide a basis for understanding in clinical practice and will allow future research in this field.

1. Introduction

The pubic symphysis is one of the last joints in the body to ossify, yet this knowledge does not seem to have transitioned into clinical practice [1]. Groin pain is common in athletes; about 2–5% of all sports injuries are groin related. This proportion is even higher (4–19%) in field sports, such as football or hockey [2–3]. In the age group 14–17 years, groin pain accounts for around 30% of all football injuries [4]. Most groin pain in athletes is located close to or at the pubic symphysis and the exact origin of the pain often remains unknown. Pubic-related groin pain is

one of the classifications of groin pain according to the Doha agreement on terminology and definitions in groin pain in athletes [5], and there is agreement that pubic-related groin pain may have several sub-classifications, including pubic apophysitis [6].

The pubic symphysis is a unique joint and the maturation is not fully understood. It ossifies with the development of dorsal and ventral ramparts, with billowing and separate ossicles on the surface of the joint [7–8]. Much of our understanding about the development comes from post-mortem studies [1,9–10]. The main maturation stages from 12 to 24 years have been described with a focus on the joint surfaces: first

Abbreviations: MAPS, Maturing Adolescent Pubic Symphysis; DH, David Hanff; AW, Adam Weir; AO, Astrid van Ovost.

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there is billowing of the joint surface and straight horizontal ridges with no clear delineation between upper or lower parts. After that, the ventral rampart begins to slowly form, and there is further development of the ridge. Following this, the ventral rampart ossifies; and once the dorsal plateau is complete, the symphyseal face looks smooth. The final shape when viewed end on is oval with a smooth joint surface.

Due to the late maturation, the pubic symphysis is susceptible to growth injuries at relatively high ages, after the adolescent growth spurt. To improve the understanding of pubic apophysitis as a potential diagnosis, the pubic symphysis has been visualised using advanced imaging techniques [11–12]. The appearance of a partially ossified pubic symphysis can easily be mistaken for disease states. Changes seen on imaging and sometimes described as ‘osteitis pubis’ may not be related to pathology at all, but possibly just reflect the normal development [11].

While the maturation process in cadaveric studies is well reported, the radiographic appearance during maturation has never been reported. Advanced imaging is not always available and a pelvic radiograph is recommended as a first line investigation for groin pain around the pubic symphysis in athletes [13]. Our clinical experience is that a partially matured pubic symphysis is often misdiagnosed as “osteitis pubis”. Serner et al. proposed a classification system which focussed on the morphological changes of the pubic symphysis in male athletes [14]. Though it is a reliable method it did not assess maturation of the pubic symphysis. The Oxford scoring system assess the developmental changes of the pelvis except the development of the pubic symphysis [15].

Our primary aim was to develop a classification of the maturation of the pubic symphysis in elite male adolescent football players. The secondary aim was to assess the intra- and inter-rater reliability of a Maturing Adolescent Pubic Symphysis classification (MAPS classification). We also investigated the inter rater reliability of scoring the development stages of the other hip/pelvic epiphyses and apophyses using the Oxford scoring system [15]. We used the Oxford scoring system if the maturation of the pubic symphysis is in line with other bony parts of the pelvis and to rule out large discrepancies.

2. Methods

2.1. Study design

We used a previously collected data set of plain (anteroposterior) pelvic radiographs in elite male adolescent football players. These were performed to assess the development of cam morphology in young male soccer players as part of a separate study. Our study is a secondary analysis on data from that ongoing prospective cohort study on adolescent male football players performed from 2010 onwards [16–17], which was approved by the Medical Ethical Committee of Erasmus Medical Centre, Rotterdam, the Netherlands (METC: 2009–235). All participants (and parents when needed) gave written informed consent. Volunteers were considered healthy young athletes and needed to fill in a questionnaire to rule out existing hip pathology. At the time of inclusion there were no validated patient reported structured questionnaires regarding hip and groin pain so we do not have any information of specific pubic related pain. Assuming the adolescents were able to play in good health we feel this cohort is representative of normal active healthy adolescents, but it cannot be excluded that they may have had some hip and/or groin pain.

2.2. Participants

The initial cohort consisted of 89 adolescent elite male football players at baseline. Ages at inclusion was between 12 and 19 years old. Inclusion criteria were playing in youth academy teams of Feyenoord football club Rotterdam (the Netherlands). Exclusion criteria were any known hip disorders. The players trained on average 7.9 h a week (\pm SD 1.8) and had played football for 4–15 years (mean 9 years) [16–17].

2.3. Radiography

All participants underwent a plain anteroposterior (AP) radiograph of the pelvis. The radiographs were performed at baseline, and again after 2.5 and 5 years. In 2009, the Medical Ethical Committee requested the use of lead gonad shields. In some cases, these obscured the view of the pubic symphysis on the radiograph and these cases were excluded in the current study. In cases where the lead shielding obscured other regions (such as the ischial tuberosity) then that specific region was noted as being not scorable.

2.4. Scoring protocol

Visible differences of the pubic symphysis joint between the radiographs were discussed within our team and an initial classification system was made. This was done with six rounds of scoring and discussing the various aspects. The same set large set of radiographs were used to develop scoring method as well as the final assessment. For assessing the development of other hip and pelvic epiphyses and apophyses the Oxford score was used [13].

2.4.1. Round 1

Initially the ‘Aspetar pubic symphysis radiographic scoring protocol’ [14], was used to grade the adolescent radiographs. This was recently developed for the adult pubic symphysis, but it became apparent that the system was not adequate to determine its maturation status. We discussed the various aspects seen on the radiographs, and developed a first draft of a new scale to describe the maturation in the age group 12–24 years.

2.4.2. Round 2

Based on round 1, we tested the initial draft scale on a number of radiographs and adjusted the terms and various scoring items. We improved the definitions according to available literature and through discussion with external experts in the area.

2.4.3. Round 3

Based on the included scoring items and the Suchey-Brooks method [18], we adjusted the classification to consist of four-stages. In this system we asked the readers to score the pubic symphysis in stages according to four different pictures at different times in development (Fig. 2). We named it the Maturing Adolescent Pubic Symphysis (MAPS) classification.

Additional pubic symphysis scoring parameters.

Several additional elements are considered to be part of the maturation process.

- Billowing; a fuzzy symphyseal joint surface with irregular shape.
- Presence of a visible ossicle at the inferior part of the joint signifying the apophysis. This may be small anilid thin, or clearer and more well-rounded.

We felt these to be normal developmental changes in the symphysis, and that recording them would be helpful to improve our understanding. These findings were based on the study of Dudzik et al in which they use forensic specimens to identify normal growth patterns and maturation in the pubic symphysis to derive precise age [19].

2.4.4. Round 4

We did an initial assessment of the classification system with 6 readers and found a fair agreement $k_{\text{Fleiss}} = 0,34$ (95% CI 0,27 – 0,41). Some varied more than two stages of the MAPS classification. We therefore decided to divide the pubic symphysis into three different regions and score them separately. We divided the pubic symphysis into the superior corner, upper region of the joint, and lower region of the joint (see Fig. 1 and Appendix A). We divided the joint line in an upper

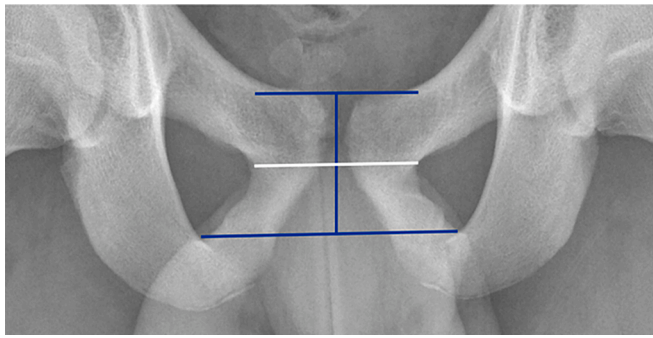


Fig. 1. Pelvic radiograph with AP view of the pubic symphysis with three lines to divide the upper and lower region of the pubic symphysis for scoring. The superior line is placed along the top of the joint. The beaks, if present, are not included in the line. The lower line is drawn along the superior aspect of the inferior ramus. The central line, that divides the two regions, is drawn halfway between these two lines.

and lower region using the superior and inferior pubic rami (Fig. 1).

It was our impression that the maturation starts at the superior corner of the joint where the ossification changes the rounded appearance to a squared corner. In some cases, the squaring of the corner will continue to ossify to form a beak-like appearance. Following this, the upper part of the joint line slowly closes, making it straighter and narrower, like closing a zipper. Finally, the lower part of the joint ossifies, creating a parallel joint (Fig. 3). This is aligned with the earlier described post-mortem stages and is clearly visible on a pelvic radiograph [19]. Based on these impressions we created four maturation stages (see Table 1 and Fig. 2). We used the scoring of the three separate regions to determine a maturation stage from 1 to 4.

2.4.5. Round 5

All radiographs were scored by two experienced researchers, a radiologist (DH) and a sports medicine physician (AW). They were also scored by an inexperienced reader (AO, a medical student who was part of all the meetings). The radiologist scored all radiographs again after four months to analyse the intra-rater reliability. The readers were blinded to each other's scoring and to the ages of the subjects. The radiographs were presented in a random order for each scoring. The scoring system was completed using LimeSurvey GmbH (Hamburg, Germany) and was used as shown in Appendix B.

2.5. Scoring items

In the final round of scoring the following items were scored in all

subjects – see Appendix A for full descriptions with illustrated examples:

1. MAPS classification items
2. Pubic symphysis irregularities
3. Pubic symphysis sclerosis
4. Inferior pubic ossicle
5. “Apple bite” sign
6. Other growth plates
 - a. Triradiate cartilage
 - b. Iliac crest
 - c. Greater trochanter
 - d. Lesser trochanter
 - e. Ischium
7. Epiphysis: head of femur
8. Cam morphology

2.6. Statistical analysis

Cohen's weighted kappa score was used to determine the inter- and intra-rater reliability for every aspect of the joint. All the responses were coded, and SPSS (version 27) was used for all analyses. A weighted kappa was used because the stages were ordinal. A kappa of 0.00 to 0.20 was interpreted as poor, a kappa of 0.21 – 0.40 as fair, 0.41 – 0.60 as moderate, 0.61 – 0.80 as substantial, and 0.81 – 1.00 as almost perfect [20]. The percentage of agreement and prevalence is also reported. The left and right side of the pubic symphysis were scored separately and added up for the stages. A McNemar test was performed to determine if there was a statistical difference between the development of the left and right side of the joint.

3. Results

3.1. Participants and radiographs

The original study started with 89 elite youth football players. The flow of patients in the study is shown in Fig. 4 there were 105 AP radiographs suitable for use in total (see Fig. 4). Since gonad protection was used, not all radiographs were eligible. There were 12 football players who had eligible radiographs at three points in time and 19 with two points. There were 31 football players where only one radiograph could be used.

The participants were between 12 and 24 years old (mean 17.2 years, SD 2.7 years) and the distribution of age is shown in Fig. 5.

3.2. Inter-rater reliability

The inter-rater reliability of the scoring between the two experienced

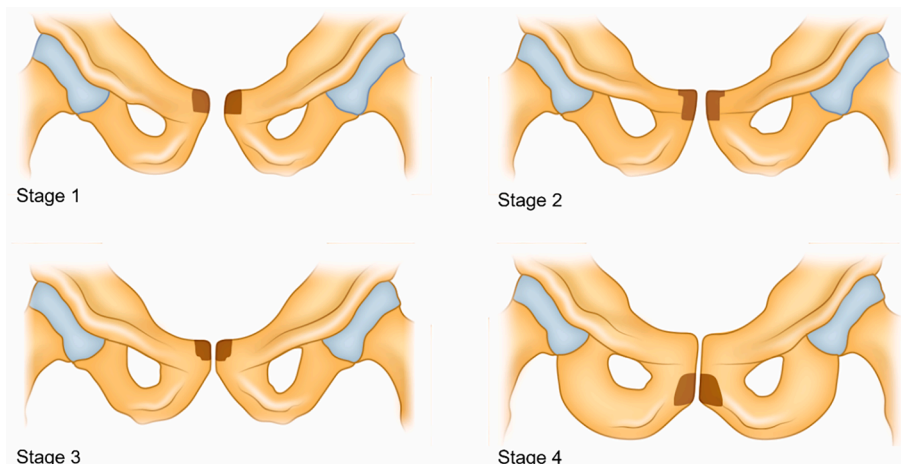


Fig. 2. Different stages of the MAPS classification. The brown highlighted section depicts the region of current maturation. **Stage 1:** The superior corner of the symphysis is still round and the upper and lower region joint lines are not yet straight or parallel. **Stage 2:** The superior corner has become squared or beaked, but the upper and lower region joint line are still round and not parallel. **Stage 3:** The superior corner is squared or beaked and the upper joint line has now become straight but the lower part is not parallel or straight. **Stage 4:** Fully matured symphysis with superior corner squared or beaked, upper and lower region joint lines are straight and parallel.

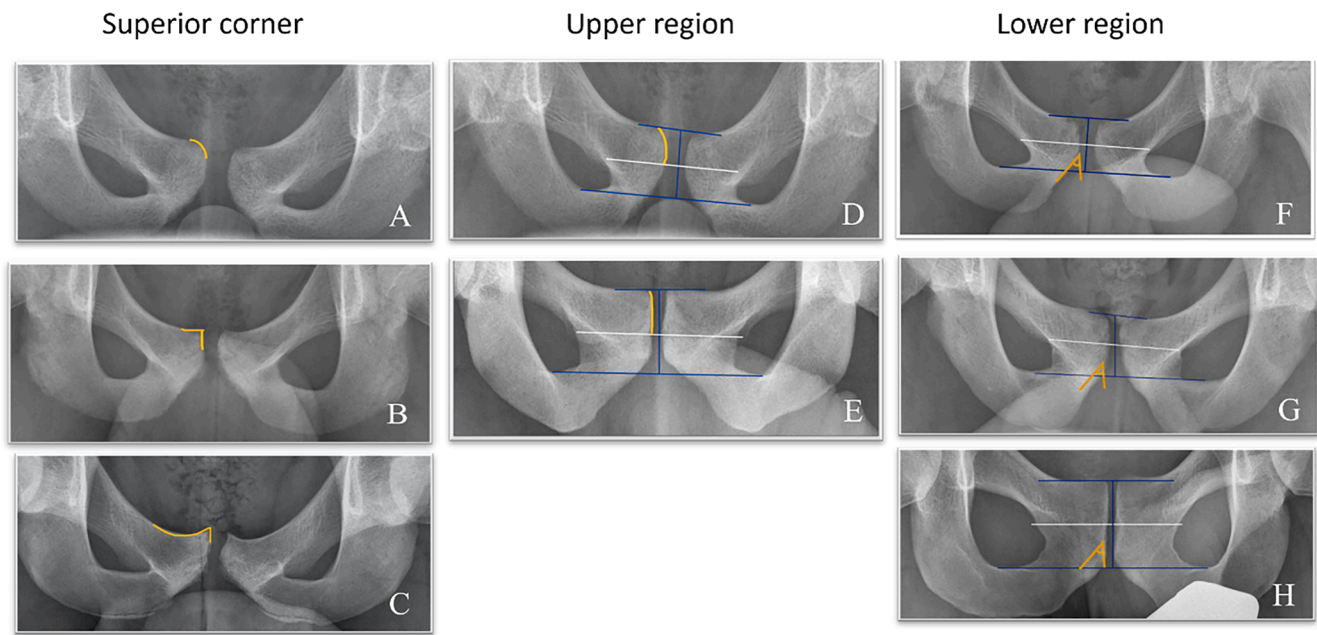


Fig. 3. The description of the maturation from top to bottom. Yellow line shows region of interest. First column: Superior corner of pubic symphysis. (A) Round, where the symphysis was still rounded with no sharp edges. Squared (B), the symphysis is filling up creating a 90 degrees angle. Beaked (C), an extra bony prominence on the superior aspect of the symphysis creating a tip. Second column: Upper region of the joint line. Round (D), a round upper symphysis, which has not yet ossified. Parallel (E), where the upper symphysis has ossified creating a straight superior part of the joint line. Third column: Lower part of the joint line. This region was divided into three categories; diagonal (F), in between (G) and straight (H). We used a 45 degree angle to represent the diagonal.

Table 1
Symphyseal stages.

Variable	Stage 1	Stage 2	Stage 3	Stage 4
Superior corner: squared or beaked	No	Yes	Yes	Yes
Upper region joint line: straight	No	No	Yes	Yes
Lower region joint line: straight	No	No	No	Yes

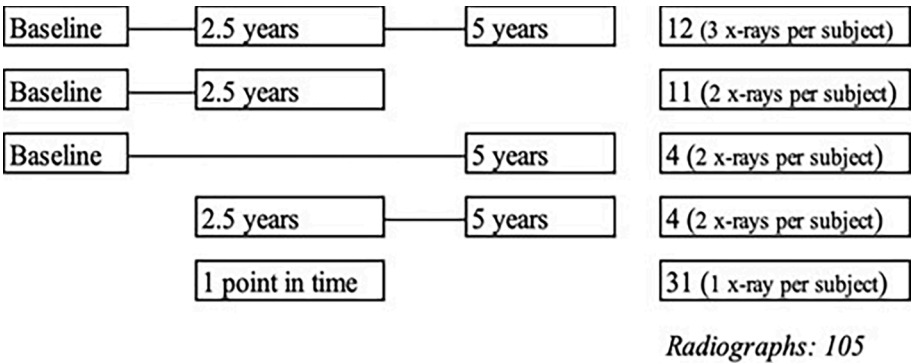


Fig. 4. Scorable X-rays.

readers (radiologist and sports physician) well as between an experienced and an inexperienced reader (radiologist and medical student) is shown in Table 2. For the experienced readers, the inter-rater reliability for the MAPS classification items was substantial for the superior corner and for the inferior joint line region, and perfect for the upper joint line region. The inter-rater reliability between the experienced and inexperienced readers showed that there was substantial agreement for all three regions of the symphysis. Only inter-rater reliability between the experienced readers was performed for the other items of the pubic

symphysis. This was found to be fair to substantial (see Table 3). For the Oxford score items the reliability was substantial to perfect.

3.3. Intra-rater reliability

The intra-rater reliability is shown in Table 2. It shows similar agreement compared to the inter-rater reliability.

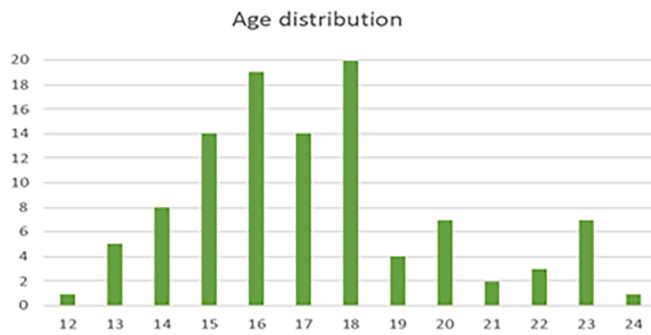


Fig. 5. Age distribution of participants at all time points.

3.4. Maturation per age group

The distribution of the stages of different age groups is shown in Fig. 6. The maturation clearly follows increasing age. We observed that the maturation status was often not symmetrical (see Appendix C). In 67% of the cases the left and right sides were at the same stage. In 29% of the cases there was one stage difference between left and right. In 3% there was a 2-stage difference. There were no cases with a 3-stage difference.

4. Discussion

We developed a new 4-stage classification system to describe the maturation of the pubic symphysis in male adolescent elite football players on pelvic radiographs. The MAPS classification items showed substantial to almost perfect reliability between two experienced readers, between an experienced and inexperienced reader and for the same reader on two occasions. We recommend assessing and scoring the three different regions of the symphyseal joint separately before determining the final stage. Other changes of the symphysis and the maturity of the other pelvic growth plates can also be assessed reliably.

4.1. The Maturing adolescent pubic symphysis (MAPS) classification

The MAPS classification is an easy way to separate the symphysis into four different maturation stages. The normal development is pictorially described by Keats but without structured detail [21]. Other classifications systems for. e.g. Risser (iliac crest) gives the reader support in understanding normal development of bony structures and especially the Risser classification is now widely used in assessing scoliosis on radiographs [22]. We hope that the MAPS classification will increase awareness of the fact that the joint matures relatively late. The final stage was mostly achieved in the early twenties and that many ‘changes’, like the fuzzy edges of the joint line, that represent normal billowing, seen on radiographs are part of the normal ossification process.

4.2. Other findings

There are some findings like a fairly large apple bite shaped lucency,

sclerosis, or a visible ossicle that are not present on all radiographs. The clinical relevance of these findings is still uncertain. It may well be that they also represent normal maturation related changes as can be seen in other parts of the body, e.g. irregular ossification of the distal femoral condyle [23]. Our experience is that the apple bite changes normally go on to ossify with advancing age. Our observation from clinical practice is that in symptomatic individuals the painful side often correlates with the less advanced maturation stage or an apple bite change. These findings agree with Saily et al who found stress related changes (widening, asymmetry and small rounded cyst-like expansions) in the pubic symphysis compared to the control group [11]. Examining the prevalence of these changes in symptomatic populations – compared with this healthy active group – could help elucidate the clinical relevance in the future.

In 29% of the cases we found one stage difference between the left and right sides. In 3% there was a 2-stage difference between sides. We believe that the discrepancy can be explained that closure of the apophysis is related to asymmetrical mechanical stress loading related to leg dominance. This can be also found in cases of delayed closure of the ischiopubic synchondrosis. Unilateral enlargement of the ischiopubic synchondrosis was related to the dominant leg and was found due to asymmetrically applied mechanical forces to the nondominant limb [24].

4.3. Strengths of the study

It is rare to have ethical approval for studies with ionising radiation in adolescents. That makes this a unique data set. Additionally,

Table 3
Reliability results of other developmental changes.

Scoring item	Interrater agreement experienced vs experienced		
	Weighted kappa (95% CI)	Overall agreement	Prevalence (%)
Other developmental changes			
Apple bite	0.47 (0.07 to 0.79)	90%	5%
Visible ossicle	0.74(0.52 to 0.95)	95%	10%
Joint surface irregularities	0.56 (0.47 to 0.64)	64%	M = 12% E = 3%
Sclerosis	0.31 (0.21 to 0.40)	55%	M = 36% E = 7%
Oxford scores			
Iliac crest	0.85 (0.80 to 0.91)	70%	
Greater trochanter	0.86 (0.77 to 0.95)	90%	
Lesser trochanter	0.70 (0.58 to 0.82)	83%	
Ischium	0.87 (0.82 to 0.93)	69%	
Head of femur	0.73 (0.64 to 0.82)	79%	

N = 105 (210 sides), CI = confidence interval, M = moderate, E = extensive. PI = prevalence index, prevalence is reported as a mean of the 2 compared scorings.

The maturation was sequential in all cases. There were no cases where the upper joint line region was straight before the superior corner had squared off. Likewise, there were no cases where the lower joint became parallel before the upper joint.

Table 2
Reliability of the MAPS stages.

Scoring item	Intra-rater agreement	Inter-rater agreement experienced vs experienced		Inter-rater agreement experienced vs inexperienced	
	Weighted kappa (95% CI)	Weighted kappa (95% CI)	Overall agreement	Weighted kappa (95% CI)	Overall agreement
MAPS-classification items					
Superior corner joint	0.74 (0.64 to 0.84)	0.70 (0.60 to 0.80)	78%	0.70 (0.59, 0.81)	84%
Upper region joint line	0.81 (0.71 to 0.91)	0.89 (0.86 to 0.91)	79%	0.65 (0.53, 0.76)	85%
Lower region joint line	0.69 (0.61 to 0.77)	0.65 (0.56 to 0.75)	65%	0.73 (0.63, 0.82)	74%

N = 105 (210 sides), CI = confidence interval.

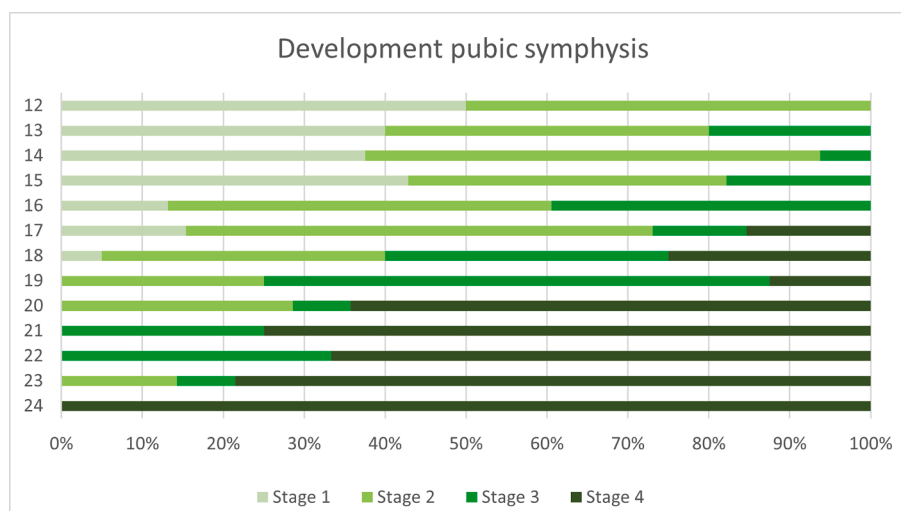


Fig. 6. MAPS classification according to age for both sides together.

radiographs were obtained at three different points in time with 2.5 and 5 year follow up where the development of different regions was visible in many cases. This gave us insight into the development. The fact that no extra software tools or measurements are needed makes it possible to use the MAPS classification in normal daily practice. Our data can be used to determine if the maturation is 'normal' for the age of that person in active individuals.

4.4. Limitations

First only male athletes were included and there are variations in pelvic anatomy and development between men and women [25]. Women's pubic symphysis are wider, shorter and more flexible during pregnancy and mature earlier. This results in a wider joint, since the fibrocartilaginous disc is not able to provide all the necessary mobility [25–26]. This means our findings may not be applicable to women. There are only athletes in this study, so we do not know if regular sports loading may affect the maturation. Since only one 12-year-old and one 24-year-old are included, it is difficult to fully generalise the findings for these age groups. Second, we do not have a control group representing a 'normal' inactive population but we feel that this cohort is a racially diverse and active group which could represent active adolescents at this age. Larger cohorts could be used to gather more information on the different stages in different populations now the classification has been developed.

Another possible limitation could be the recall bias since we used the same set of radiographs to develop the scoring method as well as the final assessment. This could lead to recall bias, but as the initial assessment of the scoring protocol was months before the final assessment and the scoring was blinded and in random order, we do not feel there was any considerable bias.

4.5. Implications for clinical practice

This study raises awareness to all health professionals that many radiographic findings at the pubic symphysis represent non-complete ossification rather than pathology. The maturation process can still be ongoing at 23 years old in males. This also suggests that pubic-related groin pain could be linked to maturation until a relatively high age.

5. Conclusion

Our study presents a new classification for the maturation of the adolescent pubic symphysis (MAPS) using anteroposterior pelvic

radiographs. Maturation in elite male athletes starts at the superior region, creating a squared edge. The joint line then gradually ossifies – from superior to inferior, like a reversed zipper. The stages can provide a basis for understanding in clinical practice and will allow future research in this field.

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CRediT authorship contribution statement

Astrid van Ovost: Writing – original draft, Methodology, Formal analysis, Data curation. **David Frederikus Hanff:** . **Andreas Serner:** Writing – review & editing. **Pim van Klij:** Writing – review & editing. **Rintje Agricola:** Writing – review & editing, Supervision. **Adam Weir:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejrad.2023.111068>.

References

- [1] T.W. T. Age changes in the pubic bone. 1920;3:43. *Am. J. Phys. Anthropol.* 1920;3.
- [2] M. Walden, M. Hagglund, J. Ekstrand, The epidemiology of groin injury in senior football: a systematic review of prospective studies, *Br. J. Sports Med.* 49 (12) (2015) 792–797.
- [3] V.J. Lacroix, A complete approach to groin pain, *Phys. Sportsmed.* 28 (1) (2000) 66–86.
- [4] O. Materne, K. Chamari, A. Farooq, A. Weir, P. Holmich, R. Bahr, et al., Injury incidence and burden in a youth elite football academy: a four-season prospective study of 551 players aged from under 9 to under 19 years, *Br. J. Sports Med.* 55 (9) (2021) 493–500.
- [5] A. Weir, P. Brukner, E. Delahunt, J. Ekstrand, D. Griffin, K.M. Khan, et al., Doha agreement meeting on terminology and definitions in groin pain in athletes, *Br. J. Sports Med.* 49 (12) (2015) 768–774.
- [6] W.M.P. Heijboer, A. Weir, E. Delahunt, P. Holmich, A.G. Schache, J.L. Tol, et al., A Delphi survey and international e-survey evaluating the Doha agreement

- meeting classification system in groin pain: Where are we 5 years later? *J. Sci. Med. Sport* 25 (1) (2022) 3–8.
- [7] Scheuer I BS. *The Juvenile Skeleton*; Elsevier; 2004. 400 p.
- [8] D. Katz, J.M. Suchey, Age determination of the male os pubis, *Am. J. Phys. Anthropol.* 69 (4) (1986) 427–435.
- [9] R.S. Meindl, C.O. Lovejoy, R.P. Mensforth, R.A. Walker, A revised method of age determination using the os pubis, with a review and tests of accuracy of other current methods of pubic symphyseal aging, *Am. J. Phys. Anthropol.* 68 (1) (1985) 29–45.
- [10] J.M.A. Fleischman, A comparative assessment of the Chen et al. and Suchey-Brooks pubic aging methods on a North American sample, *J. Forensic Sci.* 58 (2) (2013) 311–323.
- [11] M. Saily, R. Whiteley, J.W. Read, B. Giuffre, A. Johnson, P. Holmich, Pubic apophysitis: a previously undescribed clinical entity of groin pain in athletes, *Br. J. Sports Med.* 49 (12) (2015) 828–834.
- [12] E. Koh, J. Boyle, Pubic apophysitis in elite Australian Rules football players: MRI findings and the utility of VIBE sequences in evaluating athletes with groin pain, *Clin. Radiol.* 75 (4) (2020) 293–301.
- [13] M.P. Reiman, R. Agricola, J.L. Kemp, J.J. Heerey, A. Weir, P. van Klij, et al., Consensus recommendations on the classification, definition and diagnostic criteria of hip-related pain in young and middle-aged active adults from the International Hip-related Pain Research Network, Zurich 2018, *Br. J. Sports Med.* 54 (11) (2020) 631–641.
- [14] A. Serner, J. Arnaiz, A. Mosler, E. Almusa, Z. Vuckovic, I. Tak, et al., Classifying radiographic changes of the pubic symphysis in male athletes: Development and reproducibility of a new scoring protocol, *Eur. J. Radiol.* 134 (2021), 109452.
- [15] R.M. Acheson, The Oxford method of assessing skeletal maturity, *Clin. Orthop.* 10 (1957) 19–39.
- [16] P. van Klij, M.P. Heijboer, A.Z. Ginai, J.A.N. Verhaar, J.H. Waarsing, R. Agricola, Cam morphology in young male football players mostly develops before proximal femoral growth plate closure: a prospective study with 5-yearfollow-up, *Br. J. Sports Med.* 53 (9) (2019) 532–538.
- [17] R. Agricola, J.H. Bessems, A.Z. Ginai, M.P. Heijboer, R.A. van der Heijden, J. A. Verhaar, et al., The development of Cam-type deformity in adolescent and young male soccer players, *Am. J. Sports Med.* 40 (5) (2012) 1099–1106.
- [18] N. Lottering, D.M. MacGregor, M. Meredith, C.L. Alston, L.S. Gregory, Evaluation of the Suchey-Brooks method of age estimation in an Australian subpopulation using computed tomography of the pubic symphyseal surface, *Am. J. Phys. Anthropol.* 150 (3) (2013) 386–399.
- [19] B. Dudzik, N.R. Langley, Estimating age from the pubic symphysis: A new component-based system, *Forensic Sci. Int.* 257 (2015) 98–105.
- [20] J.R. Landis, G.G. Koch, The measurement of observer agreement for categorical data, *Biometrics* 33 (1) (1977) 159–174.
- [21] T.E. Keats, T.H. Smith, *An atlas of normal developmental roentgen anatomy*, 2nd ed., Year Book Medical Publishers, Chicago, 1988.
- [22] J.H. Hacquebord, S.S. Leopold, In brief: The Risser classification: a classic tool for the clinician treating adolescent idiopathic scoliosis, *Clin. Orthop. Relat. Res.* 470 (8) (2012) 2335–2338.
- [23] A.C.L. Augusto, P.C.K. Goes, D.V. Flores, M.A.F. Costa, M.S. Takahashi, A.C. O. Rodrigues, et al., Imaging Review of Normal and Abnormal Skeletal Maturation, *Radiographics* 42 (3) (2022) 861–879.
- [24] A.M. Herneth, M.O. Philipp, M.L. Pretterklieber, C. Balassy, F.W. Winkelbauer, C. F. Beaulieu, Asymmetric closure of ischiopubic synchondrosis in pediatric patients: correlation with foot dominance, *AJR Am. J. Roentgenol.* 182 (2) (2004) 361–365.
- [25] I. Becker, S.J. Woodley, M.D. Stringer, The adult human pubic symphysis: a systematic review, *J. Anat.* 217 (5) (2010) 475–487.
- [26] B. Alicioglu, O. Kartal, H. Gurbuz, N. Sut, Symphysis pubis distance in adults: a retrospective computed tomography study, *Surg. Radiol. Anat.* 30 (2) (2008) 153–157.