Eur Spine J (2013) 22:863–870
DOI 10.1007/s00586-012-2595-2

ORIGINAL ARTICLE

CT morphology and morphometry of the normal adult coccyx

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Received: 19 April 2012 / Revised: 8 August 2012 / Accepted: 13 November 2012 / Published online: 29 November 2012

Abstract
Purpose Lack of data on the in vivo morphology and morphometry of the normal adult coccyx hampers understanding of radiological abnormalities in idiopathic coccydynia. The aim of this study was to investigate normal adult sacrococcygeal morphometry.
Methods Retrospective analysis of 112 adult CT scans (mean age 63 ± 14.6 years, 50 males) evaluated the following: number of coccygeal segments; joint fusion; coccygeal spicules, subluxation, sacralization, and scoliosis; sacrococcygeal straight and curved lengths and curvature indices; sacrococcygeal and intercoccygeal angles; and lateral deviation of the coccyx tip.
Results Four coccygeal segments were present in 76 % of scans. Sacrococcygeal fusion was present in 57 % and intercoccygeal fusion was increasingly common more caudally; there was no significant association with age or gender. A bony spicule was present in 23 %. Subluxation was rare. Nine of 12 coccyges with a retroverted tip were female. Mean coccygeal curved length was 4.4 ± 0.8 cm in men and 4.0 ± 0.8 cm in women ($P < 0.01$). Mean angle between first and last coccygeal segments was 138° ± 25° in men and 147° ± 25° in women ($P = 0.08$). There was no significant correlation between coccygeal length or curvature and stature, age or BMI.
Conclusions In this first detailed study of the CT morphology and morphometry of the adult coccyx, sacrococcygeal and intercoccygeal joint fusion was common. Female coccyges were shorter, straighter, and may be more prone to retroversion, factors that may be relevant to the markedly higher prevalence of idiopathic coccydynia in women.

Keywords Coccyx anatomy · Coccydynia · Coccygectomy

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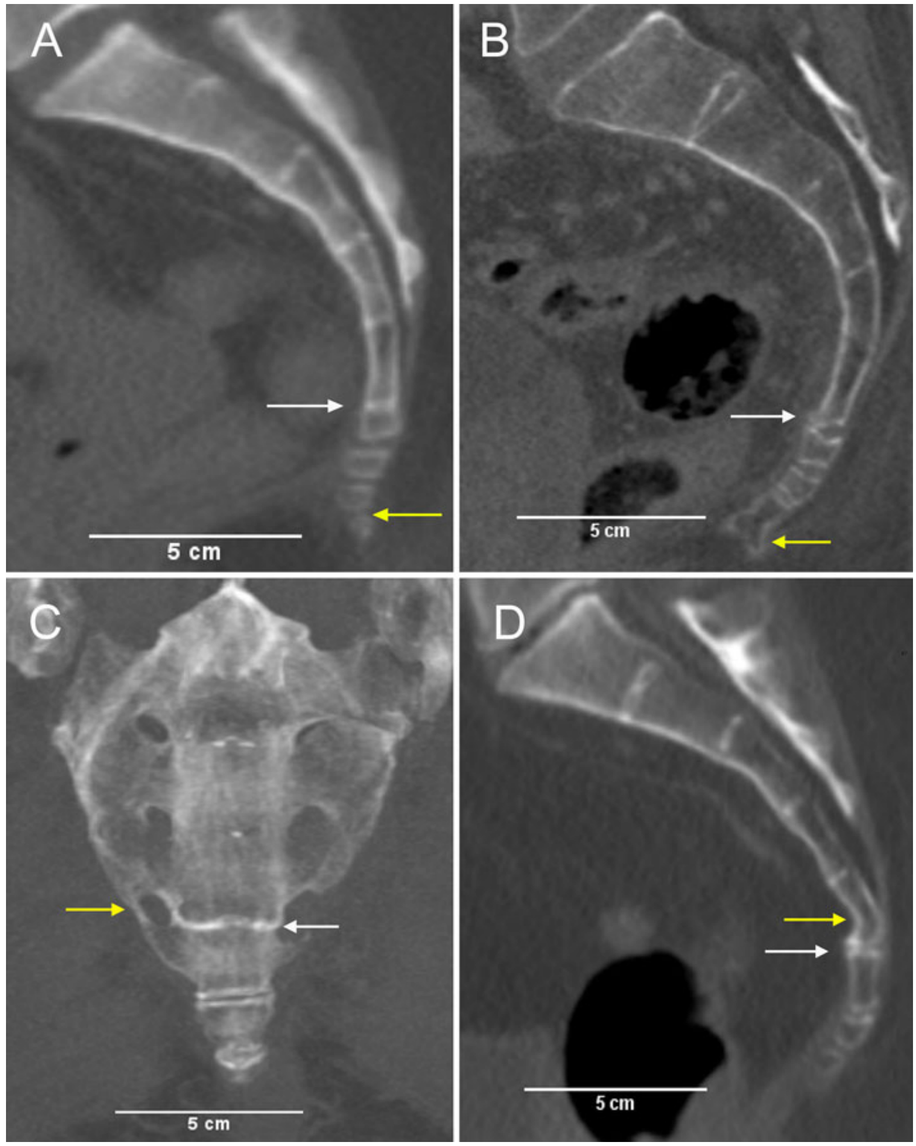
Introduction

The coccyx (from the Greek word "Κόκκυξ" due to its resemblance to the curved beak of the cuckoo) comprises the terminal vertebral segments of the human spine [1]. When subject to pathology it can be a source of debilitating localized pain [2]. There is a remarkable paucity of data on the normal in vivo morphology and morphometry of the human adult coccyx. Most observations on the length and shape of the coccyx have been derived from studies of disarticulated skeletal material [1]. One study using plain radiography in asymptomatic adults [3] and another using computed tomography (CT) in patients with vascular or suspected bowel disease [4] have been reported. This lack of information is not just of academic importance as normal reference data are essential to interpreting changes in coccygeal morphology associated with idiopathic coccydynia.

Coccydynia accounts for approximately 2,000 discharges per annum from community hospitals in the United States [5] and a similar number of affected patients are recorded each year within the public sector in the UK [6]. Patients experience debilitating pain in the coccygeal region, exacerbated by sitting, standing, and/or walking; women are four times more likely to be

Fig. 1 Qualitative observations in sagittal (**a**, **b**, **d**) and coronal (**c**) CT scans of the adult sacrum and coccyx. **a** type 5 coccyx with a retroverted tip (*yellow arrow*), **b** bony spicule (*yellow arrow*), **c** unilateral coccygeal sacralization (*yellow arrow*), **d** ventral angulation of the terminal sacral segment (*yellow arrow*). Sacrococcygeal joint (*white arrow*)



affected than men [2]. Most cases are considered to arise from sacrococcygeal or intercoccygeal joint instability, which is often traumatic in origin. Trauma may be acute from a fall or during childbirth, or chronic and repetitive, when obesity may be a predisposing factor [2, 7]. Less common causes of coccydynia may be due to local bone or soft tissue pathology [8–10]. However, one-third of cases are idiopathic [2, 9–11]. Some authors have suggested that individuals with a greater ventral angulation of the coccyx are more at risk of developing idiopathic coccydynia [3, 12]. Whether women have a more or less curved coccyx contributing to the gender bias seen in coccydynia is uncertain since the data are conflicting [3, 13].

The aim of this study was to investigate the morphology and morphometry of the normal adult coccyx in vivo by qualitative and quantitative analysis of pelvic CT scans.

Methods

CT scans of the pelvis were obtained from supine adults with no known sacral or coccygeal pathology undergoing imaging for various non-orthopedic conditions. Patients with distorting pelvic pathology such as a large mass were excluded. Scans were acquired from three sources: Christchurch Hospital, New Zealand ($n = 39$, 18 males; Lightspeed VCT scanner, GE Healthcare, Milwaukee, WI, USA); Dunedin Hospital, New Zealand ($n = 33$, 18 males; Sensation 64 scanner, Siemens AG, Erlangen, Germany); and Hôtel-Dieu Hospital, Paris, France ($n = 40$, 14 males; Brilliance 64-channel scanner, Philips Healthcare, Best, Netherlands). Slice thickness was between 1.2 and 5.0 mm. A total of 112 CT scans were available for analysis (50 males, mean age 63 ± 14.6 years [range 18–94]). Data on stature, weight, and body mass index (BMI) were available

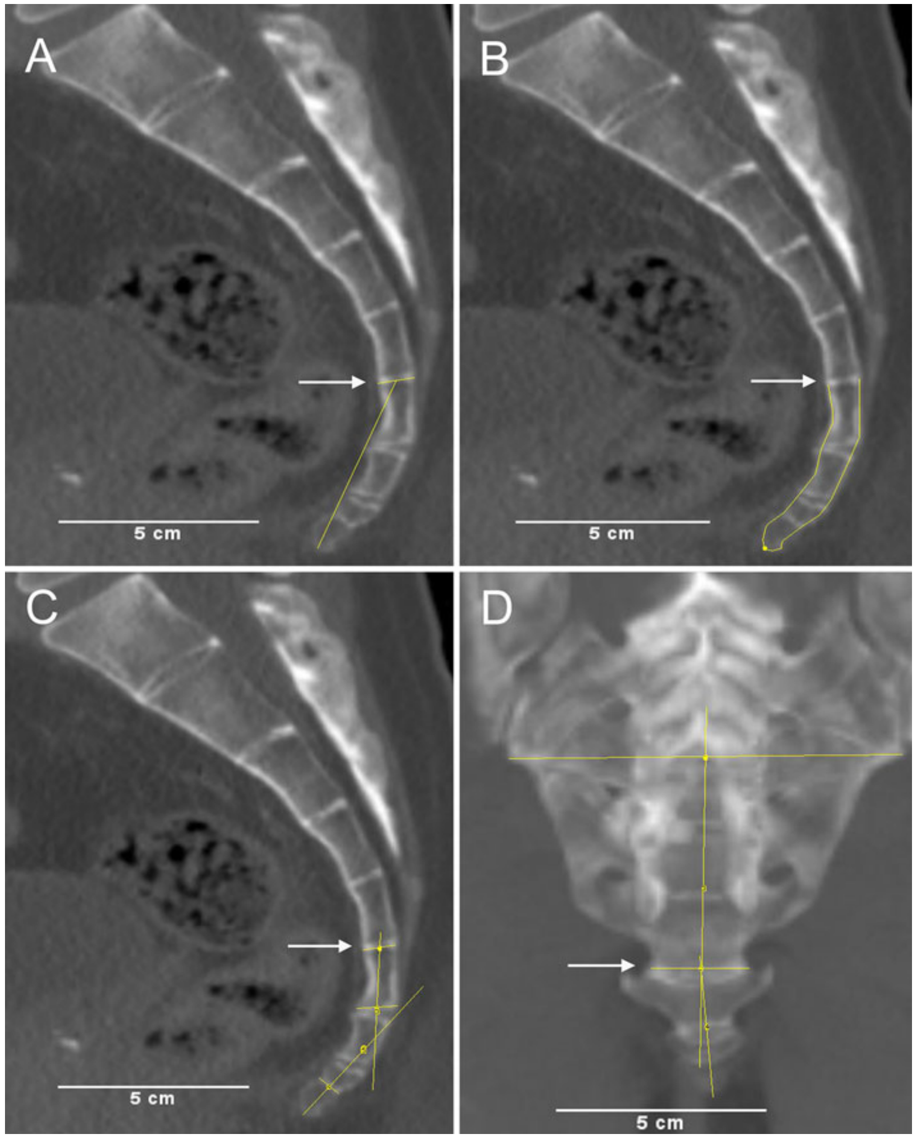


Fig. 2 Quantitative measurements in sagittal (**a**–**c**) and coronal (**d**) CT scans of the adult sacrum and coccyx. **a** Straight length of the coccyx, **b** anterior and posterior curved lengths of the coccyx, **c** intercoccygeal angle, **d** lateral deviation of the coccyx. Sacrococcygeal joint (*white arrow*)

in two-thirds of cases ($n = 74$, 29 males), 20 of whom had a BMI $\geq$30 and were classified as obese [14]. Ethnicity was not formally recorded but the vast majority of all patients were of European ancestral origin. Scans were evaluated using the software program ImageJ (National Institutes of Health, USA, v1.44p) after multiplanar reconstruction using OsiriX (OsiriX, program version 3.7.1, 2011). Linear bony measurements taken from CT scans using OsiriX have been found to be accurate and reliable [15].

Scans were analyzed using a process of dual consensus reporting similar to that described by Murphy et al. [16]. The number of coccygeal segments was determined from sagittal views, supplemented by 3-D reconstruction in the presence of joint fusion. The qualitative and quantitative parameters listed in Table 1 were assessed.

Measurements were repeated in 20 subjects after an interval of at least 1 week to assess intra-observer repeatability and by another independent observer to determine inter-rater reproducibility.

Statistical analysis

Associations between categorical variables were investigated using Chi-squared and Fisher's exact test whilst associations between continuous variables were investigated using Pearson's correlation. Means for continuous data were compared using the independent samples t test. Multiple linear regressions were used to adjust for confounders. Inter- and intraclass correlation coefficients were calculated to assess reliability of measurements and interpreted using the criteria of Landis and Koch [18].

Table 1 Qualitative and quantitative coccygeal parameters

	Definition
Qualitative	
Joint fusion	Bony continuity between adjacent vertebrae on all sagittal slices (at sacrococcygeal and/or intercoccygeal joints)
Coccygeal types	Type 1 is a slightly curved coccyx pointing downwards; type 2 is more curved and points forwards; type 3 is sharply angulated at the first or second intercoccygeal joint; type 4 is a coccyx with an anterior subluxation at the sacrococcygeal or first intercoccygeal joint [3]; and type 5, a coccyx with a retroverted tip [17] (Fig. 1a)
Bony spicule	A bone spicule projecting from the terminal coccygeal segment [7] (Fig. 1b)
Joint subluxation	Abnormal translation between two adjacent vertebrae at the intervertebral disc
Coccygeal sacralization	Unilateral or bilateral fusion of the transverse processes of the first coccygeal segment (Co1) to the inferolateral angle of the sacrum, forming 6 sacral segments (Fig. 1c)
Ventral angulation of the terminal sacral segment	A sharp angulation at the distal end of S5
Coccygeal scoliosis	Lateral deviation to one side and then the other
Quantitative	
Coccygeal straight length	Measured in a straight line from the middle of the upper border of Co1 to the coccygeal tip (Fig. 2a)
Coccygeal curved length	Average of the anterior and posterior curved coccygeal lengths measured from the upper border of Co1 to the tip of the coccyx (Fig. 2b)
Sacral straight length	Measured in a straight line from the middle of the upper border of S1 to the middle of the inferior border of S5
Sacral curved length	Average of the anterior and posterior curved sacral lengths measured from the upper border of S1 to the inferior border of S5
Sacrococcygeal curved and straight lengths	Measured from S1 to the tip of the coccyx using the same methods as applied to the coccyx
Curvature index	Calculated from straight length divided by curved length $\times$ 100
Sacrococcygeal angle	Formed by the intersection of a line between the mid point of the upper borders of S1 and Co1 and a line between the latter and the tip of the coccyx
Coccygeal angles	Intercoccygeal angle formed between lines intersecting the middle of the first and last coccygeal segments in the median plane (Fig. 2c). Sacrococcygeal joint angle (S5–Co1) and the first and second intercoccygeal joint angles (Co1–Co2 and Co2–Co3) were also measured
Sacral angle	Formed between the upper border of S1 and the true horizontal
Lateral deviation of the tip of the coccyx	Determined by measuring the angle between the tip of the coccyx and a line passing through the middle of the sacrum (Fig. 2d)

All scans were obtained with informed consent. Local ethical approval was obtained in New Zealand (LRS/09/30/EXP) but French laws on research do not require this for the study of archival anonymized scans.

Results

Coccygeal morphology

Coccyges had either 3 (13 %), 4 (76 %), or 5 segments (11 %); there was no evidence for an association with gender ($P = 0.85$). The sacrococcygeal joint was fused in 57 % of coccyges, the first intercoccygeal joint in 17 %, the second in 61 %, the third in 89 % of coccyges with 4 segments, and the fourth in all coccyges with 5 segments. All joints including the sacrococcygeal joint were fused in three individuals (1 male, 87 years; 2 females, 61 and 58 years). Joint fusion was not associated with age or gender ($P = 0.43$ and 0.85, respectively, for sacrococcygeal fusion; $P = 0.35$ and 0.19, respectively, for third intercoccygeal joint fusion). Coccygeal types were distributed as follows: 72 (64 %) type 1, 18 (16 %) type 2, 9 (8 %) type 3, 1 (1 %) type 4, and 12 (11 %) type 5. Nine of

12 type 5 coccyges were in women ($P = 0.22$). Type 2 coccyges were significantly more common in men ($P = 0.02$).

A bony spicule was observed in 26 (23 %) coccyges, with no significant gender bias ($P = 0.37$). Subluxation was rare (3 %) and coccygeal sacralization uncommon (5 % unilateral, 7 % bilateral). The S5 segment was sharply angulated forward in 18 (16 %) scans; 13 of these were in females ($P = 0.13$). Scoliosis was present in 7 coccyges, 6 of which were in females ($P = 0.13$).

Coccygeal morphometry

Coccygeal length versus gender, age and BMI

Overall mean curved and straight lengths of the coccyx were 4.2 ± 0.8 and 3.7 ± 0.7 cm, respectively, with men having significantly longer coccyges (Table 2). There was a weak correlation between curved coccygeal length and stature in women ($r = 0.37$, $P = 0.01$) but not men ($r = -0.29$, $P = 0.13$). Multiple linear regression showed no association between coccygeal length and stature ($n = 74$, $P = 0.68$). Coccygeal length was not significantly correlated with age ($r = 0.07$, $P = 0.44$) or BMI ($r = -0.15$, $P = 0.20$).

Coccygeal curvature versus gender, age and BMI

Mean joint angles are shown in Table 3. Men tended to have more ventrally curved coccyges compared to women ($P = 0.08$). There was no significant correlation between coccygeal curvature and either BMI ($r = 0.00$, $P = 0.98$) or age ($r = -0.06$, $P = 0.51$).

Sacrococcygeal parameters

Sacrococcygeal measurements versus gender, age and BMI

Overall, mean curved and straight lengths of the sacrum were 12.2 ± 1.0 and 11.0 ± 0.9 cm, respectively. Mean curved and straight lengths of the whole sacrococcygeal segment were 16.5 ± 1.4 and 12.6 ± 1.2 cm, respectively. Men had significantly longer straight and curved sacrococcygeal lengths than women (Table 2). There was a weak positive correlation between stature and both curved and straight sacral and sacrococcygeal lengths (Table 2). Both sacral and sacrococcygeal lengths were not significantly associated with age or BMI ($P = 0.50$ and 0.78, respectively, for sacral curved and straight lengths vs. age and $P = 0.16$ and 0.26, respectively, for sacrococcygeal curved and straight lengths vs. age; $P = 0.33$ and 0.78, respectively, for sacral curved and straight lengths vs. BMI and $P = 0.97$ and 0.41, respectively, for sacrococcygeal curved and straight lengths vs. BMI).

In contrast to coccygeal curvature, which was greater in men, the sacrococcygeal joint angle tended to be slightly straighter in men (males 168°, females 164°, $P = 0.06$) (Table 3). Mean sacrococcygeal angle (between S1 and tip of the coccyx) in all scans was 106° ± 13° with no significant gender bias (males 107° ± 12°, females 106° ± 14°, $P = 0.56$).

Mean sacral angle (between the upper border of S1 and the axial plane) was 43° ± 8.0°, with no significant difference between genders (males = 43° ± 8.1°, females = 43° ± 7.9°, $P = 0.92$). The tip of the coccyx was deviated laterally by a mean of 6° (range 0°–23°); this was significantly greater in men (7.3° ± 5.9°) than women (4.9° ± 4.4°) ($P = 0.02$).

Reliability

Inter- and intraclass correlation coefficients were between 0.70 and 0.99 for all quantitative measurements, indicating substantial to almost perfect reproducibility and repeatability, respectively.

Discussion

This is the first detailed study of the CT morphology and morphometry of the human adult coccyx. The main findings can be summarized as follows. The normal adult coccyx comprises 3–5 segments, 4 being present in most individuals; a greater number of segments has been reported in a few individuals in some studies [19]. Average

Table 2 Mean coccygeal, sacral and sacrococcygeal lengths

Measurement	Male ± SD (cm)	Female ± SD (cm)	P value	Pearson correlation r with stature (P value)
Coccygeal curved length	4.4 ± 0.8	4.0 ± 0.8	<0.01	0.20 (0.32)
Coccygeal straight length	3.9 ± 0.7	3.6 ± 0.7	<0.05	0.19 (0.35)
Sacral curved length	12.4 ± 1.0	12.1 ± 0.9	0.09	0.24 (< 0.05)
Sacral straight length	11.2 ± 1.0	10.8 ± 0.8	<0.05	0.35 (< 0.01)
Sacrococcygeal curved length	17.0 ± 1.4	16.1 ± 1.3	0.001	0.33 (< 0.01)
Sacrococcygeal straight length	13.0 ± 1.3	12.3 ± 1.0	0.001	0.31 (< 0.01)

Table 3 Mean coccygeal angles and curvature indices

	Total mean ± SD (°)	Male mean ± SD (°)	Female mean ± SD (°)	*P* value
Sacrococcygeal joint angle	166 ± 13	168 ± 11	164 ± 13	0.06
Intercoccygeal angle	143 ± 26	138 ± 25	147 ± 25	0.08
First intercoccygeal joint angle	155 ± 17	156 ± 16	157 ± 18	0.83
Second intercoccygeal joint angle	141 ± 16	157 ± 15	162 ± 17	0.17
Coccygeal curvature index	89.3 ± 4.9	88.7 ± 4.6	89.7 ± 5.1	0.26
Sacral curvature index	90.1 ± 4.6	90.4 ± 3.7	89.9 ± 5.3	0.56
Sacrococcygeal curvature index	76.7 ± 6.9	76.8 ± 6.5	76.6 ± 7.2	0.87

coccygeal curved length in males and females combined was 4.2 cm and the mean intercoccygeal angle 143°. However, there was considerable individual variation. The coccyx was significantly longer in men and tended to be more curved. The tip of the coccyx deviated minimally from the midline (a mean of 6°). A bony spicule was present in 23 % of coccyges whilst fixed joint subluxation was rare. Multiple linear regression showed no association between coccygeal length or curvature and age or BMI. Considering the sacrococcygeal segment as a whole, this was significantly longer but not straighter in men (the increased ventral curvature of the coccyx in men being offset by a straighter sacrococcygeal joint angle) (Table 3). These findings not only contradict statements commonly made in the literature about the coccyx (see below) but they also provide normal data from living subjects, which is essential before interpreting radiologic changes that might be associated with coccydynia.

The literature on sacrococcygeal joint fusion is confusing. Diverse results have been reported from analyses of skeletal material [20, 21], radiographs [3, 13], and magnetic resonance images (MRI) [22]. There is no consensus on the prevalence of sacrococcygeal joint fusion or whether it varies with gender or age. In our study, sacrococcygeal and intercoccygeal joint fusion were common; the former was fused in more than half of all adults and the latter was progressively more common in more caudal intercoccygeal joints. Joint fusion was not related to age or gender. Fusion of all sacrococcygeal and intercoccygeal joints was relatively rare (3 % in this study).

To our knowledge, reliable data on the length of the adult human coccyx in vivo have not been previously reported. Coccygeal length has been recorded in skeletal material [23] and Korean cadavers [24]. One MRI study recorded the sum total of individual coccygeal vertebral lengths but not the length of the coccyx together with its intervertebral discs [19]. There is a similar paucity of data on coccygeal curvature, which tended to be greater in men in our study. Kim and Suk [12] recorded a smaller mean intercoccygeal angle of 128° in radiographs of 20 Korean adults but could not comment on sexual dimorphism because 18 subjects were women. In a larger Turkish CT study of 92 patients (50 females, 42 males) that assessed the intercoccygeal angle, patients were subjectively divided into three groups based on coccygeal curvature precluding direct comparison with our results [4]. However, these authors noted that the coccyx tended to be slightly straighter in females, consistent with our findings. In contrast to our results, they recorded only two retroverted coccyges.

The mean sacral angle in our supine subjects was 43° ± 8.0°, similar to the 41° ± 7.7° measured from erect radiographs of the lumbosacral spine in men [25]. We found no significant difference in this angle between men and women. Mean sacral straight lengths in men and women in our study were very similar to values obtained from a CT study of European sacra that focused on the correlation between sacral straight length and stature [26]. However, in this study sacral lengths were recorded from the anterior margins of the sacral vertebrae. As in our study, the authors found that this measurement was significantly greater in men, and correlated significantly with stature. We found no evidence of a significant reduction in sacral length with increasing age as reported in women by Karakas et al. [26].

The fact that coccydynia is much more common in women [2] has long been attributed to a “more prominent” coccyx [13, 27]. Our findings show that the coccyx is shorter and tends to be straighter in women but other radiologic features are not significantly different between the sexes. Although not statistically significant, a retroverted tip was seen more often in women; this may be related to previous childbirth but we had no data on parity to test this suggestion. Postpartum coccydynia is relatively uncommon [2, 10, 11, 27] but vaginal delivery may be a contributing factor to the higher prevalence of coccydynia in women. As Maigne and colleagues [7, 28] have shown, obesity is an additional risk factor for both idiopathic and traumatic coccydynia. In such individuals, the coccyx tends to project more posteriorly when sitting because of reduced sagittal pelvic rotation resulting in an increased likelihood of acute or chronic trauma [7]. Other anatomical features of the coccyx that have been postulated to predispose to coccydynia (either directly or indirectly from trauma) include fusion of the sacrococcygeal joint [3], increased forward angulation of the coccyx [3], the presence of a bony spicule [7], sacrococcygeal or intercoccygeal subluxation [3, 28], retroversion of the tip [29] and scoliosis [12]. Without reliable normal data from a reasonably large sample of adults without coccydynia, which our study provides, it is difficult to explore these hypotheses. Further, it is important to use objective measures of coccygeal morphology to complement the subjective classification of Postacchini and Massobrio [3] that has been used in previous studies [4, 27].

It is important to note that our observations were restricted to coccygeal morphology in static supine adults. Coccygeal movement occurs with change in posture between standing and sitting, affecting the sacrococcygeal angle and other parameters [7]. This additional factor should therefore be considered in the etiology of coccydynia [7].

In conclusion, the CT morphology and morphometry of the human coccyx has been described in 112 adults, documenting reliable qualitative and quantitative normal data. The coccyx was shorter and tended to be straighter in women; it may be more likely to be retroverted. Sacrococcygeal and intercoccygeal joint fusion was common but not apparently related to gender or age. A bony spicule was present in almost one-quarter of coccyges but joint subluxation was rare. There was no correlation between coccygeal length or curvature and age or BMI. Coccydynia is not a diagnosis but a symptom with many potential causes including acute trauma and local peri-coccygeal pathology. Potential pain generators include the sacrococcygeal and intercoccygeal joints, local soft tissues, and coccygeal nerves. In a significant proportion of patients the condition is idiopathic. A better understanding of normal coccygeal morphology should assist the evaluation of potential anatomical factors in the etiology of this disorder.

Acknowledgments We would like to thank Rona Buttimore, Research Nurse at Christchurch Hospital for collecting CT scans and patient data. Also thanks to Dr Claire Cameron and Dr Ali Mirjalili for assistance with statistical analysis.

Conflict of interest None.

References

1. Woon JTK, Stringer MD (2012) Clinical anatomy of the coccyx: a systematic review. Clin Anat 25:158–167
2. Karadimas EJ, Trypsiannis G, Giannoudis PV (2010) Surgical treatment of coccygodynia: an analytic review of the literature. Eur Spine J 20:698–705
3. Postacchini F, Massobrio M (1983) Idiopathic coccygodynia. Analysis of fifty-one operative cases and a radiographic study of the normal coccyx. J Bone Joint Surg Am 65:1116–1124
4. Kerimoglu U, Dagoglu MG, Ergen FB (2007) Intercoccygeal angle and type of coccyx in asymptomatic patients. Surg Radiol Anat 29:683–687
5. Agency for Healthcare Research and Quality (Internet). Maryland. Department of Health and Human Services. c2000–2009. http://hcupnet.ahrq.gov/. Accessed 17 February 2012
6. Health and Social Care Information Centre (Internet). London. Hospital Episode Statistics online. c2005–2012. http://www.hesonline.nhs.uk/. Accessed 18 February 2012
7. Maigne JY, Doursounian L, Chatellier G (2000) Causes and mechanisms of common coccydynia: role of body mass index and coccygeal trauma. Spine 25:3072–3079
8. Maigne JY, Pigeau I, Roger B (2012) Magnetic resonance imaging findings in the painful adult coccyx. Eur Spine J (Epub ahead of print)
9. Bilgic S, Kurklu M, Yurttas Y, Ozkan H, Oguz E, Sehirlioglu A (2000) Coccygectomy-with or without periosteal resection. Int Orthop 34:537–541
10. Gáspár L, Jónás Z, Kiss L, Vereb G, Csernátony Z (2009) Coccygectomy has a favorable effect on the intensity, manifestation, and characteristics of pain caused by coccygodynia: a retrospective evaluation of 34 patients followed for 3–18 years. Eur J Orthop Surg Traumatol 19:403–407
11. Trollegaard AM, Aarby NS, Hellberg S (2000) Coccygectomy: an effective treatment option for chronic coccydynia: retrospective results in 41 consecutive patients. J Bone Joint Surg Br 92:242–245
12. Kim NH, Suk KS (1999) Clinical and radiological differences between traumatic and idiopathic coccygodynia. Yonsei Med J 40:215–220
13. Duncan G (1937) Painful coccyx. Arch Surg 34:1088–1104
14. World Health Organization (Internet). Geneva. Obesity. c2012. http://www.who.int/topics/obesity/en/. Accessed 20 February 2012
15. Kim G, Jung HJ, Lee HJ, Lee JS, Koo S, Chang SH (2012) Accuracy and reliability of length measurements on three-dimensional computed tomography using open-source OsiriX software. J Digit Imaging 25:486–491
16. Murphy R, Slater A, Uberoi R, Bungay H, Ferrett C (2010) Reduction of perception error by double reporting of minimal preparation CT colon. Br J Radiol 83:331–335
17. Nathan ST, Fisher BE, Roberts CS (2010) Coccydynia. A review of pathoanatomy, aetiology, treatment and outcome. J Bone Joint Surg Br 92:1622–1627
18. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. Biometrics 33:159–174
19. Pelin C, Duyar I, Kayahan EM, Zagyapan R, Aguldere AM, Erar A (2005) Body height estimation based on dimensions of sacral and coccygeal vertebrae. J Forensic Sci 50:294–297
20. Saluja PG (1988) The incidence of ossification of the sacrococcygeal joint. J Anat 156:11–15
21. Tague RG (2011) Fusion of coccyx to sacrum in humans: prevalence, correlates, and effect on pelvic size, with obstetrical and evolutionary implications. Am J Phys Anthropol 145:426–437
22. Grassi R, Lombardi G, Reginelli A, Capasso F, Romano F, Floriani I, Colacurci N (2007) Coccygeal movement: assessment with dynamic MRI. Eur J Radiol 61:473–479
23. Le Double A (1912) Traité des variations de la colonne vertébrale de l'homme et de leur signification au point de vue de l'anthropologie zoologique. Vigot Freres, Paris
24. Oh CS, Chung IH, Ji HJ, Yoon DM (2004) Clinical implications of topographic anatomy on the ganglion impar. Anesthesiology 101:249–250

25. Hellems HK, Keats TE (1971) Measurement of the normal lumbosacral angle. Am J Roentgenol 113:642–645
26. Karakas HM, Celbis O, Harma A, Alicioglu B (2011) Total body height estimation using sacrum height in Anatolian Caucasians: multidetector computed tomography-based virtual anthropometry. Skeletal Radiol 40:623–630
27. Wray CC, Easom S, Hoskinson J (1991) Coccydynia. Aetiology and treatment. J Bone Joint Surg Br 73:335–338
28. Doursounian L, Maigne JY, Faure F, Chatellier G (2004) Coccygectomy for instability of the coccyx. Int Orthop 28:176–179
29. Dennell LV, Nathan S (2004) Coccygeal retroversion. Spine (Phila Pa 1976) 29:E256–E257