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Original article

Contribution of a new radiologic calcaneal measurement to the treatment decision tree in Haglund syndrome

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ABSTRACT

Introduction: In Haglund syndrome, standard radiologic measurements lack specificity and reliability in assessing etiologic morphologic calcaneal abnormalities. We report a simple X/Y ratio to measure posterior calcaneal length, where X is calcaneal length on lateral weight-bearing view and Y is greater tuberosity length.
Objective: To compare this new parameter against the radiologic gold standard in a group of Haglund patients and a healthy control group.
Hypothesis: Measuring this ratio significantly distinguishes between Haglund patients and healthy subjects.
Material and methods: A retrospective study included 50 Haglund syndrome patients and 30 healthy controls. Standard measurements (Fowler-Philip angle, Chauveaux-Liet angle, Ruch pitch, Heneghan-Pavlov test) and X/Y ratio were calculated twice by 2 independent observers. Intra- and inter-observer correlations were calculated, as were the specificity and sensitivity of the various parameters, with a ROC curve to establish the X/Y threshold.
Results: All measurements were reproducible on intra- and inter-observer testing. There were no significant inter-group differences in standard measurement specificity or sensitivity. The Haglund group showed significantly lower X/Y ratio (2.07) than controls (2.70; $p < 0.0001$), with a cut-off at 2.5. Threshold sensitivity in confirming Haglund syndrome was 100% ($p < 0.0001$) and specificity 95% ($p < 0.0001$).
Discussion: This new parameter measures the length of the calcaneus and its greater tuberosity. It is more reliable and reproducible in terms of sensitivity and specificity than standard measurements in Haglund syndrome. The 2.5 ratio threshold can guide surgical decision-making.
Level of evidence: III.

1. Introduction

Classically, one of the many causes of posterior heel pain [1,2] is impingement between the posterior part of the greater tuberosity of the calcaneus and neighboring soft tissue: precalcaneal bursa, calcaneal tendon, retro-calcaneal bursa, and cutaneous tissue. There is often associated Achilles insertion tendinopathy of varying severity, tendon calcification at the calcaneal insertion or along the tendon toward the insertion, and excess tension in the sural-Achilles-plantar system. Causes of impingement are morphologic, and varied: the deformity described by Haglund in 1928 [3] as a painful retro-calcaneal swelling due to projection of the superoposterior angle of the calcaneus is the most classical, but not the most frequent. An abnormally steep calcaneal slope, as found in posterior pes cavus, induces impingement between the calcaneus and calcaneal tendon, increasing tendon tension at the insertion. Haglund [3] mentioned excessive heel length, but did not provide radiologic proof. These calcaneal morphologic variants may be isolated or associated, and can be brought together under the term "Haglund syndrome and variants".

Several radiologic parameters [4–7] have been described to authenticate these bone abnormalities, but all show poor specificity and reliability, which probably goes some way to accounting for the variable results of surgical treatment [6,8,9].

None of these measurements, however, takes account of calcaneal length, which may underlie impingement between the

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greater tuberosity and the calcaneal tendon in the insertion zone. We therefore describe here a new and simple radiological measurement: the X/Y ratio, where X is calcaneal length on lateral weight-bearing view and Y is greater tuberosity length. This ratio defines a new calcaneal morphologic bone abnormality, contributing to assessment of calcaneal bone pressure on the calcaneal tendon and insertion.

The aim of the present study was to implement this new radiologic measurement in a population of patients with Haglund syndrome (Haglund group) and a population of healthy subjects (control group), assessing reliability.

The study hypothesis was that this ratio significantly distinguishes between Haglund patients and healthy subjects, thus screening for calcanei inducing Haglund syndrome.

2. Material and methods

2.1. Material

A single-center retrospective observational study included 50 patients undergoing surgery for Haglund syndrome and 30 healthy subjects free of hindfoot pathology seen in consultation for other foot pathologies.

The Haglund group comprised 15 female and 35 male patients, with a mean age of 54 years (range, 26–67 years). Inclusion criteria comprised calcaneal insertion pain on palpation of the posterior tuberosity and distal calcaneal tendon insertion to the tuberosity, calcaneal hump, irritation of adjacent skin by shoewear back-strip, painful pre- or retro-calcaneal bursitis, enthesis calcification, and radiologic enthesophytes. Pes cavus was found in 76% of cases, and hindfoot varus in 48%.

The control group comprised 20 female and 10 male patients, with a mean age of 55 years (range, 19–67 years), with 24 right and 26 left feet. These patients had no hindfoot pathology or signs in the region of the calcaneal insertion onto the posterior calcaneal tuberosity, but were all consulting for forefoot pathology (20 cases of hallux valgus in women and 10 cases of hallux rigidus in men).

Exclusion criteria were the same in both groups: history of hindfoot trauma or surgery, calcaneal tendon body tendinopathy, inflammatory rheumatism, posterior impingement between ankle and trigone bone, and neuromuscular pathology.

2.2. Methods

2.2.1. Imaging

Systematic weight-bearing X-rays of the foot and ankle comprised bilateral AP view, strict lateral view, and also hindfoot view with cerclage to assess hindfoot alignment and to quantify the postural data of the clinical examination.

To quantify bone anomalies potentially implicated in such heel pain, we used the standard radiologic criteria generally agreed in the literature, measured on lateral weight-bearing foot and ankle views (Fig. 1):

- Fowler-Philip angle is subtended by a tangent to the posterior edge of the greater tuberosity of the calcaneus and a line between the lowest weight-bearing point of the posteromedial tuberosity and the end of the calcaneocuboid joint line. Normal values range between 44° and 69°, with values >75° being considered pathological [2];
- the Ruch calcaneal pitch angle is subtended by the horizontal and a tangent to the lower edge of the calcaneus, including the ground contact point. Normal values range between 15° and 18° [10], with values >30° being considered pathological. Values between 18° and 30° are difficult to classify;
- the Chauveaux angle is the difference between angles α and β, where α is defined by Ruch calcaneal pitch, and β is subtended by a line perpendicular to the ground passing through the posterior point of the calcaneus and the tangent to the posterior tuberosity passing through the same posterior point of the calcaneus. Normal values are <12° [1];
- the Heneghan-Pavlov parallel pitch lines test involves an inferior line tangential to the plantar surface of the calcaneus and a parallel superior line through the posterior edge of the talocalcaneal joint surface [4]. It assesses superior projection of the greater tuberosity with respect to the superior line, and is considered positive when the line is crossed. It does not assess anteroposterior projection or impingement with the calcaneal tendon; when projection is very posterior, it accounts for the impingement, but when it is more anterior and dorsal it does not threaten the tendon [10];
- the X/Y ratio is the new parameter we are describing here. X is total calcaneal length, from the most anterior point of the greater apophysis to the most posterior point of the physiological calcaneus (excluding calcifications). Y is the length of the greater tuberosity, from the most posterior point of the calcaneal thalamus surface to the summit of the greater tuberosity. The ratio assesses relative calcaneal length.

The Fowler-Philip angle, Heneghan-Pavlov test and X/Y ratio are morphologic criteria; calcaneal pitch and Chauveaux-Liet angle are morphostatic criteria.

To determine inter-observer reliability, radiologic measurements were taken by 2 independent observers: observer A, a senior radiologist (RB); observer B, a surgeon (AB). To assess intra-observer reliability, measurements were made twice by each observer at a minimum 7 days' interval. Measurements were made independently by the two observers, blind to the patient's group, known only to the principal investigator (YT).

2.2.2. Statistical analysis

Statistical analysis used SPSS software version 19 (IBM, Armonk, NY). For each measurement, sensitivity, specificity, and positive and negative predictive values (PPV, NPV) were calculated based on known thresholds. The X/Y ratio cut-off between the 2 groups was determined by logistic regression and ROC (receiver operating characteristic) curve.

Intra- and inter-observer reliability was assessed on intra-class correlation coefficient (ICC), calculated separately and compared against a theoretic minimum of 0.7 on one-tailed tests with the significance threshold set at 0.05. ICC > 0.7 indicated good reliability and >0.9 excellent reliability.

Normal distribution was checked on Shapiro-Wilk test, and Student *t* tests were then used to compare the means of the 4 X/Y ratio measurements made by the 2 observers between the 2 groups. The significance threshold was set at $p < 0.05$.

3. Results

3.1. Standard measurements

In the Haglund group, Fowler-Philip angle was normal in all cases, at a mean 58° (range, 35–74°). Chauveaux angle was pathological in only 56.5% of cases, with a mean value of 12.5° (range, −2° to 22°). Ruch pitch exceeded 18° in 70% of cases, but exceeded 30° in only 30.4%, for a mean 25.5° (range, 18–36°). Heneghan-Pavlov test was positive in only 47.8% of cases.

In the control group, Fowler-Philip angle was normal in all cases, at a mean 59° (range, 36–69.5°). Chauveaux angle was pathological in 40% of cases, with a mean value of 12.6° (range, −8° to 25.3°).

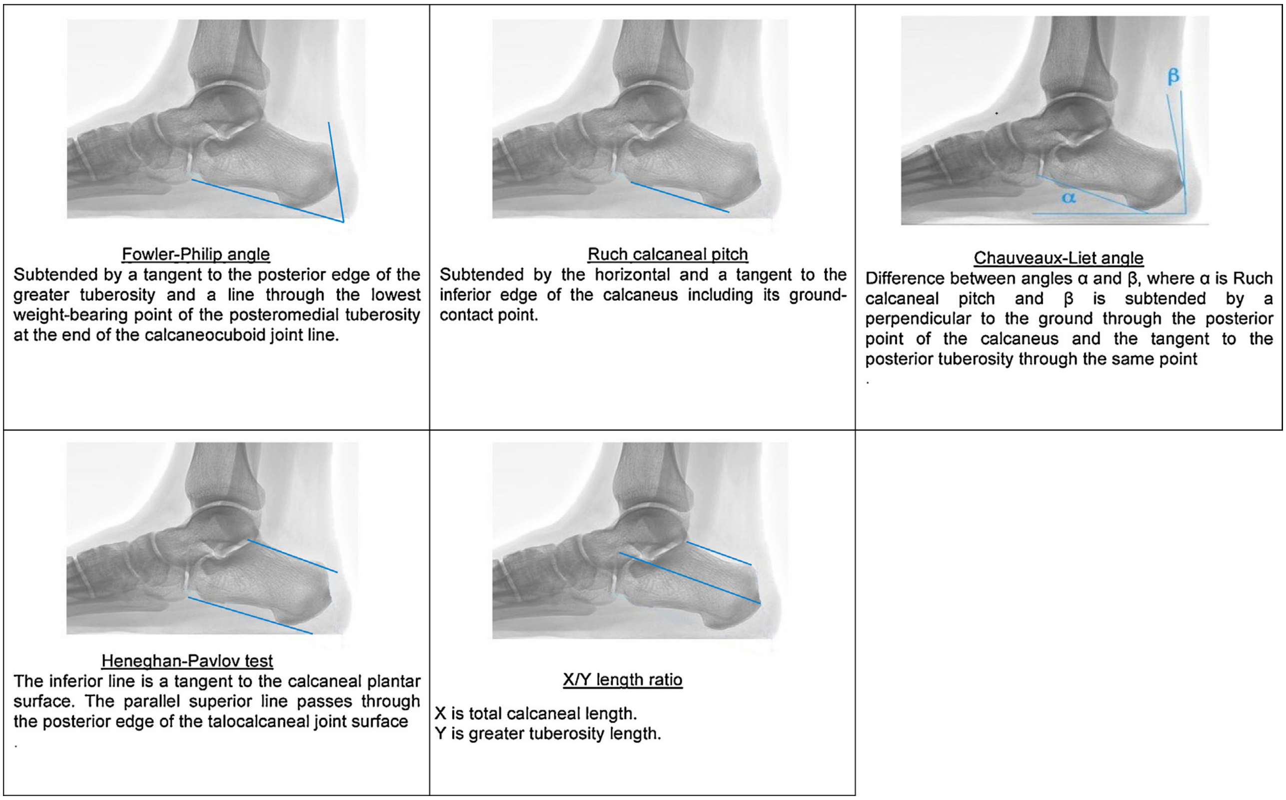

Fig. 1. Radiologic measurements.

Ruch pitch exceeded 18° in 52% of cases, but exceeded 30° in only 4%, for a mean 21.7° (range, 16.8–18.1°). Heneghan-Pavlov test was positive in only 14% of cases.

There were no significant differences between groups for Chauveaux angle, Rush pitch or Fowler-Philip angle (Table 1), or likewise for sensitivity, specificity, PPV and NPV (Table 2).

3.2. *X/Y ratio*

In the Haglund group, mean X/Y ratio was 2.07 (range, 1.58–2.4), and in the control group 2.70 (range 2.3–3.2) (Table 1): i.e., significantly lower in the Haglund group ($p < 0.00001$).

The area under the curve (AUC) was excellent (Fig. 2), confirming that X/Y ratio effectively differentiated between the Haglund group and controls ($p < 0.001$). The cut-off value of 2.49 (rounded up to 2.5) was discriminating, with sensitivity and specificity of 1 and 0.95 respectively (Table 2).

In the Haglund group, X/Y ratio was systematically <2.5, and >2.5 in 95% of cases in the control group: i.e., cut-off sensitivity of 100% ($p < 0.0001$) and specificity of 95% ($p < 0.0001$).

Intra- and inter-observer reliability values on standard measurements and X/Y ratio were good (>0.7) or excellent (>0.9) in both groups (Tables 3 and 4).

4. Discussion

The X/Y ratio is a new, simple and reproducible parameter to assess calcaneal etiological morphologic factors is posterior tarsal pain. Inter- and intra-observer correlations were excellent and significant. The ratio was systematically <2.5 in the Haglund group and >2.5 in 95% of controls. Thus, any calcaneus showing a ratio less than 2.5 can be considered "long" and responsible for impingement with posterior soft tissue and for excess calcaneal tendon tension at

Table 1
Radiologic measurement results.

	Haglund group	Control group	Stat
Fowler-Philip angle			ns
Mean-standard deviation range	58° ± 11 (35° to 74°)	59.0° ± 0.3 (36° to 69.5°)	
Pathologic if >75°	0%	0%	
Ruch calcaneal pitch			ns
Mean-standard deviation range	25.5° ± 6.6 (18° to 36°)	21.7° ± 4.3(16.8° to 18.1°)	
Pathologic if >18°	70%	52%	
Pathologic if >30°	30.40%	4%	
Chauveaux-Liet angle			ns
Mean-standard deviation range	19.1° ± 5.2(−2° to 22°)	11.5° ± 6.6 (−8° to 25.3°)	
Pathologic if >12°	56.50%	40%	
Heneghan-Pavlov test			
Positive	47.80%	14%	ns
X/Y ratio			$p < 0.05$
Mean-standard deviation range	2.07 ± 0.21(1.58 to 2.4)	2.70 ± 0.22 (2.3 to 3.2)	

Table 2
Sensitivity, specificity, PPV, NPV.

	Fowler-Philip angle, %	Ruch pitch, %	Chauveaux-Liet angle, %	Heneghan-Pavlov test, %	X/Y, %
Sensitivity	0	26	56.5	41.3	100
Specificity	97.8	93.3	47.8	85.5	95
PPV	0	66.7	35.6	59.4	86.3
NPV	65.7	71.2	68.2	74	98.7

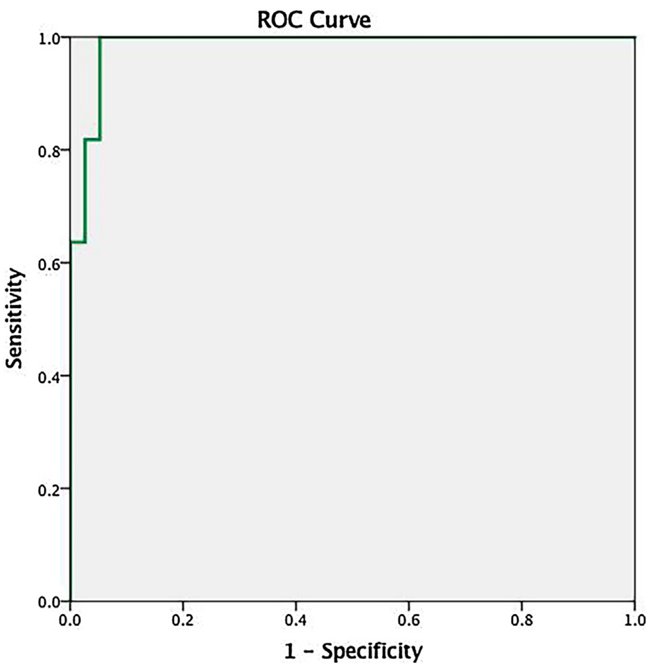

Fig. 2. ROC curve: excellent AUC.

the insertion. It is thus a reliable parameter in diagnosing posterior tarsal pain (Haglund syndrome and variants).

In the present study, standard measurements were reproducible, but neither specific nor sensitive. This discordance between clinical and radiologic data confirms literature reports for Chauveaux angle, Ruch pitch and Fowler-Philip angle. In the present series, Fowler-Philip angle was always less than 75°, and thus non-pathological even in the Haglund group. Pavlov [11] reported normal Fowler-Philip angles in 8 Haglund patients, and pathological angles in 3 healthy subjects. Kelly [12] also previously reported such unreliability. In 2007, Lu [10] found no significant difference in Fowler-Philip angle between healthy controls and patients with posterior tarsal pain (Haglund syndrome and variants). Mean physiological Ruch pitch ranges between 15° and 18° and is arbitrarily considered pathological beyond 30° [13]. In the present series, only 30.4% of patients with posterior tarsalgia showed pathological pitch (>30°), versus 4% of controls (mean, 21.7°); if, on the other hand, pitch >18° is considered *p* anthological, then 70% of patients and 52% of controls are identified. In 2008, Sing [9] reached the same conclusions, with 19.9° in the patient group and 19.7° in controls. A more recent study confirmed this lack of specificity, but with more frequent high pitch in the Haglund group than controls [14], as in the present study. The Heneghan-Pavlov test was positive in 47.8% of the present Haglund patients and in 14% of controls, whereas in 2007 Lu [12] found no significant difference between healthy controls and patients with posterior tarsal pain (Haglund syndrome and variants). Finally, in 2005, Mishra [8] concluded that the Heneghan-Pavlov test, Fowler-Philip angle and calcaneal pitch were not good diagnostic criteria, in a prospective radiologic analysis of 107 cases of tarsal pain versus controls.

A recruitment bias in the Haglund group may be suspected in a retrospective study. However, the inclusion criteria were broad, matching the definition of Haglund syndrome. Moreover, blinded measurement by 2 observers with repeated measurement at a minimum 7 days' interval should minimize any bias. Even so, despite good statistical demonstration, a larger sample and studies run by other teams would help confirm the reliability and specificity of this ratio.

Sundarajan [13] and Bulstra [14] stressed the absence or impossibility of a clear separation between pure bone abnormality and calcaneal tendon insertion tendinopathy underlying patient-reported pain; two surgical techniques, however, alter calcaneal morphology: resection (or calcaneoplasty) of the posterosuperior corner [15,16], and Zadek subtraction osteotomy with dorsal base and plantar tip [1,12,17,18]. The choice is not founded on anatomic study of calcaneal morphology. The ~~results of calcaneoplasty are controversial, as it opens up a space forward of the calcaneal tendon but does not change calcaneal slope or length or calcaneal tendon lever arm. Nesse [19] reported only 38% good results, and Taylor [1] 65%, but with 51% recurrence. Results with Zadek osteotomy, as reported by Maynou [20], are more encouraging, with 75% good and very good results. Calcaneal greater tuberosity advancement by angular correction opens the space forward of the calcaneal tendon, thus reducing greater tuberosity length and increasing the X/Y ratio. It also decreases tension in the sural–Achilles–plantar system by raising the greater tuberosity and thus reducing calcaneal slope. The X/Y ratio could contribute to surgical decision making~~

Table 3
Intra- and inter-observer reproducibility: control group ($p < 0.0001$).

Control group	Fowler-Philip angle	Ruch pitch	Chauveaux-Liet angle	Heneghan-Pavlov test	X/Y
ICC intra-A	0.9178	0.8646	0.9543	1	0.77
ICC intra-B	0.928	0.9507	0.9863	1	0.96
ICC inter-A-B	0.8087	0.8372	0.9421	0.9	0.88

Table 4
Intra- and inter-observer reproducibility: Haglund group ($p < 0.0001$).

Haglund group	Fowler-Philip angle	Ruch pitch	Chauveaux-Liet angle	Heneghan-Pavlov test	X/Y
ICC intra-A	0.9592	0.9274	0.8614	0.884	0.89
ICC intra-B	0.9272	0.88	0.9331	0.778	0.98
ICC inter-A-B	0.9013	0.7891	0.845	0.7937	0.93

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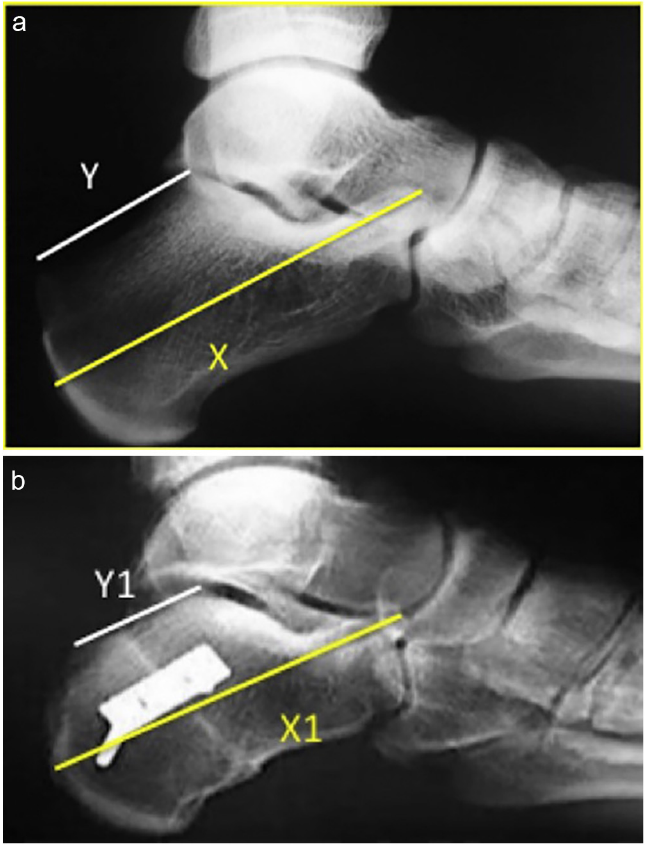

Fig. 3. a: calcaneus in Haglund syndrome: X/Y ratio <2.5; b: after Zadek osteotomy, X_1/Y_1 ratio is >2.5, and posterior heel pain is resolved.

in Haglund syndrome: Zadek osteotomy would be especially indicated to reduce the length of long calcanei: i.e., those with X/Y ratio <2.5 (Fig. 3).

5. Conclusion

The X/Y calcaneal ratio is easy to implement and reproducible, with a cut-off value at 2.5. It could contribute to a surgical decision tree in Haglund syndrome in case of failure of non-operative treatment. A prospective study of the use of this parameter is needed, and would found the choice, in terms of the bony origin of heel pain, between Zadek osteotomy and simple resection of the posterosuperior corner.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution

All authors read and approved the final submitted version of the manuscript.

Research design: Anne-Laure B3 and Yves Tourne.

Data acquisition and entry: Anne-Laure Barray, Yves Tourne and Renaud Barthelemy.

Manuscript preparation: Anne-Laure Barray, Yves Tourne and Paul Moroney.

References

[1] Taylor G. Prominence of the calcaneus: is operation justified? J Bone Jt Surg Br 1986;68:467–70.
[2] Thomas JL, Christensen JC, Kravitz SR, Mendicino RW, Schuberth JM, Vanore JV, et al. The diagnosis and treatment of heel pain: a clinical practice guideline-revision 2010. J Foot Ankle Surg 2010;49:S1–19.
[3] Haglund. Beitrag zur klinil der Achillesscehne. Z Orthop Chir 1927;49:49–58.
[4] Fowler A, Philip JF. Abnormality of the calcaneus as a cause of painful heel its diagnosis and operative treatment. Br J Surg 1945;32:494–8.
[5] Ruch JA. Haglund's disease. J Am Podiatry Assoc 1974;64:1000–3.
[6] Heneghan MA, Pavlov H. The Haglund painful heel syndrome. Experimental investigation of cause and therapeutic implications. Clin Orthop 1984;187:228–34.
[7] Chauveaux D, Liet P, Le Huec JC, Midy D. A new radiologic measurement for the diagnosis of Haglund's deformity. Surg Radiol Anat 1991;13:39–44.
[8] Mishra DK, Kurup HV, Musthyala S, Patro DK. Role of calcaneus in heel pain: radiological assessment. Foot Ankle Surg 2006;12:127–31.
[9] Singh R, Rohilla R, Siwach RC, Magu NK, Sangwan SS, Sharma A. Diagnostic significance of radiologic measurements in posterior heel pain. Foot Edinb Scotl 2008;18:91–8.
[10] Lu C-C, Cheng Y-M, Fu Y-C, Tien Y-C, Chen S-K, Huang P-J. Angle analysis of Haglund syndrome and its relationship with osseous variations and Achilles tendon calcification. Foot Ankle Int 2007;28:181–5.
[11] Pavlov H, Heneghan MA, Hersh A, Goldman AB, Vigorita V. The Haglund syndrome: initial and differential diagnosis. Radiology 1982;144:83–8.
[12] Keck SW, Kelly PJ. Bursitis of the posterior part of the heel; evaluation of surgical treatment of eighteen patients. J Bone Joint Surg Am 1965;47:267–73.
[13] Sundararajan PP, Wilde TS. Radiographic, clinical, and magnetic resonance imaging analysis of insertional achilles tendinopathy. J Foot Ankle Surg 2014;53:147–51.
[14] Bulstra GH, van Rheenen TA, Scholtes VAB. Can we measure the heel bump? Radiographic evaluation of Haglund's deformity. J Foot Ankle Surg 2015;54:338–40.
[15] Jardé O, Quenot P, Trinquier-Lautard JL, Tran-Van F, Vives P. Haglund disease treated by simple resection of calcaneus tuberosity. An angular and therapeutic study. Apropos of 74 cases with 2 years follow-up. Rev Chir Orthop Reparatrice Appar Mot 1997;83:566–73.
[16] Hardy A, Rousseau R, Issa SP, Gerometta A, Pascal-Moussellard H, Granger B, et al. Functional outcomes and return to sports after surgical treatment of insertional Achilles tendinopathy: surgical approach tailored to the degree of tendon involvement. Orthop Traumatol Surg Res 2018;104:719–23.
[17] Syed TA, Perera A. A proposal staging classification for minimally invasive management of Haglund's syndrome with percutaneous and endoscopic surgery. Foot Ankle Clin 2016;21:641–64.
[18] Zadek I. An operation for the cure of achillobursitis. Am J Surg 1939;43:542–6.
[19] Nesse E, Finsen V. Poor results after resection for Haglund's heel. Analysis of 35 heels in 23 patients after 3 years. Acta Orthop Scand 1994;65:107–9.
[20] Maynou C, Mestdagh H, Dubois HH, Petroff E, Elise S. Is calcaneal osteotomy justified in Haglund's disease? Rev Chir Orthop Reparatrice Appar Mot 1998;84:734–8.