Radiographic Validation of a Self-Report Instrument for Hallux Valgus

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Competing Interests

The authors declare that they have no competing interests.

Abstract

Background: Hallux valgus (HV) is a common condition causing substantial morbidity. Radiographic assessment is the gold standard for grading severity, but is not always feasible in clinical/research settings. Recently developed HV line-drawings, consisting of five drawings for each foot depicting a sequential increase in HV angle of 15 degrees, have been clinically validated for self-reporting severity. We aimed to undertake radiographic validation of this self-report instrument.

Methods: Adults aged ≥50 from four GP practices were sent a health survey. Responders self-reported HV severity for each foot using the line-drawing instrument. Those reporting foot pain in the last year had radiographs taken at a research clinic from which intermetatarsal, hallux abductus and hallux interphalangeal abductus angles were calculated. Ten feet were randomly selected for each HV line-drawing grade for both feet. Associations between self-reported HV line drawings and radiographic measurements were assessed using Spearman's ρ correlation coefficients, mean radiographic angle measurement (95% confidence interval) and one-way analysis of variance.

Results: Increasing HV line-drawing grade was positively correlated with radiographic measurements for intermetatarsal and hallux abductus angles (Spearman's ρ=0.602, p<0.001; 0.821, p<0.001 respectively). Hallux interphalangeal abductus angle showed an inverse correlation with increasing line-drawing grade (-0.204, p=0.053). Differences in radiographic measures between HV line drawing grades were significant for intermetatarsal (F= 13.98, p<0.001) hallux abductus (F= 38.90, p<0.001) but not hallux interphalangeal abductus angle (F=2.21, p=0.075).

Conclusion: Grading HV severity by self-reported HV line-drawings provides a valid representation of deformity determined from radiographic measurements, and is a useful screening/self-reporting tool.

Introduction

Hallux valgus (HV) is a common forefoot deformity which often leads to pain, disability and difficulty with footwear (Elton & Sanderson, 1986). It begins with lateral displacement of the great toe (hallux) and medial deviation of the distal end of the first metatarsal, and in later stages is characterized by progressive subluxation of the first metatarsophalangeal (MTP) joint (Mann & Coughlin, 1981). This often leads to the development of a 'bunion', a pressure-sensitive soft tissue and osseous prominence on the medial aspect of the head of the first metatarsal (Thomas & Barrington, 2003). With its prevalence increasing with age (Edward Roddy et al., 2008), HV is a common cause of morbidity in older people (Benvenuti et al., 1995; Black & Hale, 1987; Crawford et al., 1995). It causes problems with gait, balance and locomotion (8-9) leading to risk of falling (Hylton B. Menz et al., 2018) and impairment to quality of life (11-12). Nix et al reported pooled prevalence estimates of HV to be 23% in adults aged 18-65 years and 35.7% in those aged over 65 years (Nix et al., 2010), but prevalence estimates have been reported to range widely within literature and is likely to be due to variations in how HV is defined (Benvenuti et al., 1995; Black & Hale, 1987; Dunn et al., 2004; Elton & Sanderson, 1986).

The gold standard for grading severity of HV is radiographic measurement, however this is not always feasible in clinical or research settings (H. B. Menz & Munteanu, 2005). A validated non-invasive instrument for grading self-reported HV severity would be useful to reduce costs, time and ionizing radiation exposure. Other approaches for non-radiographic assessment of HV have included the Manchester scale where HV angle was categorized into four grades using photographic images as a reference standard (Garrow et al., 2001), and assessment of HV angle on

photographs taken by assessors (Nix et al., 2012) and by participants themselves (Yamaguchi et al., 2019).

More recently, a self-report HV instrument has been developed that comprises a set of five line drawings for each foot depicting a sequential increase in HV angle of 15 degrees developed from a photograph of a normal foot (figure 1) (E. Roddy et al., 2007). It is easy to complete without support making it ideal for survey based questionnaires. The line drawing instrument has been shown to have excellent re-test reliability and has already been validated against clinical opinion but remains to be validated radiographically (E. Roddy et al., 2007).

Therefore, the aim of this study was to validate the self-report HV line drawing instrument against angular measurements obtained from foot radiographs.

Method

Study design

The Clinical Assessment Study of the Foot (CASF) was a prospective cohort study of foot pain and foot osteoarthritis undertaken in the general population of North Staffordshire, UK. All adults aged 50 years and over registered with four general practices in North Staffordshire, UK, were invited to participate, irrespective of consultation for foot pain or problems, and were mailed a Health Survey questionnaire. All respondents who reported experiencing foot pain in the preceding twelve months were invited to attend a research clinic. At the research clinic, radiographs of both feet were obtained. The study protocol has previously been published (Edward Roddy et al., 2011).

Health Survey Questionnaire

The Health Survey questionnaire included a validated line drawing instrument which consisted of five drawings for each foot illustrating a sequential 15 degree increase in the HV angle (figure 1). Participants were asked to stand barefoot and self-select for each foot the picture which best resembled the angulation of their great toe (Edward Roddy et al., 2011).

Foot radiographs

Dorso-plantar weight-radiographs of each foot were taken according to a standardised protocol (Edward Roddy et al., 2011). The participant stood in a relaxed position with their weight distributed equally across both feet. For each foot, the x-ray tube was angled 15° cranially using a vertical central ray centred on the base of the third metatarsal.

Angular measurements

For each self-reported grade of HV severity (0, 15, 30, 45, 60 degrees) for both left and right feet, 10 participants with both radiographs and self-reported HV data were selected.

Angular measurement of the radiographs was then undertaken by a single researcher using the angle measurement tool in the Canvas™ 11 graphic software package (ACD Systems, Victoria, BC, Canada). The intermetatarsal, hallux abductus and hallux interphalangeal angles were measured in accordance with the Miller technique for scoring HV (Miller, 1974). The intermetatarsal angle was measured between the long axis of the shafts of the first and second metatarsal. The hallux abductus angle was measured between the long axis of first metatarsal and the

proximal phalanx, whilst the hallux interphalangeal abductus angle was measured between the long axis of the proximal and distal phalanx. Radiographs were scored blind to the participant's self-reported assessment of HV severity.

The same researcher re-measured 30 feet one month apart blind to the previous results and participant data to assess intra-rater reliability. A second independent researcher scored the same 30 feet blind to the measurements obtained by the first researcher and participant data to assess inter-rater reliability.

Statistical analysis

Intra-rater and inter-rater reliability of the three radiographic angles were assessed using intraclass correlation coefficients (ICCs) and 95% confidence intervals calculated for absolute agreement using a 2-way random-effects model for single measures. With regards to interpretation of ICC inter-rater and intra-rater agreement measures, a score of 0.90 and above was deemed as 'excellent', between 0.75 and 0.9 as 'good', between 0.5 and 0.75 as 'moderate' and below 0.5 as 'poor' (Koo & Li, 2016).

Subsequently, measurements from the right and left feet were pooled**.** To determine if there was a correlation between the HV severity and radiographic measurements, Spearman's rank correlation coefficient, ρ were calculated. A 'very strong' correlation was determined if Spearman's ρ was >0.80, 'strong' if ρ = 0.60-0.79, 'moderate' if ρ = 0.40-0.59, 'weak' if ρ = 0.20-0.39 and 'very weak' between 0.01 and 0.19 (Swinscow, n.d.). To determine if there were significant differences in the mean radiographic angle measurements for each of the self-reported HV line drawing severity, means and 95% confidence intervals were calculated and compared using

one-way analysis of variance (ANOVA). Results were deemed to be statistically significant if $p<0.05$.

All analyses were conducted using SPSS (version 21, IBM Corporation, NY, USA).

Ethical Approval

Ethical approval was obtained from Coventry Research Ethics Committee (reference number: 10/H1210/5) and all participants provided written informed consent.

Results

Of 9,334 adults mailed the health survey questionnaire, 5,109 participants responded. 1,635 reported foot pain in the preceding 12 months and were invited to the research clinic. Of these, 560 attended. 10 feet were randomly selected for each self-reported HV grade for each foot, however there were only 9 participants in the most severe category (depicting 60 degrees angulation) for the left foot and 6 for the right foot. In total, 95 feet were analysed from 84 participants. Mean age was 65.7 years (standard deviation (SD) 7.8), mean body mass index (BMI) was 29.9 (SD 5.6) and 58% (n=49) were female.

Intra-rater reliability was excellent for all three angle measurements whilst inter-rater reliability was excellent for intermetatarsal and hallux abductus angles and moderate for hallux interphalangeal abductus angle (Table 1).

Increasing self-reported HV grade showed a very strong positive correlation for hallux abductus angle ($\rho=0.821$, $p<0.001$) and a strong positive correlation for intermetatarsal angle ($\rho=0.602$, $p<0.001$) measurements. Hallux interphalangeal

abductus angle showed a weak negative correlation with increasing HV angle severity and did not reach statistical significance (ρ=- 0.204, *p*=0.053).

A significant difference in radiographic angles between the self-reported HV line drawing grades was seen for intermetatarsal angle (F=13.98, *p*<0.001) with a sequential rise in the angle as the severity of HV increased (Table 2). The same relationship was found for the hallux abductus angle (F=38.90, *p*<0.001) (Figure 2). The difference in radiographic measures between the HV line drawing grades for hallux interphalangeal abductus angle sequentially decreased as the grade of HV severity increased, except between 15 degrees and 30 degrees where it increased from 11.2 to 11.5 before decreasing again. The ANOVA for hallux abductus interphalangeal angle did not reach statistical significance (F=2.21, *p*=0.075) (Table 2).

Discussion

Our findings indicate that grading of HV severity using the self-report instrument of HV line drawings is highly correlated with hallux abductus and intermetatarsal angle measurements taken from plain radiographs. Increasing self-reported HV line-drawing grade was positively correlated with radiographic measurements for both angles with mean measurements also significantly differing between each HV line drawing grade, thus clearly differentiating between categories. The hallux interphalangeal abductus angle appeared to become progressively smaller with greater HV severity, however, 95% confidence intervals overlapped and the trend was not statistically significant.

Previously developed tools for non-radiographic reporting of HV severity have included measurements of forefoot girth as well as foot tracing but their validity has

been questioned (Nix et al., 2012; Panchbhavi & Trevino, 2004; Ross, 1986; Yamaguchi et al., 2019). Garrow et al developed the Manchester Scale, which consists of standardised photographs of four grades of HV severity (none, mild, moderate and severe) (Garrow et al., 2001). In their study of the radiographic validation of the Manchester scale, Menz et al. found the hallux abductus angle measurement to be strongly correlated and intermetatarsal angle to be moderately correlated with increasing ordinal grading of the Manchester Scale (H. B. Menz & Munteanu, 2005). This is in keeping with our findings, although the HV line drawings demonstrated a stronger correlation with increasing intermetatarsal angle measurement than the Manchester scale. Similarly, a weak negative correlation was reported for the hallux interphalangeal abductus angle to the Manchester scale and it was postulated that the position of the distal phalanx relative to the proximal phalanx makes a very minor contribution to the visual determination of HV severity (H. B. Menz & Munteanu, 2005). However, it must be noted that given the small sample size, a type II error cannot be excluded.

The current study demonstrated high intra- and inter-rater reliability of radiographic measurements taken (Coughlin & Freund, 2001; H. B. Menz & Munteanu, 2005; Hylton B. Menz, 2005). However, there are limitations of our study. Combining data from left and right feet is not always appropriate in clinical studies as observations from left and right feet in the same participant are unlikely to be independent from each other and, as a result of counting each participant twice, a type I error may be more likely. However, because the unit of analysis in this study was the foot rather than the participant and the objective was to investigate the correlation of measurements within the foot, we believe this approach was acceptable (Hylton B. Menz, 2005).

A further caveat is that the sequential increases in the hallux abductus and intermetatarsal angles were smaller than the 15 degree increases on which the line drawings are based, something which would need to be considered when using the tool. However, if the measurements taken for hallux abductus angle and intermetatarsal angles are added together it correlates closely to the hallux abductus angle severity for the corresponding line grade. This suggests that the line drawings provide a representation of the overall severity of HV deformity relative to the axis of the foot.

It must also be noted that only people over 50 years were included and radiographs obtained only from those reporting foot pain and therefore, findings may not be generalisable to younger people or those without pain. However, correlations between these observations seem unlikely to differ in these groups.

The majority of previous studies on HV have had to rely on clinical or radiographic assessments which are time, labour and resource intensive, and not always feasible. The self-report instrument of HV line drawings is a useful tool to differentiate HV severity. The HV line drawing instrument can therefore be recommended for use in epidemiological and clinical research for the self-reporting of HV severity.

Conclusion

The results of this study indicate that the HV line drawings are strongly correlated with hallux abductus and intermetatarsal angle measurements taken from radiographs. The HV line drawing instrument is a valid tool for grading and self-reporting of HV deformity.

Abbreviations

HV	Hallux Valgus
CASF	Clinical Assessment Study of the Foot
BMI	Body Mass Index
ICC	Intraclass correlation coefficients
ANOVA	Analysis of Variance

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Table 1: Reliability of radiographic angular measurements

Radiographic measurement	Intra-rater reliability ICC* (95% CI)	Inter-rater reliability ICC* (95% CI)	Spearman's Rho (p value)
Intermetatarsal angle	0.957 (0.909, 0.980)	0.912 (0.811, 0.959)	**0.602 (p<0.001)**
Hallux abductus angle	0.998 (0.995, 0.999)	0.995 (0.989, 0.998)	**0.821 (p<0.001)**
Hallux interphalangeal abductus angle	0.987 (0.972, 0.994)	0.581 (0.268, 0.782)	**-0.204 (p=0.053)**

** Intraclass correlation coefficients (ICCs) were calculated for absolute agreement using a 2-way random-effects model for single measures. 95%CI; 95% Confidence interval.*

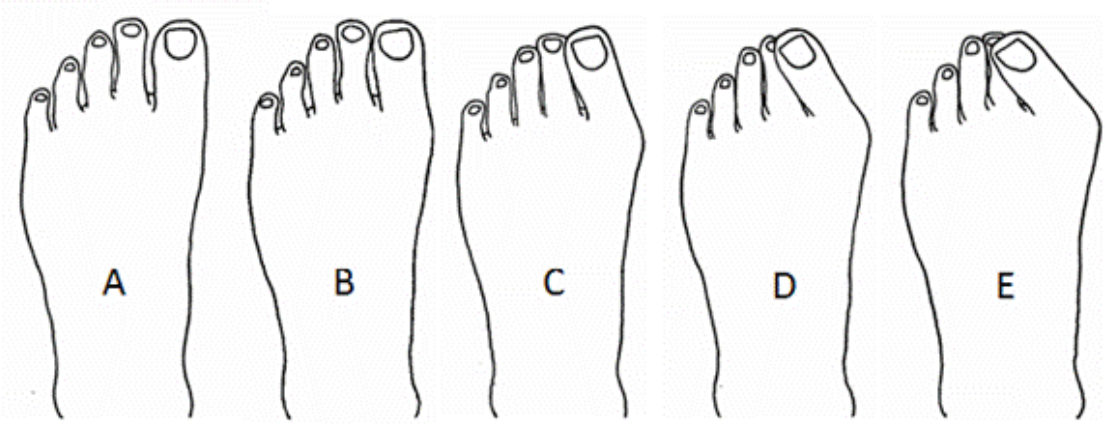
Table 2: Radiographic angular measurements for grades of self-reported hallux valgus severity

	Self-reported hallux valgus severity; degrees (Line drawing grade)					**ANOVA**
Radiographic measurement	0º (A/F)	15 º (B/G)	30 º (C/H)	45 º (D/I)	60 º (E/J)	F value (p value)
Intermetatarsal angle; degrees (95%CI)	9.51 (8.80, 10.22)	10.31 (9.02, 11.59)	11.25 (10.36, 12.15)	14.12 (12.54, 15.69)	15.53 (12.77, 18.30)	13.977 (p<0.001)
Hallux abductus angle; degrees (95%CI)	7.76 (5.83, 9.69)	12.75 (9.75, 15.76)	20.69 16.90, 24.48)	28.40 (23.91, 32.90)	43.15 (33.27, 53.03)	38.895 (p<0.001)
Hallux interphalangeal abductus angle; degrees (95%CI)	12.46 (10.10, 14.83)	11.22 (9.20, 13.24)	11.45 (8.48, 14.42)	7.25 (3.23, 11.28)	6.38 (2.49, 15.25)	2.205 (p=0.075)

95%CI: 95% Confidence interval.

Figure 1: Self-report instrument for assessment of Hallux Valgus

First, please look at your left big toe whilst standing without shoes and socks on. Ignore the positioning and the gaps between your other toes and try to focus only on your big toe. Select from the first set of pictures below labelled from A to E which one best shows the angle of your left big toe. Please circle the letter of that picture.



Now do the same for your right big toe joint using the set of pictures below labelled from F to J. Again please circle the letter of the picture that best shows the angle of your right big toe.

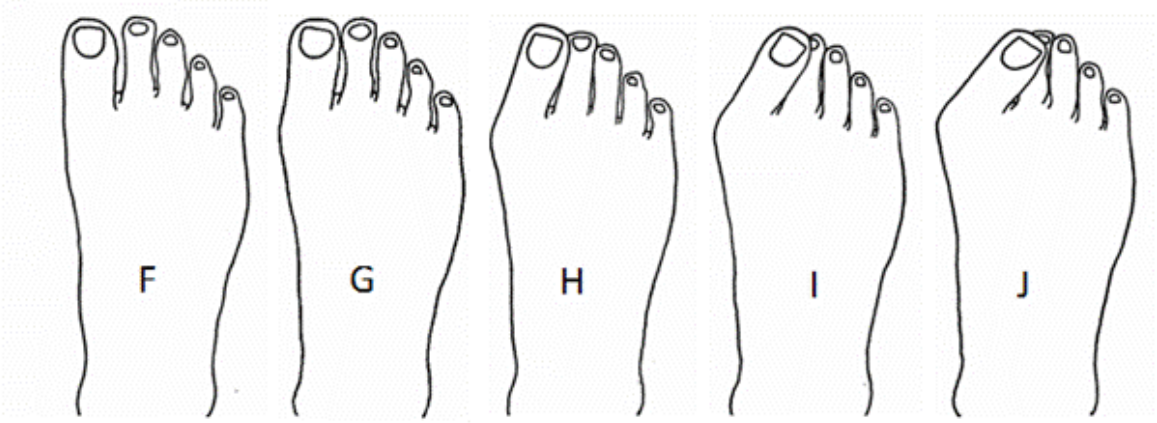


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Figure 2: Mean hallux abductus angle (95% confidence intervals) for grades of self-reported hallux valgus severity