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Assessment of digital clubbing in medical inpatients by digital photography and computerised analysis

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Summary

Background: Digital clubbing has been associated with a large number of disorders. To overcome the limitation of subjective clinical assessment, several objective measurements have been developed among which the hyponychial angle was considered most accurate for quantification of finger clubbing.

Methods and results: Here we investigated hyponychial angles in 123 healthy subjects and 515 medical inpatients from a tertiary hospital. Healthy subjects had a mean angle of 178.87 ± 4.70° (range: 164.78–192.10°), a finding that is well in accordance with previous results obtained using other techniques, underlining the accuracy of the chosen method of assessment. The mean angle of patients was 181.65 ± 7.18° (range: 162.22–209.19; p <0.0001 compared to healthy controls). When the upper limit of normality, i.e. 192.10°, was used to define digital clubbing, the prevalence of digital clubbing in our patients was 8.9%; the percentage of clubbed fingers varied substantially among the various disease states (up to 80% in patients with cystic fibrosis).

Conclusion: The use of digital photography with computerised analysis was found to be an easy, fast and inexpensive method for the quantification of hyponychial angles with excellent intra and inter observer reliability whilst causing no discomfort to patients. This tool may therefore be useful in further longitudinal and cross-sectional studies of finger morphology and may become an accepted standard in the diagnosis of digital clubbing.

Key words: digital clubbing; digital photography; hyponychial angle; prevalence; quantification

Introduction

Since the first description of finger clubbing in a patient with empyema by Hipprocrates in the fifth century BC, this deformity has been associated with a large number of disorders [1, 2]. Features of clubbed fingers on physical examination are a shiny and smooth appearance of the cuticle with increased sponginess, a flattening of the normal obtuse angle on the dorsal surface of the finger at the base of the nail, an increase in volume of the distal segment of the finger and an increase in the curvature of the nail in one or both planes [2, 3]. However clinical assessment is subjective, often difficult in mild cases and therefore unreliable [4–8]. To overcome this limitation several methods have been developed over the past century for quantification of clubbing. Attempted approaches include matching brass templates with arcs of various sizes to measure longitudinal curvature [9], plethysmography [10], casts with planimetry [11] or measurement of finger depth rates [12, 13] and a shadowgraph technique [14–16]. None of these, however, was accepted as a standard of diagnosis,

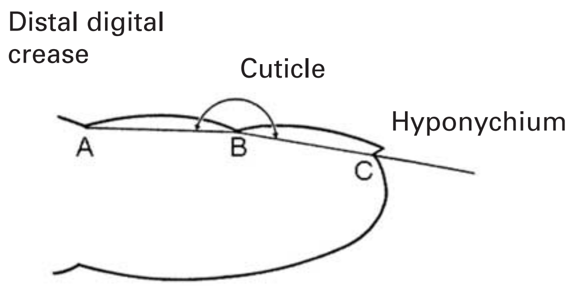

Figure 1

Construction of hyponychial angle. The hyponychial angle was constructed by a line AB drawn from the distal digital skin crease to the cuticle, and a line BC drawn from the cuticle to the hyponychium (thickened stratum corneum of epidermis lying under the free edge of the nail [11].

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Table 1

Summary of historical studies investigating hyponychial angles for assessment of digital clubbing.

Reference	Regan et al. [11]	Bentley et al. [15]	Sinniah et al. [16]	Kitis et al. [18]
Healthy controls				
Hyponychial angle (°)	187.0	180.1 ± 4.2	180.7 ± 5.2	177.9 ± 4.6
Range	176.5–192	n.d	165–189	n.d.
Age (years)	n.d.	11.25	6.7 ± 3.4	29
Number of subjects	18	25	20	116
Patients				
Hyponychial angle (°)	209.4	194.8 ± 8.3[1], 194.8 ± 8.3[2] 194.8 ± 8.3[3], 194.8 ± 8.3[4]	194.5 ± 7.5	n.d.
Range	n.d.	n.d.	178–205	n.d.
Age (years)	n.d.	16.2[1], 12.3[2], 17[3], 11[4]	6.9 ± 2.7	n.d.
Number of patients	7	50[1], 25[2], 5[3], 20[4]	19	90[1], 2[2]
Characteristics	Asbestos workers	Cystic fibrosis[1] Asthma[2] Cyanotic c.h.d.[3] Acyanotic c.h.d.[4]	Thalassemia major Cyanotic heart disease Malabsorption syndrome Bronchiectasis	IBD[1] Proctitis[2]

Abbreviations: c.h.d. congenital heart disease; n.d., no data available; IBD, inflammatory bowel disease.
Note: the study by Kitis et al. [18] found digital clubbing present in 75 out of 200 patients with Crohn's disease, and 15 out of 103 with ulcerative colitis, however, no precise data on mean hyponychial angles in these groups were provided.

and all proved impracticable as a method for verifying the clinical impression of clubbing. Recently digital cameras and computerised analysis have accurately been used to assess fingernail morphometry and offer obvious advantages over previous techniques [17].

Among several objective measurements, the hyponychial angle (figure 1) correlated strikingly with the physician's subjective score, and was considered "best discriminator" by Regan et al. [11] since it distinguished normal and clubbed fingers without overlap. The accuracy of the hyponychial angle as an indicator of finger clubbing was later confirmed by other investigators [15, 16, 18]. The original findings of these early studies are summarised in table 1. In a recent review of the literature, a pooled weighted mean value for the hyponychial angle of 179.0 ± 4.5° was calculated. None of the 171 healthy subjects who have been assessed to date had angles that exceeded 192° and an angle less than 190° was therefore assumed to describe normality [2]. Although several studies reported mean values of hyponychial angles in a number of disease states [2], only very limited data on finger morphology and the prevalence of digital clubbing in unselected hospitalised medical patients is available [19]. Thus the present study was designed to investigate the distribution of hyponychial angles in a large group of both healthy volunteers and medical inpatients from a tertiary hospital. For quantification the hyponychial angle was calculated by means of digital photography and computerised analysis.

Materials and methods

Subjects

Healthy controls: after verbal consent was obtained, fingers of subjects who reported no acute or chronic illness were photographed as healthy controls. *Medical inpatients:* during the three month enrolment period from September 25, 2000 to December 22, 2000, patients admitted as inpatients to the medical clinic of the Department of Internal Medicine (University Hospital, Zürich, Switzerland) were eligible when hospitalised for more than 2 days. This minimal length of hospitalisation was arbitrarily chosen to select patients more characteristic of medical inpatients in a tertiary hospital and as a means of excluding patients hospitalised simply for short interventions. There were no other predefined exclusion criteria, and only the patient's verbal consent was required. Patients who were admitted repeatedly during the period of enrolment were examined only during their first admission.

Acquisition of digital images

A simple and inexpensive system was developed using a digital camera (Coolpix 990, Nikon, Küsnacht, Switzerland) fixed 12 cm in front of a bar to obtain standardised and reproducible images of the radial view of the right index finger. The bar (on which the extended finger was placed for assessment) and the wooden support (on which the remaining flexed fingers were placed) was secured in a controlled position in front of the camera in order to avoid rotation. The left instead of the right index finger was used in cases where traumatic or surgical deformities prevented correct measurement of the hyponychial angle on the right side. Predefined settings of the camera were used for acquisition of images in normal resolution with an automatic flash. For further analysis digital images were stored on CD-ROM.

Measurements

Using Quartz PCI Scientific Image Management System Software (Version 4.20, Quartz Imaging Corporation, Vancouver, Canada), the images were displayed on a computer screen. The angle measurement tool was used to calculate the hyponychial angle according to Regan et al. [11] as outlined (fig. 1). Each single picture was analysed by three investigators (DH, SRV, MM) repeating the angle calculation in triplicate and at random.

Statistical analysis

Results are presented as means ± SD. Nonparametric statistical tests were used throughout. Continuous variables between groups were compared using a two-tailed Mann-Whitney *U* test or a Kruskal-Wallis one-way analysis of variance test as appropriate, whereas discontinuous variables were compared using the two-tailed Fisher's exact test. Inter-rater and intra-rater reliability were assessed using intraclass correlation. In addition, Spearman rank correlations were performed. Statistical calculations were done using InStat version 3.05 (GraphPad, San Diego, CA, USA); $p < 0.05$ was considered significant.

Results

123 healthy subjects participated in the study; their characteristics and the results of the measurement of the hyponychial angles of their right index fingers are shown in table 2. Women were significantly older than men (p = 0.0197). They also had a slightly larger mean hyponychial angle, but this difference did not reach statistical significance (p = 0.0719). The distribution of the hyponychial angles is shown in figure 2. Table 3 lists mean hyponychial angles of different age groups. Mean hyponychial angles among different age groups were similar for subjects of both sexes together (p = 0.9733) as well as for women (p = 0.9585) and men (p = 0.8815) separately. There was no correlation between the age of the subjects and the hyponychial angle (for both sexes: r = 0.0070, p = 0.9387; for women: r = –0.0158, p = 0.9082; for men: r = –0.0317, p = 0.7988).

In a subgroup of 26 healthy volunteers, digital images of both index fingers as well as the right middle finger were taken. Measured hyponychial angles were 176.15 ± 4.34° (right middle finger), 178.60 ± 4.38° (right index finger), and 180.40 ± 5.46° (left index finger) respectively. Compared to the right middle finger, the index fingers of both sides had significantly larger hyponychial angles (right side: p = 0.0002; left side: p = 0.0043), whereas the difference between the hyponychial angle of the right compared to the left index finger did not reach statistical significance (p = 0.1427; all data not shown).

During the three-month enrolment period, a total of 576 patients were eligible for study participation. Of these, 53 patients were not included for the following reasons: personal (12), impossibility of communication due to language problems (9), severe or terminal illness or death (13), patient was not accessible (19). Of the remaining 523 patients, the digital images of 8 subjects were excluded for technical reasons. Therefore, a total of 515 patients were included in the final analysis; their characteristics are outlined in table 2. Although women were slightly older than men and had larger hyponychial angles, these differences did not reach statistical significance (p = 0.0802 for age and p = 0.0710 for hyponychial angles, respectively). However men reported a history of regular alcohol consumption ($p < 0.0001$) and a positive cigarette smoking status ($p < 0.0001$) significantly more frequently than women. The angle distribution of the patients are shown in figure 3 and mean hyponychial angles for different age groups are listed in table 3. Hyponychial angles of patients aged 30–44 years were significantly larger than those from patients between 60–98 years of age ($p < 0.05$), otherwise no differences between hyponychial angles of different age groups were found. Furthermore there were no statistical differences

Table 2

Characteristics of control subjects and patients.

	women	men	both
Control subjects (n)	67	56	123
Mean age (years) ± SD	39.5 ± 12.5	34.9 ± 12.4	37.4 ± 12.6
Range	22–77	19–72	19–77
Mean hyponychial angle (°) ± SD	179.60 ± 4.76	178.01 ± 4.52	178.87 ± 4.70
Range	164.78–191.98	168.01–192.10	164.78–192.10
Patients (n)	216	299	515
Mean age/years) ± SD	62.2 ± 19.5#	59.7 ± 17.3#	60.7 ± 18.3#
Range	15–98	16–91	15–98
Mean hyponychial angle (°) ± SD	182.17 ± 7.00*	181.27 ± 7.29**	181.65 ± 7.18***
Range	166.28–201.82	162.22–209.19	162.22–209.19
Regular alcohol consumption (y/n)	11/205	51/248	62/453
Cigarette smoking (y/n)	187/66	70/95	257/161

Note regular alcohol consumption was assumed when patients reported drinking of >1 glass of wine daily. Smoking status was only assessed in 416 patients.

\# $p < 0.0001$ compared to corresponding healthy subjects;

* p = 0.0054 compared to healthy women;

** p = 0.0011 compared to healthy men.

*** $p < 0.0001$ compared to healty subjects of both sexes.

between hyponychial angles of women and men within the same age groups. Angles of patients with regular alcohol consumption did not differ from those who reported no regular alcohol consumption (180.9 ± 7.7° vs. 181.8 ± 7.1°; p = 0.3321). This was also true when women and men where analysed separately (for women: 182.1 ± 7.5° vs. 182.2 ± 7.0°, p = 0.8760; for men: 180.7 ± 7.7° vs. 181.4 ± 7.2°, p = 0.5052).Where the smoking history was known, smokers had slightly larger hyponychial angles than non-smokers (181.9 ± 7.4° vs. 180.7 ± 6.9°), but this difference did not reach statistical significance (p = 0.1329). Smoking women, however, had larger angles than non-smoking women (183.5 ± 7.5° vs.

Figure 2

Distribution of hyponychial angles in healthy subjects. The distribution of hyponychial angles assessed by digital photography and computerised analysis is shown for healthy women (upper panel), healthy men (middle panel) and for both sexes (lower panel) respectively.

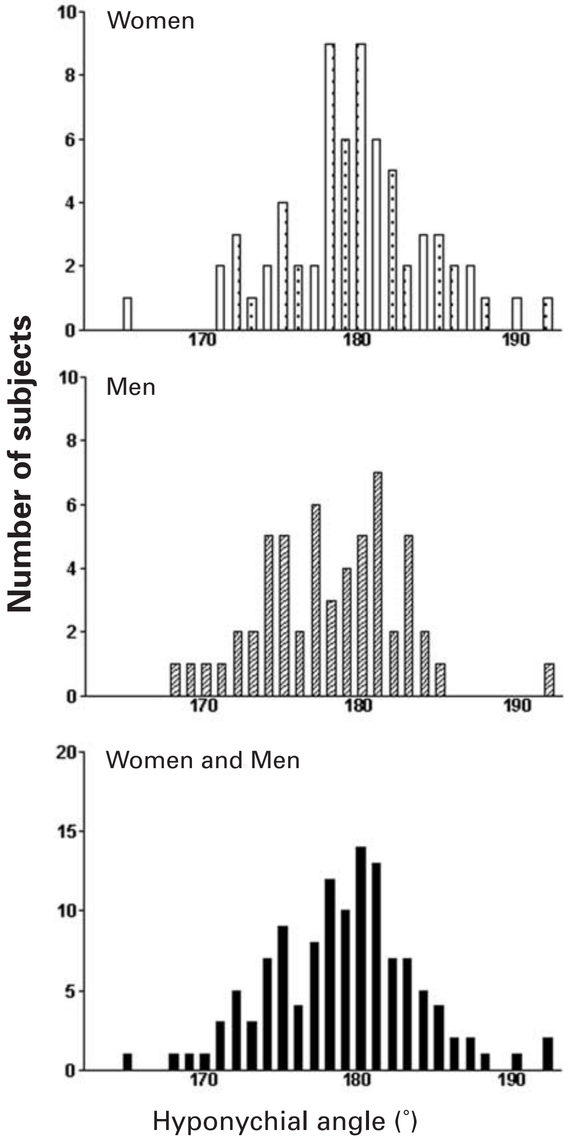

Figure 3

Distribution of hyponychial angles in medical inpatients. The distribution of hyponychial angles assessed by digital photography and computerised analysis is shown for female patients (upper panel), male patients (middle panel) and patients of both sexes (lower panel) respectively.

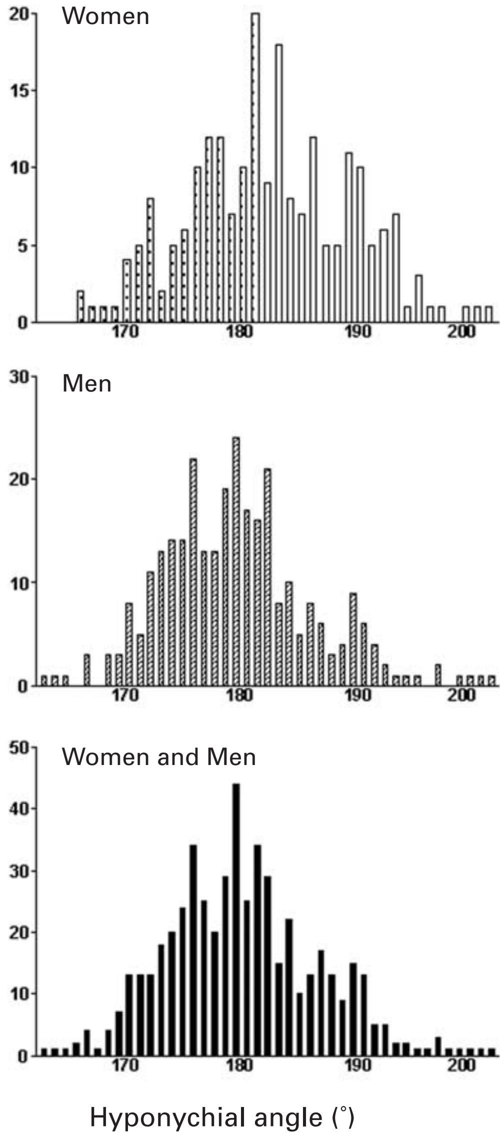

Table 3

Age distribution of hyponychial angles among control subjects and patients.

Age	women + men	control subjects		women + men	patients	
		women	men		women	men
15–29	179.0 ± 4.2 (45)*	180.3 ± 4.4 (19)	178.0 ± 3.9 (26)	183.6 ± 7.4 (40)	183.6 ± 5.6 (17)	184.0 ± 8.7 (23)
30–44	178.5 ± 4.9 (46)**	179.0 ± 4.9 (25)	177.9 ± 4.9 (21)	183.4 ± 7.5 (75)#	184.2 ± 7.8 (35)	182.7 ± 7.2 (40)
45–59	179.6 ± 5.4 (26)	179.9 ± 5.0 (20)	178.6 ± 7.1 (6)	181.6 ± 7.3 (121)	182.7 ± 6.9 (40)	181.1 ± 7.5 (81)
60–98	177.8 ± 4.1 (6)	178.4 ± 6.0 (3)	177.2 ± 2.4 (3)	180.9 ± 6.9 (279)	181.2 ± 6.9 (124)	180.6 ± 6.9 (155)

Note: results are shown as mean ± SD; the number of patients is given in parenthesis.
* p = 0.0027, ** p = 0.0004 compared to patients of the same age group; # p <0.05 compared to patients aged 60–98.

Table 4

Hyponychial angles of various patient groups.

Disease	n[1]	hyponychial angle	p-value[2]	p-value[3]	x[4]
Heart diseases					
Acquired valvular heart disease	81	180.57 ± 7.39	0.1342	0.1493	7 (8.6%)
Endocarditis	7	186.34 ± 9.94	0.0466	0.2229	2 (28.6%)
Heart failure	95	182.02 ± 6.72	0.0003	0.4834	9 (9.5%)
Ischaemic heart disease	170	181.95 ± 7.32	0.0002	0.6096	16 (9.4%)
Lung diseases					
Bronchiectasis	5	186.42 ± 7.66	0.0453	0.1653	2 (40%)
COPD	62	184.83 ± 7.70	<0.0001	0.0003	9 (14.5%)
Cystic fibrosis	5	193.17 ± 8.44	<0.0001	0.0050	4 (80%)
Emphysema	9	181.72 ± 9.04	0.1618	0.8247	2 (22.2%)
Hypertension, pulmonary	31	182.36 ± 8.62	0.0079	0.4585	3 (9.7%)
Lung transplantation	12	184.99 ± 8.55	0.0219	0.2102	3 (25%)
Pneumonia	47	184.32 ± 9.24	0.0002	0.0504	11 (23.4%)
Infectious diseases					
HIV infection	19	186.55 ± 7.84	<0.0001	0.0018	3 (15.8%)
Liver diseases					
Hepatitis (chronic)	21	185.20 ± 8.44	<0.0001	0.0115	3 (14.3%)
Liver cirrhosis	19	184.08 ± 7.75	0.0049	0.1686	3 (15.8%)
Malignant diseases					
Leukaemia*	13	183.34 ± 6.70	0.00112	0.2774	2 (15.4%)
Solid tumors, malignant (all)	84	182.02 ± 6.16	<0.0001	0.3007	5 (6.0%)
Anal	6	185.45 ± 6.41	0.0106	0.1463	2 (33.3%)
Lung	17	182.51 ± 7.29	0.0141	0.4220	2 (11.8%)

COPD = chronic obstructive pulmonary disease;
[1] total number of patients suffering from the specified disease;
[2] compared to healthy controls;
[3] compared to remaining patients;
[4] number of patients with hyponychial angles that exceed the range of normal subjects (i.d. >192.10*);
* included 12 patients with acute and one patient with chronic leukaemia
Note: the sum of patients with digital clubbing does not yield 46 since only diseases that affected more than 4 patients are shown and, in addition, several patients had more than one disease and were therefore listed more than once.

181.0 ± 6.8°; p = 0.0310), whereas the angles of smoking men and non-smoking men were equal (181.4 ± 7.3° vs. 180.5 ± 7.4°; p = 0.3771).

Patients were significantly older than healthy controls (p <0.0001 for both sexes as well as for women and men separately; see table 2), and mean hyponychial angles of patients were significantly larger than those of healthy subjects; for both sexes, p <0.0001; for women, p = 0.0054; for men, p = 0.0011. When mean hyponychial angles of healthy subjects and patients of different age groups were compared, patients aged 15–29 and 30–44 years had significantly larger hyponychial angles (p = 0.0027 and p = 0.0004, respectively). 46 patients (18 female/ 28 male; mean age: 54.3 ± 21.0 years) had hyponychial angles that did not overlap with the range of hyponychial angles of healthy subjects (164.78–192.10°). When the upper limit of normality is used to define the "beginning" of digital clubbing, a prevalence of 8.9% could be calculated; the mean hyponychial angle of these 46 patients was 195.76 ± 4.29°. The percentage of female patients (8.3%) featuring digital clubbing was not statistically different compared to the percentage of male patients (9.4%; p = 0.7554). Table 4 lists mean hyponychial angles of different patient groups and the percentage of patients with digital clubbing among patients suffering from the same specific disease. The percentage of clubbed fingers varied substantially among the various disease-states and was as high as 80% in patients with cystic fibrosis. As shown, patients suffering from acquired valvular heart disease, bronchiectasis, chronic hepatitis, chronic obstructive pulmonary disease, cystic fibrosis, pulmonary emphysema, endocarditis, heart failure, HIV infection, ischaemic heart disease, leukaemia, liver cirrhosis, pneumonia, pulmonary hypertension and certain solid malignant tumours, as well as subjects who had had lung transplantation in the past were identified as having clubbed fingers. In addition, digital clubbing was found in patients with atrial myxoma (1), complex cyanotic congenital heart anomaly (consisting of a single ventricle, ventricular septum defect and pulmonary hypertension: 1 patient), cystic renal disease (1), pulmonary fibrosis (1) and lymphoma (1).

As stated in the methods the hyponychial angles of both healthy subjects and patients were determined by three investigators who repeated each measurement three times in a randomised fashion. Intra-rater reliability was excellent with coefficients of 0.969, 0.994, and 0.958 for assessment of hyponychial angles in healthy volunteers by rater 1, rater 2, and rater 3, and 0.981, 0.997, and 0.981 for measurement of hyponychial angles in patients by rater 1, rater 2, and rater 3 respectively. Likewise inter-rater reliability was high; corresponding coefficients were 0.839, 0.810, and 0.825 for rating 1, 2, and 3 in healthy volunteers, and 0.915, 0.906, and 0.910 for rating 1, 2, and 3 in patients respectively.

Discussion

In the present study, we found a mean hyponychial angle of right index fingers among healthy subjects that was very similar to those reported in previous studies (see table 1 and reference [2]). Since angles were determined with plaster cast or shadowgraph techniques in earlier reports, this result confirms the accuracy of digital photography and computerised analysis as a modern method for quantification of finger morphology. Also in agreement with previous findings, [2] none of the healthy volunteers had angles above approximately 192°, accordingly this value was confirmed as describing the upper limit of normality. Preliminary data obtained in 26 healthy volunteers indicated that hyponychial angles of index and middle fingers may be slightly but significantly different. Therefore in the future it may be important to restrict this range of normality to hyponychial angles of (right) index fingers.

To date only very limited information about the prevalence of digital clubbing in unselected medical patients is available. In one study, clubbed fingers were found in 29 out of 117 adult patients (24.8%) admitted in medical wards [19]. In our group of medical inpatients from a tertiary hospital, mean hyponychial angles of index fingers were significantly larger than those of healthy subjects, although the mean difference was only 2.78° and there was considerable overlap. Nevertheless 46 patients had hyponychial angles that exceeded 192.1° resulting in an overall prevalence of digital clubbing of 8.9° when the upper limit of normality is used to define the "beginning" of clubbed fingers. Difference in characteristics of patients, assessment method and definition of digital clubbing may explain the difference between the results from our study and previous results. As outlined in detail in table 4, the percentage of patients with clubbed fingers varied substantially among the different disease states: from 0% up to 80% in patients with cystic fibrosis. Mean hyponychial angles in our patients with cystic fibrosis were very similar to those assessed by Bentley et al. [15] and Pitts-Tucker et al. [20] (193.2 ± 8.4° in our study compared to 194.8 ± 8.3° and 192° respectively), once again confirming the accuracy of the method used in the present study.

An obvious limitation of our study is that the detailed analysis of the patient's records necessary to associate digital clubbing with an underlying disease was complicated by the fact that most medical patients had more than one significant disease. Nevertheless patients with diseases known to be associated with digital clubbing, such as bronchiectasis, cystic fibrosis, pulmonary fibrosis, endocarditis, chronic hepatitis or cirrhosis, HIV infection, infectious lung disease and lung cancer could be identified. One patient with clubbed fingers was found to have an atrial myxoma, another had a complex cyanotic congenital heart anomaly. Two other patients with pulmonary hypertension were also found to have digital clubbing. In one, pulmonary hypertension was due to heart failure; in the other pulmonary hypertension was associated with HIV infection. In addition, there were some diseases that so far have only rarely, if at all, been associated with digital clubbing, e.g. leukaemia (both patients had acute lymphoblastic leukaemia, with one having no other disease, whilst the other suffered from heart failure and fungal pneumonia) or heart failure (among these some merely had underlying ischaemic heart disease and no other concurrent disease). Two patients with anal cancer were also identified as having digital clubbing and of these only one had further disease (lung cancer). One patient with bronchiectasis and digital clubbing also had chronic hepatitis, a second one concomitantly suffered from ischaemic heart disease. In the group of patients with cystic renal disease, digital clubbing was found in one subject, who also had pulmonary emphysema.

Over the last decades several objective methods have been developed to defeat the limitations of subjective clinical assessment of finger morphology. However, previous techniques had several draw-backs, e.g. finger casts took several hours to make, were perhaps faulty and had to be repeated or were too time-consuming for routine use [11–13]. Shadowgraphs allowed serial measurements with minimal time requirement but results could not be stored, precluding repeated analysis and long-term studies, [14, 15] shadowgrams were cheap and simple to obtain but necessitated outlining of finger silhouettes on paper [16]. Recently digital cameras and computerised analysis have been introduced as a means of evaluating digital clubbing [17]. Moreover, the use of digital photography with computerised analysis has proved to be an easy, simple and relatively cheap method of quantification of hyponychial angles. Data thus obtained showed only minimal variation in inter- and intra-rater reliability as determined by repetitive analysis by three different investigators in the present study. Digital acquisition and storage of images offer long-term storage of original "data" and repeated analysis without loss of quality by different investigators at different time points. It can be assumed that determination of both nail-fold angles and phalangeal depth ratios are both accurate [2] and direct comparison of these methods awaits further analysis. Since the measurements can be recorded within a few minutes without causing discomfort this method allows serial measurements or investigation of very large populations, rendering it a tool useful for further longitudinal and cross-sectional studies of finger morphology and digital clubbing. The clinical value for modern medicine of a standardised assessment of digital clubbing remains to be determined.

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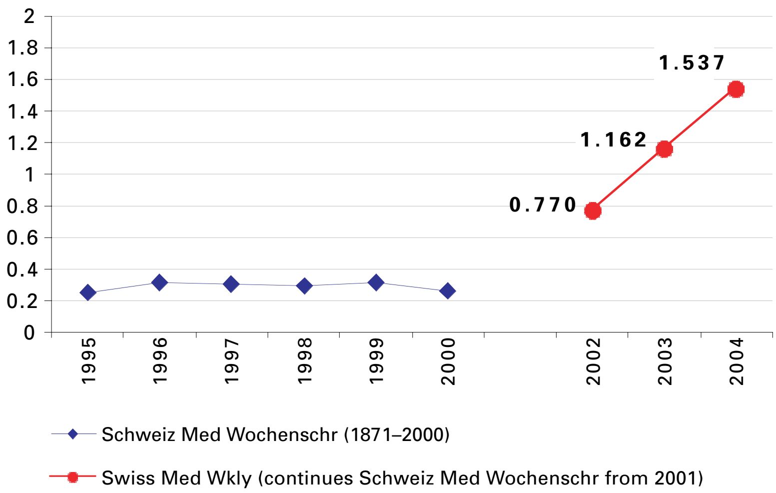

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