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SPECIAL ARTICLE

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Skin-fold thickness and reproducibility of the skin-roll test: Vågå study

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Abstract In the Vågå study of headache epidemiology, the "skin-roll test" was carried out at the top ("arch") of the shoulder girdle. For this purpose, a skin caliper (Servier, Leiden) was used. A total of 1796 parishioners aged 18–65 years (51% women) was examined. A repeat test was also carried out. The skin-roll test consists of two components: measurement of skin-fold thickness and assessment of the pain level. The average arch skin-fold thickness on the right side, was 15.0 (SD=5.9 mm; range, 3–60) and was significantly lower in men (mean, 13.8 mm) than in women (16.1 mm). Among the subjects without headache (n=246), the average skin-fold thickness was 14.3 (SD=5.7 mm). Immediately repeating the test revealed a measurement error >3 mm in 1.1% of cases. Asymmetry in the shoulder arch area exceeded the measurement error in 6.1% of the cases. The skin-fold thickness at an anterior site in the shoulder area was always less than that at the shoulder arch.

Key words Skin-roll test • Headache • Hemicrania • Skin-fold thickness • Fibromyalgia

Introduction

In headache research, much attention has been directed towards local muscles, in particular the temporal and neck muscles. Much less attention has been paid to the skin in the same areas.

Some years ago, Meloche and co-workers gave an account of their experience with the so-called skin-roll test or "pinch and roll" test [1]. This test can be carried out in various areas, for example in the shoulder area, supraorbitally, and in the mandibular area. We have carried out this test mainly in the shoulder area [2–4].

There are two components of the test: skin-fold thickness and skin tenderness. Although each of the components may be abnormal separately, a positive test, according to our previous, clinical impression, frequently involves skin that is both tender and thickened. If both skin and muscles in a given area seem to be affected, this could be indicative of a situation differing from one where only the muscle is painful. In unilateral headaches, assessment of skin-roll test asymmetry may be meaningful. The possible connection between a pathological skin-roll test and hemicranias has been explored to some extent [1, 4], but this association needs further exploration.

Meloche et al. [1] assessed skin-fold thickness visually. This approach to the problem hampers interindividual com-

parisons; it hampers intraindividual comparisons along the time axis; to a lesser extent, it also hampers the comparison of the two sides.

In our setting, we have introduced instrumental measurements of skin-fold thickness [2, 4], so that also the asymmetry can be quantified. We have had the impression that the skin-roll test findings are rather reproducible, but any formal testing of reproducibility has not previously been done in large series. A testing of reproducibility was an integral part of the Vågå study of headache epidemiology [5, 6]. A comparison was made between results obtained from the top of the shoulder ("arch") and values from a more "anterior site". This was done in order to obtain a numerical expression for the rather clear, clinical impression: measurements at the anterior site render lower values than measurements made at the top of the shoulder. Measurements are easier to carry out anteriorly, and this area of interest is easier to outline topographically than the arch. Is it possible that altogether the anterior zone is better suited for such measurements? Another objective was to obtain a survey of the entire panorama of skin-fold thickness at the grass-roots level, not taking particular disorders into account. Headache was graded on a 0–6+ scale [7]. There were 246 parishioners in category 0 (without headache). A comparison was made between the total series and the headache-free cases. The development over time has also been followed in some parishioners.

Subjects and methods

In Vågå, there were 3907 parishioners just prior to the start of the Vågå study of headache epidemiology in 1995. Details of the study have been published elsewhere [5]. All parishioners in the age group 18–65 years were invited to participate. In the study as such, 1838 parishioners were examined (88.6% of the available ones). Overall, 51.3% of the parishioners were women and 48.7% were men, with a female/male ratio of 1.05 [5]. The mean age was 42.8 years. Skin-roll test was carried out in 1796 parishioners, 917 women and 879 men, with a female/male ratio of 1.04.

The average skin-fold thickness values refer to the population-based, unselected Vågå population, with all kinds of headache included. Comparison with headache-free parishioners has also been carried out.

Skin-roll test procedure

All the measurements were carried out by the principal investigator (O.S.). The test subject was seated comfortably in a chair. Pinching of the skin was started at the lower end of the scapula. Three radial fingers were used for holding the skin in the grip and then, alternatively using the right- and left-hand fingers, the skin was rolled upwards. The skin was rolled until the very top of the shoulder - the arch - was reached, midway between the spine and the distal end of the acromion. The skin thickness was then measured with calipers (Servier, Leiden, The Netherlands), to the nearest millimeter. The right side was invariably tested first. After the first paired right-left tests, the values were recorded, and the test was then repeated immediately for assessment of reproducibility. The calipers exert a constant 5 g/mm^2 pressure (S. Bergmann, Technical Division, Trondheim University Hospitals). The pressure exerted is, in other words, independent of the opening of the "jaw" of the calipers. This enables comparison of tenderness and thickness at various sites and at various times. Tenderness was recorded only at the first measurement. Tenderness recorded as "none" or "minor" was not paid any particular attention. "Moderate" or "marked" tenderness was scored as 0.5+. A 1+ value was used when particularly intense tenderness seemed to be present.

After the second assessment of skin-fold thickness, the skin-fold was moved 2.0–2.5 cm anteriorly, to the anterior end of the trapezius muscle (at the beginning of the fossa supraclavicularis), where another measurement of the skin-fold thickness was made on both sides. The possibility that the anterior measurements may give more symmetrical values in healthy individuals was also tested (this may be so partly because of the smaller width of the skin-fold). Anterior asymmetries may possibly be more clinically relevant than asymmetries at the "top" of the arch. The relationship – if any – between anterior and top of the shoulder (arch) measurements, in particular as regards asymmetries, is of interest.

Two tests have been used to evaluate the quality of the measurement system in this study. First, the assessment system per se has been evaluated, on the basis of the measurements already mentioned: the variability of the four first measurements, carried out sequentially, two on each side. The issue of true asymmetry can then be examined. To what extent does asymmetry exceed the measurement variability? How frequently does "real" asymmetry exist in the entire population and in those with no headache?

In another section of the study, an entirely different assessment was done. In 40 parishioners, re-check was carried out, after a mean of 14.8 months (range, 4–23 months). The selection criteria for these 40 parishioners have been detailed previously [5, 6]. At the re-check, skin-fold thickness was recorded at the anterior site; the thickness measurements were also repeated and the tenderness was recorded for the two measurements on either side at the arch.

Did the variability *between* the original examination and the re-check exceed the variability *within* the two original, separate sets of examinations on each side? Would there be any systematic alteration? Would an asymmetry from the first examination be maintained at this second examination?

Comparison between skin-fold thickness, tenderness and features indicative of cervical abnormalities

In order to test the connection between skin-fold thickness and skin tenderness, two subgroups were constructed from consecutive parishioners. One group comprised subjects with skin-fold thickness <10 mm (n=106) and another had subjects with thickness ≥25 mm (n=100).

Skin-fold thickness has also been compared with nuchal abnormalities or "features indicative of cervical abnormalities". These features consist of five different factors: range of motion in the cervical spine; precipitation of discomfort or pain from nuchal ten-

dons by graded external pressure; precipitation of pain from nuchal muscles and from face joints. The features were scored on a scale of 0-5+, as described elsewhere [8].

Results

Average skin-fold thickness, arch area

The average skin-fold thickness at the top of the shoulder (Table 1) was of similar magnitude on the two sides, with both sexes combined: on the right side 15.0 mm (SD=5.9), and on the left side 15.2 mm (SD=6.1). The mean values were significantly higher in women than men on both sides (p<0.0005). There was no significant mean asymmetry in women (p=0.174).

The average values seemed to change with age and mostly so in men (Table 2).

In the entire Vågå population skin-fold thickness varied considerably (Fig. 1). Most parishioners had a skin-fold thickness between 7 and 22 mm. There was a clear, positive skewness in the histogram (Fig. 1). The shape of the curve deviated significantly from a Gaussian distribution (p<0.0000001; Kolmogorov-Smirnov one-sample test).

Table 1 Skin-fold thickness at the top of the shoulder area, n=1796. Values are mean (SD; range)

	Right side	Left side
Whole series	15.0 (5.9, 3–60)	15.2 (6.1; 3–60)
Women (n=917)	16.1 (6.2; 3–60)*	16.5 (6.4; 3–60)*
Men (n=879)	13.8 (5.3; 4–40)	13.8 (5.5; 5–40)

*p<0.0005 vs. men

Table 2 Skin-fold thickness, according to age, gender and headache. Values are mean (SD)

	Age group, years	
	18–32	>53
Women	15.4 (5.8)**‡	16.7 (5.8)§
Men	12.4 (4.9)*	14.4 (5.0)
Men, stage 0[a]	10.7 (4.4)***	–

**p<0.0005 vs. men in same age group
‡p=0.014 vs. older women
§p<0.0005 vs. men in same age group
*p<0.0005 vs. older men
***p<0.057 stage 0 on a 0–6+ scale [7] vs. all men in same age group
[a] Stage 0 on a 0–6+ scale [7]; mean skin-fold thickness (n=246); 14.3±5.7 mm

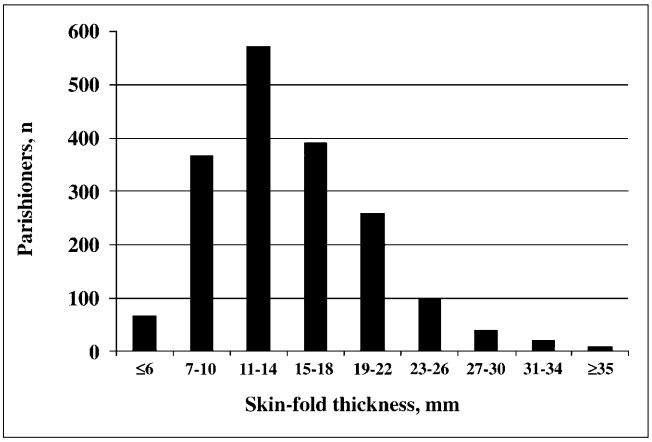

Fig. 1 Skin-fold thickness at the arch, for the entire Vågå study population. Values represent the means of all combined mean values of the right and left sides for each parishioner

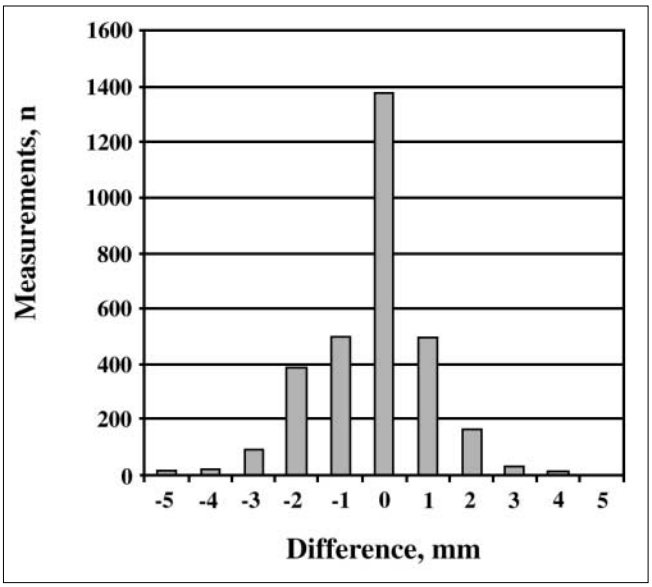

Fig. 2 Difference between two sucessive measurements of skin-fold thickness at the arch (measurement error)

Measurement error

The measurement error was defined as the difference between the two original tests on each side, arch area, carried out within one minute. A histogram of the errors is presented in Fig. 2. The range of measurement errors was -5 to +5 mm. There was only one parishioner with a difference of 10 mm. In this particular case, with an original skin-fold thickness of 45 mm (a high value, see Fig. 1 and Table 1), a note had been made on the record that the measurements probably were unreliable due to the measurement conditions. This value should accordingly be excluded (not

Table 3 Interdependence of original skin-fold thickness (measured at the top of the shoulder) and error on immediate re-measurement

Original thickness	Subjects, n	Errors <-1 mm or >1 mm, n (%)
5–7 mm	137	7 (5)
8–10 mm	290	67 (23)
≥ 30 mm	44	26 (59)*

*p<0.0005 vs. subjects with 5–7 mm skin-fold

included in Fig. 2). A measurement error of >2 mm occurred in 4.4% of the cases; of >3 mm in 1.1% of the cases, and of >4 mm in 0.4% of the cases (Fig. 2). As a reasonable compromise between specificity and sensitivity, a workable, practical rule could be that an asymmetry or a difference between two measurements made at different times, exceeding 3 mm should be considered clinically relevant.

The measurement error to some extent depended upon the thickness of the skin-fold. In cases of relatively thick skin, there was a more marked variation between measurements than in those with relatively thin skin, in absolute figures (Table 3).

Skin-fold thickness asymmetry, arch area

As depicted in Fig. 3, a number of right/left thickness differences exceeded the stipulated measurement error of >3 mm, i.e. 109 cases, or 6.1%. This figure, 6.1%, should be compared to that for measurement error of >3 mm magnitude, i.e. 1.1%; these proportions are significantly different. The maximal asymmetries in the unselected population were -11 and +10 mm.

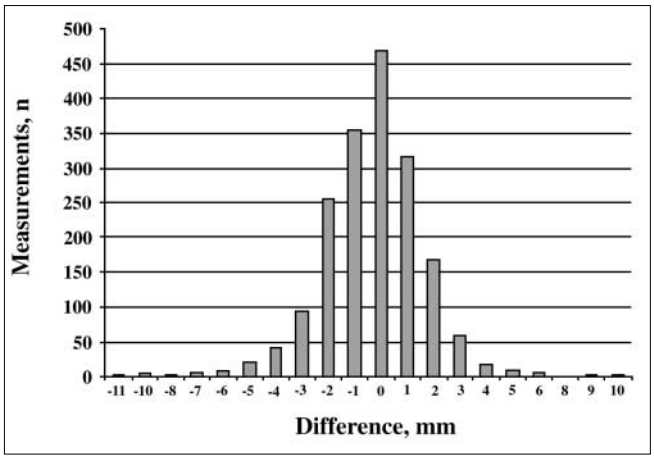

Fig. 3 Skin-fold thickness asymmetry at the top of the shoulder (arch), determined by the difference between measurements on right and left sides

Table 4 Persistence of asymmetry (>3 mm) on repeat testing of skin-fold thickness at the shoulder arch, as observed in 3 of 40 subjects submitted to recheck at mean of 14.8 months (range, 4–23 months)

	Asymmetry, mm	
Subject	First examination	Recheck
1	4	3
2	4	1
3	9[a]	6

[a] The thicker side had a skin-fold of 25 mm. This subject also had marked tenderness asymmetry

A subgroup (n=40) was rechecked blindly after a mean of 14.8 months (range, 4–23 months). In three of these cases, the clear asymmetry observed on the first examination persisted (Table 4). In these cases, the laterality was unchanged but the asymmetry was reduced at recheck, partly to a non-relevant level. In another case, a de novo borderline asymmetry (3 mm) was recorded on examination II.

Changes over time

In the 40 parishioners who were rechecked blindly after an average of 14.8 months, the asymmetry of both sides was taken into consideration; there were thus 80 pairs for comparison. A test/recheck discrepancy ≥4 mm on at least one side was found in 13 (33%) of the 40 parishioners and in 21 (26%) of the 80 solitary observations (Table 5). These figures should be compared with the measurement error of ≥4 mm in 1.1% of the observations. Surprisingly, in cases of marked changes between examinations I and II, a *reduction* in skin-fold thickness invariably took place. In 10 of the 11 observations with a reduction ≥5 mm between the two

Table 5 Appreciable change (≥4 mm) in skin-fold thickness between first and second examinations in 40 subjects submitted to recheck at mean 14.8 months (range, 4–23 months). Data refer to either side (80 observations)

Difference, mm[a]	Observations, n
4	10
5	6
6	4
9	1

[a] All differences correspond to decreases in skin-fold thickness over time

measurements, there was, originally, a higher than average initial skin-fold thickness. A decrease of 3 mm (a non-significant change) was present in another 14 observations.

Of the 40 parishioners in this re-examined group, 3 had in the meantime become pensioners (two of them had previously done hard manual work). The reduction in thickness in these re-examined parishioners, nevertheless, probably cannot be explained on this basis alone. The majority (10 of 13) was made up of women with "easy" work (e.g. home work, teaching). Otherwise, there were no identified or even suspected causative factors to explain the reduction in skin-fold thickness. In our files, it was not registered systematically whether there for instance had been any physiotherapy. The parishioner with the most marked reduction in skin-fold width (9 mm, i.e. a decrement of 47%, from 19 to 10 mm) was a 62-year-old female office worker with only "heaviness" – and no headache [7]; to the best of our knowledge she had had no major change in her life situation. In one case only, there was a unilateral increment in thickness of 3 mm (in other words, a non-significant change).

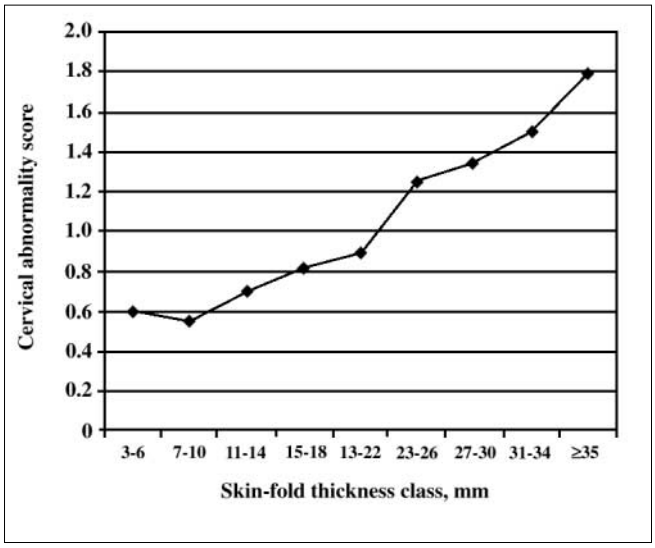

Fig. 4 Interdependence of skin-fold thickness at arch area and features indicative of cervical abnormalities, measured on a 0–5 scale [8]. Values are means

Is there a connection between skin-fold thickness and extent of headache?

A total of 246 parishioners had no headache, according to the 0–6+ headache scale [7]. The mean skin-fold thickness was 14.3 mm (SD=5.7) in this group (Table 2). The asymmetry was less marked in this group than in the whole series, with an asymmetry ≥4 mm in only 0.6%, which should be compared with the asymmetry in the whole population (6.1%). While skin-fold thickness among pain-free, 18- to 32-year-old men was 10.7 mm (SD=4.4), that for all men in the corresponding age group (all pain stages) was 12.4±4.9 mm (p<0.057) (Table 2). These measurements, suggest that there is a slight, but non-significant tendency to an interrelationship between head pain intensity and skin-fold thickness.

Dependence of skin-fold thickness on features indicative of cervical abnormalities

We calculated the mean scores for cervical abnormalities on a 0–5+ scale [8] for all the parishioners grouped into classes according to skin-fold thickness (Fig. 4). The mean cervical abnormality score increased approximately threefold from the class with smallest skin-fold thickness to that with the greatest skin-fold thickness. This interdependence was not totally unexpected, since the skin-roll thickness has been proposed [8] to be an integral part of "features indicative of cervical abnormalities". The latter factor, nevertheless, has a much wider scope, comprising five distinct diagnostic elements.

Pathological skin-roll test

A pathological test as far as skin-fold thickness (as measured at the top of the shoulder area) is concerned can, therefore, probably manifest itself in various ways:

1. Asymmetry ≥4 mm.
2. Changes over time ≥4 mm.

Since the average skin-fold thickness in those with "no headache" (stage 0; n=246) was 14.3 mm (SD=5.7), the upper limit of "normal", therefore, can be calculated as 14.3 + 2 SD, or approximately 25 mm. Alternatively, if we choose to use 2.5 SD to obtain the upper limit, the value will be 28 mm. The normal values are lower in men than women (Tables 1, 2).

Anterior site skin-fold thickness

The skin-fold thickness measured at the anterior site most frequently was between 4 and 11 mm in the unselected group of parishioners (Fig. 5). The mean thickness at this site was 8.3 mm (SD=3.1) and there was no asymmetry between the mean values for the right and left sides (Table 6).

There was a clear difference between the average anterior (8.3±3.1 mm) and arch (15.0±5.9 mm) skin-fold width

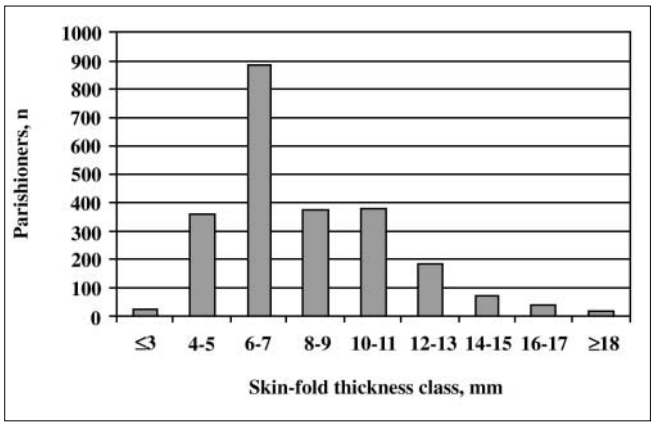

Fig. 5 Skin-fold thickness measured at an anterior site, both sides

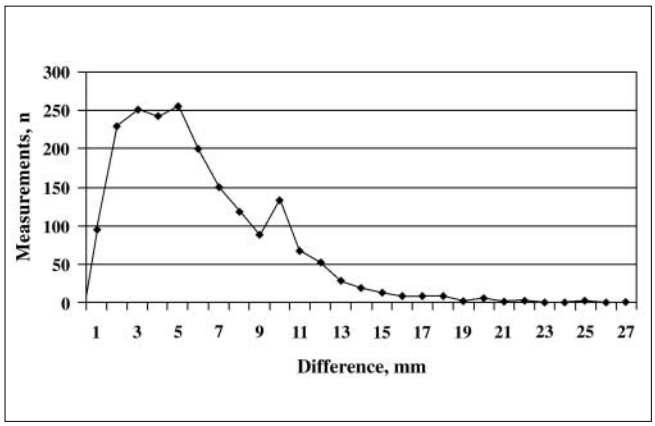

Fig. 6 Difference between arch and anterior measurements of skin-fold thickness

Table 6 Skin-fold thickness measured at an anterior site, according to side of the body

Reference	Right side	Left side
Bansevicius [4]	10.1 (3.6; 4–22)	9.8 (3.4; 4–23)
Present work	8.3 (3.1; 2–21)	8.3 (3.1; 2–21)

$p<0.0005$ vs. data from Bansevicius, right side [4]

values ($p<0.0005$, right side). The individual differences in skin-fold thickness between the arch and the anterior site are presented in Fig. 6. The skin was never thinner at the arch than at the anterior site. The mean differences between the arch and the anterior measurements were: right side, 5.9 mm; left side, 6.1 mm; both sides, 6.0 mm (range, 0–27; usual range, 1–10 mm). In 12 cases, there was no difference between the thicknesses at the two locations.

The measurement error at the anterior site has been examined in 78 subjects. A difference exceeding 1 mm, i.e. 2 mm, was found in only one case. Just by chance, all the test persons had an anterior skin-fold thickness ≥8 mm, i.e. they were in the *upper* strata in the distribution of skin-fold thickness values (Fig. 5).

In the entire population, asymmetry at the anterior site (right side - left side thicknesses) mostly varied between -1 and +1 (82% of the cases); in 4.5% of the cases, the asymmetry was ≥3 mm (Fig. 7). Therefore, asymmetry at the anterior site seems to be rather common. In 10 exceptional cases (approximately 1%), an asymmetry ≥5 mm was observed. In all the cases of such marked asymmetry, there was a corresponding asymmetry also at the top of the shoulder.

In 10 pairs of measurement, i.e. 20 solitary comparisons, the anterior skin-fold thickness was rechecked after a mean of 14.8 months. The most marked changes found were between -1 and +5 mm; the mean change was +1.4 mm. Mostly, the thickness increased during the interval; only in 20% of the measurements was a decrease observed. This seems to be the opposite tendency to what was observed for the arch values. The number of re-examinations was, however, limited.

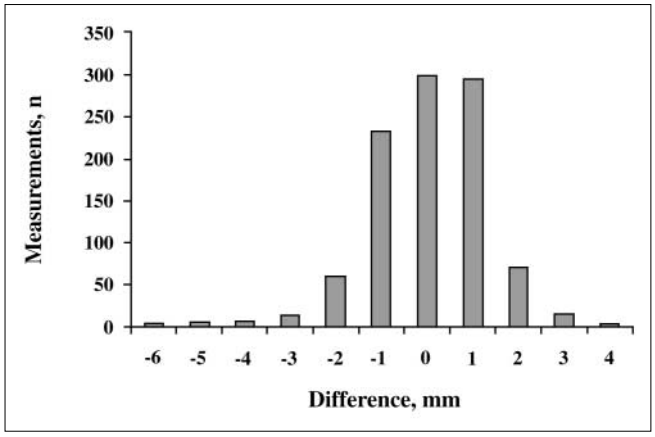

Fig. 7 Skin-fold thickness asymmetry at the anterior site, determined by the difference between measurements on the right and left sides

Tenderness

In cases of clear skin-fold asymmetry, skin tenderness frequently seemed to follow the thicker side. There was, however, a not inconsiderable number of exceptions. In the solitary case, demonstration of tenderness may not necessarily indicate any laterality of disease. But, in a large group of individuals, a tendency to the combination: ipsilateral thickness and tenderness may possibly surface.

In parishioners with a relatively thin skin, i.e. <10 mm (n=106), 25% had increased tenderness. In contrast, among

those with thick skin, i.e. ≥25 mm (n=100), 53% had increased tenderness. Skin-fold thickness >25 mm is a borderline or abnormal finding. When followed over time, a clear decrease in skin-fold thickness could or could not be accompanied by a decrement in tenderness; over time, a de novo tenderness could even appear.

As a consequence of the present study, we realized that tenderness irrespective of headache category after all may not be so meaningful. Tenderness will, therefore, be studied in connection with specific diseases in future studies.

Discussion

In the shoulder area, skin-fold was significantly thicker in women than in men. A significant asymmetry was found in approximately 6% of the cases.

The reproducibility study at the original examination illustrates the absolute error made. *Asymmetries* in skin thickness exceeding 3 mm may be characterized as real asymmetries (with only few exceptions). Asymmetries in skin-fold thickness may be important in unilateral headaches.

After an average of 14.8 months, skin-fold thickness in the arch area changed in excess of the measurement error in 13 (33%) of 40 cases, and changes of considerable magnitude were observed. It, therefore, seems that real changes in skin-fold thickness in this area occur as a function of time.

Reproducibility studies should preferably be carried out within a short period or, as in the present study, on the same day. The anterior site is easier to locate than the arch. The skin-fold thickness is also appreciably less anteriorly than at the arch, and – probably for both these reasons - the reproducibility of the test is far better at the anterior site than at the arch. Asymmetry was also present in an appreciable number of cases anteriorly, and there seems to be ample correspondence between the asymmetry anteriorly and at the arch. It is therefore possible that anterior skin-fold thickness measurements might prove more apt for diagnostic purposes than arch measurements. This conjecture can probably best be scrutinized when studying specific headaches.

The discriminatory power of the skin-roll test is not entirely obvious, not even as far as hemicranias are concerned. There is clearly not a one-to-one relationship. Positive tests may be observed in connection with panniculosis [9], hypometabolism and obesity [2], and fibromyalgia [10]. In allodynia [11], there may also be positive tests, as well as in cases where the underlying disorder is unknown. It has also been noted that extreme leanness or anorexia influences skin-fold thickness. The skin-roll test is not mentioned in the IHS classification [12].

A gravely increased skin-fold thickness in the shoulder area – and in particular in connection with asymmetry – is probably an indication that something is wrong. It may possibly be a diagnostic aid if it matches with the clinical symptoms and signs.

The skin-roll test has also been used by Bansevicius et al. [2, 4]. There is a significant difference between the first series of Bansevicius et al. [2] and the present series (Table 7). There is also a significant difference between the two control series of Bansevicius, pertaining to the arch area (Table 7). Our values, at the arch area, resemble more those in Bansevicius' later [4] study than those from the former one [2].

Table 7 Skin-roll test ("pinch and roll test"): thickness, shoulder "arch" area

Reference	Group	Subjects, n	Side	Thickness, mm
Bansevicius et al. [2]	Controls**	95	–	11.2 (3.9; 5–26)
Bansevicius [4][a]	Controls *	51	R	17.0 (5.5; 9–36)
			L	17.3 (5.4; 9–35)
Present study	All parishioners	1796	R	15.0 (5.9; 3–60)
			L	15.2 (6.1; 3–60)
Present study	Women	917	R	16.1 (6.2; 3–60)
			L	16.5 (6.4; 3–60)
Present study	Men	879	R	13.8 (5.3; 4–40)
			L	13.8 (5.5; 5–40)

**$p<0.0005$ vs. Bansevicius [4], controls, right side (17.0±5.5 mm)

[a] Only pinching – not rolling the skin. Patients were from a neurological outpatient service. Patients with chronic headache and "any suspicion of fibromyalgia" were excluded

*$p=0.017$ vs. present series, right side (15.0±5.9 mm)

R, right; *L*, left

The discrepancy between the two arch area control series, studied by Bansevicius, is so marked that it probably has a methodological explanation (Table 7). Both were carried out in control subjects and by the same investigator, presumably at the same level of the shoulder arch. The second series [4] comprises neurological outpatients with non-serious illnesses may be more similar to ours. The authors tried to weed out cases of headache. The results in the first series [2] are probably more comparable to those from stage 0 subjects ("no headache" [7]) in our series (Table 2). There seems to be a body weight difference [4] between the two Bansevicius series. This factor alone may account for upwards of 2.5 mm of the difference between the means [4], but it does probably not account for the whole difference. There was no appreciable difference between the mean ages of the two Bansevicius series.

There is *one* clear, technical difference between the two Bansevicius series. In the first series [2], "rolling" of the skin has been used; in the second series [4], only "pinching" the skin has been used (without any rolling). It is uncertain whether - and in case to which extent - the two techniques will render different results. In preliminary tests, we have not been able to demonstrate marked differences between the two techniques.

A final possibility is that defining the end point localization at the top of the arch may cause some problems. Rolling the skin only a few millimeters to the anterior from the intended end point at the arch may create appreciable differences.

A methodological study comparing the two techniques, pinching and rolling the skin, may, nevertheless, in the end have to be done to solve the problem of the different skin thicknesses in various series. Weighing of the individuals should then be an integral part of the procedure. For the time being, we will probably have to live with some limited uncertainties.

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