

The role of body size in somatosensory testing

S. Lautenbacher and F. Strian¹

Abstract

To try to replicate our earlier findings of body size influences in somatosensory testing we measured thresholds of heat pain, warmth, cold and vibration in 66 young, normal-weight women. Our assumption was that true body measure effects have to be demonstrable even in a sample limited with regard to age and sex and without extreme body size variation (which may be linked to pathology). In the present sample, body size (a linear combination of height and weight) did not have a very strong relation with any of the somatosensory thresholds (slightly stronger for the warmth and cold thresholds than for the heat pain and vibration thresholds). Hence, we could not fully replicate our earlier findings of marked body size effects on warmth and cold thresholds obtained in a sample without such limits. A measure of the body fat content seemed to have some explanatory power, but only for the vibration thresholds. We conclude that body measures, age and sex may be confounded in a way that cannot always be sorted out by a posteriori analyses and should therefore be treated a priori as independent variables for purposes such as establishing normal values in somatosensory testing.

Introduction

In the past decade it has been widely acknowledged that somatosensory testing including the use of thermal, vibratile and electrical stimuli is a very useful tool in the diagnosis of peripheral neuropathies, especially of the diabetic type (5, 14, 17, 18, 21). In addition to the diagnostic applications, those technique also produce results that may be indicative of the morphometric status of the peripheral nerve fibre systems involved (15). There is general agreement that age must be considered in somatosensory testing, e.g. when normal values are established (2, 3, 6, 12, 16). Up to now less emphasis has been given to the role of body measures, such as height and weight. This has been true despite the fact that there may be a link between body size and the development of neuropathic symptoms and sensory deficits (7, 19).

In an earlier study we found that in healthy persons body size (a linear combination of height and weight) seemed to have a strong influence on thermal sensitivity thresholds but not on heat pain thresholds (13). Body size explained 9% (hand) and 21% (foot) of the variance in the warmth thresholds and 14% (hand) and 15% (foot) of the variance in the cold thresholds. Sex differences could be explained by considering them to be body size differences. Similar results with respect to putative sex differences were produced by Larkin and coworkers (11) with electrocutaneous stimulation. For vibration thresholds significant correlations with height have been found in several studies with healthy subjects (6, 9, 20). These findings are reason enough to study body measure influences on the results of somatosensory testing more closely.

The investigation of body measure effects in somatosensory testing provides more difficulties than would be expected at first glance. Body measures are correlated with age and sex, and an a posteriori analysis may not always help to

¹ Max Planck Institute for Psychiatry, Clinical Institute, Department of Neurology, Munich, Germany.

separate these variables. Furthermore, extreme variations in body measures may be linked to pathological alterations. These problems have not been considered sufficiently in previous studies. Therefore we decided to test body measure influences in a sample that was homogeneous with regard to age and sex and that did not contain extreme variations in body size. Our hypothesis was: If true body measure influences exist then no variations in age and sex and no pathological degrees of body size are necessary to demonstrate them. Accordingly, we measured the thresholds for heat pain, warmth, cold and vibration in a sample of young, normal-weight females. The basic covariates were height, weight and a linear combination of both as a measure of body size. As local skin temperature may influence somatosensory tests to some degree (22) and body size/skin temperature correlations might exist we also assessed this variable. In a subsample we additionally investigated whether the body fat content had any influence because it might affect the stimulus transduction process from the stimulator to the receptive organs.

Method

Subjects

Sixty-six women aged 19 to 30 years (mean = 24.1, SD = 2.5) were investigated. The inclusion criterion "normal weight" was defined according to the criterion of Bray (1) as a body mass index (kg/m^2) between 19 and 24. The height, weight and body fat content values for our sample are given in table 1. Somatosensory disturbances were excluded by an anamnestic checklist. All subjects gave written informed consent.

Procedure

Thresholds for heat pain, warmth, cold and vibration were measured in that sequence on the right foot. Pain and thermal thresholds were obtained with a PATH Tester MPI 100

[Phywe Systeme GmbH, Göttingen, for details see (8)]. The thermode was attached to the lateral dorsum pedis with the long edge at a distance of about 1 cm from the toes and with a contact pressure of $0.4 \text{ N}/\text{cm}^2$. Vibratory thresholds were assessed by a VIBRA Tester (Phywe Systeme GmbH, Göttingen). The site for threshold determination was the dorsomedial aspect of the first metatarsal bone, where the stimulator was fixed with a contact pressure of $3.7 \text{ N}/\text{cm}^2$.

For determination of the pain threshold 8 heat stimuli were applied with a rate of temperature change of $0.7^\circ\text{C}/\text{s}$, beginning at 38°C . The subjects were instructed to press a button as soon as they felt pain. Each time they pressed the button the temperature returned to the base value at a cooling rate of $1.5^\circ\text{C}/\text{s}$. The pain threshold was calculated as the mean of the peak temperatures of the last 5 stimuli. The start of each trial was announced visually and acoustically, but the stimulus was presented with a pseudorandomized delay of between 1 and 3 seconds.

For determination of the warmth and cold threshold, 7 warm stimuli and then 7 cold stimuli were administered, starting at a temperature of 32°C . The rate of the temperature change was again $0.7^\circ\text{C}/\text{s}$. The subjects had to press a button as soon as they noticed a change in temperature. Thereupon, the temperature

Table 1. — *Body measures (height, weight, body fat content), local skin temperature and somatosensory thresholds (heat pain, warmth, cold, vibration) in 66 women (body fat content: $n = 41$); the values are mean \pm SD*

Body Measures			
Height (cm)	Weight (kg)	Body Fat (%)	
169.2 \pm 5.3	60.8 \pm 5.3	27.4 \pm 3.2	
Skin Temperature ($^\circ\text{C}$)			
26.9 \pm 2.6			
Somatosensory Thresholds			
Pain ($^\circ\text{C}$)	Warmth ($^\circ\text{C}$)	Cold ($^\circ\text{C}$)	Vibration (μm)
43.2 \pm 1.8	4.9 \pm 2.7	1.2 \pm 0.8	0.81 \pm 0.60

returned to the base value (1.5 °C/s). The mean differences between the base temperature and the peak temperature in the 2 sets of 7 trials were the measures of the warmth and cold thresholds.

For the assessment of the vibration threshold the vibration amplitude was increased from zero with a rate of change of 0.2 µm/s until the subject felt the vibration for the first time and pressed a button (vibration perception threshold, VPT). There were 3 trials. Then, in another 3 trials, the vibration amplitude was decreased with the same rate of change from a supra-threshold level, which resulted from the addition of the VPT and its square root, until the sensation disappeared (vibration disappearance threshold, VDT). The average of the VPTs and VDTs measured in the 6 trials was taken as the vibration threshold (VT).

Skin temperature was assessed on the dorsal side of the same foot by a thermistor in 3 readings (pain threshold — reading 1 — warmth and cold thresholds — reading 2 — vibration threshold — reading 3), from which the average was taken.

The body fat content was determined according to the method of Durning and Womersley (4): Skinfold thickness was measured with a calliper (Ponderal, Leiden) at four sites, biceps, triceps, subscapular and supra-iliac areas and then averaged. The body fat content was read from the correspondence table of Durning and Womersley. This measure was obtained for 41 subjects.

Evaluation

Multiple and simple correlations for the relationship of the threshold measures (pain, warmth, cold, vibration) on the one hand and the body size measures (height, weight, body fat content) and skin temperature on the other were calculated in a multiple regression analysis. Because for both body measures and skin temperature a directional hypothesis was available (positive relations with somatosensory thresholds in the first case, negative relations in the second case) one-sided tests were used.

Results

The basic statistics for all variables measured are given in table 1. The possibility that body measure effects on somatosensory thresholds are due only to a substantial covariation with local skin temperature can be excluded because of the low correlations between the body measures and the skin temperature (see Table 2). As expected the intercorrelations between the body measures were stronger, but they were weak enough that each variable can be considered as having a possible explanatory power by itself.

The correlations between the body measures height and weight and the somatosensory thresholds are presented in table 3. The only significant simple correlation found was for the relation between height and cold threshold. The linear combination of height and weight as the measure of body size was not significantly correlated with any of the thresholds. The body size measure explained 3% (heat pain), 5% (warmth), 7% (cold) and less than 1% (vibration) of the total variance. Neither did the local skin temperature show any significant simple correlations with any of the thresholds (see Table 3). The introduction of this variable into the multiple regression equation produced neither significant multiple correlations nor significant changes in the explained variance.

In the subsample of subjects ($n = 41$) for which the measure of body fat content was available the multiple regression analysis was repeated with body fat as the third variable

Table 2. — Pearson correlation coefficients for the relation between the covariates of the somatosensory threshold: height, weight, body fat content and skin temperature ($n = 66$ with the exception of the correlations where body fat content is involved; there $n = 41$)

	Weight	Body Fat	Skin Temperature
Height	0.69*	0.15	0.10
Weight		0.50*	0.18
Body Fat			0.24

* $p < 0.001$

Table 3. — Results of the multiple regression analysis (simple and multiple correlation coefficients), with height (*H*) and weight (*W*) in predictor set 1 and additionally skin temperature (*ST*) in predictor set 2, and with heat pain, warmth, cold and vibration thresholds as criteria; *n* = 66

Thresholds	Predictor Set 1			Predictor Set 2	
	H ^a	W ^a	H/W ^b	ST ^a	H/W/ST ^b
Pain	0.04	-0.09	0.16	0.06	0.18
Warmth	0.14	-0.03	0.22	0.12	0.26
Cold	0.23*	0.07	0.26	-0.10	0.28
Vibration	-0.03	-0.05	0.05	0.12	0.14

^a Simple correlation (Pearson)

^b Multiple correlation

* $p \leq 0.05$

Table 4. — Results of the multiple regression analysis (simple and multiple correlation coefficients), with height (*H*) and weight (*W*) in predictor set 1 and additionally body fat content (*BF*) in predictor set 2, and with heat pain, warmth, cold and vibration thresholds as criteria; *n* = 41

Thresholds	Predictor Set 1			Predictor Set 2	
	H ^a	W ^a	H/W ^b	BF ^a	H/W/BF ^b
Pain	-0.02	-0.15	0.19	-0.18	0.21
Warmth	0.10	-0.06	0.22	0.08	0.30
Cold	0.19	0.10	0.19	0.03	0.20
Vibration	-0.19	-0.13	0.19	0.25	0.39

^a Simple correlation (Pearson)

^b Multiple correlation

instead of skin temperature (see Table 4). Again there were no significant correlations, but the simple correlation between body fat content and vibration threshold did approach significance ($p = 0.06$), and the same was true for the multiple correlation ($p = 0.06$) when body fat was introduced into the multiple regression equation, with height, weight and body fat as predictors and vibration threshold as criterion. The change in explained variance, as shown by the increase in the multiple correlation from $r = 0.19$ to $r = 0.39$, was significant ($p = 0.02$).

Discussion

The findings in the present study suggest only weak influences of the body measures

height and weight on the somatosensory thresholds measures (heat pain, warmth, cold and vibration). The influences seem to be slightly greater for the thermal sensitivity thresholds (with the effect being greater on cold than on warmth sensitivity) than for the heat pain and vibration thresholds. This is to some degree inconsistent with our earlier study (13), where height and weight were also not related to heat pain but were much more strongly related to thermal sensitivity than in the present study (cf. Introduction and Results). One difference in the design of the two studies is that in the first one we had both sexes and a broad age range whereas in the present study our subjects were all young women. As the body measure/threshold relations were also stronger in our first study when women were evaluated separately

than in the second one it is tempting to conclude that age effects were confounded with body measure effects.

A further good example of how age and sex may interact in determining the degree of body measure influences observed is a study by Halonen (9). The author did not find a significant correlation between height and vibration threshold when he considered the full age range in each sex separately; however, he did find significant correlations when he considered only young men or young women, and also for the total.

We did not find a significant correlation between height and vibration thresholds as others have (6, 20). Instead a relatively large part of the variance was explained by the variable body fat content. This seems to be a plausible result because a large proportion of total body fat is situated in the subcutis (4); the thickness of this tissue may influence the degree to which vibrations reach bone, and bone has a much better resonance capacity than skin. We would therefore suggest that in future studies on the vibration threshold more attention be paid to measures of the thickness of the subcutaneous fat. Furthermore, our findings again corroborate the view that the local skin temperature does not play an important role in somatosensory testing when a physiological range is not exceeded (9, 10, 20, 22).

In summary, the findings of Halonen (9) on vibration threshold just mentioned and the fact that we could not fully replicate our earlier findings (13) of body size effects on thermal sensitivity threshold in a sample more limited with respect to age, sex and body size provide some ideas for future research designs: Age, sex and body measures may interact in determining somatosensory thresholds and therefore must be treated a priori as independent variables. A posteriori analyses may not always help to solve the problems of confounding. The usefulness of somatosensory testing for the diagnosis of peripheral neuropathies is undisputed, but it depends to some degree on the quality of normal values, and such values are meaningful only if all important nonpathological influences are taken into consideration.

Acknowledgements

We want to thank Katja Barth, Anja Thomas and Stephan Roscher for their assistance in data collection.

References

1. BRAY, G.A.: Definition, measurement, and classification of the syndrome of obesity. *Int. J. Obes.*, 2: 99-112, 1978.
2. CLAUS, D., HILZ, M.J., HUMMER, I. and NEUNDÖRFER, B.: Methods of measurement of thermal thresholds. *Acta Neurol. Scand.*, 76: 288-296, 1987.
3. CLAUS, D., HILZ, M.J. and NEUNDÖRFER, B.: Thermal discrimination thresholds: a comparison of different methods. *Acta Neurol. Scand.*, 81: 533-540, 1990.
4. DURNING, J.V.G.A. and WOMERSLEY, J.: Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women from 16 to 72 years. *Br. J. Nutr.*, 32: 77-97, 1974.
5. DYCK, P.J., BUSHEK, W., SPRING, E.M., KARNES, J.L., LITCHY, W.J., O'BRIEN, P.C. and SERVICE, F.J.: Vibratory and cooling detection thresholds compared with other tests in diagnosing and staging diabetic neuropathy. *Diabetes Care*, 10: 432-440, 1987.
6. ERA, P., JOKELA, J., SUOMINEN, H. and HEIKKINEN, E.: Correlates of vibrotactile thresholds in men of different ages. *Acta Neurol. Scand.*, 74: 210-217, 1986.
7. GADIA, M.T., NATORI, N., RAMOS, L.B., AYYAR, R., SKYLER, J.S. and SOSENKO, J.M.: Influence of height on quantitative sensory, nerve-conduction, and clinical indices of diabetic peripheral neuropathy. *Diabetes Care*, 10: 613-616, 1987.
8. GALFE, G., LAUTENBACHER, S., HÖLZL, R. and STRIAN, F.: Diagnosis of small fibre neuropathy: computer-assisted methods of combined pain and thermal sensitivity determination. *Hospimedica*, 8(7): 38-48, 1990.
9. HALONEN, P.: Quantitative vibration perception thresholds in healthy subjects of working age. *Eur. J. Appl. Physiol.*, 54: 647-655, 1986.
10. KATZENWADEL, A., SACHSE, G. and FEDERLIN, K.: Messung von Vibrationsempfinden und Temperaturdiskrimination bei der peripheren Neuropathie. *Aktuelle Endokrinologie und Stoffwechsel*, 8: 155-160, 1987.
11. LARKIN, W.D., REILLY, J.P. and KITTLER, L.B.: Individual differences in sensitivity to transient electrocutaneous stimulation. *IEEE Trans. Biomed. Eng.*, 33: 495-504, 1986.
12. LAUTENBACHER, S. and STRIAN, F.: Similarities in age differences in heat pain perception and thermal sensitivity. *Funct. Neurol.*, 6: 129-135, 1991a.

13. LAUTENBACHER, S. and STRIAN, F.: Sex differences in pain and thermal sensitivity: the role of body size. *Perception and Psychophysics*, in press, 1991b.
14. LEVY, D., ABRAHAM, R. and REID, G.: A comparison of two methods for measuring thermal thresholds in diabetic neuropathy. *J. Neurol. Neurosurg. Psychiatry*, 52: 1072-1077, 1989.
15. LLEWELYN, J.G., GILBEY, S.G., THOMAS, P.K., KRING, R.H.M., MUDDLE, J.R. and WATKINS, P.J.: Sural nerve morphometry in diabetic autonomic and painful sensory neuropathy. *Brain*, 114: 867-892, 1991.
16. MERCHUT, M.P. and TOLEIKIS, S.C.: Aging and quantitative sensory thresholds. *Electromyogr. Clin. Neurophysiol.*, 30: 293-297, 1990.
17. NAVARRO, X. and KENNEDY, W.R.: Evaluation of thermal and pain sensitivity in type I diabetic patients. *J. Neurol. Neurosurg. Psychiatry*, 54: 60-64, 1991.
18. RENDELL, M., KATIMS, J.J., RICHTER, R. and ROWLAND, F.: A comparison of nerve conduction velocities and current perception thresholds as correlates of clinical severity of diabetic sensory neuropathy. *J. Neurol. Neurosurg. Psychiatry*, 52: 502-511, 1989.
19. SOSENKO, J.M., BOULTON, A.J.M., GADIA, M.T., WARD, J.D. and SKYLER, J.S.: The association between symptomatic sensory neuropathy and body stature in diabetic patients. *Diabetes Res. Clin. Pract.*, 4: 95-98, 1988.
20. SOSENKO, J.M., KATO, M., SOTO, R. and AYYAR, D.R.: Determinants of quantitative sensory testing in non-neuropathic individuals. *Electromyogr. Clin. Neurophysiol.*, 29: 459-463, 1989.
21. VAN DER NAALT, J., FIDLER, V. and OOSTERHUIS, H.J.G.H.: Vibration perception threshold, complaints and sensory examination in diabetic patients. *Acta Neurol. Scand.*, 83: 297-300, 1991.
22. VERRILLO, R.T. and BOLANOWSKI, S.J.: The effects of skin temperature on the psychophysical responses to vibration on glabrous and hairy skin. *J. Acoust. Soc. Am.*, 80: 528-532, 1986.

Address reprint requests to:
 Stefan Lautenbacher, Ph. D.
 Max Planck Institute for Psychiatry
 Kraepelinstrasse 10
 D-8000 Munich 40
 FRG