

Age effects in kyphosis and lordosis in adults

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Summary. A surveyor's flexicurve has been used to measure kyphosis and lordosis in a cross-sectional study of men and women aged 20-90 years. No age effect was found in men aged 20-59 years or in women aged 20-49 years. Linear regressions showed an increase in kyphosis with age in older men and women. Various indices were examined to test their suitability as estimates of kyphosis. Lordosis was absent in an increasingly large proportion of men and women as age rose above 60 years.

1. Introduction

A clinical impression that kyphosis increases with increasing age, especially in women, is widespread. This paper describes methods of measuring age differences in kyphosis and lordosis.

2. Subjects and methods

The persons examined, 413 men and 406 women, formed a sample obtained from two sources. The first sample of older people was obtained from the medical lists of 91 doctors in 50 general practices with surgery addresses in a defined area of Edinburgh. A total of 27 000 persons born in 1905 or earlier was available for sampling. From this total a simple random sample was drawn, of 215 men and 272 women aged 62-90 years. Full details of sampling with a comparison of respondents and non-respondents have been given elsewhere (Milne, Maule and Williamson, 1971). The second group, 198 men and 134 women aged 20-65 years, were donors providing blood at the Regional Blood Transfusion Service in Edinburgh. One of us (JSM) visited donor sessions and circulated a leaflet asking for volunteers for anthropometry. More people volunteered than could be measured in the time available. Bias was introduced by the Blood Transfusion Service policy of rejecting donors under 5 feet (1525 mm) in height or 112 lb (51 kg) in weight and by self-selection.

The curvature of the spine and of the overlying soft tissues was recorded with a surveyor's flexicurve. This instrument is a strip of lead covered with plastic, 60 cm in length, which can be bent in one plane only. Since it retains the shape into which it is bent, it can be used to copy any curved surface. The flexicurve was placed on the subject's back, with one end on the seventh cervical spine, and closely applied to the midline of the back, the subject being asked to

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stand as erect as possible. The level of the lumbosacral joint was marked on the flexicurve with a grease pencil, after which the instrument was laid on a piece of paper and the spinal curve copied by running a pencil along the flexicurve. The letters used in describing the curve are shown in figure 1 (2). *H* (not shown) represents the whole length of the curve and for convenience is called spinal length. The ends of the curve have been joined with a straight line. Perpendiculars *B* and *D*, drawn to the points on the curve farthest from the straight line, measure kyphosis and lordosis respectively. Dimension *E* is that part of the straight line from the cephalic end of the curve to the point where the curve crosses the straight line. Dimension *G* is that kyphotic part of the curve which corresponds to *E*. All records were made by one observer (JSM).

Reproducibility of method

Ten persons had their spinal curvature copied by the observer on two occasions. The pairs of measurements were examined by the analysis of variance. A reliability coefficient was calculated by dividing the variance for persons by the sum of the variances for persons, occasions and error. Variance due to error was the residual mean square after removing variance due to persons and occasions. Coefficients determined in this way for dimensions *B* and *E* and for the index *B/E* were respectively 0.78, 0.94 and 0.78. The contributions to the total variance made by persons and occasions were examined using the *F* test. The ratio of mean square for persons to mean square for error was significant at the 1% level for *B* and *E*, and at the 5% level for *B/E*. The corresponding ratio for occasions was not significant for any of the variables. Since the principal contributor to the total variance was persons, the observations may be accepted as reproducible.

3. Results

The types of curve obtained are shown in figure 1. The upper curve (1), most usually found in younger people, has well marked lumbar lordosis. The lowest curve (4), with no lordosis, was usually found in the elderly. In this curve dimension *E* is the length of the line joining the ends of the curve. The second curve (2) might be found at any age. A variant of this (3) has no lordosis, the lumbar part of the curve coinciding with the straight line joining the ends of the curve. This differs from curve (4) in that *E* is shorter than the straight line joining the ends of the curve. Curve (3) is common in older people. It is possible to find subjects with any of these curves at any age.

A. Kyphosis

Perpendicular *B* which measures kyphosis is significantly correlated with age and spinal length. Details of the relationships will emerge as the results are described. An ideal variable would not only truly measure kyphosis and reflect the effects of age upon it, but would also be independent of spinal length. In the male and female groups, the sampling distributions of spinal length for small age ranges are very similar. This means that straightforward application of regression techniques can be used to describe the behaviour of the variables, and in particular good estimates of age effects can be obtained. The effects of age and spinal length on *B* and on variables derived from *B* were estimated from linear regressions with *B* or the derived variable as the dependent variable and age or spinal length as

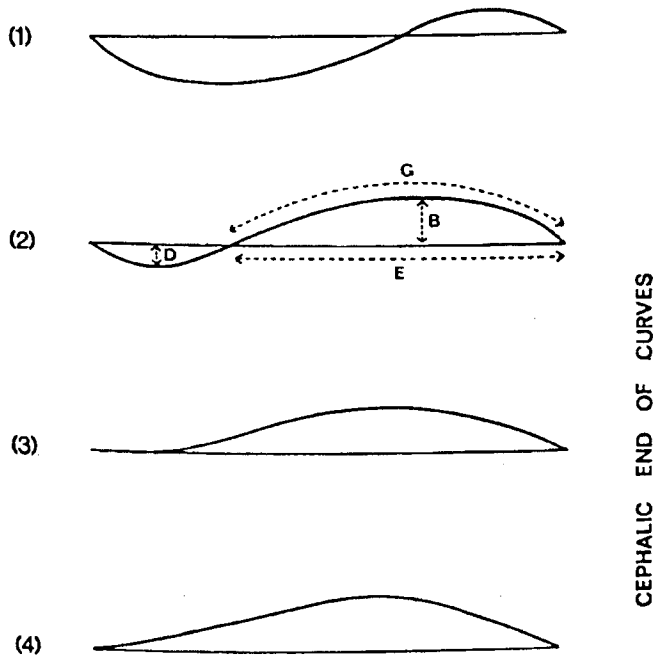


Figure 1. Types of spinal curve recorded with the flexicurve.

the independent variable. To select the index or variable derived from B closest to the ideal, the following variables were examined: B , $\log B$, B/E , B/G , B/H and B_c . These are self-explanatory apart from B_c , which is B corrected for spinal length according to an equation of the form

$$B_c = B - kH$$

where B and H are observed values and k is the linear regression coefficient for B on H (table 2). The value of the regression coefficient k , used in this equation, was computed for men aged 20-59 years and for women aged 20-49 years. B_c was then calculated for all men and all women in the sample over the age range 20-90 years, using respectively the male and female coefficients for the younger groups. The coefficients were computed from the younger groups because of the absence of detectable ageing effects on B in these age ranges (*vide infra*), which allows estimation of the effect of H on B without bias due to age.

The effect of age is shown in figure 2 which gives mean values of B with standard deviation in men and women. The means increase in value as age increases, after the age of 50 years in women and 55 years in men.

The age effect is also shown in table 1 where B and the indices derived from it are dependent variables which have been regressed on age, regression and correlation coefficients being given in the table. No age effect was found on B in men aged 20-59 years or in women aged 20-49 years. Regressions of B on age were also computed in men aged 55-90 years and in women aged 45-90 years. These regressions showed a significant increase in the value of B with increasing age (table 1). The variables derived from B were also studied in the age ranges

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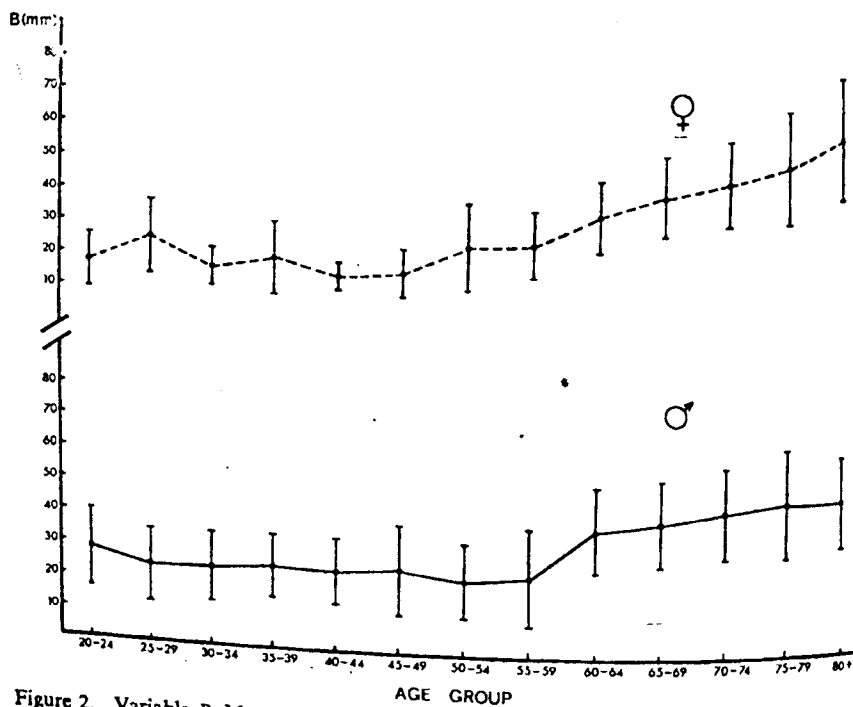


Figure 2. Variable B. Mean values with SD in men and women aged 20-90 years.

Index	Men 20-59 N=188		Men 55-90 N=235	
	k	r	k	r
B	-0.07	0.07	0.55*	0.27
log B	-0.002	0.10	0.01*	0.29
B/H	0.0	0.0	0.001*	0.31
B/E	0.0	0.0	0.001*	0.25
B/G	0.0	0.0	0.001*	0.25
B _c	-0.05	0.05	0.63*	0.33

Index	Women 20-49 N=103		Women 45-90 N=307	
	k	r	k	r
B	-0.16	0.15	1.0*	0.56
log B	-0.003	0.12	0.01*	0.60
B/H	0.0	0.15	0.003	0.60
B/E	0.0	0.14	0.002*	0.55
B/G	0.0	0.14	0.002*	0.56
B _c	-0.18	0.18	1.0*	0.61

Table 1. Regressions of B and derived indices on age.

*P<0.05. Levels are approximately 5% since not all distributions are normal.
 k=linear regression coefficient for index on age.
 r=correlation coefficient between index and age.
 N=sample size.

used for B since all these variables are simple functions of B . These derived variables all behave in similar fashion to B in respect of first order age effects (table 1).

The overlap of age in these regressions covers a transition period within which the effects of age on B begin to appear. The overlap is justified by its small range relative to the total age range and by the fact that any bias introduced by the overlap will increase age effects in younger people and reduce them in older people.

Variable B and its derived indices were each regressed on spinal length in the same age groups as those used in the regressions on age. The regression coefficients and correlation coefficients are given in table 2. The clearest evidence of the dependence of the first four variables in table 2 on spinal length is found in the younger groups of men and women in whom no age effect was found which could bias the regression on spinal length (table 1). The indices least dependent on spinal length are B/E and B/G . The comparison is not straightforward in the older groups because of age effects. B_c has already been corrected for spinal length.

It was not found necessary to include higher order terms in the regressions for any of the independent variables apart from in the sample of women aged

Index	Men 20-59 N=188		Men 55-90 N=235	
	k	r	k	r
B	0.22*	0.5	0.23*	0.43
$\log B$	0.04×10^{-1} *	0.42	0.02×10^{-1} *	0.37
B/H	0.38×10^{-3} *	0.38	0.31×10^{-3} *	0.26
B/E	0.26×10^{-3} *	0.30	0.32×10^{-3} *	0.27
B/G	0.24×10^{-3} *	0.29	0.28×10^{-3} *	0.26
B_c	0.0	0.0	0.01	0.02

Index	Women 20-49 N=103		Women 45-90 N=307	
	k	r	k	r
B	0.11*	0.26	0.27*	0.44
$\log B$	0.02×10^{-1}	0.19	0.02×10^{-1} *	0.36
B/H	0.16×10^{-3}	0.15	0.40×10^{-3} *	0.27
B/E	0.11×10^{-3}	0.12	0.48×10^{-3} *	0.34
B/G	0.10×10^{-3}	0.11	0.41×10^{-3} *	0.33
B_c	0.0	0.0	0.16*	0.27

Table 2. Regressions of B and derived indices on spinal length.

*approx. 5% levels.

k =linear regression coefficient for index on spinal length.

r =correlation coefficient between index and spinal length.

N =sample size.

45-90 years. In this group there is an age spinal length interaction effect on B . To test for this type of effect, multiple regressions were made of the dependent variables on A (age), H , $A \times H$ (table 3). It can be seen that of the dependent variables only B , B/E , B_c demonstrate this effect. The regression coefficient for $A \times H$ is

Index	A (age)	Regression coefficients for		Partial F
		H	A × H	
B	-2.01	-0.27	0.8 × 10 ⁻²	*
log B	0.03 × 10 ⁻¹	0.01 × 10 ⁻¹	0.0	
B ₀	-2.0	-0.38	0.8 × 10 ⁻²	
B/E	-0.03 × 10 ⁻¹	-0.04 × 10 ⁻²	0.01 × 10 ⁻³	*
B/G	-0.02 × 10 ⁻¹	-0.03 × 10 ⁻²	-0.01 × 10 ⁻³	*
B/H	-0.02 × 10 ⁻¹	-0.05 × 10 ⁻²	0.01 × 10 ⁻³	

*P < 0.05.

Table 3. Multiple regressions of B and derived variables on A, H and A × H in women aged 45-90 years.

positive in each case which implies that a more marked age effect is present in women with longer backs.

The effect of weight on B and the derived indices is not marked in any of the groups and it is therefore not necessary to compare the behaviour of the indices with respect to weight.

Comparison of B and derived variables

Variable B and log B behave similarly. Both exhibit greater dependence on spinal length than the other indices (table 2) and are therefore unsuitable for measuring kyphosis.

B₀, which is variable B corrected for spinal length, might be expected to be a good estimator of kyphosis. However, the coefficients of regression of B on spinal length used in computing B₀ have large standard deviations, particularly in young women (table 4). This leads to an unstable estimate of the effect of spinal length. The dependence of B₀ on spinal length in women aged 45-90 years

Sex and age range	Regression coefficient	S.D.
Men 20-59	0.22	0.03
Women 20-49	0.11	0.04

Table 4. Regression coefficients with standard deviations for regression of B on spinal length.

could result from this instability. Efficient estimation of the effect of spinal length would need larger samples in which the effect of age on B was absent or known. Correcting for spinal length in older people with a coefficient derived from younger persons assumes the same relationship between B and spinal length in all age groups. Secular trend altering this relationship could also explain the dependence of B₀ on spinal length in older women. Another possible cause in older women is the A × H interaction effect.

The three remaining indices, B/H, B/E and B/G, are all dependent on spinal length in younger men and independent of it in younger women. B/E and B/G behave almost identically and reflect the recorded types of spinal curvature, particularly curve (3) in figure 1. The other indices, including B/H, do not allow for this type of spinal curve in which the lumbar end of the curve merges with

the line joining the ends of the curve (figure 1, curve 3). For this reason B/E or B/G seems preferable to B/H . Dimensions E and G are positively correlated with spinal length (table 5). Hence, apart from the exception given above, B/E and B/G should behave similarly to B/H . This means that B/E and B/G will allow for any effect of age and secular trend on spinal length. Finally these two

Sex	r_{H-E}	r_{H-G}
Men	0.43*	0.44*
Women	0.25*	0.28*

* $P < 0.01$.

Table 5. Correlation coefficients between spinal length (H) and E, G in men and women.

indices are not based, as is B_s , on parameters estimated from the sample. Of the variables studied which could be used to measure kyphosis these two seem preferable. B/E is marginally better because the measurements are easier to make, and because B/E demonstrates the $A \times H$ interaction effect in older women while B/G does not.

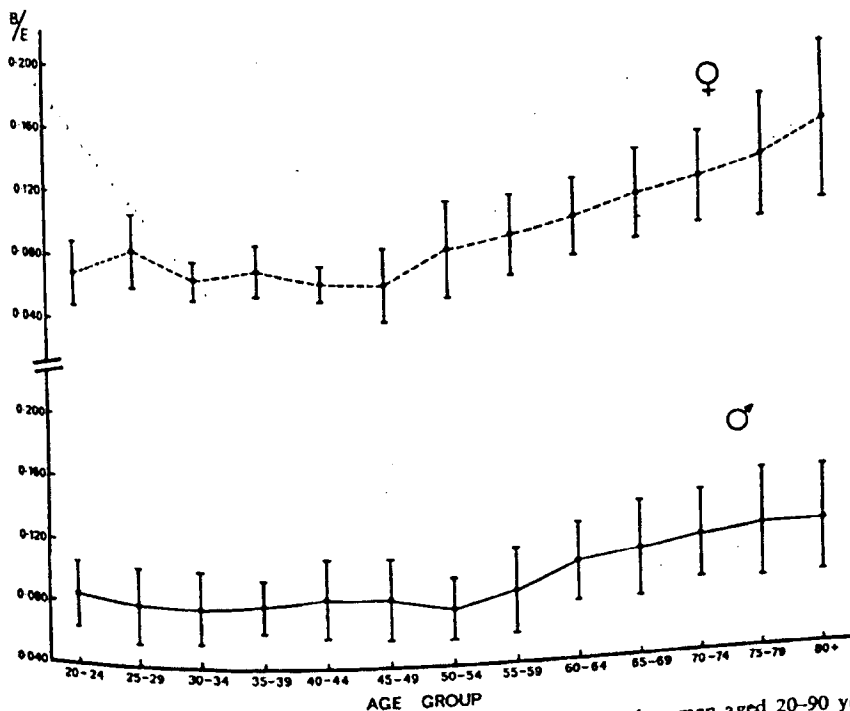


Figure 3. Derived variable B/E . Mean values with SD in men and women aged 20-90 years.

Mean values with standard deviations of B/E are given in figure 3 and show increases after 55 years in men and 45 years in women. Regression relationships of B/E with age are given more fully in table 6, and shown graphically in figure 4. These demonstrate the significant increase of B/E with age in the older groups of men and women. The increase is more marked in women than in men.

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Sex and age range	Constant	Regr. Coeff. k	S.E. k	t	r	N	S.E. abt. Regr.
Men							
20-59	0.08	0.0	0.15×10^{-3}	0.0	0.0	188	0.02
55-90	0.03	0.11×10^{-2}	0.29×10^{-3}	3.9*	0.25	235	0.03
Women							
20-49	0.08	0.32×10^{-3}	0.22×10^{-3}	1.46	0.14	103	0.02
45-90	-0.04	0.02×10^{-1}	0.21×10^{-5}	11.24*	0.55	307	0.03

* $P < 0.05$.
 r = correlation coefficient between B/E and age.
 N = sample size.
 t = value of t -test for $k=0$ against $k \neq 0$.

Table 6. Regressions of B/E on age.

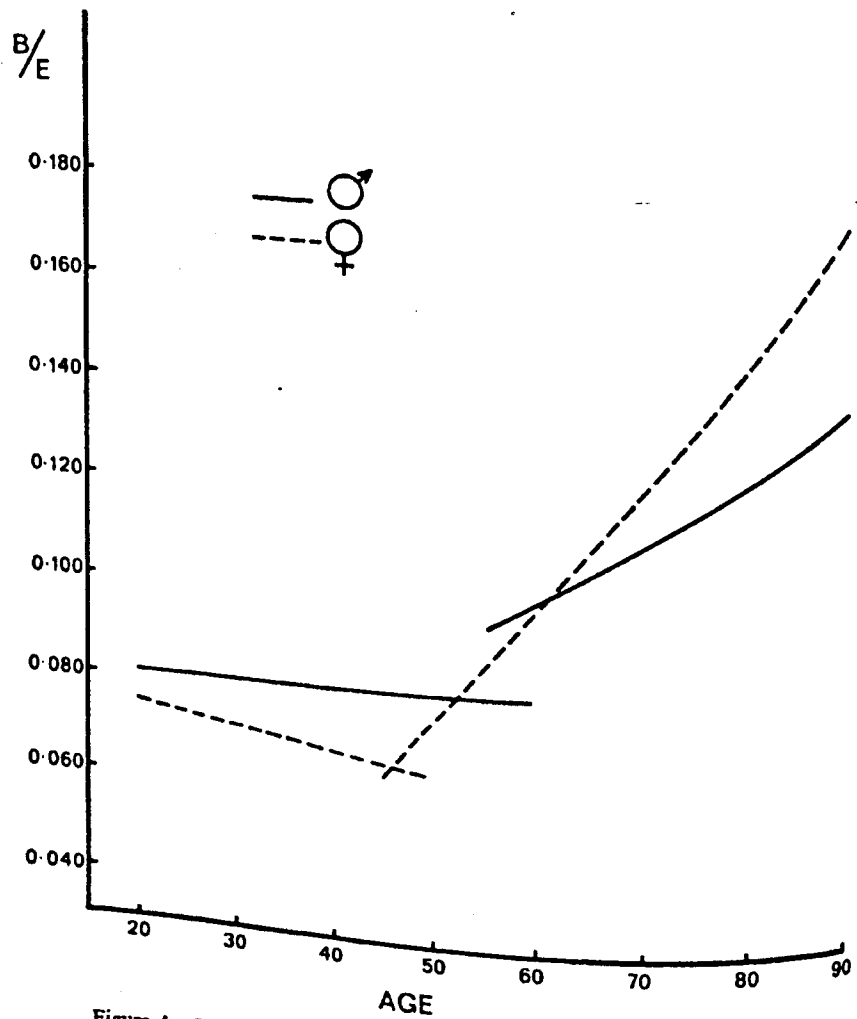


Figure 4. Regressions of B/E on age in men and women aged 20-90 years.

B. Lordosis

This is estimated by perpendicular *D* (figure 1) of which mean values with standard deviations are given in figure 5. These mean values show a steep fall in men and women over the age range 55-64 years. With increasing age, an increasing proportion of persons in the sample have values of *D* equal to zero. This is shown in table 7 which gives, in five-year age groups for men and women,

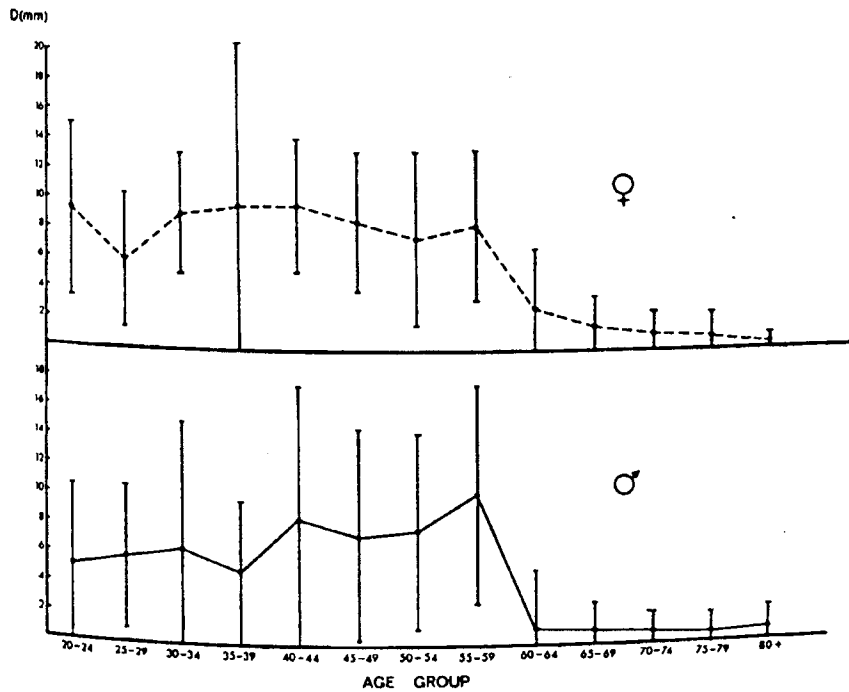


Figure 5. Variable *D*. Mean values with SD in men and women aged 20-90 years.

Age group	Men		Women	
	<i>N</i>	% with <i>D</i> >0	<i>N</i>	% with <i>D</i> >0
20-24	33	85	37	97
25-29	33	88	19	95
30-34	28	82	18	100
35-39	30	87	7	71
40-44	15	80	11	100
45-49	17	88	11	100
50-54	20	90	13	92
55-59	12	92	8	100
60-64	55	39	51	65
65-69	77	35	94	54
70-74	38	37	55	47
75-79	34	21	45	33
≥ 80	20	20	30	17

No data in 2 men and 7 women.

Table 7. Percentages of men and women in 5 year age groups in whom variable *D* exceeds zero.

the percentage in whom D is greater than zero. Up to age 60 this varies between 75 and 100%. In older people the percentage falls, reaching in the age group 80 years and over, 20% in men and 17% in women.

4. Discussion

Takahashi and Atsumi (1955) described the use of the flexicurve in copying spinal curvature. In their analysis they used as an index variable B divided by the length of the spinal curve, i.e. B/H . This index was negatively correlated with height and positively correlated with age. The subjects studied were elderly Japanese, all of whom had spinal curves resembling that in figure 1 (4). The authors attributed this to life-long habits of posture and occupation.

In the present study it was possible, because of the absence of age effects on kyphosis in younger men and women, to study the effect of spinal length on the indices uncomplicated by age. An index could hence be chosen which measured kyphosis, allowed for age and was only minimally dependent on spinal length.

Cowan (1965) described kyphosis using the kyphotic angle which was formed by the intersection of lines drawn through the anterior borders of the bodies of 2nd and 3rd and of 12th and 11th thoracic vertebrae. This estimate of kyphosis cannot be compared with that in the present study but the kyphotic angle does measure the increase of kyphosis with age. It is possible that this angle would be significantly correlated with spinal length. The measurements used in estimating the kyphotic angle are not easy to make because of the difficulty of deciding exactly where to draw the necessary lines on the X-ray film. The kyphotic angle would also need specially taken lateral chest films, since the routine lateral films used in clinical work do not clearly outline the 2nd and 3rd thoracic vertebrae.

The reasons for kyphosis increasing as age increases are probably many. The effects of occupation and of habitual posture, with loss of muscle tone as age increases, are added to such causes as spinal osteoporosis, and senile emphysema. The absence of lordosis, which is increasingly common in this cross-sectional study after 64 years of age, may result from increasing kyphosis pushing the centre of gravity of the body forwards with loss of lordosis from compensatory straightening of the lower spine. Urist, Gurvey and Fareed (1970) reported, in a study of osteoporosis in ageing women, accentuation of the dorsal posterior curve with increasing age and reversal of the anterior lumbar curve.

The flexicurve has been found satisfactory, used clinically, in following the progress of patients with spondylitis (Chalmers, J., personal communication). The present analysis would suggest the instrument could also be used in cross-sectional and longitudinal population studies.

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Zusammenfassung. Das Kurvenbiegungsmass eines Landvermessers wurde benützt um Kyphosis und Lordosis zu messen im Studium eines Querschnittes von Männern und Frauen im Alter von 20 bis 90 Jahren. Es wurde gefunden, dass Alter keine Auswirkungen verursachte auf Männer im Alter von 20-59 Jahren und auf Frauen im Alter von 20-49 Jahren. Lineare Regressionen zeigten ein Ansteigen von Kyphosis mit dem Alter in älteren Männern und Frauen. Verschiedene Anzeichen wurden studiert um ihre Eignung als Kyphosis-Einschätzungen zu prüfen. Lordosis war bei Männern und Frauen nicht vorhanden in steigender grosser Proportion mit steigendem Alter über 60 Jahre.

Résumé. Un curvimètre d'enquête a été utilisé pour mesurer la cyphose et la lordose, lors d'une enquête transversale portant sur des hommes et des femmes de 20 à 90 ans. Aucune influence de l'âge n'a été décelée pour les hommes de 20 à 59 ans, et les femmes de 20 à 49 ans. Chez les hommes et les femmes plus âgés, il existe une liaison linéaire positive entre l'âge et la cyphose. Plusieurs indices ont été essayés pour évaluer la cyphose. La lordose est absente dans des fractions de plus en plus importantes des populations masculine et féminine examinées lorsque l'âge augmente au delà de 60 ans.

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