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POSTURE, MOBILITY AND STRENGTH OF THE BACK IN BOYS, 7 TO 16 YEARS OLD

By

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It is the purpose of the present investigation to find out if there is a demonstrable correlation between form and function of the back in school children, and further to see how form and function of the back change, during the school years. It has often been postulated that school life with its compulsory sedentary work acts deteriorating on the backs of the children, even though gymnastics and other forms of physical education are thought to compensate for it. The curves of the spine, which form the basis for what is generally called posture, are believed to change in a harmfull way from the natural form found in pre-school ages to a too curved or too flat back in the adolescent school child. Hand in hand with this unhappy deformation of the back a general weakening of the back and a decreased flexibility is thought to take place. Teachers of physical education, physiotherapists and physicians have been anxiously on the look-out for any such changes, and special emphasis has been put on formative exercises intended to prevent or cure malformation of the back during school years. In spite of this almost alarming reports have been published on the bad condition of the backs of school children.

In recent reports on the posture of school children from Copenhagen (*Bang* and *Bojlén* (1950)) it was found that out of more than 1000 school children, boys and girls, only about 25 % had postures that were termed "excellent" or "good", whereas about 55 % had postures that were "poor" and 20 % were "very poor". Attempts to demonstrate the influence of formative gymnastics on the posture of school children have been attempted several times, last initiated by a discussion on the 11. Nordic Congress of School Hygiene in Norway, 1950. The reports from the 3 Scandinavian countries (*Johansson* (1953), *Ingelmark*

(1954) and *Meidell Sundal* (1953)), have been preliminary in form and have if anything shown a tendency towards a more curved back as the result of intensive gymnastic as compared to games and sport. Individual physical therapy in the form of passive and active exercises on the other hand had no demonstrable effect on the posture of 40 children with "very poor" postures (*Ibsen Bak & Holle* (1957)).

Much of the confusion regarding postures can be traced back to the difficulty in describing postures and in the criteria used for calling one posture "good" and another "poor". In recent years it has been customary to use the 4 types described as A–D by the *Department of Hygiene and Physical Education, Harvard University,* as standard types although serious doubts may be raised as to the justification e.g. of calling type A "good" and type C "poor".

The concepts "good" or "poor" postures are very subjective and to a high degree based on esthetical criteria rather than on mechanical or physiological principles. Further, posture is so complicated a reflex dependent on so many incoming signals from different receptors, on the sensitivity of these receptors as governed by other reflexes or by impulses from different parts of the brain (e.g. the gamma-system and its efferents) that the same individual at different times, in different moods or with a different motivation may adopt very different postures. Any attempt to classify children's backs as "good" or "poor" will, therefore, invariably run into difficulties, and even a neutral classification is difficult because the basis for comparison usually is pictures or silhuettes of the children in some more or less free standing position, which most often do not show the curves of the spine. X-ray pictures or curves drawn from devices that can be brought into contact with the spinal processes are better, but still suffer from the want of objective measurements to be expressed in numbers and compared to a normal or standard value. The standing posture itself is also difficult to define so that it can be reproduced with any degree of accuracy.

An attempt to overcome some of these difficulties has been made by *Mølhave* (1956) whose technique has been used in the present work. Details of it have been published by *Mølhave* (1958) and only a very short description of it will be given here.

METHODS

The measurements are made by means of a specially constructed "inclinometer", or "goniometer" by means of which it is possible to measure the angles between a vertical frontal plane and the projection onto a sagittal plane of any line connecting two chosen points on the surface of the body. For the curves of the spine the following points have been chosen (cf. *Mølhave*):

1. Spin. iliac. post. sup., 2. the deepest point of the lumbar lordosis, 3. the highest point of the thoracic kyphosis and 4. the proc. mastoideus. The sum of the inclinations of line 1–2 and 2–3 is called "lordosis", and the sum of the inclinations of 2–3 and 3–4 is called "kyphosis". (Actually, if the lordosis is considered to be an angle, v, the values used here are $(180° - v)$ and correspondingly for the kyphosis. Further, this latter in the here used measure includes the forward tilt of the neck). The inclination of the pelvis was measured as the angle between the horizontal and the projection on a sagittal plane of the line connecting spin. iliac. post. sup. and tuberculum pubicum. During the measurements the subject was standing on a wooden board, feet slightly apart and toes up to a fixed mark. He was requested to relax and often allowed to move in standing-walking untill he got accustomed to the procedure. When natural postural sway was observed a pair of pointers mounted on a stand were aligned with his right ear opening at the moment when his quadriceps muscles relaxed during a forward sway or contracted during a backward sway, which was easily observable from the side (cf. *Mølhave*). All measurements were thereafter taken when a helper announced that the subject during his postural movements passed the same position. Maximal flexibility of the spine in the sagittal plane is expressed as the angular movements of the line between spin. iliac. post. sup. and the highest point of the kyphosis when standing erect during maximal flexion and maximal extension of the back after correction for the concomitant movements of the pelvis.

The strength of the muscles of the back and of the abdominal wall was measured by means of dynamometers during maximal isometric contractions. The subject was for these measurements placed front or back against a vertical pole with a strap across his chest just under his arms. The strap was tightened and each end connected with a dynamometer fixed to the pole by means of a horizontal bar, that kept the two dynamometers apart corresponding to the width of the shoulders. During the measurements the pelvis was kept pressed against the pole, and no fixation was necessary at this point. The readings of the two dynamometers in kgs. were added and used as an expression of the muscular strength.

The height of the subjects was measured to nearest centimeter, and the distance between outer and inner epicondylus femoris to nearest millimeter. By expressing the distance between the epicondyles as per thousand of total height an expression was formed—here called breadth-index—which is used to distinguish between a broad and a more slender type. A series of other anthropometric measurements were also made but will not be considered here. They will be published separately (see *Heebøll-Nielsen* (1958)).

Subjects were 201 school boys, aged 7 to 16 years, from a surburban community school north of Copenhagen in Gentofte kommune. They all took part in the compulsary physical education of the school, 3 to 4 hours a week. Boys with distinct scoliosis and pathological cases were sorted out but else no selection was made. For comparison the boys were divided in groups according to their height, each 10 cm increase in height representing a new group. Average values for each height group were established and the standard error calculated in the usual way.

In order to study the correlation between e.g. muscular strength and other functions, each height group was subdivided in an above-the-average strength group, and a below-the-average strength group. For all boys in each sub-group the values of the functions to be correlated to muscular strength then were averaged and the results plotted as two curves against height as abscissa. The mean of all sub-groups was also determined. In this way it is possible to visualize possible correlations. A statistical treatments of the results was also attempted but offered no additional advantage on account of he large scattering of the individual values.

RESULTS

The factors studied can be divided in 1) anatomical measures, 2) tests of muscular strength and 3) tests of flexibility. In the present paper the following values will be recorded and discussed. 1) Height, weight, breadth-index, lumbar lordosis, kyphosis, inclination of pelvis. 2) Strength of back-muscles, strength of abdominal muscles, strength of finger-flexors (handgrip). 3) Forward flexion of the trunk, backward flexion of the trunk (extension).

The results of the anatomical measurements are given in fig. 1 and table 1.

The weight increases exponentially and the curve for these 201 boys fits in nicely with the curve of 400 boys presented earlier (*Asmussen*

TABLE I

Height group	120-129		130-139		140-149		150-159		160-169		170-	
n	30		37		48		37		29		20	
	m	± e	m	± e	m	± e	m	± e	m	± e	m	± e
Height	126.5	± 0.45	136.5	± 0.44	144.7	± 0.33	153.5	± 0.46	163.3	± 0.58	176.3	± 1.02
Weight	24.3	± 0.34	30.8	± 0.56	35.5	± 0.41	42.2	± 0.60	50.3	± 1.1	60.6	± 1.2
Breadth-index	5.97	± 0.033	5.89	± 0.028	5.84	± 0.034	5.73	± 0.038	5.67	± 0.041	5.51	± 0.057
Kyphosis	34.2	± 0.81	35.4	± 0.74	34.2	± 0.54	31.8	± 0.95	33.3	± 1.04	34.2	± 0.88
Lordosis	19.7	± 0.74	21.3	± 0.83	21.2	± 0.71	21.7	± 0.81	23.2	± 1.30	22.3	± 1.19
Inclin. pelvis	43.9	± 0.47	43.2	± 0.57	42.6	± 0.58	42.6	± 0.61	42.7	± 0.50	41.5	± 0.60

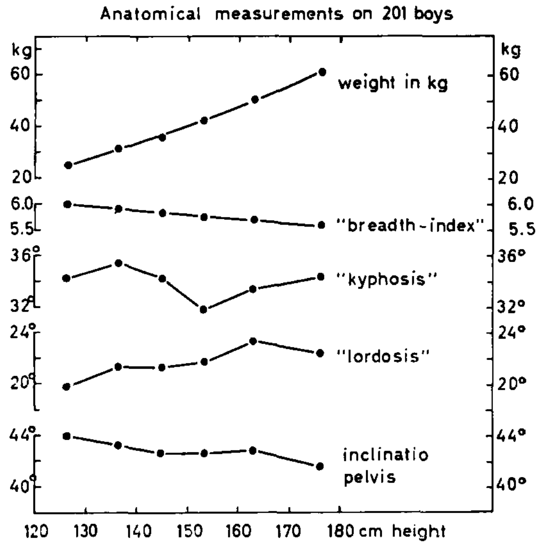

Fig. 1.

Anatomical data in relation to body height in boys. "Kyphosis", "lordosis" and inclinatio pelvis measured as described in text. "Breadth index" is distance between femoral epicondyles in per thousand of body height. Dots represent means of each 10 cm height group.

& *Heebøll-Nielsen* (1956)) and both again with the height-weight curve of about 8–9000 boys presented by *Døssing* (1952). The present material, therefore, may be assumed to represent an average sample of Danish school boys. The "breadth-index" can be seen to decrease, apparently linearly, with increasing height. This means, that as the boys grow taller, they approach a more slender body-build. The values for "kyphosis" and especially for "lordosis" scatter much more than the two previous mentioned functions (table 1), and for this reason it is not possible to say if the trends shown in fig. 1 are truly significant. The trends are that the "kyphosis" seems to decrease slightly and the "lordosis" to increase with increasing height. This would imply that as the boys grow taller their backs become more concave in the lumbar region and more straight in the upper part. It must, however, be remembered that in the measurement, which here is termed „kyphosis", the forward tilt of the head is included so that the less pronounced kyphosis may be due to a somewhat more pronounced cervical lordosis. The inclination of the pelvis decreases with increasing height and although the change is not great, the overall trend seems to be significant (table 1).

TABLE II

Height group	120-129		130-139		140-149		150-159		160-169		170-	
n	30		37		48		37		29		20	
	m	± e	m	± e	m	± e	m	± e	m	± e	m	± e
Back strength	26.7	±0.97	36.7	±1.51	44.8	±0.98	49.9	±1.48	66.0	±2.48	81.0	±2.97
Abdom. strength	21.2	±1.02	27.9	±1.18	34.4	±1.10	39.4	±1.49	62.7	±2.07	63.0	±2.84
Handgrip	12.6	±0.51	17.1	±0.49	19.8	±0.51	24.3	±0.60	31.2	±1.29	43.0	±1.86
Flexion of spine	48.3	±1.58	52.5	±1.56	52.1	±1.32	52.4	±1.68	55.6	±1.31	55.2	±2.49
Extension of spine	33.8	±1.15	35.4	±1.13	34.5	±1.00	32.5	±1.32	34.7	±1.68	34.6	±1.49

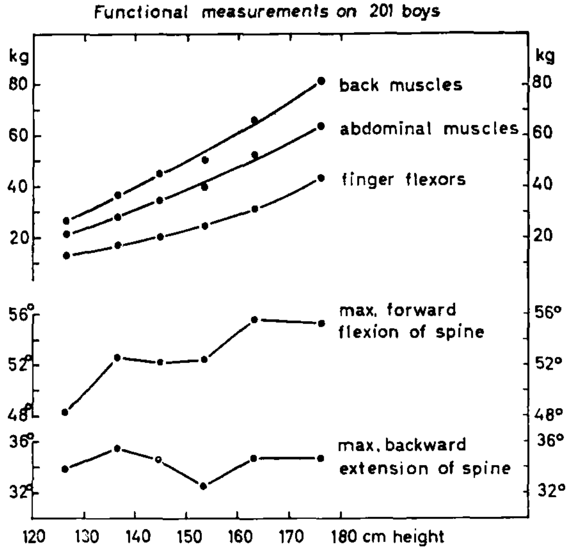

Fig. 2.
Muscular strength and mobility of spine in relation to body height in boys.

In fig. 2 and table II the results of some of the functional tests are presented. The curves representing muscular strength of back, abdominal and finger muscles are exponential, corresponding to previous findings in other muscle groups (*Asmussen & Heebøll-Nielsen* (1956)). The curve for the flexibility of the spine shows a tendency to increase with height for forward flexion but is almost constant for backward flexion. The standard errors of these last functions are quite large as compared to the variations from height group to height group (table II).

Correlations between form and function were estimated from curves as those in figs. 3–5. We have chosen to correlate graphically 1) "lordosis", 2) strength of back muscles and 3) flexibility in forward flexion, to one another and to some other functions (see figs. 3–5). The correlations between "breadth-index" and other functions, and between inclinatio pelvis and other functions have also been investigated but the results will be mentioned without documentation.

For the lumbar lordosis (fig. 3) it can be seen that when each height group is divided according to whether the "lordosis" was above or below the average of the group, two curves can be drawn for the "kyphosis" indicating that those boys who have the larger "lordosis" also tend to have a more pronounced "kyphosis".

It is further seen that with a more pronounced "lordosis" goes a

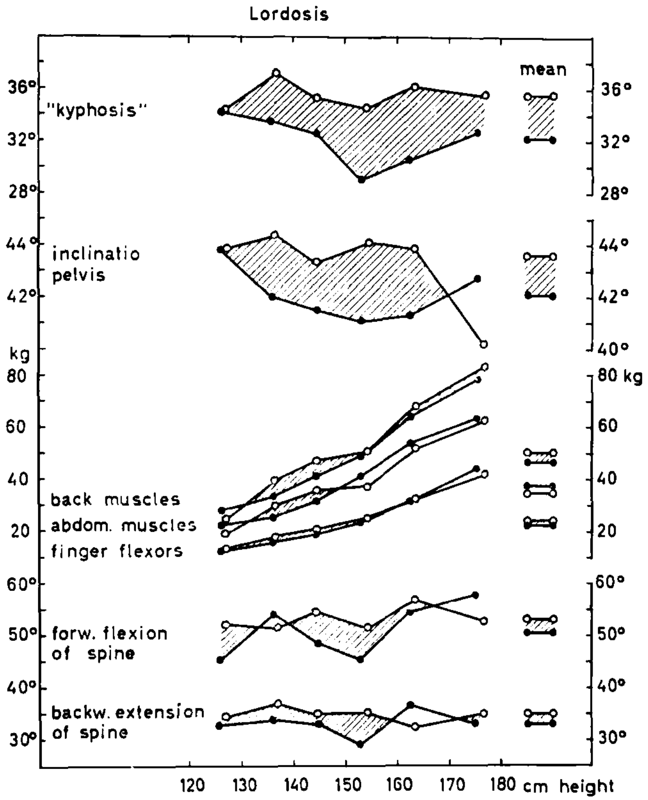

Fig. 3.

Correlations between lumbar lordosis and some anatomical and functional measures at different body heights.

o-o-o Boys with above-the-average lumbar lordoses.

•—•—• Boys with below-the-average lumbar lordoses.

Hatched areas signify positive correlations.

larger pelvic inclination. The flexibility of the spine is, in an average, larger in those with the more pronounced "lordosis" and the strength of the back muscles is greater. For the abdominal muscles the tendency goes slightly in the opposite direction, and also for the finger muscles there seems to be no positive correlation.

In a corresponding way it can be seen that *strength of the back muscles* appears to be positively correlated to strength of other muscle groups (fig. 4) and to more pronounced "kyphosis" and "lordosis". Strength of the back, however, can not be seen to be correlated to the mobility of the spine.

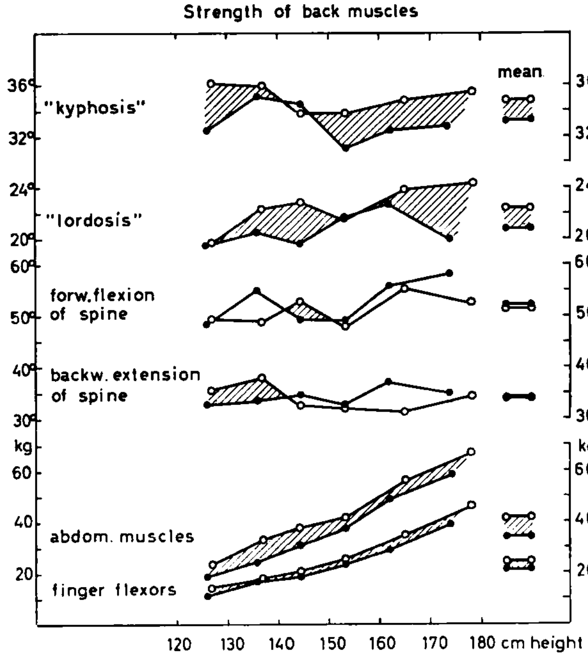

Fig. 4.
Correlations between strength of back muscles and some anatomical and functional measures.
o-o-o Boys with above-the-average muscular strength.
•—•— Boys with below-the-average muscular strength.
Hatched areas signify positive correlations.

When the flexibility of the spine in forward flexion was compared to other functions (fig. 5) it was found, that a greater mobility in forward flexion generally was positively correlated to a greater mobility in backward extension. The more flexible backs were also positively correlated with a more pronounced "lordosis", but apparently not with a greater "kyphosis". The correlation to muscular strength in back, abdomen and hands was positive only in the upper height groups (140–150 and upwards).

The breadth-index (not shown) was positively correlated to several functions, e.g. to weight, to muscular strength in all investigated muscle groups, and to a greater "lordosis" and "kyphosis". The *pelvic inclination* (not shown) was positively correlated to the curves of the back, but showed no distinct correlation to the other functions here treated.

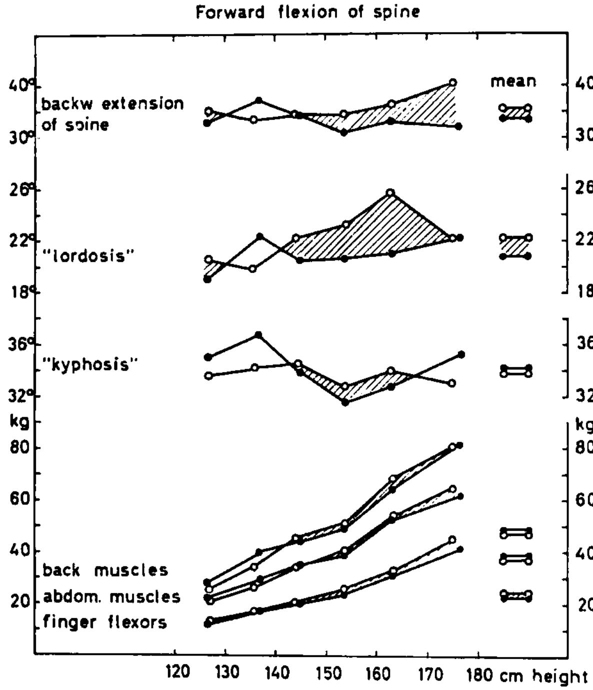

Fig. 5.
Correlations between mobility of the spine and some anatomical and functional measures.
o-o-o Boys with above-the-average flexibility of the spine.
•—•—• Boys with below-the-average flexibility of the spine.
Hatched areas signify positive correlations.

COMMENTS

The rather wide scattering of the individual values around the means (cf. table 1) for most of the functions studied makes it difficult to draw clear cut conclusions from the present material. Only general trends can be stated, and—especially in the question of correlations—even these are not too securely demonstrated.

The mean values for the height groups, when plotted against body height, gives an impression of the development of the functions through the growing age from about 7 years of age to about 17 years of age—i.e. including most or all of the school age. The general trend in the anatomical design seems to be (cf. fig. 1) a development towards a relatively more slender type with a less pronounced forward tilt of the upper part of the back and neck (smaller "kyphosis") and a somewhat more pronounced "lordosis". The inclination of the pelvis is declining during the same ages, which may seem contradictory to the generally found positive correlation between pelvic inclination and lumbar lordosis (also clearly demonstrated in the present investigation, when these two functions were compared for each height group, cf. fig. 3). The decrease in pelvic inclination with increasing height and age, therefore, seems to be independent of the concomitant increase in lumbar lordosis and is most probable a natural development in growing children.

The increase in muscular strength (fig. 2) with height follows exponential curves and is similar to that found in other muscle groups on earlier occasions (*Asmussen & Heebøll-Nielsen* (1956)). The reason for the exponential increase of strength with height is probably, as pointed out before, that muscular strength is proportional to the transverse sectional area of the muscles, which must be expected to increase with height or any other linear measure in the second power. Mostly —and also here,—the increase follows a steeper curve than the expected, showing that the development of muscular strength is dependent on other factors than simply linear growth (cf. ref. above). The flexibility of the spine as expressed by the maximal forward and backward flexion (fig. 2) is difficult to evaluate because of the wide scattering but there seems to be an increasing ability for forward flexion with height, whereas maximal extension is practically unchanged during the school age.

The correlations (figs. 3–5)—without beeing statistically significant —suggest that the backs with the larger "lordosis" are the stronger and—vice versa—that the stronger backs do exibit more pronounced curves. The greater lordoses are accompanied by a larger pelvic inclination. There is no clear cut correlation between "lordosis" and strength of abdominal or finger muscles.

If strength and mobility of the back are considered valuable qualities the present investigation seems to indicate that these qualities are positively correlated with more pronounced sagittal curves of the spine. An attempt to find out if the more extreme values for lumbar lordoses—i.e. those deviating more than $\pm$ *d* from the mean value—were correlated with especially weak backs came out negative. Nor was there any sign of a decreased flexibility of the spine even in those with extremely large lordoses or—vice versa—of a better function of those with extremely flat backs. It must be remembered, though, that all of the boys investigated were considered clinically sound and therefore, in spite of the very wide scattering of the individual values (d = ± 25 % for the "lordosis") apparently come within the normal range. The scattering of the individual values around the mean was quite regular, following the usual bell-shaped curve. When the whole material was treated as one (on the basis of *percentage* values of "lordosis", strength of back muscles, flexibility etc.) it could be seen from a diagrammatic representation that a faint positive correlation exists between lumbar lordosis and strength of back muscles and between lumbar lordosis and pelvic inclination. This strengthens the impression one gets from fig. 3, and is also further supported by the finding that the correlation coefficient for these values were found to be + 0.2 and + 0.3, respectively. A correlation between flexibility and form or strength could not be demonstrated in this way.

The present attempt at finding correlations between form and function of the back seems to demonstrate that,—inside the normal range, which on the other hand is rather wide—a more curved back is positively correlated to a stronger and, possibly, also to a more flexible back. This finding fits in well with the observations of *Ingelmark* (1954) on a group of Swedish school-boys, viz. that after a winter's special training with gymnastics the backs of the boys were generally more curved than in a similar group which had not received this special training. It further puts grave doubts on the value of the *Harvard* standard-types, A–D, in which type A and, to a lesser degree, type B have rather flat backs. It is interesting to note that the ideal, type A, is very seldom. *Bang & Bojlén* (1950) found it in only 2.4 % of Danish school children. One cannot avoid the thought that it has been fostered in the brains of people with prefixed ideas on how a good soldier ought to look and that, consequently, esthetic more than physiological criteria have been the guiding principle. The difficulty in transforming C-type backs into B or A types by extra training or special exercises encountered both by physical educators and by physical therapists also adds weight to the assumption, that the more curved back is the more functional. There are of course several other functions than strength and flexibility of the spine to consider when the adjectives "good" or "poor" are used in connexion with posture. These, however, are difficult to evaluate and some may not show their dependency of posture untill later in life.

The fact that the lumbar lordosis apparently increases during school life while the pelvic inclination decreases (fig. 1) seems to place this trend among the natural developments of growth, and as both relative muscle power and flexibility of the spine increases during the same time it seems to indicate that school life as lived by these Danish boys has not debased the function or form of their backs.

The influence of body type on form and function of the back has only been touched upon in the present investigation. Using the "breadth-index" as a criterion we can divide the boys in a broader type and a more slender type. Of these the broader type seems to be both heavier and stronger and to have more pronounced curves (both lordosis and kyphosis) of the back. *Bang & Bojlén* (1950) found that leptosome (slender) children in their material had more postural defects than the mesosome or amplosome, but it must be remembered that their criteria for "good" or "poor" were based upon the Harvard types, which as mentioned above, have other standards for the form of the back than those considered valuable in this investigation.

The conclusion reached in the present attempt of evaluating form and function of the backs of school boys, is that a strong and flexible back most often also has more pronounced curves—and vice versa. The normal—i.e. non pathological—range of degrees of curvatures is large, (d approximately equal to $\pm$ 25 % of the mean), but the above mentioned correlations seem to exist throughout the whole range. Any attempt to "straighten" a curved but otherwise normal back by exercises or training consequently should be discouraged and most probably will fail by itself.

SUMMARY

The form and function of the backs of 201 Danish school boys, aged 7 to 16 years, have been registered and an attempt to find correlations between them has been made. The form was expressed as angles between well defined points of the body in an easy standing position. The function was measured as strength of the back muscles and as maximum movements of the spine in the sagittal plane.

It was found that the lumbar lordosis increased, while the kyphosis and pelvic inclination decreased with increasing body height. Muscular strength increases exponentially with height. Flexibility of the spine seems to increase with height in forward flexion and to remain constant in backward flexion.

A tendency to a positive correlation between lumbar lordosis, kyphosis, pelvic inclination, muscular strength and flexibility of the spine was found.

RESUME

La forme et la fonction du dos de 201 écoliers danois âgés de 7 à 16 ans ont été enregistrées et on a essayé de trouver une corrélation entre elles. La forme a été exprimée sous forme d'angles entre des points bien définis du corps dans une position debout aisée. La fonction a été mesurée en se basant sur la force des muscles du dos et les mouvements maxima de la colonne vertébrale dans le plan sagittal.

Il a été découvert que la lordose lombaire augmente, alors que la cyphose et l'inclinaison pelvienne diminuent avec la croissance du corps. La force musculaire augmente exponentiellement avec la hauteur de la taille. La flexibilité de la colonne vertébrale paraît augmenter avec la hauteur en flexion en avant et rester constante en flexion arrière. Une tendance à une corrélation positive entre la lordose lombaire, la cyphose, l'inclinaison pelvienne, la force musculaire et la flexibilité de la colonne vertébrale a été trouvée.

ZUSAMMENFASSUNG

Die Form und Funktion der Rücken von 201 dänischen Schulknaben im Alter von 7 zu 16 Jahren wurde registriert und ein Versuch Beziehungen zwischen ihnen zu finden, wurde gemacht. Die Form wurde mittels Winkeln zwischen gut umschriebenen Punkten des Körpers bei bequemer Haltung in stehender Stellung festgelegt. Die Funktion wurde an der Kraft der Rückenmuskulatur und der maximalen Bewegungen in der Sagittalebene gemessen.

Man fand, dass die Lumballordose mit zunehmendem Gewicht ebenfalls zunimmt, während die Kyphose und die Beckenneigung abnimmt. Die Muskelkraft steigt mit der Grössenzunahme. Die Beugungsfähigkeit der Wirbelsäule scheint zusammen mit der Grösse hinsichtlich Vorwärtsbeugung zuzunehmen, hinsichtlich der Rückwärtbeugung jedoch konstant zu bleiben.

Eine gewisse positive Korrelation zwischen Lendenlordose, Kyphose, Beckenneigung, Muskelstärke und Beugungsfähigkeit der Wirbelsäule wurde gefunden.

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