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A BIOSTATIC INVESTIGATION

The standing posture of man theoretically and statometrically illustrated

By

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The object of this research is to show the results of a number of static investigations into the upright, standing position employing a procedure which has made it possible to obtain numerical values for the spatial orientation of the weight-bearing segments.

An understanding of the function of the locomotor apparatus in the upright position is essential to rearch into the dynamics of the body, as this position is frequently the starting position in the transition to dynamic function.

As an introduction those anatomic structures and physiological functions are emphasized which have a particular relationship with the function of the locomotor apparatus in the upright position. The aim was to show appropriate correspondence between structure and function, and afterwards to compare the theoretically determined, optimal spatial orientation of the weight-bearing segments and the practically determined values.

It must be stressed that in all analyses of the function of the locomotor apparatus there must be a clear realization that a great part of the dynamics are so complicated and the result of so many varying factors that an attempt to investigate and explain the problems mechanically necessitates the elimination of biological factors of apparently less importance to the investigation. The difficulty lies not so much in the danger of making an error in the observation of whether a mechanical law is valid or not, but rather in overlooking the existence of other factors of non-mechanical nature, which may possibly accumulate to a degree which makes all biomechanical analysis of the Locomotor apparatus useless.

Functional anatomy.

The main emphasis is laid upon the description of the bone structure of the weight-bearing segments, of the articular surfaces, the relevant muscle function, and, in connexion with this, on previous investigations into the body's centre of gravity and the muscle activity in the upright, standing position.

The inner structure and outer shape of the foot, the location of the ankle-joint and arrangement of the muscles requires, for optimal static function, that the line of gravity falls in front of the joint midway approximately between the tuber calcanei and the capitulum of the first metatarsal bone. The forward opening angle between the long axis of the foot and the median plane, to which tibial rotation is chiefly due, is moderate (from 0° to 20°). The longitudinal axis of the tibia and the mechanical axis of the femur are said to lie in the same sagittal plane and, owing to the shape and inclination of the articular facets, to form a slightly forward, upward opening angle. This orientation also corresponds with the direction of the trajectories. The flexion and extension axes of the knee-joint must be in a frontal plane. With the line of gravity a little in front of the knee-joint axis and with the segments arranged as stated above, the available musculature will have favourable working conditions. The angle of application shows that the effect is chiefly stabilizing.

The weight of the trunk is transmitted to the lower extremities through the main beam of the pelvis which possessing a rearward-opening angle of roughly 45° produces favourable conditions for the relationship between stability and the spring effect.

The muscles from the trunk and pelvis to the femur are granted especially favourable working conditions, amongst other things, because they can function in parallel shifts. If the trunk's centre of gravity oscillates directly over the hip-joint axis, the muscle work necessary to maintain balance will be least.

The shape of the column is partly genetically, partly functionally determined. With fairly flat, smooth arches and with even transitions which have to be in the line of gravity, there is probably optimal morphology and arrangement. It is also to be desired that the length of the arches corresponds with the anatomical segments. In sagittal balance the abdominal and back muscles are of especial significance. These are equally capable of functioning with parallel shifts. In the upright, standing position the maintenance of the balance involves segmentary collaboration with compensatory postural alterations of head, neck, back, loin, pelvis and legs.

The body's centre of gravity.

According to all recent authors the centre of gravity of the body is at a level corresponding to 55 % of the total height. In the sagittal plane and in the standing posture, this is slightly above and a little behind the frontal hip-joint axis, with some variation both individually and in the same person. The vertical projection of the centre of gravity strikes the supporting surface somewhat in front of the ankle-joints and oscillates in all examined persons with considerably greater sagittal than lateral oscillations. The hip-joint axis and the knee-joint axis is respectively in front and behind the line of gravity. The cranial projection of the line of gravity cuts the column at the atlas and in the 3 places where the curves merge into each other, The trunk's centre of gravity is fixed at the foremost, lowest rim of thoracal vertebral 11, and in relation to the hip-joint axis further ventrally than the centre of gravity of the entire body.

The probable optimal position of the trunk is determined by the placing of the vertebral column in relation to the vertical line which in the sagittal plane is said to strike the atlas and those points where the curves pass into each other. The line of gravity is said to pass through the hip-joint axis or near this, pass immediately in front of the knee-joint axis and somewhat in front of the ankle-joints. Thanks to the physiological oscillations which almost exclusively occur in the ankle-joints, the mutual position of the weight-bearing segments is not absolutely, but relatively stable.

From a biodynamic point of view the spatial orientation described is optimal in respect of the distribution of the translatory and rotatory components, just as it corresponds with the anatomical structures of the segments.

Electromyographic investigations show that activity is always present in the postural muscle groups in the standing posture. The degree of activity varies in accordance with the changes, caused by physiological oscillations, of the rotatory components of the body weight.

Biostatic investigation.

In investigations into the balance of the locomotor apparatus in the standing position there is greater interest from a clinical view-

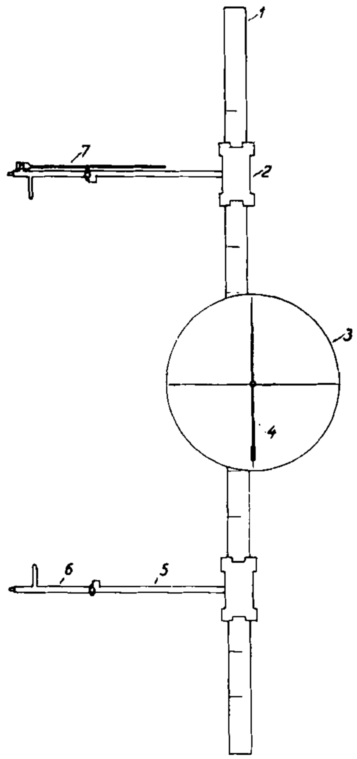

Fig. 1.
Diagram of statometer.
1. Main rod.
2. Armature to branches.
3. Disc showing degrees.
4. Pointers with counter weight.
5. and 6. Inner and outer branch tubes.
7. Metal extensors.

point in determining the orientation of the weight-bearing segments than in the analysis of the body profile, which has been previously studied in the great majority of such investigations. Thus one can avoid the vaguely defined term "posture", and instead employ clear definitions such as bodily balance and statics of the body.

For use in the biostatic investigations conducted her, an apparatus was constructed, see Fig. 1,—the statometer—which functions according to the goniometer principle. It is possible with this apparatus to determine the obliquity of the individual weight-bearing segments in relation to the plumb line in the three main planes. Moreover, the statometer can be used measuring the length of the individual segments. Moreover, an indicator apparatus was constructed and used to record the mean values of the oscillations of the locomotor apparatus in the standing position. In this way the identical position of the body is ensured for each measurement.

In the symmetrical, standing position the sagittal orientation of the

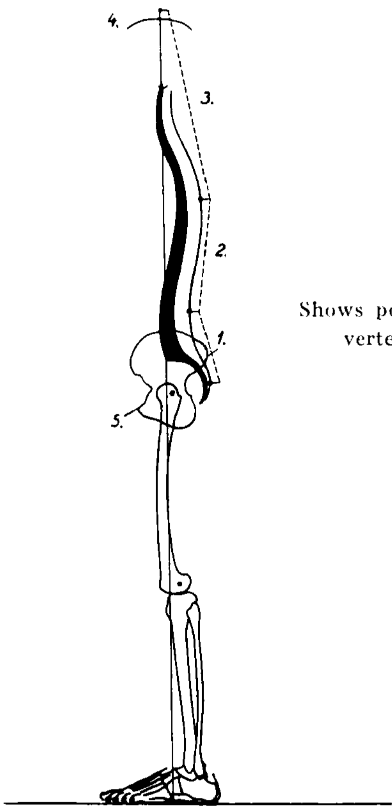

Fig. 2.
Shows points of measurements and division of vertebral column into three segments.

crus, femur, pelvis and the vertebral column is of decisive importance to the magnitude and distribution of the translatory and rotatory components of gravity. The mechanical long axes of the segments are therefore suitable reference lines in determining their spatial positioning. The reference lines are drawn from palpable bone projections which are selected so as to represent the mechanical axes in the best possible way. See Fig. 2.

In all biostatic analysis there is one necessary presupposition, that the starting position of the locomotor apparatus is not only clearly defined, but in addition can be reproduced. In the present study the position of intention of the locomotor apparatus, from standing position to walking, will be called A-position. If the orientation of the weight-bearing segments is conditioned by the habitual tonus distribution, this position must be regarded as the most suitable for the purposes of measuring. It is designated ortopositio. A standing position in which

STATOGRAM

Name: Age:

Indicator distance:	*Height:*		*Weight:*		
Inclination in	Data 1	Data 2	Data 3	Data 4	Data 5
Sagittal plane					
Leg/Crus	5	5	6	4	11
Femur	5	5	6	5	4
Extrem. inf.	5	6	7	5	9
Trunk: Troch.-Proc. mast.	0	—2	—1	—1	—5
Column: Intersp.-V. prom.	3	2	2	2	—2
Lin. sacrolumb.	8	8	6	10	14
Lin lumbdorsal.	—10	—10	—11	—9	—21
Lin. dorsocervic.	16	15	15	13	9
Horizontal plane					
Pelvis	37	35	37	36	43
in flexion	—	—	—	—	—
in extension	—	—	—	—	—
Frontal plane					
Column	0	0	0	0	0
Pelvis	0	0	0	0	0
Extrem. inf.: dxt	—	—	—	—	—
– – sin	—	—	—	—	—

Fig. 3.

Statogram. Columns 1 and 2 indicate the mean figures for respectively men and women. Columns 3 and 4 show the measurements for a male and a female individual tested at random. Column 5 shows the measurements of a woman with ortopositio dysstatica.

visible alterations in the orientation of the weight-bearing segments occur before the function of walking starts, will be called B-position.

A statometric investigation is performed with the aid of the statometer and the indicator apparatus after marking the long mechanical axes of the segments. Thus numerical values are obtained for the obliquity of the segments in relation to the plumb line or a horizontal plane.

The test individual or patient is brought into the ortopositio and the inclination of the individual segments is read off with the aid of the statometer. The results are included in a diagram—a statogram—see Fig. 3.

Statometry of a selected material.

The material used here is selected from amongst 816 students from 18 to 25 years of age and comprises 106 men and 104 women; thus all with clinically demonstrable changes in the locomotor apparatus or other organic systems which might possibly prevent biostatic and dynamic function, are excluded.

At the outset the stability of ortopositio in relation to B-position was examined. In the case of all segments, the ortopositio was found to be the most stable and easiest to reproduce. In this position the standard deviation of the inclination of the segments in the same person measured on two different days is on average 0.5°. An examination of the variation in the course of a day showed no systematic difference in measurements undertaken in the morning and those taken in the afternoon.

This was followed by statometric investigations of the above test material, in that measurements were taken twice one day and once every other day. A number of the test individuals were measured up to 30 times.

The statistical study of the inclinations in the case of men produced the following mean values:— crus: 5° ± 2°, femur: 5° ± 2°, inf. extremity: 5° ± 1°, pelvis: 37° ± 4°, trunk: 0° ± 2° and the vertebral column: 3° ± 2°.

In the case of women the following findings were made: crus: 5° ± 2°, femur: 6° ± 2°, inf. extremity: 6° ± 1°, pelvis: 35° ± 4°, trunk: — 2° ± 2° and the vertebral column: 2° ± 2°.

The figures show that the inclination of the pelvis in both sexes shows the most marked standard deviation. This is probably due to individual anatomical differences and the fact that an alteration in the pelvic inclination may be compensated only by an alteration of the inner balance of the vertebral column. Moreover, the main beam of the pelvis happens to be the shortest of the weight-bearing segments which makes probable a greater freedom in orientation.

The difference demonstrated in the inclinations between the trunk and vertebral column in the two sexes shows that the cervical section or dorsocervical section on average has greater ventral inclination in men than in women.

In order to obtain an estimate of the effect of the force of gravity upon the vertebral column and the degree of curve of the arches, the spinal column was divided into 3 segments: sacrolumbar section, lumbodorsal and dorsocervical. See Fig. 2. The average inclinations in men were respectively: $8^\circ \pm 4^\circ$, $-10^\circ \pm 3^\circ$ and $16^\circ \pm 2^\circ$. In women the corresponding values are: 8°, -10° and 15° with the same standard deviation.

If the numerical values of these findings are compared two and two, an evaluation is obtained of the degree of curve of loin and back.

The correlation between the inclination of the segments.

It was sought to illustrate the connexion between the variations of the segments' obliquity amongst individuals by setting against each other the individual average values of the segments two and two for both sexes.

A positive correlation was found between the entire inf. extremity and the crus and to a lesser extent the femur which in return has a negative correlation with the trunk. No relationship could be found between the inclination of the crus and the trunk and since, moreover, no definite correlation was found between the pelvis on the one side and the inf. extremity on the other, this indicates that in the regulation of balance in ortopositio there is a coordination between femur and trunk.

The tendency to positive correlation found between pelvis and trunk in women and to negative correlation between pelvis and vertebral column in men, shows that the loin section in men takes a greater part in the regulation of balance than in women. This is confirmed by the fact that the connexion between the pelvis and the sacrolumbar section is found to be more pronounced in man than in women.

The correlation between the segments was further illustrated by comparing groups with roughly the same inclination of the trunk with the other segments. As expected it was not possible to demonstrate the connexion between trunk and pelvis in the case of men and between trunk and inf. extremity in the case of women. The other measurements were found to rise or fall with rising values of the inclination of the trunk.

It is therefore probable that the orientation of the spinal column and the head is of decisive importance to the inclination of the other segments, when the locomotor apparatus is in ortopositio.

CONCLUSION

On condition that the measurement position—ortopositio— has been correctly estimated and the selection of the test material has been efficient, one may be justified in assuming that the average inclination, findings for the weight-bearing segments are optimal under the physiological conditions for people between 18 and 25 years.

The results of the investigation have shown quite smooth transitions from the one biostatic "type" to the other, and so one must prefer to let the figures guide in evaluating the biostatics of a test individual rather than built up a "type system".

Each upright, standing posture in which the inclination of the weight-bearing segments fall within the physiological variation can be designated: ortopositio eustatica. If the inclination findings diverge from the physiological the posture can be called: ortopositio dysstatica.

By means of the method employed here it is possible to determine the orientation of the weight-bearing segments of the locomotor apparatus in the upright, standing posture in a more objective manner than previously. Since the results of the present investigations have provided information about biostatics under physiological conditions, it has amongst other things created the possibility, in systematic investigations, of arriving at a possible connexion between poor biostatics and disease in the mobility mechanism which might be caused by such biostatics.

SUMMARY

Briefly an account is given of the relevant functional anatomy and previous research into the centre of gravity of the body and its muscular activity, investigated with the aid of electromyography.

A new apparatus is described, a statometer and indicator apparatus, with which it is possible to obtain numerical values for the inclination of the weight-bearing segments of the body. The method of measurement—statometry—is described, and an account is given of the results of a number of investigations into a selected material and also of correlation calculations made of the weight-bearing segments in pairs. The probable physiological standard deviation of the inclination of the segments is stated in diagrammatic form.

RESUME

Il est sommairement rendu compte de l'anatomie fonctionelle essentielle et des recherches antériures sur le centre de gravitation du corps et l'activité musculaire examinée à l'aide de l'électromyegraphie. Un nouvel appareillage est décrit, un statomètre et un indicateur au moyen duquel il est possible d'obtenir des valeurs numériques sur l'inclinaison des segments portateurs du corps. Description de la méthode de mesure, la statométrie et exposé des résultats d'une série de recherches sur un material sélectionné, ainsi que calculs de correction effectués pour les segments portateurs deux par deux. La largeur des variations physiologiques pour l'inclinaison des segments est indiquée schématiquement.

ZUSAMMENFASSUNG

In kurzen Zügen berichtet man über die wesentliche funktionelle Anatomie und frühere Untersuchungen über das Schwergewichtszentrum des Körpers und über die mittels der Elektromyographie untersuchte Muskelaktivitet. Eine neue Apparatur, Statometer und Indikatorapparat, wird beschrieben, mit der es möglich ist zahlenmässige Werte für die Haltung der gewichtstragenden Segmente des Körpers zu erhalten. Die Messungsmethode – Statometrie – wird beschrieben und man berichtet über die Ergebnisse eine Reihe von Untersuchungen an einem ausgewählten Material, zusammen mit Korrelationsberechnungen, die für die gewichtstragenden Segmente paarweise ausgeführt wurden. Die wahrscheinliche Variationsbreite für die Haltung der Segmente wird an Hand von Schemen erläutert.

REFERENCE

Mølhave, A.: En biostatisk undersøgelse. Ejnar Munksgaard, København, 1958.