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Orthopaedic Clinic *Head: Professor Sten Friberg*
Anatomical Institution *Head: Professor Ture Petrén*

STUDIES ON WEIGHT-DISTRIBUTION UPON THE LOWER EXTREMITIES IN INDIVIDUALS WORKING IN A STANDING POSITION

Assessing the results of the measurements of load-pressure differences against the background of handedness and some clinical observations

BY

AXEL MARSK

EJNAR MUNKSGAARD
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INTRODUCTION

The purpose of this study is to throw light, albeit to a limited degree and from a special angle, upon the factors which influence and decide the distribution of load-pressure upon the lower extremities of a person engaged in work demanding the maintenance of a standing position.

The load-pressure is determined by the weight of the body, clothes and tools, and also the object upon which the person is working, if this adds to the load. To this must be added the varying magnitude of power of acceleration.

The gravitational force acts upon the body, when the latter is in an upright position, through a line called the line of balance, or the gravity line.

When the individual takes up the anatomical basic standing posture, with the head erect in a central position, the arms at the sides, the legs a little apart with slight external rotation in the hip-joints, and the weight of the body divided as evenly as possible between both feet, this line passes a little behind the hip-joints and in front of the knee-joints and ankle-joints.

The effect of the gravitational force upon the body is neutralized by the ligaments and muscles, stabilizing the joints.

Balance is maintained automatically by reflexes, which are evoked by stimuli in receptors (labyrinths, and muscle and tendon proprioceptors), engaged in securing balance. Normally, this automatism functions perfectly, and is not much noticed, either by us or by those around us.

If, owing to illness, the fine and intricate combination of forces in the neuromuscular apparatus is disturbed, so that the gravitational force cannot be combatted with the normal antagonistic muscle effect, there arises a resulting difficulty of maintaining the balance of the upright body.

The most stable equilibrium for a body is obtained if the supporting base is as great as possible and if the gravity line coincides with the centre of the supporting base. This also applies to the human body in a standing position, with the restriction, however, that the distance between the feet must not be permitted to be too great. If the legs are too wide apart the flexors and extensors of the hip-joints are partially put out of action, so that they become incapable of adjusting the body to any "new" vertical projection of the centre of gravity in the frontal plane.

If we imagine that, when a person is in a standing position without footwear, straight lines are drawn through the most lateral point on the os calcaneus and on the 5th metatarsal head, then through the most anterior point on the head of the 5th to the same of the 1st metatarsal bone, and this with regard to each foot, the lateral border-lines and part of the anterior border-line of the supporting base are formed. By drawing a straight line connecting the most anterior points on the heads of the 1st metatarsal bones and another connecting the most posterior points on the os calcaneus of each foot, the supporting base is obtained.

Regarding the distribution of the total load-pressure, optimal conditions are fulfilled if the load which is transmitted to the ground through the feet is equally divided between them.

A broad supporting base, one of the prerequisites for a stable equilibrium, can easily be arranged by standing with the legs apart (observing the restriction mentioned above), but if a conscious effort is made to distribute the load-pressure as evenly as possible on the right and on the left foot, this is rather difficult. This fact can be proved by anyone attempting to stand with the right foot on one scale and the left foot on another, equally balanced.

Consequently there is every reason to assume that the load-pressure upon the feet is unequally divided between them when the individual takes up an upright position.

The position of the arms in relation to the body, and the turning and bending of the body to the right or to the left, cause the centre of gravity to be thrown on to the right or the left leg, with the result that one leg receives more load-pressure than the other.

Standing is thus an act of balance, the vertical projection of the centre of gravity upon the supporting base shifting irregularly, sometimes falling to the right and sometimes to the left of an imaginary vertical line, representing the line of gravity when the weight of the body is evenly distributed between the feet.

The leg (foot) receiving more load-pressure is herein designated the standing-leg (standing-foot).

I found it therefore to be of interest to study the distribution of the load-pressure upon the right and the left leg by individuals working in standing positions and under similar conditions, and to see if there was any correlation between the hand which was preferably used (the "working" or "best" hand) and the standing-leg—if either of the legs merited this nomination. I further wished to see if there were any stigmata of increased function on the hand of preference (the working-hand) and on the standing-foot.

As there are reasons to expect that a one-sided load, carried over a longer period, can give rise to both static pressure deformities and unhealthy conditions of different kinds in the supporting tissues, and, because of the static action of the muscles, can also unfavourably influence circulation in the lower extremities, the matter should be of interest both to orthopaedists and to all engaged in problems dealing with the health of industrial workers.

The problems with which this study is dealing are thus seen as follows.

How is the load-pressure distributed over the right and the left leg by people maintaining an upright position, and working as far as possible under identical conditions on an unobstructed floor-space, with the object worked upon in front of them in most cases, and with possibility for the worker, according to spontaneous predisposition, to move the body to the right or left and to use either the right or the left hand?

Has handedness any influence upon the individual's choice of standing-leg? (To answer this question the same investigation was carried out as above, but executed on a group, consisting of an equal number of right-handers and left-handers, performing absolutely identical work.)

Are there any stigmata of increased function on the hand of preference, and on the foot designated standing-foot?

Unfavourable static conditions, *e.g.*, resulting from inequality in length of the two legs, may be thought to influence the dividing of the total load-pressure between the lower extremities in a standing position. In this investigation, therefore, due consideration has been given to this possibility, but as normal material was used (*vide infra*), of course only smaller differences were met with; the conclusions drawn, as regards influence caused by difference in leg-length, thus refer to such smaller discrepancies.

According to STEINDLER (1935), the static compensation for a shorter leg is as follows:

Up to 5 cm.: the tilting down of the pelvis on the affected side.

Up to 7·5 cm.: the addition of equinism of the foot.

Over 12 cm.: flexion of the knee of the non-affected leg.

The asymmetries in the lower extremities have interested both anthropologists-anatomists as well as those working in the clinical field. In this review of literature reference is made to only those authors who have studied disparity in length between the right and left legs on material considered as normal, *i.e.*, without any pathological underlaying factor, trauma or illness, being known or suspected as causing the difference.

HASSE and DEHNER (1893), measured the right and left legs of 5,141 soldiers. Measurements were taken from the major trochanter and a slide-measure was used. They found disparity in length in 68% and parity in the remainder. In the former group the left leg was the longer in 52% of the total number and the right in 16%. Of the total number 99% were right-handed and only 1% left-handed.

MATIEGKA (1893), working on osteologic material (53 skeletons from both sexes, children and adults), also found the left leg to be longer than the right. The difference was greatest among men and smallest among children. He attributes this fact to functional hypertrophy. He also found the existence of a crossed asymmetry: right arm—left leg were the longer extremities. This should be a further manifestation of increased function, as most persons are right-handed.

GARSON (1899), MOLLISON (1908) and SCHWERZ (1914), all using osteologic material, composed of 70, 148 and 239 bones respectively, measured the lengths of the right and left legs, and found the left to dominate.

HAGLUND (1916), measured the lengths of the right and the left legs in 265 children between the ages of 6 and 12 years, showing scoliosis, and then found the left leg to be up to 2·75 cm. shorter.

ROMICH (1927), considers this finding of Haglund's not contradictory to the findings of earlier writers, stating that it may be true that in infancy and childhood the left leg is the shorter, but under the stimulus of puberty it becomes the longer. Romich himself found the left leg to dominate in length in adults. The number of measurements was not recorded.

The above-mentioned reasoning of Romich seems to me to postulate the possibility that sometimes the right leg and sometimes the left, during different periods in life, is the standing-leg, and also presupposes the assumption that the shorter leg is the standing-leg.

INGELMARK (1943), working on osteologic material, composed of 1,917 bones, reports that he found a slight, though not statistically verified, dominance in length as regards the left leg in adults, but no difference in the length of legs of foeti (71 cases) in the last two months of gravidity. When corresponding components of the legs (the bones belonging to the right side and those belonging to the left) were compared with each other, he found, however, the left tibia to dominate with a mean of $4 \cdot 26 \pm 0 \cdot 20$ cm., whereas the right and left femurs had on the whole the same length.

He also found a hint of a crossed asymmetry: the right arm and the left leg were slightly longer. Ingelmark adopted the theory of functional hypertrophy and expounded his view on clinical aspects.

The same author (1946), by using a roentgenologic as well as an anthropologic method, and comparing the reliability of the two methods with each other, measured the lengths of the upper and lower extremities on both sides. The material, 150 individuals, consisted of both right-handers and left-handers, and represented an equal number of both sexes, five in each age-group, the ages ranging from six years up to and including twenty years. From the age of six up to puberty there was a homo-lateral conjunction arm—leg as to dominance in length, in right-handers the right side dominating and in left-handers the left side. From about the age of puberty he found a crossed asymmetry arm—leg to exist in the sense that in right-handers the contra-lateral left leg, and in left-handers the contra-lateral right leg, were the longer.

REDLER (1952), made a clinical investigation of 99 individuals, both adults and children. He found the left leg to be shorter four times as often as the right. By putting plates of varying thickness under the shorter leg, he got the spina iliaca anterior superior on each side to be located in the same horizontal plane. He found such an adjustment to be more accurate than measuring with a tape. The correlation right-left was the same both in adults and children, and there was no correlation between the dominant hand and the shorter lower extremity. He found it "therefore probable that the onset of discrepancy occurs early in infancy, and most likely is the result of the greater functional impetus given to the growth of the major extremity during early development. With the advent of accomplished walking it probably remains static and persists into adult life".

Closely connected with the question of asymmetries in length of the lower extremities is that of the possibility that each individual, when standing, uses one leg more than the other, which leg is called the standing-leg, and, as a consequence of that circumstance, distributes the load-pressure more or less over the right or the left leg.

Most of the authors previously mentioned have interpreted the dominance in length of the one leg as an expression of increased function, that is to say, the leg was the longer owing to its being used more for standing; but unanimity on this point is lacking.

Haglund, though he found the left leg to be shorter in children, at the same time found that the left foot more often than the right presented static deformities in the form of plano-valgus, registrable on footprints, and he also found that cases of knock-knee occured more often on the left leg. "Durch diese Beobachtungen muss ich das Überwiegen der linken Seite betreffs der Frequenz und des Grades der sog. Belastungsdeformitäten als festgestellt betrachten".

Romich states that he finds it more natural that the shorter leg should be the standing-leg.

Redler found the shorter leg to be the standing-leg.

Without giving consideration to any asymmetries of the lower extremities, the question of standing-leg has also been elucidated by physiological and psychological camps.

HELLEBRANDT *et al.* (1938), in studying the location of the centre of gravity in a group of young women (445 college freshmen), found its vertical projection, in the majority of cases, to fall to the left of the midpoint of the line connecting the centres of the two heels, when the subjects had a comfortable stance, and to the right of that mid-point when they were asked to assume their "best posture".

The authors consider this transverse shift in the vertical projection of the centre of gravity, associated with voluntary correction, as an "unconscious overcorrection of a natural tendency to attain balance by holding the weight on the less developed side". They also consider this unequal development of the two halves of the body to have connection with handedness.

Steindler believes that in the majority of humans "there is a time in life when apparently complete and stable symmetry of the body exists", but that "the one-sided preponderance of habitual movement-patterns and occupational posture suggests, on *a priori* grounds, that their equilibratory compensation will automatically induce attitudinal anomalies, giving rise to a physiologically normal posture, characterized by a frank asymmetry in configuration".

HUELSTER (1953), in a study, using a motion-picture camera, photographed the contours of the nude bodies of young women, with surface land-marks as points of reference to the skeleton.

She found bilateral contour asymmetry to develop in both standing and walking. The left leg was found to be the standing-leg more often than the right and when, in walking, the weight of the body was supported on the left leg, the most marked bilateral contour asymmetry could be registered. The weight and height of the subjects had no correlation to the degree of bilateral contour asymmetry, nor had handedness.

SMITH (1953), by observing 250 subjects at a distance, studied the intermittent shift of the standing-leg of persons standing in bus-queues, on platforms, etc., and also the manner in which they stood. He found that, on the average, a shift from one leg to the other took place every 30 seconds. Concerning the manner of standing, he found an asymmetrical standing, *i.e.*, a standing in which he considered nearly the whole weight of the body to be on one leg, to be about four times as frequent as what he considered to be a symmetrical standing, with the body-weight evenly distributed between the two feet. He found no significant difference between right and left leg as to frequency of either being used as standing-leg.

As to the question of stigmata of increased function in hand and foot, MARSK (1954), called attention to the diminished extent of extension in the metacarpo-phalangeal joint of the thumb of the hand of preference, or working-hand. Most working-grips with the hand are connected with a more or less flexed position of the thumb in its two joints and at the same time have a tendency to spread the 1st and 2nd metacarpal bones. This occurs owing to the fact that in the majority of cases the thenar regions of a person working with the hands are subject to pressure, *e.g.*, by placing the hand or hands on something for support or by grasping a tool or other object. Automatically, as a result of the spreading above referred to, the muscular balance of the metacarpo-phalangeal joint of the thumb gets disturbed. The stabilizing barrier, formed by the muscles, may be defective from the beginning, or may be broken through in course of time, by reiterated and hard manual work, so that an exaggerated angle of flexion in the basal joint of the thumb appears, sometimes permitting a real deformity in flexion to develop. It is natural to think that this restricted extension should be most marked in the best co-ordinated and, consequently, the most used hand.

As to the genesis of the syndrome of hallux valgus, the predominance of which on the one side is considered by the author as usually indicating increased pressure, *i.e.*, increased function on that side, the view generally adopted is that this is caused by loading. Formerly ill-fitting shoes and stockings were blamed for the development of this syndrome, but nowadays there seems to be great unanimity among authorities that the real cause cannot be attributed to these factors, which are considered to be of only secondary importance (ERLACHER, HAUSER, HOHMANN, HOWORTH, LAKE, SCHANZ, STEINDLER, WILES).

Of course a shoe, whatever fashion it may have, is unphysiological in so far as it partially restricts muscular action, and this circumstance may thus indirectly favour the development of a hallux valgus. Yet this deformity is seen in native tribes who have gone barefoot all their lives. In another direction, too, the shoe surely has a harmful effect: the higher the heel, the more the stress is forced upon the front part of the foot. This may, at least in part, account for the predominance of hallux valgus in women over that in men.

There has been some discussion as to whether or not the valgus position of the foot is a *conditio sine qua non*, for the development of the syndrome of hallux valgus. The general opinion is that the valgus component is not necessary, though it is often to be found in the mechanism. Yet in the cavus foot, where a marked disturbance in the muscular balance exists, with the balls of the toes on the same horizontal plane as the heel, the valgus component is in most cases entirely lacking.

An essential element in the mechanism for the development of the hallux valgus is the broadening of the front part of the foot, especially a spreading of the 1st and 2nd metatarsal bones. It is here that loading or pressure comes into the picture as a working agent, particularly during the "take off", when a considerable amount of strain is sustained by the anterior part of the foot, even in a normal gait. It is also natural to think that the valgus position of the foot, bringing with it increased pressure on the medial part, should tend towards a spreading of the 1st and 2nd metatarsal bones. Also in severe cases of valgus feet in rather young children the presence of the hallux valgus deformity may already be seen.

The abnormal varus position of the 1st metatarsal bone, as a sequel of the metatarsus latus, brings with it a subluxation in the basal joint of the great toe, as an inward deviation of the great toe also, is resisted by the attachment of the adductur muscle to the basal phalanx. Once the subluxation of the basal phalanx has been established, the eccentric pull of the long tendons to the great toe helps to increase the deformity.

In order to obtain information regarding variations in the size of feet among the Swedish population, the Swedish Shoe Industry's Research Institute, in the year 1951, made measurements of the naked feet of 200 young adults, representing varying professions, the men being registered for military service. This was done by means of a specially constructed apparatus. Among other things the ball breadths of both feet, *i.e.*, the distance between the most medially and the most laterally located point of the 1st and 5th metatarsal heads respectively, were recorded for each individual. When the breadths of the right and those of the left feet were compared with each other, the sum of the latter was found to predominate, even though no statistically significant difference was obtained.

This circumstance is reflected fairly well in the fact that, on inquiry, most assistants in shoe-shops declared that they had found the left foot to be larger than the right in the majority of cases when customers tried on shoes.

Most of the authors referred to in this survey have studied differences in lengths of the two upper and of the two lower extremities, and the majority of them have attributed the cause of such disparities to functional hypertrophy. Supporting such a view, the theory has also been presented that during different periods of life one leg or the other may be the longer. With such reasoning a certain degree of regularization is thinkable, and possible as long as growth continues. The leg longest in the adult would then be the one that the individual has most used as the standing-leg during a particularly intensive period of growth, *e.g.* in puberty. After this period the possibility of regularization is but small.

In connection with determination of the location of the centre of gravity and of its projection in various planes, the question of any difference in the distribution of the total load-pressure on the right and the left leg is actualized. With few exceptions, however, interest does not seem to have been given to it by clinicians, which seems to me somewhat surprising, as many clinical problems, according to my opinion, must be worthy of being treated with due consideration to the distribution of the total load on the lower extremities.

A study of this same distribution ought therefore to be able to enrich the discussion on many questions, particularly in orthopaedics and in industrial medicine.

APPARATUS

As has been previously mentioned, the problem of weight-bearing and the distribution of load-pressure over the right and the left leg in a standing position has been discussed by different authors, but, as far as I am aware, it has not formerly been the object of direct investigation in which, by some method of measurement, an effort has been made to form some conception of load-pressure by means of registrable results in figures.

Naturally the definite load-pressure upon the right and the left foot is far from being without clinical importance. The investigation here under consideration was, however, intended only as a study of load distribution over the right and the left leg during work in a standing position. The apparatus used was constructed in such a way that, from the basis of a state of equilibrium where both feet support an equal measure of the total load, every divergence from the equilibrium, with the resulting difference of pressure between the right and the left foot, would be registered. As far as only the weight of the body is reckoned with as an operating force, the apparatus gives a mean of the proportion right — left as to the distribution of the body weight between the feet during the testing time.

Measurement is obtained by means of strain-gauges in a slipper-like arrangement strapped under the shoes of the individual experimented upon (figs. 1 and 2).

Fig. 1. Test-subject wearing transmitter and slippers.

The strain-gauges are fastened on springs made of steel band which, via levers, are influenced by the load-pressure, so that the springs become more and more bent with the increasing load-pressure.

The strain-gauges form two arms in a Wheatstone-bridge which, by means of a variable resistor, is balanced when load-pressure on each foot is equal. When the load-pressure is unequal a non-balance voltage is received from the bridge, which voltage is proportional to the difference of load-pressure. In order to

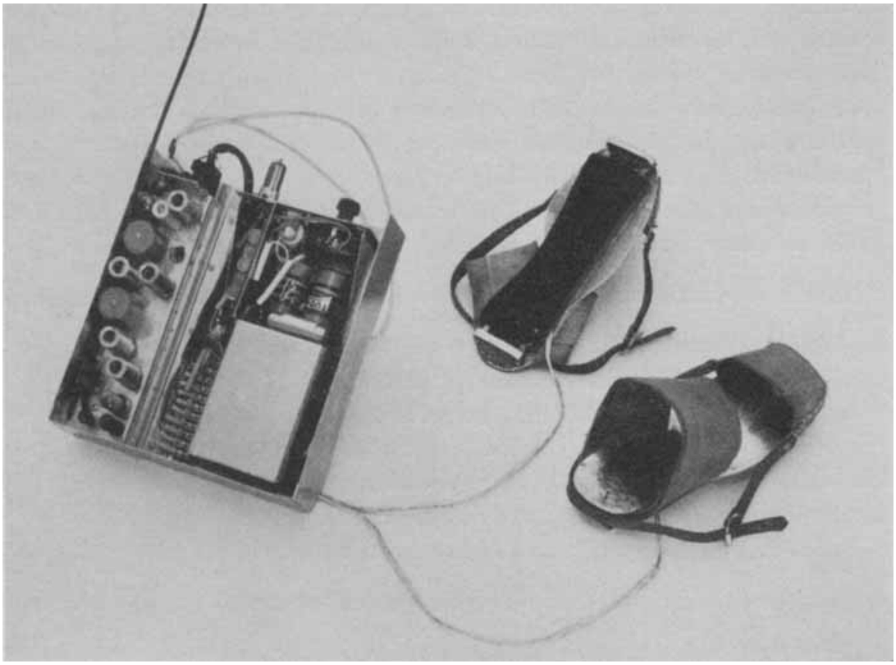


Fig. 2. Part of apparatus borne by test-subject; slippers and transmitter.

enable, in the simplest manner, the amplification of the small voltages given off by the bridge when balance is disturbed, the bridge is supplied by alternating current (appr. 1,000 c/s), and the non-balance voltage is amplified in an electronic tube amplifier, and then rectified in a rectifier, where the phase-position in relation to that of the voltage of the bridge-supply is taken into consideration, as by this the direction of the non-balance is shown, *i.e.*, it can be seen whether the right foot or the left receives the greater load-pressure. A D.C. voltage is received from the rectifier, the magnitude of which is proportional to the difference in load-pressure, and the polarity of which shows the sign of the difference.

The signification of the D.C. voltage thus received is transmitted by a wireless apparatus to the registering apparatus, and in order that the variable qualities of the transmission shall not influence the results of the measurement, the D.C. voltage is transformed into an A.C.voltage, the frequency of which is influenced by the intensity and sign of the D.C.voltage in such a manner that the frequency is appr. 700 c/s when the D.C.voltage is zero, gets lower when the D.C.voltage is negative, and rises above 700 c/s when this becomes positive.

This A.C.voltage with varying frequency is modulated on a small crystal-controlled transmitter and is received in the ordinary way by a short-wave receiver which is furnished with an electronic impulse-counter (A) to enable continuous registering of the total sum of transmitted cycles. Another impulse-counter (B), the reference-counter, is fed with a fixed frequency, equal to the "balance-value" of the variable frequency, *i.e.* the value when each foot has equal load-pressure (fig. 3). The difference between the sums of the counters expresses in cycles the integrated overweight of the one foot in comparison with the other at a given time. Dividing by some measure of time gives a mean value of this relative overweight. The best available measure of time is furnished by the reference-counter (B). Accordingly, the author has defined the mean load difference as M.L.D. $= k \times \frac{A-B}{B}$, where A is the reading from the counter fed by the variable frequency, B the reading from the reference-counter, and k a proportional-constant for converting the quotient into kilogrammes.

A requisite of fundamental importance for using this method and for ensuring the reliability of the results obtained, is that there is a linear correlation between load-difference and variation in frequency of the A.C. voltage, and also that this correlation is the same above and below the balance-point.

By loading the "slippers", each in turn, with known weights ranging from 15 to 70 kgs. the author computed the regression of kilogrammes on $\frac{A-B}{B}$ and estimated the regression coefficients to be:

for frequencies above the balance-point: $287 \cdot 66 \pm 1 \cdot 97$

for frequencies below the balance-point: $290 \cdot 13 \pm 1 \cdot 74$.

The difference between the coefficients was not statistically significant ($0 \cdot 4 > p > 0 \cdot 3$). Tests of departure from linearity were likewise negative for the two regression lines ($p > 0 \cdot 5$). A second control of the apparatus was arranged in the following manner. A pair of known, different loads were put on the slippers, first with the heavier load on the one of them and then on the other. This procedure was repeated 25 times with load-differences ranging from 0·7 to 33·6 kgs.

Using the proportional constant for the slipper that gave frequencies above the balance-point the M.L.D.'s were computed. The measurements were paired according to the load-differences established in such a way that each pair comprised a negative and a positive M.L.D.-value, obtained by putting the heavier load on the left and the right slipper respectively. The positive value was subtracted from the absolute value of the negative one and the series of differences thus obtained statistically analysed. If the slippers were of the same sensitivity, the mean-value of the difference-series would be zero. A moderate negative figure, minus $0 \cdot 36 \pm 0 \cdot 17$ kg. was obtained, however, indicating a slightly higher sensitivity of the slipper that had positive influence upon the balance-frequency. This difference, which is significant ($0 \cdot 05^{x} > p > 0 \cdot 01$), reflects the insignificant difference between the k-constants. The smallness of the figure, however, seemed in a very minor degree to influence the results.

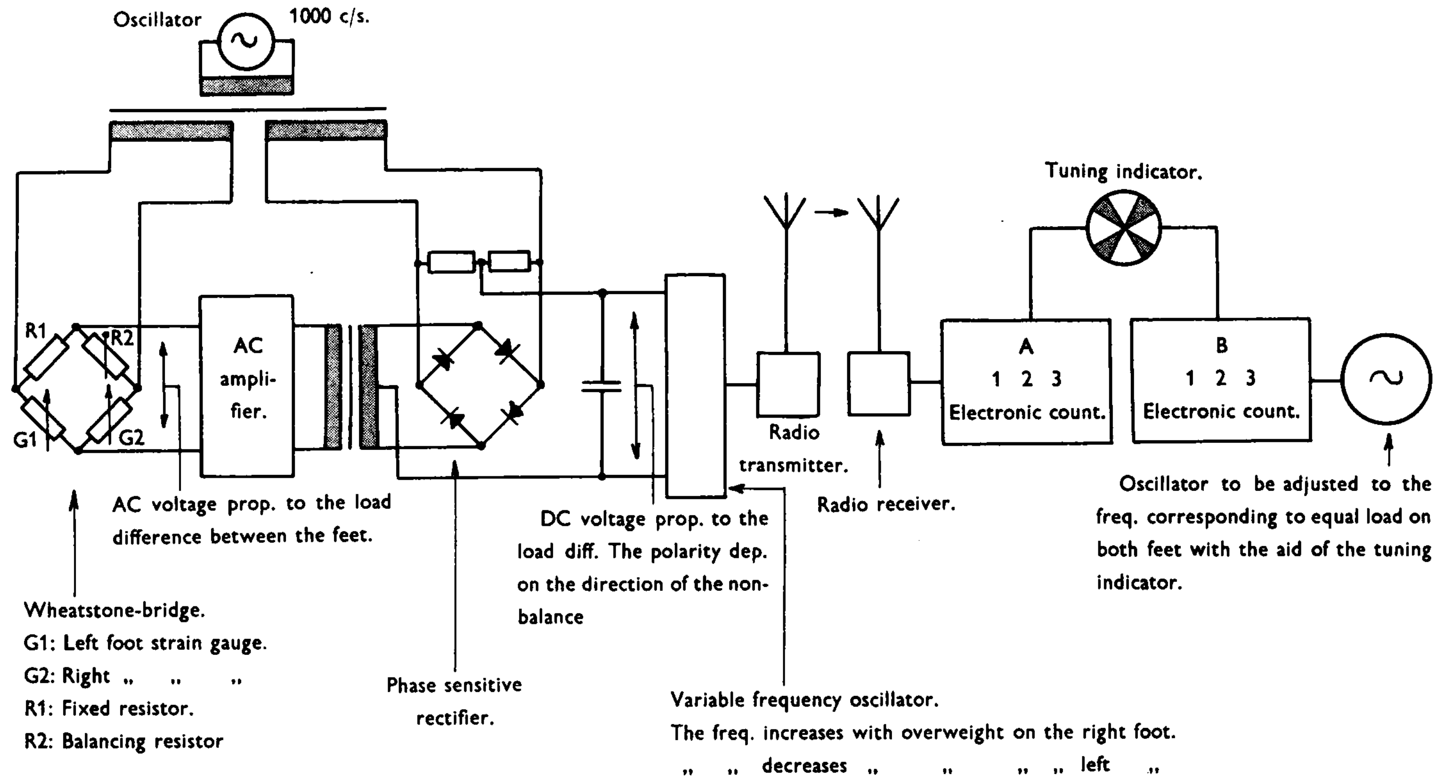


Fig. 3. Block diagram.

From a clinical background most facts indicated the left foot as being, as a rule, the one most loaded. A connection of the slippers to the arms of the Wheatstone-bridge in such a way that a positive sign of the M.L.D. meant greater pressure on the right foot in comparison with the left, and a negative sign meant greater pressure on the left foot in comparison with the right, seemed thus most suitable. It could not then be urged that the above-mentioned theory of presumed difference between the feet in sustaining load-pressure had been favoured by some opportune, experimental conditions. The coupling in the bridge was also arranged in such a manner that any external disturbing impulses coming into the short-wave receiver added to the sum of pressure on the right foot. Thus, the pressure on the right foot, as obtained from the readings of the apparatus, may be too high, and, as a consequence of that fact, the pressure on the left foot too small. The risk from external impulses adding to the incorrectness is, however, almost negligible, as such disturbing elements can be controlled fairly well in the receiver. The experiments were not carried out when conditions were unfavourable.

The proportional-constant which is dependent upon the tension of the batteries furnishing electric energy to the various parts of the bridge and of the wireless apparatus, was checked at close intervals during the experiments, as a rule before starting and after finishing each test. Maximum 3% drift of the proportional-constant from the beginning to the end of each measurement was accepted. A surpassing of this margin led to the exchange of one or more batteries. At short intervals the stability of the whole apparatus was controlled and routine-checking diagrams recorded by calibration.

The manufacturers of the apparatus, Svenska AB Philips, claim an accuracy of a single measurement: $\pm$ 1 kg. $\pm$ 5%, which well covers the above mentioned errors.

The short-wave receiver, and the two counters together as a unit, are each separately enclosed in a case something like a hand-bag, which case acts as a kind of chassis. The two cases are portable so that they can be placed on a table, for example (fig. 4).

The other parts of the apparatus are carried by the subject under investigation, the part receiving the load-pressure strapped, slipper-like, under the shoes, and the other part carried on the back in a haversack-like arrangement (fig. 1).

The weight of this haversack with contents is about 4·5 kgs.

Graphical analysis showing how apparatus works.

For a better comprehension of the manner in which the apparatus works, and to assure a more concrete conception of M.L.D., the results of a graphical analysis made upon a small group of individuals, otherwise not included in the

Fig. 4. Receiver (left) and calculating mechanism.

material, will be presented before an account is rendered of the main investigation.

The value of the M.L.D. may be looked upon as the mean of smaller load-differences during the test-period in question. The magnitude of these smaller load-differences is determined by two variables, the pressure-difference between the two feet, and the length of time during which this difference has the opportunity of working. It is obvious that a small load-difference working during a long period will give the same final result, as regards the magnitude of pressure-difference, as a greater load-difference working during a shorter time. It could therefore be of some interest to study the reciprocal relation of those two factors as influencing the final result, the M.L.D. For that reason a graphical study of the standing pattern was made by connecting a potentiometer recorder to the apparatus. An analysis was made in six individuals during ten minutes, and the experiment was repeated on the same individuals after some days. Thus 12 records were obtained.

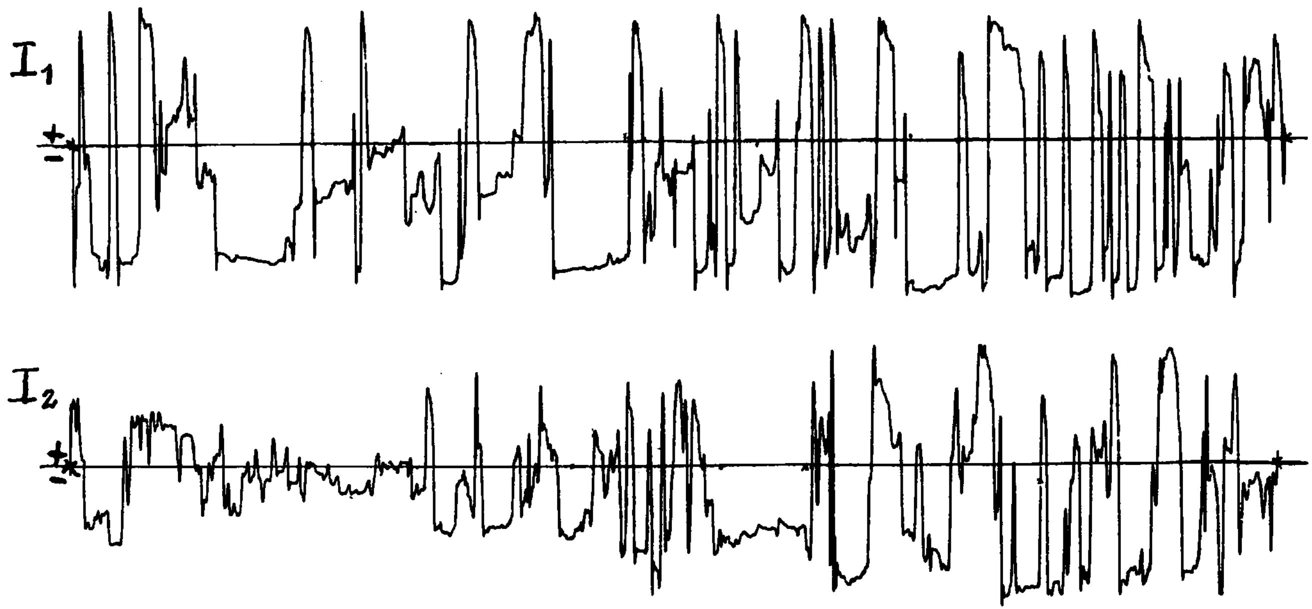
The test-subjects were occupied by assembling a puzzle while in a standing position and under identical local conditions. The records are presented on pp. 18—21 and the results extracted from them in table 1.

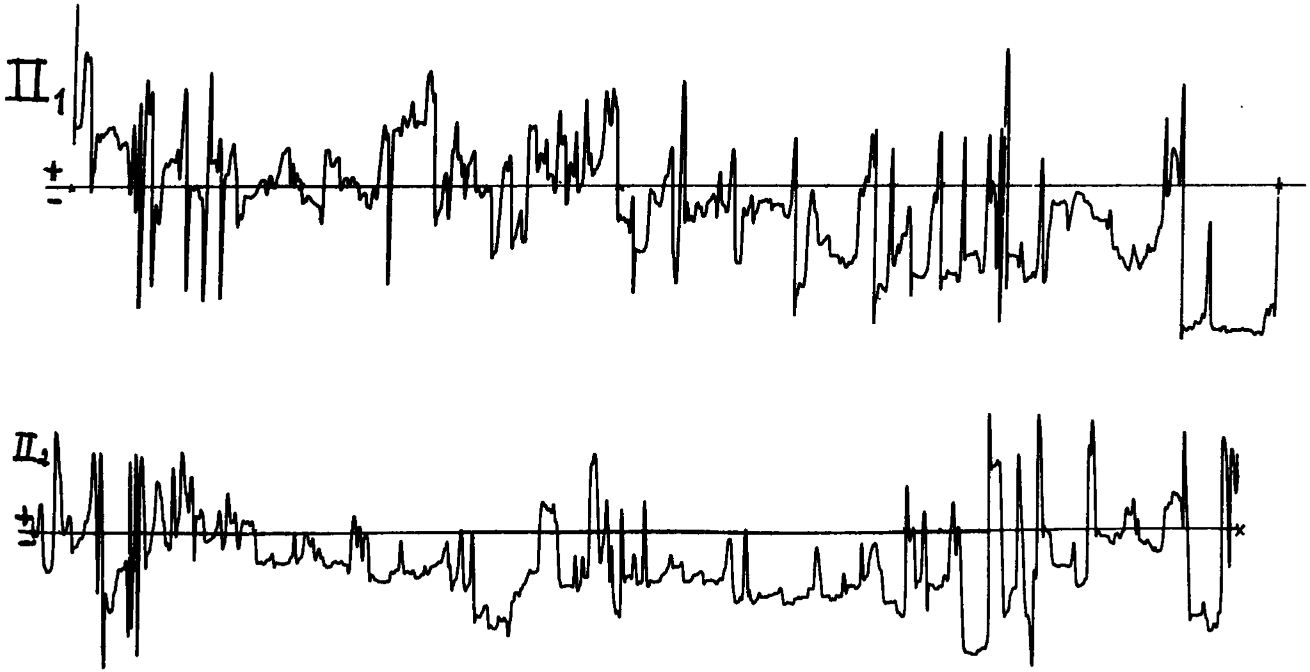
Records of standing.

Scale 1: 2.

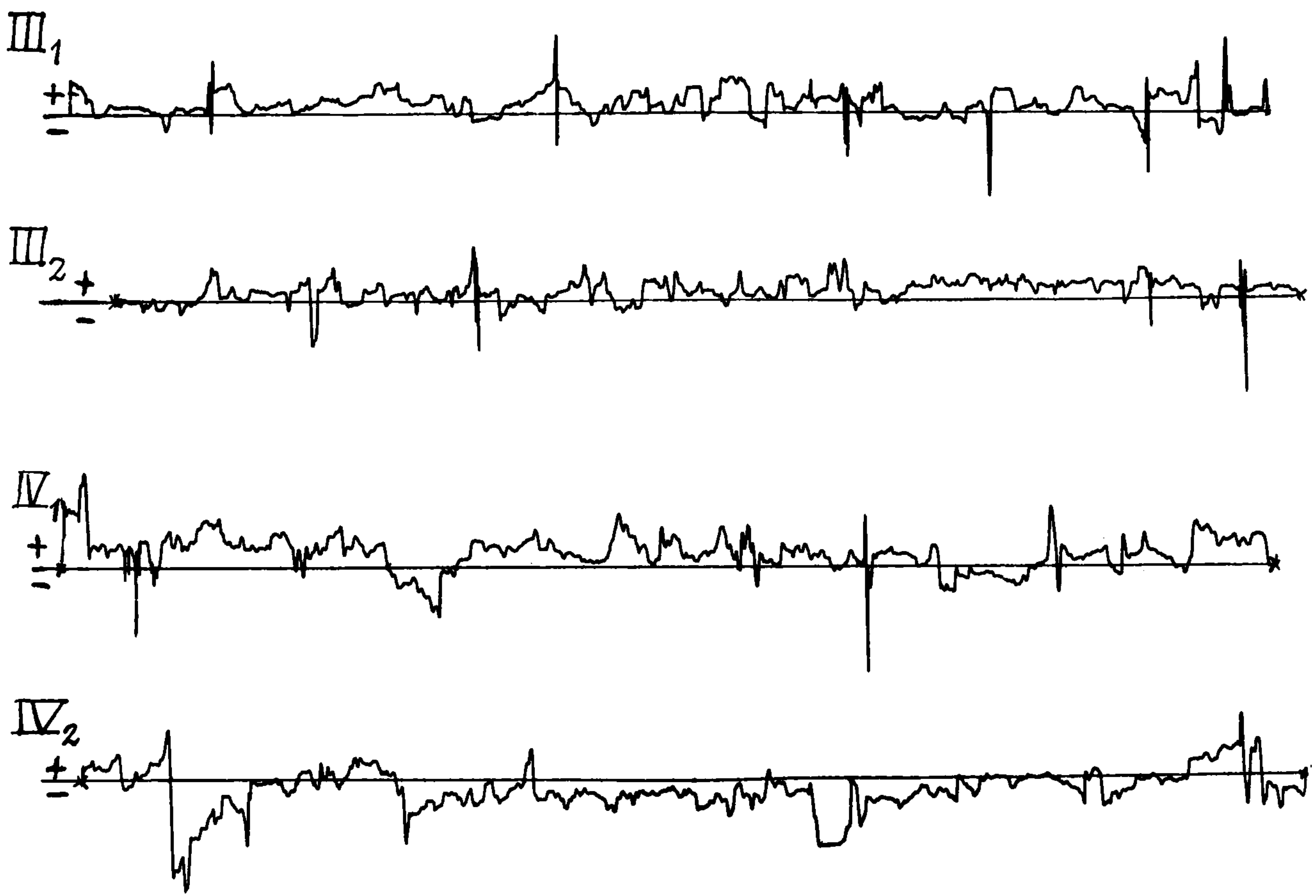
+ denotes greater pressure on right foot.
— denotes greater pressure on left foot.

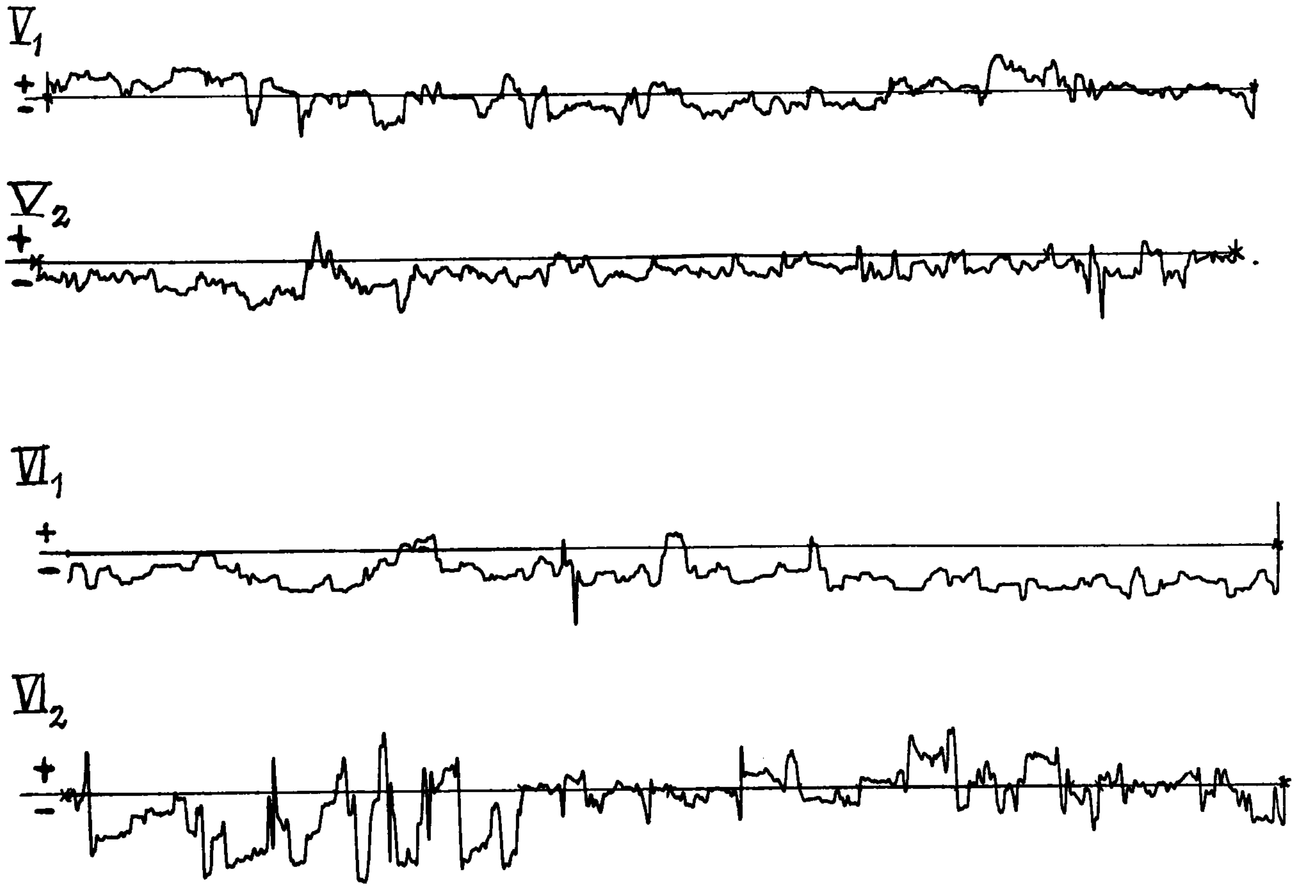
Straight line (zero line) represents time. Period from beginning to end of curve about 10 minutes.





Π1
+
−
Π2
+
−


III1
III2
IV1
IV2



V1
+
-
V2
+
-
VI1
+
-
VI2
+
-

Table 1.

		V.C.	R.C.	M.L.D.	T_r	T_l	P_r	P_l	A_r	A_l	Ampl. r	Ampl. l	M.L.D. planim.
I	1	422	445	—15·5	10·1	22·2	31	69	18·0	56·7	1·78	2·55	—17·8
60 kgs.	2	439	451	—8·0	11·2	20·2	36	64	13·2	32·2	1·18	1·59	—8·7
II	1	436	444	—5·4	11·6	20·2	36	64	12·1	30·3	1·04	1·50	—8·6
62 kgs.	2	435	454	—12·6	7·6	24·8	23	77	6·8	29·6	0·90	1·19	—10·4
III	1	445	443	+1·4	26·4	5·7	82	18	9·3	1·8	0·35	0·32	+3·4
64 kgs.	2	453	452	+0·7	24·1	7·1	77	23	8·5	1·1	0·35	0·15	+3·5
IV	1	450	446	+2·7	25·3	6·6	79	21	14·9	2·1	0·59	0·32	+5·9
80 kgs.	2	445	453	—5·3	7·6	24·9	23	77	2·8	12·9	0·37	0·52	—4·6
V	1	446	447	—0·7	16·7	18·4	48	52	5·0	5·1	0·30	0·28	±0
59 kgs.	2	438	450	—8·0	3·0	29·5	9	91	0·7	14·1	0·23	0·48	—6·1
VI	1	380	403	—17·1	1·8	32·3	5	95	0·5	22·5	0·28	0·70	—9·6
77 kgs.	2	357	360	—2·5	11·6	20·8	36	64	5·0	14·8	0·43	0·71	—4·4

The Roman letters to the left denote the first, second etc. test-subject, whose body-weight is also stated, and the smaller figures indicate the first and second experiment made upon each individual. The following designations are used:

V.C. = number of kilocycles, counted by the variable counter.

R.C. = number of kilocycles, counted by the reference counter.

M.L.D. = mean load-difference in kilogrammes, calculated upon the data given by the counters and using a proportional constant of 300.

T_r = period of time, measured in cm. on the zero-line of the curve, when the right foot was more loaded than the left.

T_l = the same for the left foot.

P_r and P_l = percentages of the test-period, calculated upon T_r and T_l, with dominance of pressure on the right and left foot respectively.

A_r = area in cm.^{2} obtained by planimetry, representing the amount of greater pressure on the right foot during the test.

A_l = ditto—left foot.

Ampl._r = mean amplitude in cm. during the test, when the right foot was heavier loaded than the left.

Ampl._l = ditto—left foot.

$\text{M.L.D.}_{\text{planim.}}$ = M.L.D. obtained by the planimetric method:

$$\frac{Q\,(P_r \times \text{Ampl.}_r - P_l \times \text{Ampl.}_l)}{100}$$ where Q is a proportional constant, obtained by calibration, giving the amplitude in kilogrammes. During the test 1 cm. = = 14·7 kgs.

By observing the curves it is striking that each test-subject's pattern of standing on the whole has something characteristic.

No. I, for example, represents a rather "stormy" standing, with fairly great amplitudes indicating greater pressure on one foot or the other. The left-sided pressure dominance as regards time is also well illustrated. No. III, on the other hand, shows another pattern: a comparatively even standing with small amplitudes, broken by peaks here and there. This subject discloses a right-sided dominance in time as to pressure-difference.

Another interesting fact is that all but one of the individuals at the iterated test showed on the whole the same pattern as during the first test. Thus it seems that each individual in a given situation has in a rather high degree his own particular pattern of standing.

The following conclusions may be drawn from the data presented in table 1.

The sign of the M.L.D., + or —, indicating a mean greater pressure on the right or left foot respectively during the test-period, corresponds in each of the curves to relative dominance in length of time of existing greater pressure on the foot in question. In addition, the magnitude of difference between the mean amplitudes (*i.e.* the difference in intensity of mean greater pressure between the two feet), also contributes to the final figure of the M.L.D. No correlation seems to exist between body-weight and magnitude of M.L.D., sign ignored.

As is to be expected, there is a rather great divergence between the values of the M.L.D. obtained by means of the counters and those obtained by means of the graphic method. The determination by planimetry of such small and irregular areas as was here the case must always be connected with great sources of error. A possible "wandering" of the zero-line from the horizontal plane may also add highly to incorrect values of the A_r and A_l even though, as was the case in these studies, a correction for the drift is made.

The changing of signs concerning the M.L.D. of test-subject IV in the two experiments made may be of some interest, as the cause may have a psychological background.

The person in question was aware of his tendency to generally load his right leg more than his left. This, he claimed, was a result of a fracture of his left leg earlier in life. That this fact was commented upon after the first experiment was finished could not be avoided, as the man himself began to discuss the matter. The last value of the M.L.D. may be an effect of a more or less conscious correction on the part of the individual in question.

MATERIALS AND METHODS

Studies of the distribution of load-pressure on the right and the left leg in a standing position were carried out along two lines.

On the one hand the conditions among a professional group, whose members were considered suitable objects of investigation, were studied (Part I of the material). On the other hand persons whose handedness had been verified previously by tests, and who were engaged in absolutely identical work (Part II of the material), were investigated. Only men were concerned.

The material upon which the study is based thus consists of two parts, each of which will be treated in all respects separately, although in discussing the results, and in the conclusions drawn from them, the two sections will be converged.

Part I, the professional group, is represented by 199 hand-compositors from various printing-works in Stockholm, it being considered that those workers filled in a very high degree the demands outlined below with respect to free and non-restrained working-positions.

The members of this group were selected at random and consequently included both right-handers (188), left-handers (8), and ambidexters (3). In selecting the subjects, however, the only restriction made was that no persons were accepted in whom the distribution of the load-pressure in a standing position could be assumed not to be the object of a presumptionless study. Current injuries or post-traumatological final results with stated or assumed one-sided functional impairment of the lower extremities, current affections of lumbo-ischias, arthroses, metatarsalgias, calcaneodynias or other similar one-sided pains, which could be thought to be the cause of disturbing, or affecting, a spontaneous pattern of standing, thus formed contra-indication for participating in the investigation. The interrogation to disclose such affections frequently demanded psychological insight and caution so as not to reveal the real meaning of the investigation. The interrogation was therefore given a natural insertion as anamnesis in that clinical investigation which was made on each subject.

During this investigation an attempt was made to find out the handedness of each subject as accurately as possible. The handedness acknowledged by the subject was verified by inquiry and, when necessary, confirmed by testing according to Trankell's scale of impulses.

Simultaneously a comparison was made between the right and the left hand on the degree of existing "thumb-syndrome" and, if any difference existed, the degree of difference was registered.

By "thumb-syndrome" is meant the diminished degree of extension in the metacarpo-phalangeal joint of the thumb.

It is to be observed that it is a question only of comparison between right and left. An equal extent of this syndrome in the right and the left hand is thus recorded with an "equal" mark.

In the lower extremities a comparison was made between the degree of any existing syndrome of hallux valgus.

The estimation was made with the subject in a lying position without any load-pressure upon the feet.

As in the case of the hand, an "equal" mark may mean absence of this syndrome on the whole, or may mean that the same degree is to be found on each side.

A kind of graduating of the degree of those syndromes in hand and foot was made by using from one up to three plus, whereby the last designation was affixed to those showing the syndrome in a very marked degree.

However, no attempt was made to "press" the material upon the existence of such syndromes. Any uncertainty about dominance for one or the other side was recorded with an "equal" mark.

Finally, any measurable difference in the lengths of the two legs was registered.

The measurements were made with a tape, and as corresponding landmarks the anterior superior iliac spine and the lateral malleolus were chosen, between which points measurement was made. These points were chosen as being considered, even in corpulent individuals, most easy to delimit palpably. However, I wish to declare that I am fully aware of the very inexactitude of the method, as it is easy to embrace many sources of error. The only justification for its use is that, as far as I know, no better method is to be found for practical use "in the field", and that in the cases in question all measurements were executed by one and the same person.

The distributions of ages, weights and heights in this part of the material are presented in figs. 5—7.

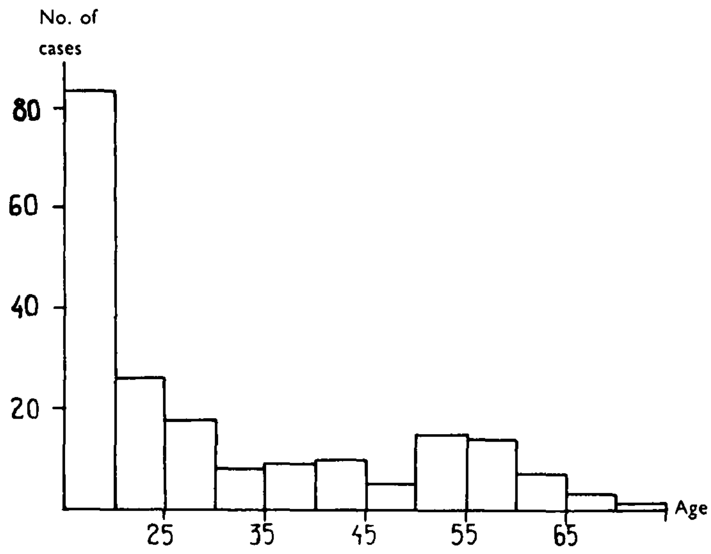


Fig. 5. Distribution of age.

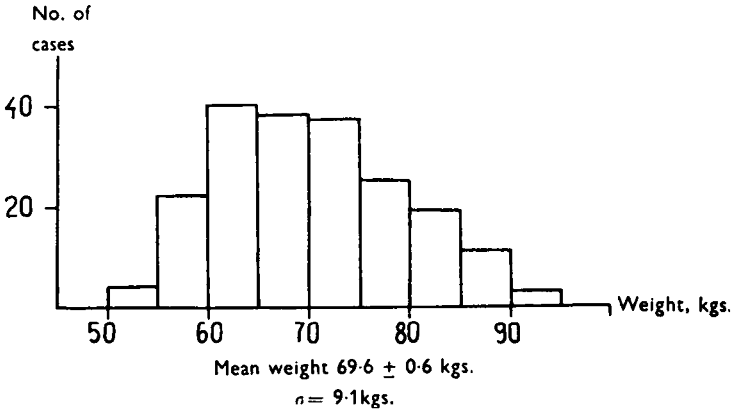


Fig. 6. Distribution of weight.

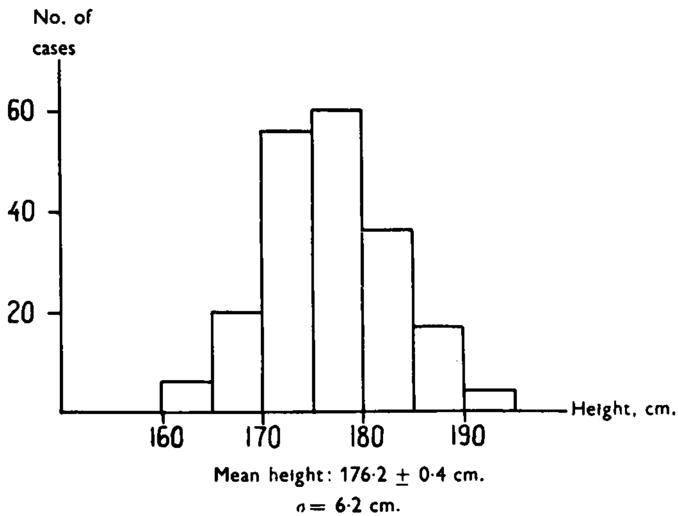


Fig. 7. Distribution of height.

The *median of the age-distribution* is 23·1 years with a range from 15 to 72 years.

The *mean weight* is 69·6 ± 0·6 kgs. with a standard deviation of 9·1 kgs.

The *mean height* is 176·2 ± 0·4 cm. with a standard deviation of 6·2 cm.

Part II consisted of 132 subjects, divided into 66 pairs. In each pair one was right-handed, and the other left-handed.

These were gathered from various sections of society; some were pupils at a marine school, others at grammar schools, and, finally, some were apprentices at a trade school.

In the cadre of the right-handers none was enrolled in whom near relationship to left-handers could be detected, and none was enrolled who was left-footed.

As in the case of the first part of the material, all of the subjects were examined clinically, and the same conditions concerning the absence of disorders or complaints in the lower extremities were required as was the case in the first section.

Just as was the case for the first part of the material, the handedness of the subjects was confirmed as carefully as possible and along the same lines as mentioned above.

The degree of left-handedness was graded on a scale, according to Trankell's scale of impulses. One point was given for each manifestation of left-handedness. "Full hand" was given 9 points. As the best co-ordinated foot was also recorded, estimated as the one used for a penalty kick in foot-ball, and scored one point, the highest degree of "left-manifestations"—as far as could be judged—scored 10 points.

The nine behaviours tested, and the performance of which with the left hand was interpreted as a manifestation of left-handedness, were:

1. Writing—the hand holding the pen.
2. Sawing—the hand holding the saw.
3. Nailing—the hand holding the hammer.
4. Screwing—the hand holding the screw-driver.
5. Cutting—the hand holding the pair of scissors.
6. Filling a glass of water—the hand holding the carafe.
7. Striking a match on a friction-surface—the hand holding the match.
8. Throwing darts at a target—the hand holding the dart.
9. Shovelling, *e.g.* coal through the door of a furnace—the hand highest on the handle of the shovel.

Any existing stigmata of increased function or increased pressure in either of the hands or either of the feet respectively were registered, as well as the degree of same, and any measurable difference in lengths of the two legs was also recorded.

The distributions of *ages, weights* and *heights* of the two groups, right-handers and left-handers, hereafter referred to as "R" and "L" respectively, are seen in figs. 8—10, and the statistics are presented in tables 2—4. The figures and tables indicate that as to means and dispersions of ages, weights and heights the two groups are so uniformly chosen as can reasonably be demanded.

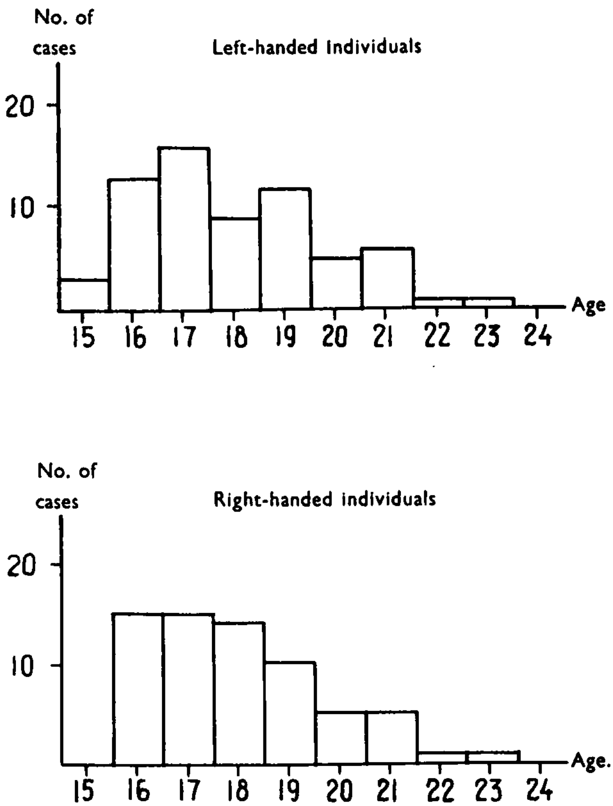


Fig. 8. Distribution of age.

Table 2.

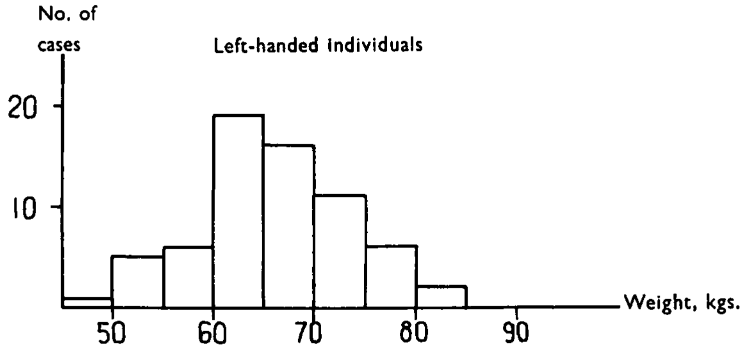
	L	R
Median	17·2 yrs.	17·2 yrs.
Range	15—23	16—23

Table 3.

	L	R
Mean	65·2 ± 1·2 kgs.	64·7 ± 1·0 kgs.
Standard deviation	7·9 kgs.	7·8 kgs.

Table 4.

	L	R
Mean	176·2 ± 0·7 cm.	177·7 ± 0·7 cm.
Standard deviation	5·9 cm.	5·9 cm.



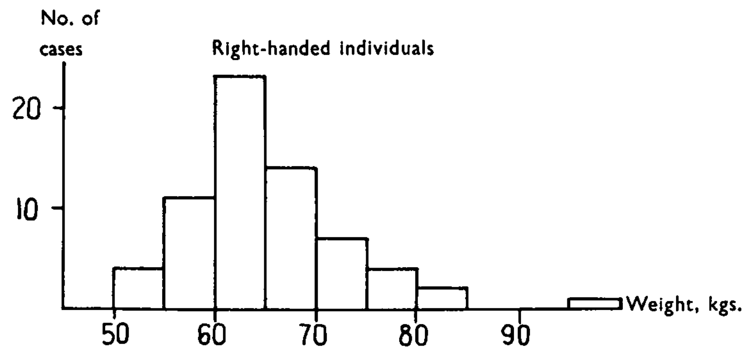


Fig. 9. Distribution of weight.

The members of the professional group were working under normal conditions. During the whole period of the test the persons in question carried out work for which they were paid, frequently piece-work, and any reduction in working output could not be noticed.

Necessary care was taken to withold from those examined the real purpose of the experiment, and it was strictly forbidden to use the words "right" and "left" during the concurrent conversation.

On the other hand, everything was done to carry out the experiment in the environment to which the workers coming under the examination were accustomed, in order to avoid engendering some "new" or "made-up" action from the worker's side, which could have been thought to affect the individual manner of standing or standing-pattern.

The work was carried out on unobstructed floor-space, well illuminated from

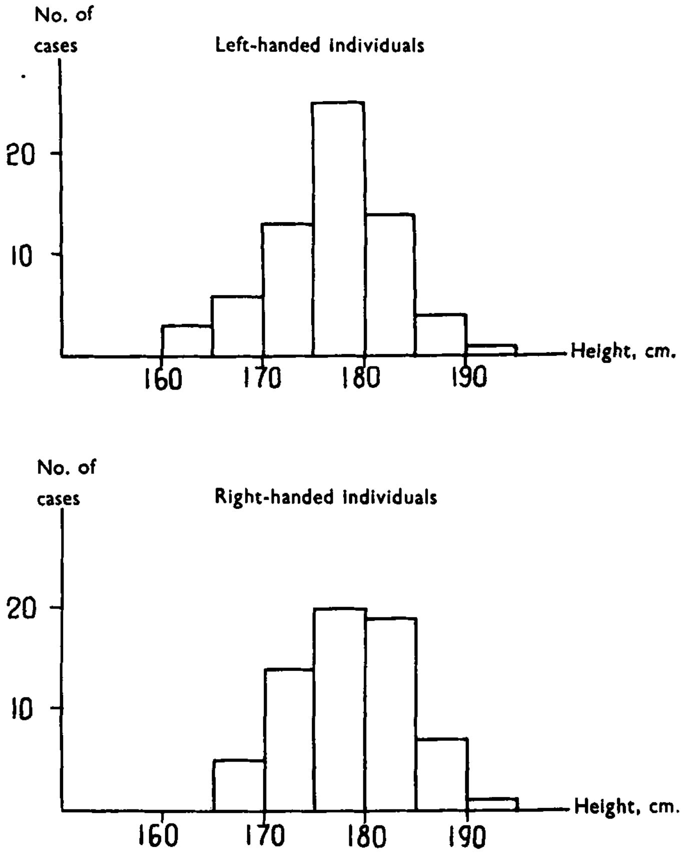


Fig. 10. Distribution of height.

all sides, and, in the main, the object worked upon was directly in front of the worker, with the possibility for the latter, according to spontaneous predisposition, to move the body to the right or left and to use either the right or the left hand.

As a rule, the working act was executed with hands not engaged in any other way, *e.g.*, by a grip on a handle or a similar object, as, on *a priori* grounds, it would be otherwise possible to assume that the worker in question will adopt a certain course of action, irrespective of the spontaneous tendency to use the right or the left arm, and further it also is to be expected that his equilibrium will be secured just by means of such a grip.

After some time elapsed to allow the individual to get familiar with the slippers and the portable part of the apparatus, the experiment was started.

Readings were made from the calculating mechanisms every 10 minutes, so that the whole time of observation was divided into six periods.

The time taken for the experiments in this group was one hour.

The other group executed a prearranged working-test, thus performing absolutely identical work during exactly the same time and under local conditions as similar for all as could possibly be arranged.

Each of the subjects was engaged, in a standing position, in putting plates, perforated with three or four holes, each orientated to just fit on a single group of vertical spikes, congruent with the holes in the plate.

The test was selected bearing in mind the drawing-forth of the hand of preference.

No attempt was made, however, to force the right-handers to use their right hand exclusively or the left-handers their left, as it was thought to be most rational to leave to the individuals themselves the distribution of the work between the two hands. Just as the right-handers in certain situations of the working act took to their left hand, so the left-handers did with their right—only to a greater degree—without warranting the justification of their nomination as left-handers being set in doubt.

The time taken for the experiments in this group was 20 minutes, divided into two periods of 10 minutes each.

Statistical note. Before presenting the results, a brief comment is here made on the statistical methods employed.

The statistical treatment generally follows the principles of variance analysis (*vide e.g.* SNEDECOR: Statistical Analysis, Iowa State College Press, Iowa, 1950).

Through partitioning of the total variation into separate components, estimates of "between-individuals" dispersion and "within-individual" dispersion were accomplished. The analysis of correlation was based on the method of least squares. The statistical comparison of more than two variances was carried out by means of Bartlett's test. Chi-square analysis was applied to some frequency-comparisons.

Without exception the methods used are elementary, and is was considered unnecessary to present any formulae.

The statistical interpretation of the results is discussed in each paragraph.

RESULTS

The results from the statistical treatment of the main investigations are presented in two parts.

The first part deals with the compositors' series, the second with those of the two groups, right-handers and left-handers.

The following calculations were made for each of the three series:

a. Medians of the distribution of the total load, signs ignored.
b. Mean-values and dispersions of the M.L.D.'s.
c. Possible connection between certain clinical observations and the mean-values. In part II a special score-test of the degree of left-handedness is attached to this question.

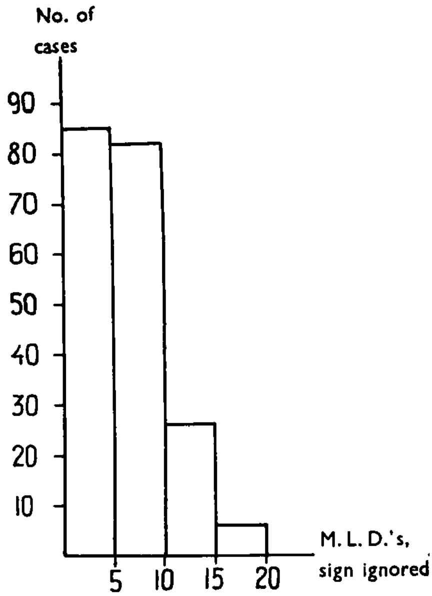
The total set of data from the 199 test-subjects was arranged in rows (individuals) and columns (time-periods) in such a way that the mean of each row is an unbiased estimate of the individual's mean-value and the mean of each column is an unbiased estimate of the time-period mean in question. Furthermore in this design the dispersions of the row-means and the column-means can be estimated separately and compared with the remaining variation. The dispersion of the row-means denotes the "between-individuals" variation *i.e.*, the test-subject's average deviation from the population mean. The dispersion of the column-means, if significantly larger than can be explained by random variation, has interest in so far as it calls attention to any possible tendency among the column-means to decrease or increase as a token of some exogeneous influence, or as a manifestation of a systematic error of method.

A third cause of the total variation is the "within-individual" dispersion, *i.e.* the variation from time-period to time-period as far as only one individual is concerned. This dispersion has an important bearing on the possibility of determining the reliability of the mean for the test-subject in question. In the present paper it may also be looked upon as a measure of stability.

PART I

a. The *median* was estimated in kilogrammes from the M.L.D.'s, without giving consideration to which of the feet had been the one most loaded. It expresses the degree of unevenness in standing for the group, and refers to the situation after 1 hour (fig. 11).

b. The *mean of the M.L.D.'s* (in the following as well as in other means of groups designated M.M.L.D.) was found to be minus 4·54 ± 0·21 kgs. with standard deviations as below (table 5).



Median 5·91 kgs.

Fig. 11. Distribution of M.L.D., sign ignored.

Table 5.

M.M.L.D.	—4·54 ± 0·21 kgs.
Standard deviation between individuals	5·40 kgs.
Standard deviation within individual	5·00 kgs.
Standard deviation between time-periods	0·81 kg.

The total mean is significantly less than zero ($p < 0{\cdot}001^{xxx}$). The means of the time-periods (fig. 12) differ significantly more than can be explained by random variation ($p < 0{\cdot}001^{xxx}$).

The distribution of the individual means is graphically presented in fig. 13. Zero is here chosen as class-mark, and the figure demonstrates clearly the left-sided over-representation. With the class-intervals used, the distribution seems considerably skew. If the total mean, minus 4·54 kgs., is taken as reference-

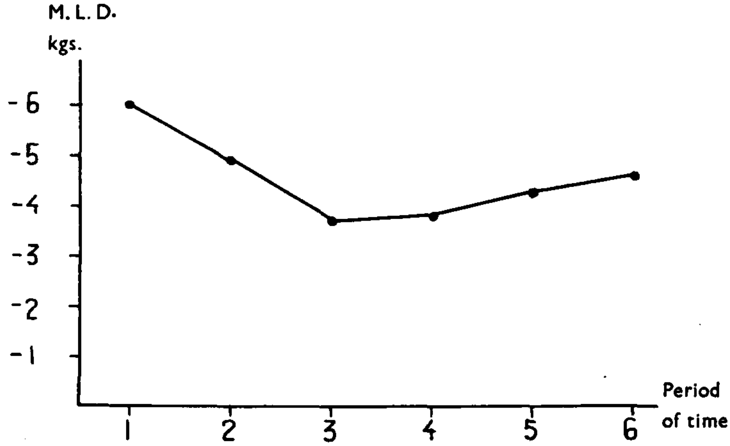


Fig. 12. Mean of time-periods.

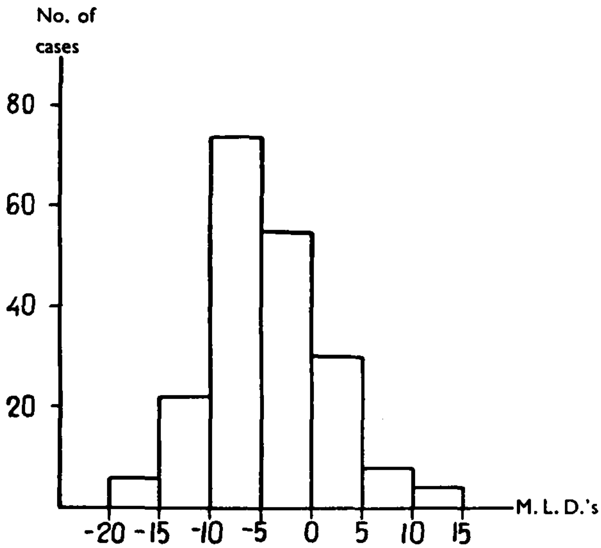


Fig. 13. Distribution of M.L.D. about zero.

point, and the standard deviation between individuals, 5·40 kgs., is used as class-interval, the distribution is shown to be normal (fig. 14).

The distribution of standard deviation within individual is presented in fig. 15.

Age, weight, and *height* were investigated (with the aid of correlation analysis) as to any possible influence of these factors on the M.L.D. as well as upon the within-individual standard deviation. The findings were all negative, which is well in accordance with the graphical studies made upon the small group previously referred to, the results of which are presented on p. 22.

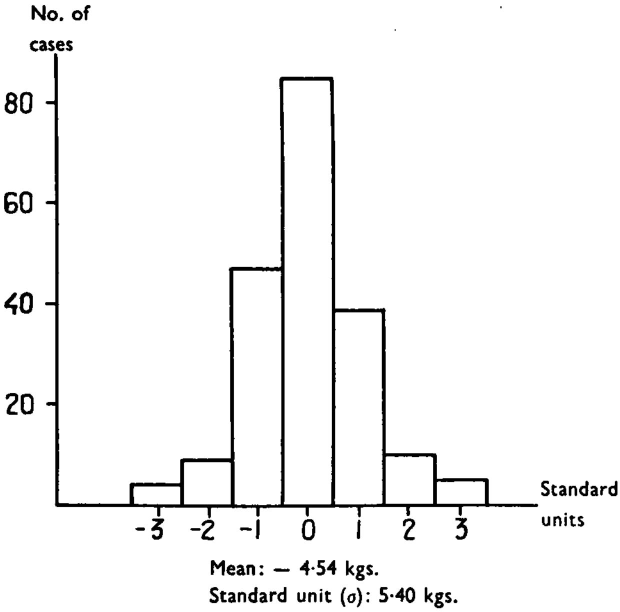


Fig. 14. Distribution of M.L.D. about the mean.

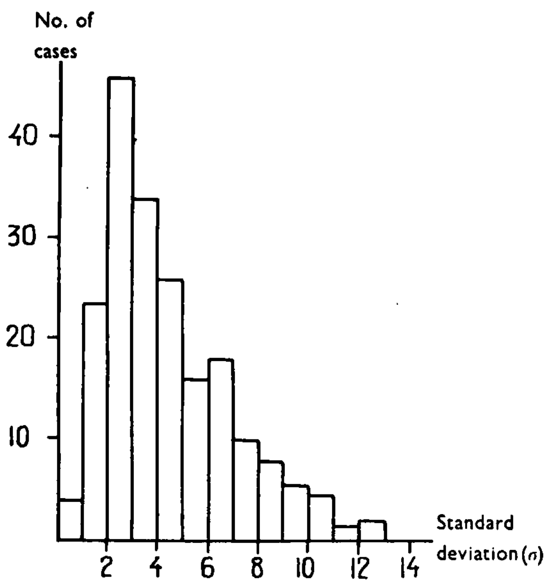


Fig. 15. Distribution of standard deviation within individual.

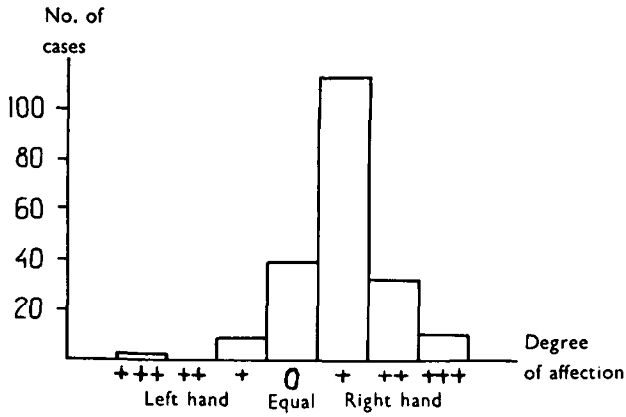


Fig. 16. Distribution of hand-syndrome ("thumb-syndrome").

c. The distribution of the *hand-syndrome* is to be seen in fig. 16.

Out of 197 subjects examined, 8 (4%) showed predominance of the syndrome on the left hand, while 152 (77%) showed predominance of it on the right hand. The right-dominance is significant ($p < 0 \cdot 001^{xxx}$).

In table 6 the pooled mean-values for each side are given.

Table 6.

	No. of cases	M.M.L.D.
Predominance of syndrome on left hand	8	—2·23
„ „ „ „ right „	152	—4·51

The statistical analysis shows no significant difference between the group-means ($p > 0 \cdot 2$).

The distribution of the *foot-syndrome* is presented in fig. 17.

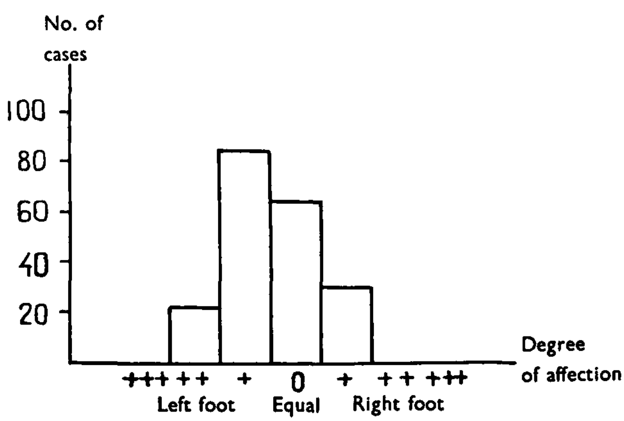


Fig. 17. Distribution of foot-syndrome (hallux valgus).

Out of 199 subjects examined, 135 (68%) showed a difference in manifestation of the hallux valgus syndrome on both feet to a degree sufficient to make possible a distinction as to predominance of side.

The right foot was the "leading" in 29 subjects (15%), and the left in 106 (53%). The left-dominance is significant ($p < 0 \cdot 001^{xxx}$).

Table 7 gives the mean-values for each side of predominance. A graduating of the syndrome on the left foot in "marked" and "slight" has been made.

Table 7.

		No. of cases	M.M.L.D.
Predominance of syndrome on left foot	Marked	22	—6·18
	Slight	84	—4·66
„ „ „ „ right „		29	—4·19

The statistical analysis gives no significance ($p > 0 \cdot 2$).

The *difference in length* between right and left leg is distributed as shown in fig. 18.

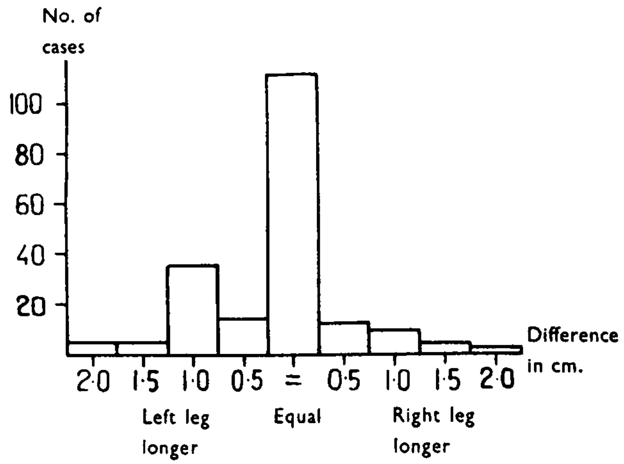


Fig. 18. Distribution of difference in length between left and right leg.

Out of 197 cases examined, 59 (30%) had a longer left leg, while 27 (14%) had a longer right leg. The left-sided dominance is significant. The pooled means are shown in table 8.

Table 8.

	No. of cases	M.M.L.D.
Left leg longer	59	—3·62
Equal	111	—4·82
Right leg longer	27	—5·27

The statistical analysis gives no significance ($p > 0 \cdot 2$).

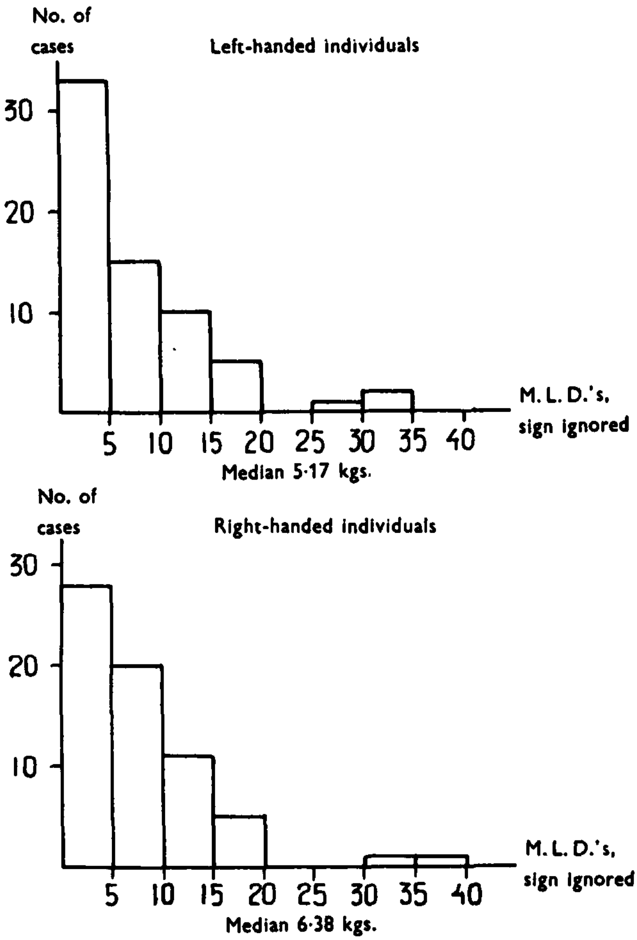


Fig. 19. Distribution of M.L.D., sign ignored.

PART II

a. The *medians* of the distribution of the M.L.D.'s in kgs. (sign ignored) are for the left-handed group 5·17, and for the right-handed group 6·38 (fig. 19).
b. The *mean-values* and *dispersions* of the M.L.D.'s are presented in table 9.

Table 9.

	L	R
M.M.L.D.	—0·95 ± 1·06 kgs.	—3·68 ± 0·91 kgs.
Standard deviation between individuals	7·30 kgs.	8·11 kgs.
Standard deviation within individual	9·73 kgs.	6·62 kgs.

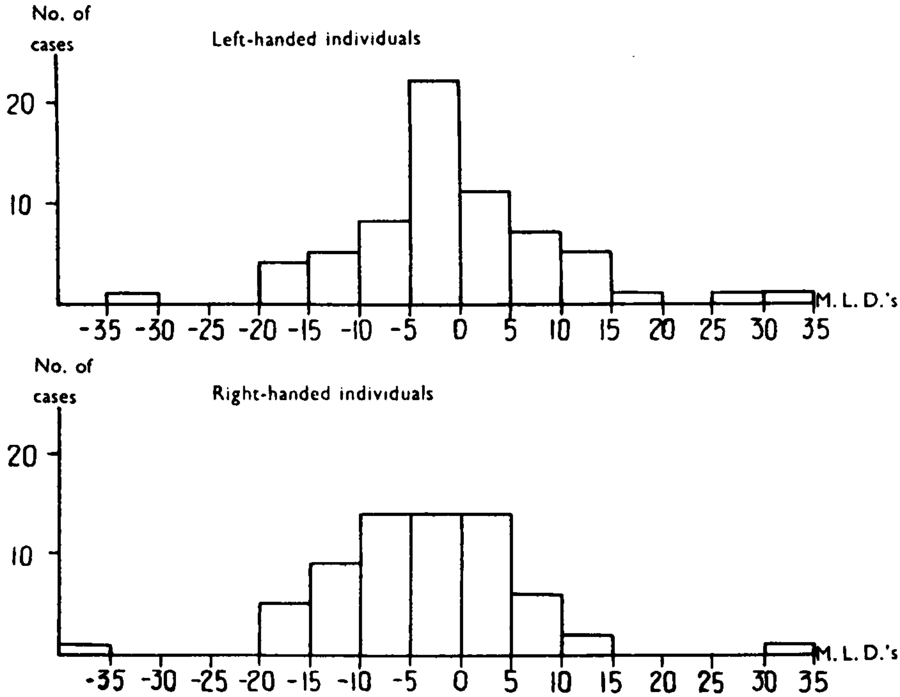


Fig. 20. Distribution of M.L.D. about zero.

The M.M.L.D. of the left-handed individuals is not significantly different from zero ($p > 0 \cdot 2$), while the M.M.L.D. of the right-handed group is statistically less than zero ($p < 0 \cdot 001^{xxx}$).

The dispersion within the individuals is significantly larger in group L than in group R ($p < 0 \cdot 001^{xxx}$), which circumstance may be of interest as a token of less stability among the left-handed individuals.

The means of the two time-periods do not differ significantly in either group ($p > 0 \cdot 2$).

The distribution of the individuals' M.L.D.'s is shown in fig. 20. The disparity is greater in these test-series than in the compositor series. This is quite natural, however, as the individuals' difference-means are based on a shorter period of time.

The distribution of the standard deviation within individual is more spread in these series and most markedly for the left-handed individuals (fig. 21).

In this part of the material also, *weight* was found to have no influence upon the M.L.D.

c. The distribution of the *hand-syndrome* is given in fig. 22. Out of 66 right-handed test-subjects examined, only 2 (3%) showed predominance of that

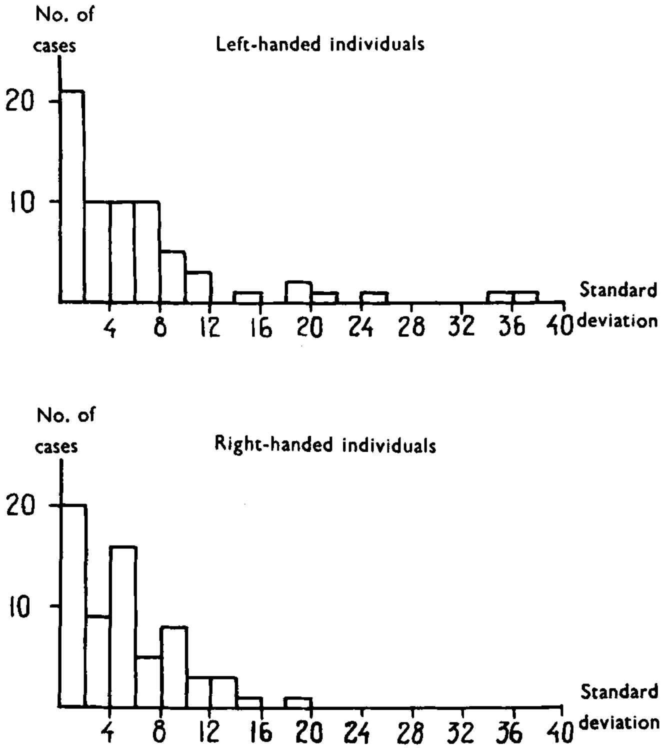


Fig. 21. Distribution of standard deviation within individual.

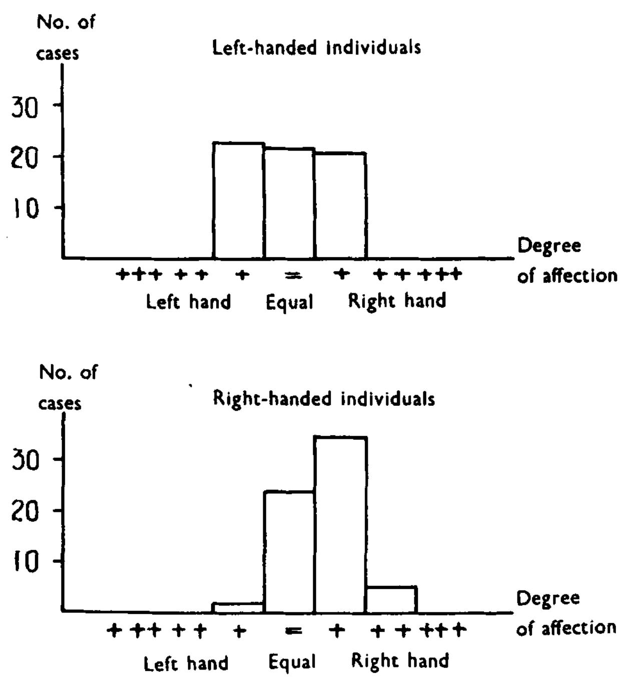


Fig. 22. Distribution of hand-syndrome ("thumb-syndrome").

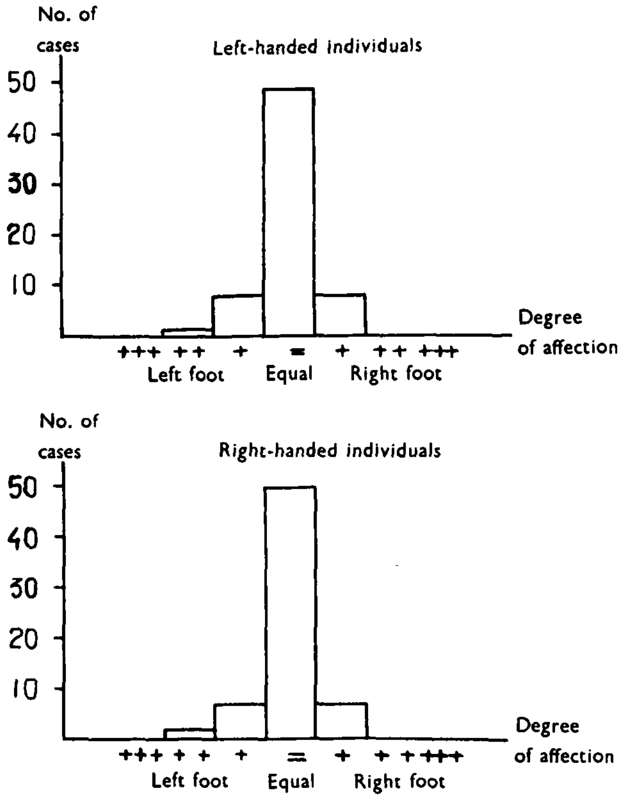


Fig. 23. Distribution of foot-syndrome (hallux valgus).

syndrome on the left hand, while 40 (61%) showed predominance on the right hand. This right-handed dominance is significant ($p < 0\cdot001^{xxx}$). Out of 66 left-handed individuals, 23 (35%) revealed the syndrome more markedly left than right, the contrary being the fact in the case of 21 individuals (32%). The discrepancy between side-dominance of syndromes in the right-handed and in the left-handed group is significant ($p < 0\cdot001^{xxx}$).

The pooled mean-values for each side are given in table 10.

Table 10.

	L		R	
	No. of cases	M.M.L.D.	No. of cases	M.M.L.D.
Predominance of syndrome on left hand	23	—2·92	2	+3·52
„ „ „ „ right „	21	+0·18	40	—2·63

In neither the L nor the R group are the M.M.L.D.'s significantly different ($p > 0\cdot2$).

The distribution of the *foot-syndrome* is presented in fig. 23.

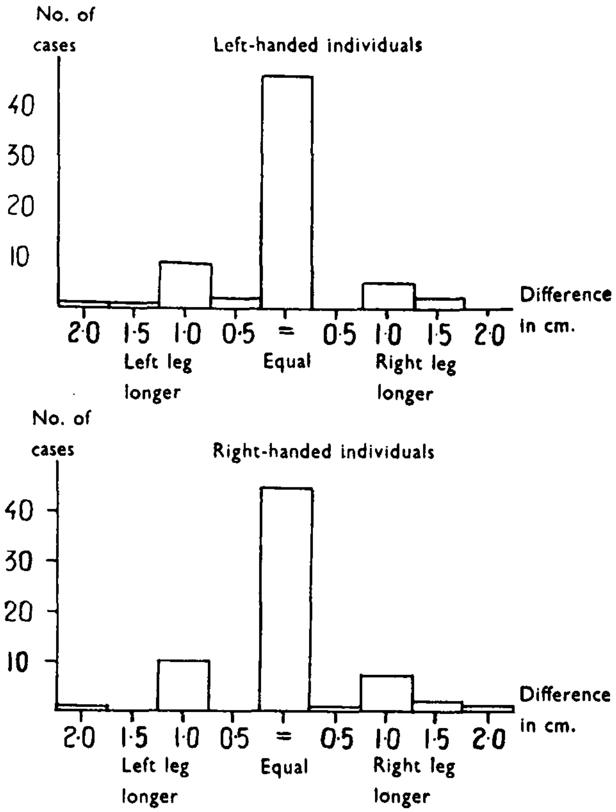


Fig. 24. Distribution of difference in length between left and right leg.

In both the L and the R group the percentages of dominating syndromes on the left and right foot are alike, and are approximately 12.

The M.M.L.D.'s are given in table 11.

Table 11.

	L		R	
	No. of cases	M.M.L.D.	No. of cases	M.M.L.D.
Predominance of syndrome on left foot	9	—4·67	9	—10·09
„ „ „ „ right „	8	+2·80	7	—1·51

In neither the L nor the R group are the M.M.L.D.'s significantly different ($p > 0 \cdot 2$).

The distribution of the *difference in length* between the right and the left leg is presented in fig. 24. There is no significant difference in either group ($p > 0 \cdot 2$).

The pooled group-means are given in table 12.

Table 12.

	L		R	
	No. of cases	M.M.L.D.	No. of cases	M.M.L.D.
Left leg longer	13	—0·17	11	—6·26
Right leg longer	7	+1·38	11	—6·23

In neither the L nor the R group are the M.M.L.D.'s significantly different (p> 0·2).

As previously mentioned, a system of *scoring* was undertaken as to the degree of left-handedness in the L group.

The individuals who used their left hand as the writing-hand were separated from the rest, and the M.M.L.D. was computed on the two groups obtained.

Out of 66 subjects, 34 (52%) used their left hand for writing (fig. 25). The M.M.L.D. for this group was plus 0·72 against minus 2·73 for the other individuals. The within-individual dispersion was by and large the same for the two groups, 10·4 and 8·97 kgs. respectively.

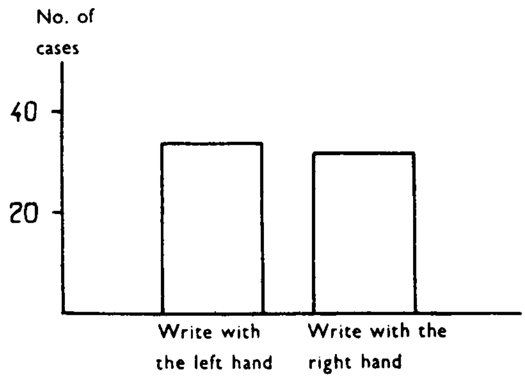


Fig. 25. Distribution of "writing" hand.

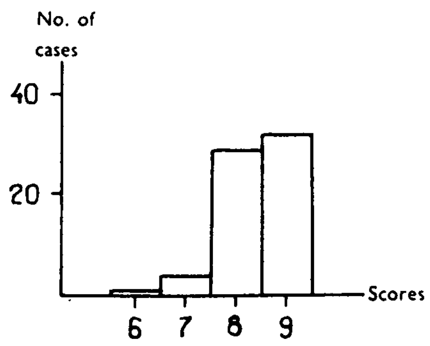


Fig. 26. Distribution of scores of "left-manifestations".

Neither difference was statistically significant (p> 0·2).
The distribution of the scores are presented in fig. 26.
The M.M.L.D.'s and the within-individual dispersions can be seen in table 13.

Table 13.

Scores	No. of cases	M.M.L.D.	Standard deviation within individual
6—7	5	—9·01	4·79
8	29	—1·51	10·15
9	32	+0·81	9·91

No significance could be noted (p> 0·2).
In the score-test the dominant foot was recorded.

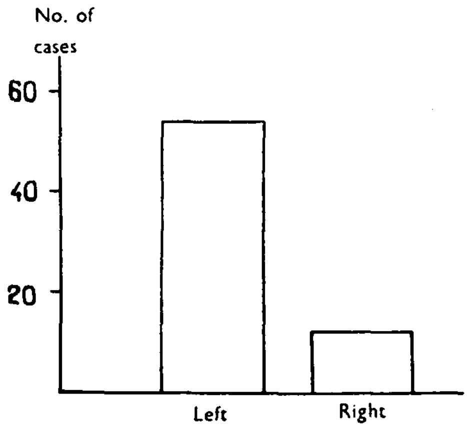


Fig. 27. Distribution of "dominant foot".

It was considered that in 82% of the left-handed individuals the left foot was predominant (fig. 27).

The M.M.L.D. for these subjects, minus 0·18, was not significantly different from minus 4·45, representing that for the remaining group (p> 0·2).

DISCUSSION OF RESULTS

A detailed analysis of what actually happens during a test-period would demand a graphical study of each individual's manner of standing, as was the case with the six persons whose curves have been previously commented upon (p. 22). For practical reasons such a graphical study was not possible.

To a certain extent, however, this delimits the possibilities of penetrating the problem. For example, the M.L.D. of each individual gives no information as to the ranges within which the greater pressure on one foot or the other has varied. This information could be of interest as it would show the real steadiness or stability in the standing of the individual in question.

An equal loading of the two feet would demand a symmetrical arrangement of the two halves of the body around a supposed line, representing the vertical projection of the centre of gravity. It is obvious that such a condition is hardly ever realised when people are working in a standing position. This investigation has also shown that an uneven distribution of the total load is registered in all of the test-groups. As the distribution of the algebraic values of the M.L.D.'s is extremely skewed, the medians are more representative than the arithmetical means (figs. 11 and 19).

The question as to whether the mean greater pressure has a tendency to be bound to one foot more than to the other, and, if this is the case, which factors influence this distribution, would, however, be more interesting. In part I of the material the total mean is significantly less than zero. With the electrical connection used in the apparatus it constitutes a statistical proof that the left leg balances the greater part of the sustained load-pressure. The same is the case for the right-handed group of part II.

For the left-handed group the total mean is not significantly different from zero.

The magnitudes of the M.M.L.D.'s in each group are:

In part I: minus $4 \cdot 54 \pm 0 \cdot 21$ kgs.

In the right-handed group (part II): minus $3 \cdot 68 \pm 0 \cdot 91$ kgs.

In the left-handed group (part II): minus $0 \cdot 95 \pm 1 \cdot 06$ kgs.

There is no great difference between the means of the right-handers in either part I or part II. The mean of the left-handed group is very near zero.

From these figures it will be seen that people coming under experimental conditions as outlined above, have a tendency to load the left leg more than the right. The difference is not so great, expressing the mean greater pressure during one hour and during twenty minutes respectively, which is to say that one leg has, during this period, received a greater average pressure, expressed by those values in kilogrammes.

During a day of work at the same ratio, however, the total sum of greater pressure on the one leg in comparison with the other would be quite large, and during a longer period of time this greater loading cannot be ignored. It would not, of course, be correct to draw from a single test any definite conclusions as to the standing behaviour so far as the distribution of the total load between the two feet is concerned, but one is led to fear that to a large extent the test has reflected the usual manner of standing during actual work.

As seen in fig. 12 the difference of the time-period means is somewhat larger in the beginning of the experiments. The cause of this cannot be faulty registering by the apparatus. As part I of the material consists to an overwhelming degree of right-handers, the pattern of standing for this group can, on the whole, be considered to be representative of persons showing right-handed activity. The investigation has shown that persons working with the right hand have a marked tendency to use their left foot as the supporting foot. From a psychological point of view it is not surprising, then, that the test-subjects in the beginning of the experiments showed greater time-period means. The new situation with which they were confronted made them disclose their pattern of standing in the most original manner. During such conditions it seems only natural and significative that, in the beginning, the new burden with which they were loaded was counterbalanced to the greater extent over the left leg. Later on during the test, when the person had been accustomed to the haversack, the load-pressure was more equally distributed between the two feet. One could expect that if part I of the material had consisted of persons working with the left hand, one should have got a curve being the reflection of that presented in fig. 12.

It is reasonable to think that a certain degree of unevenness in the distribution of the total load-pressure between the feet is to be found in all standing-patterns. It seems on the other hand very likely that the kind of work, and the manner in which it is performed, must have a deciding influence upon both the selection of the standing-leg and upon the magnitude of the load-difference. It may be questioned whether, in spite of all efforts to get a group of workers representative for non-restrained working-positions, the manner of work during this investigation, as far as part I of the material is concerned, has not yet been such as to force the subjects under investigation into certain positions. The result would then have been that all in the group, both right-handers and left-handers, would have been bound to take up a given working-position, identical for all of them. This would explain the relative uniformity of the results as regards the selecting of the standing-leg.

To argue against such a reasoning, the eight left-handers and the three ambidextrous individuals in part I of the material were taken separately as a group, and their M.M.L.D. was computed. (I think that it can be considered on rather good grounds that the three ambidextrous individuals are, primarily, left-handers). From the remaining part of the material 11 right-handers were then taken, each of them being the subject coming immediately before or after the left-handed or ambidextrous individual in question during the investigation carried on, and their M.M.L.D. was also computed. On the figures thus obtained a statistical analysis was made. The M.M.L.D. of the left-handed plus ambidextrous group was minus $0{\cdot}14 \pm 2{\cdot}01$, without statistical significance from zero, against minus $4{\cdot}25 \pm 1{\cdot}43$, showing statistical significance on the negative side ($p < 0{\cdot}05$). This gives a difference of $4{\cdot}11 \pm 2{\cdot}47$ between the two groups, without significance, but, however, with a strong conformity, in the two parts of the material, as to difference in the pattern of standing between right-handers and left-handers.

As regards the magnitude of the load-difference, this is seen to be greater among right-handers than among left-handers. The greater "within-individual" dispersion, as well as the greater "between-individuals" dispersion, in the left-handed group of part II of the material, as compared with those of the right-handed, may be interpreted as pointing to less stability, bearing witness to a greater heterogenity and complexity in the left-handers' pattern of standing on the whole.

What is, then, the cause of the general greater loading of the left leg? As has already been stated, there is a difference between the right-handers and the left-handers; the mean of the former being statistically different from zero on the negative side, that of the latter being very near zero, without statistical significance above or below, but becoming more displaced towards the positive side as the degree of manifestation of left-handedness increases (table 13).

For most people there is a great difference in functional ability between the right and the left hand, the hand of preference being the one best co-ordinated, in the case of right-handers the right hand, and in the case of left-handers the left. As regards the feet, there are not the same high-qualitative demands, as in most situations the best co-ordinated foot is not required, and the supporting function, if dominated by one or the other of the feet, in many cases can be furnished as well by either of them. It is when a person is working in a standing position that conditions, governed by principles of statics and dynamics, are first established, which conditions may demand consideration as being guiding factors in determining which of the feet should be chosen as the standing-foot. It is therefore not to be wondered at that, when persons are observed standing idly, no difference is to be noted between the feet as to frequency and duration of either being used as the standing-foot.

It seems, thus, that the use of the right or left hand by the individual in question has a bearing influence upon the selecting of the standing-foot; those working with the right hand being more inclined to use the left foot for that purpose and those working with the left hand more inclined to use the right foot. Right-hand workers forming the majority, the result is that most use the left foot as the standing-foot. As regards the left-handers, their standing habits are not so fixed. During 20 minutes they showed a rather even standing in the final result.

Judging from the results, the assumption of a crossed adjustment arm—leg therefore finds support. The cause of this fact seems to be that basic principles of statics and dynamics act in favour of using the contra-lateral leg as the standing-leg. The most stable equilibrium—doubtless of fundamental importance when working in a standing position—is then achieved by establishing a diagonal adjustment between arm and leg.

As there is, as a rule, a homolateral conjunction between the best co-ordinated hand and foot, also, by this arrangement, the best co-ordinated foot gets free for more qualitative requirements.

As an explanation to the circumstance that the left-handers have got a mean-value without significance on either side of zero, I assume that this is due to the fact that they have been working as more or less temporary right-handers during the test; or at least that they are accustomed to use their right hand in a rather high degree, so that force of habit has had an effect upon the final result. One may ask how and in what degree the left-handedness scored by the individuals in the group manifests itself in life in common with their right-handed fellow-beings. It must not be forgotten that the left-handers form a minority. It may be one thing to perform an isolated test-action as a spontaneous manifestation of left-handedness, and their behaviour thereby may be correct, but it is surely another case for this left-handed minority to live in a society controlled by, and adjusted to suit, right-handers.

As they get accustomed to meet right-handed activity from their fellow-men, and on the whole are reminded all the time of the manifestations of the right-handed-ruled world around them, they more and more adapt themselves to the behaviours of the majority (the right-handers), and so their pattern of standing cannot help being influenced by this overwhelming strain of the milieu.

Difference as to disparity in length of the two legs was found in part I of the material but the findings were not able to be verified in part II. In section I the left leg was found to be longer than the right and the difference is statistically significant.

As already mentioned, in neither of the sections was any correlation found between leg-length and standing-leg.

I view this question in the following manner:

The left leg in section I of this material has been shown to be longer than the right and it has also been shown that the left leg is the one most loaded.

This may mean that, owing to functional hypertrophy, the left leg is the longer because it has been more loaded than the right during a period of particularly intensive growth, but the fact that one leg is longer than the other does not justify its being designated as the standing-leg. One may even say that, in spite of the fact that one leg has surpassed the other in length, the individual still continues to use it as the standing-leg on account of, perhaps, handedness or habit. Tables 8 and 12 give, to some extent, support to such a reasoning.

Considering the points of view presented above, however, the relative uncertainty which is attached to the premise (the knowledge of the real difference in leg-length) must be stressed.

To sum up, the results obtained admit of only limited generalization.

This material has the restriction of referring only to those working "freely" and non-restrained as far as floor-space and working-position are concerned. This may be valid for a great many people, but it must also be said that for many workers in industry, for example, the working-position is anything but non-restrained. They may be more or less "anchored" at handles, or may have to stretch themselves very much to reach the working-object, perhaps at the same time getting support from it. In such positions it is natural that a right-handed individual, as well as, of course, a worker using the right hand, may use his right leg as the standing or supporting leg, and a left-hander his left leg. Even other requirements may be best satisfied by using the homo-lateral leg as the standing-leg.

One of the possibilities provided by the using of the contra-lateral leg as the standing-leg is the "unlocking" of the whole homo-lateral side, making co-operative bending and turning of that side more possible. But sometimes the contrary may be desirable: a "locking" of the homo-lateral side, *e.g.*, to attain more steadiness.

As posture in a high degree ought to be bound up with habit it seems most reasonable to assume that the selecting of the standing or supporting leg is not on all occasions controlled with regard to the act of balance. So "bad habits" may develop. A right-hander may continue to use his left leg as the standing leg even if there is no actual need for him to balance his body in just that way.

Consequently, the whole question cannot be answered easily by saying that right-handers use their left foot and left-handers their right as the standing foot. One may, however, say that there is a marked tendency to such a diagonal correlation. One is also justified in saying that left-handers disclose a much more marked tendency to use their right foot as the standing foot than do right-handers, and that they do it in a degree proportional to their "practical" manifestation of left-handedness.

In any case it may be said that the act of weight-bearing seems to be subject to basic principles of statics and dynamics, even if many factors may disturb and upset them.

The last subject of investigation in this study was the question: Does handedness manifest itself in any way clinically in the hand of preference or in the one most used, and does the foot actually most loaded, judged from the test, show any sign of having been also previously more loaded than the other?

As assumed criteria of such a hyperfunction I have considered what I have called the "thumb-syndrome" in the hand, *i.e.* any diminished degree of extension in the metacarpo-phalangeal joint of the thumb in comparison with that of the other thumb, and in the foot a more marked syndrome of hallux valgus, comparing the two feet with each other.

One may criticize the method of collecting the material, as it is based on estimations where subjectivity, it is feared, will influence. The estimations were, however, made by one and the same person, and great caution was taken not to "press" the material upon any existence of difference. Any uncertainty as to dominance of side was registered with an "equal".

There are, however, certain restrictions as regards the existence of the syndromes on the whole and, especially, as regards the possibility of correctly connecting the magnitude of the same in hand or foot to the degree of hyper-function. The possibility of estimating difference to such a degree as permits of registration regarding dominance of side, is to a certain extent connected with a special constitutional type of the subject in question, his age and profession.

The importance of the two last-named factors appears clearly in part II of the material, which, to a large degree, was chosen from younger, and partly non-manual-working people. The number of "equals" is here very great.

The constitutional type plays a rôle inasmuch as the "thumb-syndrome" and the syndrome of hallux valgus reveal themselves most markedly in hypotone individuals.

Such individuals, owing to diminished tone in all their soft tissues, often disclose to a very high degree ability to over-stretch their joints. On account of this loss of stability such a joint is more prone to the development of a hallux valgus deformity, or of a marked "thumb-syndrome", the latter being most clearly demonstrated in hypotone individuals, who are at the same time hard-manual-working people.

It is significative that in the left-handed group in part II of the material there is hardly any difference in the number of those showing dominance of the "thumb-syndrome" right and that of those showing it left. This circumstance must be interpreted as an expression of a high degree of right-handed activity among the left-handers. Even if they perform an isolated test-action as genuine left-handers they, to a great extent (surely much greater than they themselves are aware), use their right hand in common life. It must also not be forgotten that there are left-handers who are conscious of the fact that their behaviours differ from those of the majority, and try to conceal that fact.

The assumption presented that dominance of the "thumb-syndrome" is a manifestation of hyper-function of the hand most used, finds support in so far as handedness or working-hand is well reflected by clinical findings.

An attempt to correlate the hand which discloses predominance of "thumb-syndrome" with the algebraic value of M.L.D., gives no statistical significance, but the analyses presented in tables 6 and 10 give support to the assumption that to a certain degree a diagonal adjustment exists between working-hand and standing-foot, concerning subjects maintaining an upright position. As regards the syndrome of hallux valgus, there is not the same conformity between side-dominance and actual value of M.L.D.

The negative mean-value of the M.L.D.'s of the individuals showing predominance of hallux valgus on the right foot may seem contradictory to the assumption that hallux valgus is a pressure syndrome. One might suspect the apparatus of incorrectness, or one might suppose that the author's opinion of the genesis of hallux valgus is wrong. As the objectivity of the apparatus on *a priori* grounds must be left out of the discussion, it remains to examine the latter alternative. If, in the material, the frequency of the side of dominance of the syndrome is registered, a statistically significant difference between right and left foot is obtained, favouring the latter. As side-dominance coincides with most-used standing-foot, the most simple explanation seems to the author that the first is an effect of the latter. A certain trend indicating connection between predominance of hallux valgus and actual value of M.L.D. is also expressed by the values in tables 7 and 11.

I am inclined to find the most reasonable explanation of the lack of conformity between syndrome-dominance and M.L.D.-value in the fact that the apparatus of course only indicates the *actual* standing-foot, *i.e.* the one in the mean most loaded during the test-period. There are reasons to assume that, as a rule, for the majority of people, owing to influence of habit, this foot preferably is used, and, which is most essential in this connection, also *has* been the one most used previously for standing by the individual in question. But there may be exceptions to the rule and it cannot be justified from a single test, as far as a few members of a group are concerned, to draw any definite conclusions in one or the other direction as to their most used standing-foot. To answer that question, the clinical findings, according to my opinion, must be given greater importance than a single test; or, at least, the two findings, the M.L.D.-value obtained from the apparatus and the clinical observation, must be thoroughly weighed against each other. An iterated test is already more valuable than a single one, but it must be kept in mind that the kind of work surely has a decided influence upon the individual's manner of distributing the total load between the feet. It may be interesting to note that of the individuals disclosing lack of conformity between apparatus-value and registered syndrome-dominance, many belonged to the higher ages. It is clear that work previously executed by them, and the working-positions taken up thereby, have had the opportunity of operating during a longer period of life, thus forming "mixed" and somewhat embarrassing syndromes, without relevance to the actual manner of work or standing-pattern of the individuals in question. Of course it must also be admitted that it cannot be stated dogmatically that the syndrome of hallux valgus must have its genesis in pressure on the foot during a rather long period of time. Comparatively "silent" attacks of rheumatoid arthritis may disturb the peri-articular stability and muscular balance in the joint, slightly, but sufficiently to contribute to the development of a hallux valgus. The person in question may feel, *e.g.* in connection with a sore throat, some vague discomfort from the joints, perhaps stiffness in the morning in some finger-joints, or tenderness in one of the feet. Without really being aware of it he begins to avoid using that foot, which he has previously used as the standing-foot, and begins to use the other foot for this purpose to a greater degree than he did formerly. The result may be that a syndrome of hallux valgus will be recorded most markedly on the foot which actually it not the standing-foot. The magnitude of the syndrome will also be without proportional relevance to formerly sustained greater pressure on that foot. Such cases are most difficult to disclose anamnestically, as the persons may be in good faith when they negate every sort of earlier disorder in the foot.

An attempt has been made to ascertain the degree of genuineness of the handedness of the left-handers by means of a score-test according to Trankell's scale of impulses, and also by registering their writing-hand and their dominant foot. The degree of handedness thus obtained seems to reflect itself in the standing-pattern of the individual in question. The findings give support to the theory of a crossed correlation hand—foot (pp. 43—44 and table 13).

CONCLUSIONS

It must be accepted from both a physical as well as a physiological point of view that the most desirable and optimal conditions regarding weight-bearing in an upright position are realized when the total load-pressure is distributed as evenly as possible between the two feet.

This study has shown that a more or less uneven distribution of the load-pressure exists in the sense that one of the feet is subjected to more pressure than the other—a fact that may seem quite natural concerning persons working in an upright position.

The harmful effect of this uneven standing would be negligible in practice if one could assume that the greater pressure over the one foot during, say, half a working day were, so to say, neutralized by an equal greater pressure over the other foot during the other half of the working day. But the findings in this paper argue against the existence of such desirable, intermittent conditions.

The investigation has shown clearly that handedness is a most guiding factor as far as the individual's selection of standing-foot is concerned, and also that the feet of most adult manual workers usually show syndromes, the existence of which must be interpreted as a sign of pressure. The dominance of that syndrome on one side thus indicates a greater pressure on that side.

These syndromes can be classified as definite deformities and a rather long period of time is as a rule necessary for their development. The unevenness in the act of standing and the greater pressure on the one foot must therefore have had the possibility of being effective over a long period. As the choice of standing-leg seems to be induced by principles of statics and dynamics (a diagonal adjustment being preferred), and as most people are right-handed, the result is that in most persons the left foot sustains more load-pressure than the right.

A sort of regularization would consequently be expected if people could be induced to show a more left-sided activity. In practice this is, of course, only possible to a limited degree, and the realization of the thought will always be associated with Utopian cogitation. Some realistic points of view are, however, worth calling attention to.

In planning factories, workshops, etc., as well as in the location of machines and tools, and also in their construction, it seems well to keep in mind, more than at present is the case, that those who are to work in such factories and who are to use such tools etc., should not be forced into a fixed position. The person in question should have the possibility of changing feet, or taking to the other hand, so that the normal reflex answer upon exhaustion is not consciously restrained or delayed. If the working act is performed under local conditions where the individuals are not bound (or in any case not markedly bound) to take up a certain position, it seems advisable to point out for the right-handers the presumable tendency they have to load their left foot more than the right.

In conversation with older men during the investigation among typography workers it was interesting to hear that they sought to impress upon apprentices the importance of standing in such a manner as to ensure as far as possible even distribution of the weight of the body between the two feet. To this end the apprentices were recommended to stand with the legs wide apart, and not to allow a large portion of the body-weight to fall on one leg or the other. Long experience had shown the older ones that such a working-position was the least tiring.

The results reported in this paper could well have the effect of bringing about a degree of surrender in the fight for good standing-habits. There is, however, reason to hope that if the problem is more focused, and if attention and interest is given to it from various sections of society, propaganda for sensible standing habits can bear fruit.

Of course it should not be forgotten that if the same work can be performed as effectively in a sitting as in a standing position, the former should be adopted. At least the importance of changing the working position should be pointed out.

As to the interpretation given to the existence of predominance of the syndrome of hallux valgus as being an expression of increased function (*i.e.*, when referring to the lower extremities, increased pressure on the side in question where the syndrome is more marked), I wish to conclude: Predominance of hallux valgus seems on the whole to be a greater-load-pressure syndrome, though, owing to the fact that its magnitude is created not only by the amount of pressure sustained, but also by the easiness with which the deformity is developed (constitutional laxity being a predisposing factor), there is, of course, no quantitative correlation between the degree of the syndrome and the load-difference in question. There are also some sources of error as concerns the connection of the syndrome with the actual, more-loaded side. The picture may be clouded by injuries to one of the lower extremities during some period of life, as well as by diseases affecting the connective tissue, *e.g.* rheumatoid arthritis affecting one foot more than the other. The necessity of thoroughly penetrating the anamnesis must be kept in mind.

As to connection between leg-length and standing-leg, the fact that one leg is longer or shorter than the other (the difference being within the ranges generally met, 0·5—2 centimetres, and being compensated biologically only by tilting down of the pelvis or by some equinism of the foot) does not seem to determine the individual's choice of one of them as the standing-leg (tables 8 and 12). Other factors, first and foremost handedness and habit, ought thereby to be of much more guiding importance.

On the whole, the pattern of standing ought to have in its composition a mosaic structure: personality, influence from environment, and habit (the last two factors often being very intricate and difficult to trace and analyze) forming elements in it. This is in full agreement with the fact, well-known to all psychiatrists, that posture, of which standing is a part, reflects in a high degree the psychic condition and mood of the individual.

SUMMARY

Weight-distribution upon the lower extremities in persons working in a standing position was studied on the one hand among a professional group of 199 compositors in the typography trade, and on the other hand in a test-group of 132 individuals, in pairs, one of the pair being right-handed, the other left-handed. Only men were concerned.

Measurements were made by means of an apparatus by which, using a slipper-like arrangement under the shoes, the load-pressure was caught according to the principles of resistive transducers—strain-gauges—being components in a Wheatstone-bridge, which bridge is balanced when the right and the left foot sustain an equal load-pressure. The non-balance output A.C. voltage from the bridge is proportional to the difference in load-pressure between the right and the left foot and is converted into another A.C. voltage, the frequency of which deviates from its nominal value proportionally to the difference in load-pressure between the feet. This A.C.voltage feeds a counter, counting the number of cycles received during the testing time. Another counter is fed with a voltage of fixed frequency, being equal to that of the first counter when the bridge is balanced. The counters can be started or stopped simultaneously. The difference between them then gives the amount of load-pressure-difference existing during a fixed period of time.

The investigation refers only to test-subjects working, in the main, freely and non-restrained with regard to floor-space and working-position.

It has been shown that handedness has a decided influence upon the individual's manner of weight-distribution, *i.e.* upon his selection of the standing or supporting leg. The contra-lateral leg as a rule being preferred as the standing-leg, suggests that its selection is induced from static principles because, as a rule, the most stable equilibrium is achieved by a crossed, diagonal adjustment of forces. Thus right-handers are inclined to use their left leg as the standing or supporting leg.

The left-handers' pattern of standing is more complex, owing to the surmise that they in practice use their left hand less exclusively, but are more apt to take to sometimes the left, sometimes the right hand, whereas right-handers disclose a more one-sided motor activity in corresponding situations. Thus the stress from the environment to which the left-handers are subject seems to be reflected also in their pattern of standing. Surely as a consequence of the

supposition that they in practice share the use of their left and right hands more equally than do right-handers, they have, as a group in this material, shown a mean of their mean-load-pressure differences between the feet equal to zero.

Clinical stigmata of increased function are to be found, as a rule, in the hand most used and in the foot most loaded.

The stigmata referred to by the author are, in the hand the "thumb-syndrome", and in the foot the syndrome of hallux valgus.

The former syndrome means (the hand is thought to be held pronated) an angulation of the thumb in its basal joint with the angle open laterally, *i.e.* in a minor or higher degree of flexion, having induced, in course of time, a diminished degree of extension in the metacarpo-phalangeal joint of the thumb. The mechanism of its origin bears, in all probability, close relationship to that of hallux valgus. Between handedness and stigma of hyperfunction of the hand of preference there is a stronger correlation than between the most loaded foot, as registered by the apparatus, and stigma of hyperfunction of that foot. The qualitative demands upon the upper extremities are in most circumstances much higher than upon the lower ones. Even if, as a rule, a diagonal conjunction hand—foot seems to be preferred by individuals working in a standing position, preponderance of the supporting function is not infrequently taken up by the homo-lateral foot.

It is hoped that constructors of machines and tools, as well as all those connected in any way with industrial medicine, will pay more interest and attention to the importance the working-position has to sensible standing habits, created, first of all, by the possibility of evenly distributing the load-pressure between the two feet. To this possibility a higher degree of option in the use of the right or left hand seems to be a prerequisite.

Everything that in practice facilitates a shift from right to left, or *vice versa,* concerning both arms and legs, should therefore be favoured.

RÉSUMÉ

La répartition du poids sur les extrémités inférieures chez les personnes travaillant dans la position debout a été étudiée d'une part dans un groupe professionnel de 199 typographes, d'autre part dans un groupe-test de 132 personnes, par séries de deux sujets, un droitier et un gaucher.

Les mesures ont été faites à l'aide d'un appareil dans lequel, des dispositifs spéciaux semblables à des pantoufles étant placés sous les chaussures, la pression résultant du poids supporté pouvait être mesurée selon le principe des transducteurs résistifs ou jauges de contrainte, composantes d'un pont de Wheatstone. Ce pont se trouve compensé lorsque le pied droit et le pied gauche supportent une pression égale. La tension du courant alternatif non compensé à la sortie du pont est proportionnelle à la différence de la pression résultant du poids supporté par le pied droit et le pied gauche. Cette tension est convertie en une autre tension de courant alternatif dont la fréquence dévie de sa valeur nominale proportionnellement à la différence de la pression supportée par chacun des pieds. Ce courant alternatif alimente un compteur qui enregistre le nombre de périodes reçues pendant la durée du test. Un autre compteur est alimenté par une tension de fréquence fixée qui est égale à celle du premier compteur quand le pont est compensé. Les compteurs peuvent être mis en marche ou arrêtés simultanément. La différence entre ces deux compteurs donne ainsi le total de la différence de pression résultant du poids supporté pendant une période donnée.

L'expérience se rapporte principalement seulement à des sujets travaillant sans qu'il leur soit en général imposé de restriction ni de contrainte en ce qui concerne la surface de plancher et la position de travail.

Il a été montré que l'adoption d'une main préférentielle a une influence marquée sur la répartition individuelle du poids, c'est-à-dire sur le choix de la jambe d'appui ou d'aplomb. La jambe contra-latérale est en principe préférée comme jambe d'appui, ce qui indiquerait que cette sélection se fait sous l'influence de principes statiques parce que, en règle générale, l'équilibre le plus stable est obtenu par un ajustement diagonal ou croisé des forces. Les droitiers sont donc inclinés à utiliser leur jambe gauche comme jambe d'appui.

Le type de position debout des gauchers est plus complexe du fait que, dans la pratique, ils utilisent moins exclusivement leur main gauche, mais sont plus aptes à se servir parfois de la main gauche, parfois de la main droite, tandis que chez les droitiers placés dans des situations correspondantes, l'activité motrice

apparaît comme plus unilatérale. Ainsi, l'influence du milieu environnant subie par les gauchers semble se retrouver aussi dans le type de position debout qu'ils adoptent. On suppose qu'ils répartissent en principe l'utilisation de leur main gauche et de leur main droite plus également que les droitiers, et c'est sans doute en conséquence de ce fait que le groupe des gauchers donne, dans ce matériel, une moyenne des différences de pression supportée par chacun des pieds égale à zéro.

Les stigmates cliniques d'hyperfonction se trouvent en général dans la main la plus utilisée et dans le pied le plus chargé.

Les stigmates mentionnés par l'auteur sont, pour la main, le syndrome du pouce, et pour le pied, le syndrome du hallux valgus.

Dans le premier syndrome, la main étant supposée en position de pronation, il y a un angle du pouce à son articulation de base, par rapport à l'angle ouvert latéralement, c'est-à-dire dans un degré de flexion plus grand ou moindre, ce qui entraîne ultérieurement un degré moindre de l'extension de l'articulation métacarpo-phalangienne du pouce. Le mécanisme de l'origine de ce syndrome est, selon toute probabilité, en relation étroite avec celle du hallux valgus.

Entre la main préférentielle et le stigmate d'hyperfonction de cette main de préférence, il y a une plus forte corrélation qu'entre le pied le plus chargé, d'après les enregistrements de l'appareil, et les stigmates d'hyperfonction de ce pied. Les demandes qualitatives sont dans la plupart des circonstances beaucoup plus élevées pour les extrémités supérieures que pour les extrémités inférieures. Même si, en règle générale, une conjonction diagonale main-pied semble être préférée par les individus travaillant dans la position debout, il n'est pas rare que la prépondérance de la fonction de support appartienne au pied homolatéral.

On espère que les constructeurs de machines et d'outils, aussi bien que tous ceux qui ont des rapports quelconques avec la médecine du travail, voudront bien montrer plus d'intérêt et porter plus d'attention à l'importance que la position de travail a pour l'adoption d'habitudes rationelles dans l'attitude debout, habitudes crées avant tout par la possibilité d'une égale distribution de la pression du poids entre les deux pieds. Pour qu'une telle possibilité existe, il semble qu'il doit y avoir, comme condition préalable, un plus grand degré de choix dans l'utilisation de la main droite ou de la main gauche.

Il faudrait donc favoriser tout ce qui, dans la pratique, facilite un changement de la droite à la gauche ou vice-versa, aussi bien pour les mains que pour les pieds.

ZUSAMMENFASSUNG

Die Verteilung des Belastungsdrucks auf die unteren Extremitäten bei im Stehen arbeitenden Personen wurde untersucht, einerseits in einer Berufsgruppe von 199 männlichen Typographen, Handsetzern, andrerseits in einer Testgruppe von 132 männlichen Individuen, die paarig in solcher Weise eingeteilt wurden, dass in jedem Paar einer Rechtshänder war, der andere Linkshänder.

Die Messungen wurden ausgeführt mit Hilfe eines auf die Prinzipen einer Wheatstone-Brücke gegründeten Apparats. In einer spezial-konstruierten Pantoffel-ähnlichen Anordnung für den rechten und linken Fuss, unter gewöhnliches Schuhwerk gespannt, wird der Unterschied des Belastungsdrucks gemessen durch je einen Dehungsmesstreifen. Diese Streifen bilden zwei Komponenten in der Wheatstone-Brücke. Die Brücke ist im Gleichgewicht, wenn der Belastungsdruck auf die beiden Füsse gleich verteilt ist. Jede Störung des Gleichgewichts wird als Variation der Frequenz eines verstärkten Wechselstroms aus der Brücke registriert. Die Frequenzvariation is dem Unterschied des Belastungsdrucks zwischen rechtem und linkem Fuss direkt proportional. Über einen Gleichrichter wird ein Gleichstrom genommen, dessen Zeichen den mehrbelasteten Fuss angibt. Dieser Gleichstrom "steuert" einen neuen Wechselstrom, von fester Frequenz bei ausbalancierter Brücke, in solcher Weise, dass die Frequenz sinkt oder steigt im Verhältnis zum Mehrdruck auf den linken, resp. rechten Fuss. Der Unterschied der Frequenz der ausbalancierten und der nicht ausbalancierten Brücke, der mit Hilfe zwei elektronischer Rechenwerke registriert wird (von denen der eine die Perioden bei ausbalancierter Brücke zählt), ist ein Mass des Mehrdrucks auf den linken bzw. rechten Fuss.

Die Untersuchung hat, unter Berücksichtigung gewisser versuchsmässiger Einschränkungen: freier Arbeitsstellung und freien Bodenraums, gezeigt, dass die Wahl des Standbeins in enger Beziehung steht zu der von dem Individuum am meisten benutzten Hand. Das kontra-laterale Bein wird in der Regel als Standbein bevorzugt, was vermuten lässt, dass die Wahl von statischen Rücksichten bedingt ist, weil das stabilste Gleichgewicht erreicht wird durch eine gekreuzte, diagonale Anordnung der Kräfte hinsichtlich Arm—Bein. So sind die Rechtshänder mehr geneigt, das linke Bein als Standbein zu benutzen.

Das Stehschema der Linkshänder ist komplizierter, was darauf beruhen dürfte, dass sie in der Praxis nicht so einseitig wie die meisten Rechtshänder betreffs der Wahl der Hand arbeiten, sondern mehr die Arbeit auf beide Hände verteilen. Hier dürfte der Einfluss von der Umgebung sich geltend gemacht haben. Die gleichmässigere Verteilung der Arbeitshand der Linkshänder spiegelt sich, aller Wahrscheinlichkeit nach, in dem Durchschnittswert des Belastungsunterschieds zwischen linkem und rechtem Fuss, den sie als Gruppe in diesem Material gezeigt haben: er liegt nämlich sehr nahe Null.

Die mehr benutzte Hand wie der mehr benutzte Fuss weisen in der Regel klinische Zeichen gesteigerter Beanspruchung auf.

Als solche Zeichen erwähnt der Verf. bezüglich der Hand das "Daumen-Syndrom" und bezüglich des Fusses das Syndrom des Hallux valgus. Unter "Daumen-Syndrom" wird verstanden (die Hand ist in Pronation gedacht) eine laterale Abwinklung im Grundgelenk des Daumens, d.h. eine mehr oder weniger ausgesprochene Flexion des letzteren, was im Laufe der Zeit einen verminderten Grad der Streckung bewirkt hat (Flexionskontraktur). Der Entstehungsmechanismus hat, aller Wahrscheinlichkeit nach, grosse Ähnlichkeit mit dem des Hallux valgus.

Im Material des Verf's ist die Korrelation stärker in den oberen als in den unteren Extremitäten betreffs wahrnehmbarer Zeichen einer Mehrfunktion und die vermutliche Ursache dazu: Rechts- bzw. Linkshändigkeit, resp. Mehrbelastung (die aktuelle aus dem Apparatwerte erhaltene). Die Erklärung dürfte die sein, dass die qualitativen Anforderungen an die oberen Extremitäten grösser sind als an die unteren, wenigstens, wenn wie in dieser Untersuchung nur die stützende Funktion der unteren Extremitäten untersucht wird. Die Untersuchung lässt vermuten, dass in der Regel eine gekreuzte Orientierung Hand—Fuss bevorzugt wird, wenn Personen aufrecht arbeiten, was natürlich nicht ausschliesst, dass manche Arbeitsstellungen es natürlicher machen, den homo-lateralen Fuss als Standfuss zu verwenden.

Es ist zu hoffen, dass Werkzeug- und Maschinenkonstrukteure, wie alle, die in irgendeiner Weise etwas mit Arbeitsmedizin zu tun haben, mehr Interesse und Aufmerksamkeit der Frage der Bedeutung der Arbeitsstellung zuwenden, indem geeignete Voraussetzungen für gute Stehgewohnheiten geschaffen werden. Hier scheint vor allem eine gleichmässigere Verteilung des Belastungsdrucks auf die beiden Füsse erstrebt werden zu müssen, was seinerseits einer gewissen Bedingung untergeordnet sein dürfte: der Möglichkeit der Wahl der rechten oder linken Hand.

Alles was diese Möglichkeit erleichtert betreffend sowohl die oberen als die unteren Extremitäten, sollte darum gefördert werden.

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