Upsala J Med Sci 91: 53–66, 1986

Perception of Efforts in Working Postures

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ABSTRACT

The aim of this study is to obtain an understanding of the subjective discomfort of working postures and the degree of physical effort these postures give rise to. 31 students have rated their perceived exertion on Borg´s scale (1982) based on a collection of photographs of different work postures of varying complexity, including a kinaesthetic description (2). Each one of the 78 postures was held for 45 seconds, with rated perceived exertion (RPE) given after 15, 30 and 45 seconds. The whole test series was repeated twice. The results show that it is possible to evaluate different body postures by RPE achieving a total reliability α-value over 0.96. Despite the fact that the rating pattern between the different postures was the same for all subjects, it is shown that each person assessed according to a certain individually-influenced pattern. A certain person can for example, deviate consistently towards higher values on Borg´s scale, a so-called "high rater". Finally, the different postures were grouped according to how the ratings changed in time (regression slope between the RPE´s after 15, 30 and 45 seconds). The third-cluster, which showed a high basic rating-level and the greatest regression slope, included only extreme outer limits of movement. This indicates that the outer limit postures have a tendency to static load and need to be studied by more additional methods when remaining unchanged even for short periods.

INTRODUCTION

The ability to adapt and freely maintain a body posture, e.g. a posture without external support always involves a certain degree of physical stress. The degree of stress differs of course from one posture to another. It is the weight of the different parts of the body, the so-called functional units (FU), and the energy required to make them move that causes the stress. This stress involves load on joints and muscles. As the torque around the joints changes, so does the perception of effort or discomfort.

When making an ergonomical evaluation of body postures occurring in physical work, in other words work postures, an anatomical/ physiological analysis should also be performed parallel to a psychological subjective assessment, to come as close as possible to a reliable "diagnosis" (8).

The aim of this study is to obtain an understanding of the subjective discomfort of working postures and the degree of physical effort these postures give rise to.

Carlsöö et al (2) have described different work postures from a kinaesthetic, that is anatomical physiological basis. They describe the characteristic features of the muscular activity around the joints. Each posture is illustrated by a split image picture.

In order to make the description sufficiently detailed while remaining at the same time easy to follow, the body was divided up on the basis of the great joints and joint-systems into 14 "functional units". The 14 FUs are: head/neck, back/trunk and 12 extremity FUs. Each extremity has been broken down into three parts. Each part covers one of the three major joints as well as the distal part, shoulder/upper arm, elbow/forearm and so on. It is these pictures of different postures for each FU which form the material for subjective evaluation of exertion in the present study.

Whatever ergonomic evaluation technique is adopted, the purpose is to obtain a quantitative and/or qualitative evaluation of even a complex posture. Questionnaires are commonly-used for work-postures e.g. in offices or motor vehicles. Laboratory construction of a replica of a work situation and biomechanical analysis is another, more objective method (3).

Man´s ability to grade and give verbal expression to the discomfort and stress experienced in different work postures has also been employed as an investigative method (10). Van Wely (10) has shown that a high degree of correlation exists between subjective perception of a work-posture and the complaints to which it gives rise. Work psychologist Gunnar Borg (1) showed that subjective perception can be quantified using a category scale with ratio properties. It is this method which has been used in the present study.

The scale used in the following tests consists of a limited range of numbers, 0-10. Different verbal expressions are correlated to the numbers. 0 represents nothing at all, 0.5 extremely weak, 1 very weak, 2 weak, 3 moderate, 4 somewhat strong, 5 strong, 7 very strong and 10 extremely strong.

The perceived exertion to which a posture gives rise, depends of course on whether the posture is momentary, forming part, for example, of a sequence of movements, or of longer duration (4). In the latter case, the isometric muscular load plays such a decisive and special role in the evaluation of the work posture that a special study such as Rohmert (9) suggests, would be necessary.

The study described below related only to momentarily-adopted postures of short duration. In a pilot study the postures were evaluated after 6 seconds. Whatever the results showed that the threshold of perception occurs later. Therefore evaluation was made after 15, 30 and 45 seconds.

MATERIAL AND METHODS

The subjects were 8 male students, aged 23-35 years and 20 female students aged 20-38 years from the Physiotherapy Department, University Hospital, Uppsala. None had any previous record of complaints of the muscular-skeletal system. The subjects were asked to take up and hold the various postures described in the previously mentioned collection of posture photographs.

Each posture was adopted from a symmetrical upright stance at rest, and compared with this stance. Though the lower extremities as well as the back are subject to stress due to the fact that the postural muscles are to some extent active in the upright stance, the healthy subject does not perceive this as stressful as long as the duration of the posture is limited to 45 seconds. The degree of exertion of the posture has therefore been graded 0 in the evaluation scale given above. The posture differs from the internationally-accepted anatomic posture only insofar as the arms hang free by the sides and are not, as in the anatomic posture, supined.

The postures the subjects were required to adopt are shown in figs. 2-9. These are 10 different head postures, 8 shoulder-arm postures, 12 elbow postures, 9 hand-wrist postures, 10 back-trunk postures, 12 hip postures, 13 knee postures and 5 foot postures. All 78 postures, were held unchanged for 45 seconds. So-called normal postures (for each FU) as well as mirror-image postures (crossed-out in figures 2, 3 and 6) were not rated. The subject evaluated the degree of exertion associated with each posture after 15, 30 and 45 seconds respectively. The RPE was rated according to the previously mentioned scale ad modum Borg (1). Before the tests began, each subject was carefully instructed in the various postures and had an opportunity to practise using the scale in different tests. In the first test an evaluation of the area of different geometrical surfaces was made. In the second test different shades of white and grey were evaluated. Taste tests were also performed using solutions of varying acidity. Finally the subjects were asked to demonstrate given percentage parts of their maximal strength of grip and back extension.

To prevent perception of one posture influencing evaluation of the next, there was constant variation between the functional units employed and of more and less stressful postures. The whole series was repeated twice.

RESULTS

An analysis of variance* was performed on the entire material, 78 body postures, 3 ratings (15, 30 and 45 sec.) and two repetitions of the entire test series for 31 subjects. The analysis showed that as expected, the ratings of the different postures varied significantly ($p<0.001$). Different observational times (15, 30 and 45 sec.) produced significantly varying results. That is: all ratings at 15 sec. had a trend dissimilar to the ratings at 30 and 45 sec. Analysis of the repetition of the entire test gave no significant difference between the two test series.

Table 1 gives the correlation coefficients, mean values, standard deviations and range (difference between highest and lowest values used on Borg´s scale) for each subject on the entire material.

Despite the fact that the rating pattern between the different postures was the same for all subjects, certain postures were rated high in relation to the others, and, conversely, it is shown that every person tended to assess according to a certain individually-influenced pattern. It is primarily true that certain persons tend either to deviate consistently toward lower or higher values, the so-called "high raters" and "low raters". For example, individual 4 had a mean (RPE) value of 0.52 and individual 26 a mean (RPE) value of 5.72 for the 45 second ratings (Table 1). Another type of personal deviation is the range covered by the estimater, that is, the difference between the highest and lowest ratings used. Here we find individuals who use the whole of the 10-point range and others

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*Data program BMDP8V: BMDP Biomedical Computer Programs. P-series, 1979. University of Califonia Press.

who try to keep within a limited part of the scale. For example, individual 24´s range was 10 and individuals 3 and 29 had a range 4 for the 45-second ratings (Table 1).

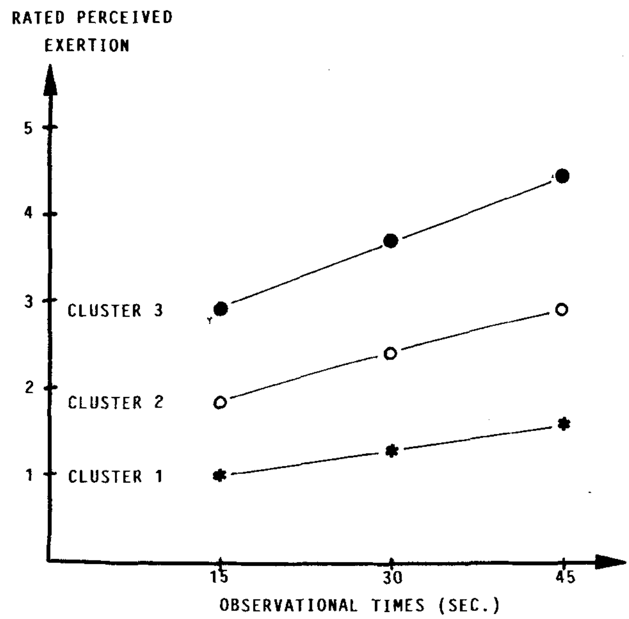
The ability of the individuals to repeat their ratings at exactly the same exposition was good. A collation of the correlation co-efficients at the three time intervals is presented in Table 1. This is complemented by an alfa-model reliability test (5, 6). 28 subjects with an α-value 0.96 or more were selected for further processing: 3 were dropped. The 3 who were dropped, individuals 2, 3 and 28, α - values 0.94 - 095), also had the lowest correlation co-efficients (Table 1). These three differed in their ratings of some situations, thereby demonstrating inability to perceive body postures.

An analysis was performed of 28 reliable individuals´ rating patterns, based on a classification of their total mean values over all the ratings (78 postures, 30 second ratings, repeated twice). After dividing the individuals (into three groups of equal size) according to low mean rating combined with low standard deviation (S.D.), intermediate mean rating/S.D. and high mean rating/S.D., an analysis of variance was performed on 6 persons in each of the three groups. The most important result to emerge from this analysis was that the three groups showed a non-significant difference in the trend of their rating-patterns.

The different postures were also grouped according to the rating change in time. A cluster analysis called MICKA using 3 groups (7) produced the best values and is presented in fig. 1. Cluster 3, which showed a high basic rating-level and as figure 1 indicates a great regression slope between 15, 30 and 45 seconds, included only extreme outer limits of movement, apart from two upper-arm postures at headlevel. Clusters 1 and 2 included less stressful postures. The above time-development tendencies indicating that the outer limit postures in figures 2-9 have a tendency to static load and need to be studied by other means when remaining unchanged even for short periods.

Table 1. Correlation coefficients between the two test series, mean values, standard deviation and range (difference between zero and highest values; all persons had 0 as lowest rating) for all 78 postures, 2 test series and 3 observation times (15, 30, 45 sec.). RPE-rated perceived exertion on Borg's scale. S.D. Standard deviation.

SUBJECT	CORRELATION COEFFICIENT			MEAN RPE			SD			RANGE		
	15	30	45	15	30	45	15	30	45	15	30	45
1	0.77	0.89	0.91	0.58	0.99	1.43	0.59	1.01	1.28	3.5	5.0	6.0
2	0.61	0.73	0.81	1.82	2.24	2.67	0.74	0.91	1.21	3.5	5.0	6.0
3	0.73	0.70	0.65	0.58	1.12	1.66	0.47	0.62	0.77	2.5	3.5	4.0
4	0.79	0.88	0.92	0.50	0.92	0.52	0.72	1.16	1.72	3.0	4.5	7.5
5	0.78	0.76	0.85	1.10	1.63	2.18	0.69	1.01	1.33	3.3	4.3	5.3
6	0.80	0.77	0.79	2.94	3.45	3.95	0.84	1.08	1.26	4.8	6.0	6.8
7	0.81	0.84	0.86	2.17	2.73	3.11	1.16	1.30	1.47	4.5	5.0	6.0
8	0.86	0.82	0.77	1.11	1.47	1.98	1.09	1.17	1.36	4.0	4.0	5.5
9	0.87	0.91	0.90	0.79	1.23	1.71	0.86	1.08	1.24	3.5	5.0	5.5
10	0.78	0.81	0.82	2.33	2.56	2.79	0.93	0.99	1.12	4.0	4.5	4.8
11	0.88	0.91	0.94	1.31	1.69	2.04	1.22	1.53	1.82	4.5	6.0	7.0
12	0.84	0.91	0.91	0.80	1.17	1.49	0.90	1.18	1.40	3.5	4.5	5.5
13	0.84	0.88	0.90	2.30	2.97	3.42	0.93	1.17	1.36	4.3	5.0	5.8
14	0.76	0.87	0.97	2.56	3.52	4.14	1.00	1.25	1.37	4.0	6.0	7.0
15	0.86	0.89	0.91	1.38	1.69	2.00	0.76	0.89	0.97	3.0	3.8	3.7
16	0.83	0.87	0.94	2.11	2.92	3.78	0.99	1.29	1.61	3.5	5.0	6.8
17	0.85	0.89	0.93	1.41	1.89	2.61	0.98	1.23	1.56	4.5	6.5	7.8
18	0.82	0.90	0.91	2.67	3.47	4.26	0.98	1.43	1.84	5.0	7.3	8.3
19	0.82	0.86	0.83	3.83	4.17	4.55	1.04	1.22	1.22	7.5	8.0	8.5
20	0.83	0.88	0.89	1.70	2.25	2.86	1.12	1.40	1.59	4.0	5.0	5.8
21	0.71	0.78	0.84	1.60	3.12	4.59	0.90	1.43	1.92	3.0	6.0	9.5
22	0.82	0.87	0.91	2.59	2.99	3.30	1.03	1.32	1.52	5.0	6.0	7.0
23	0.89	0.84	0.89	2.02	2.83	3.51	1.26	1.64	1.98	6.0	8.0	9.5
24	0.83	0.83	0.88	2.96	3.57	4.00	1.28	1.57	1.76	6.5	8.5	10.0
25	0.71	0.77	0.82	1.68	2.14	2.70	1.10	1.28	1.50	4.0	5.5	7.0
26	0.72	0.80	0.76	4.23	5.05	5.72	1.60	1.84	2.04	7.5	7.0	8.0
27	0.83	0.90	0.92	2.92	3.55	4.01	1.12	1.34	1.54	6.0	6.8	7.8
28	0.48	0.80	0.83	0.43	0.76	1.20	0.66	0.77	1.00	3.0	4.0	5.0
29	0.73	0.82	0.83	0.75	1.14	1.55	0.62	0.82	0.98	2.5	3.5	4.0
30	0.88	0.89	0.91	1.54	1.70	1.85	1.15	1.21	1.26	5.0	5.0	4.3
31	0.87	0.92	0.92	2.57	3.18	3.54	1.43	1.71	1.91	6.5	7.5	9.0



POSTURES INCLUDED IN:

CLUSTER 1	CLUSTER 2		CLUSTER 3
1.1.12	1.2.6	$8.1.4^{30}$	1.2.12
1.1.3	$1.1.1^{30}$	8.1.6	$1.2.1^{30}$
$1.1.4^{30}$	$2.1.4^{30}$	9.1.1	1.2.3
1.1.6	2.1.6	9.1.4	$1.2.4^{30}$
3.2.1	3.3.2	9.2.2	2.2.12
3.1.1	3.3.1	9.2.3	$2.2.1^{30}$
3.0.1	3.3.3	10.0.1	2.2.3
8.1.3	3.2.2	10.0.2	$2.2.4^{30}$
9.1.2	3.2.3	10.1.1	2.1.12
9.0.1	3.1.2	10.1.2	$2.1.1^{30}$
9.0.2	3.1.3	10.2.2	4.1.12
9.1.3	3.0.2	10.3.1	4.1.3
9.3.1	3.0.3	10.3.2	4.1.9
9.3.2	4.1.6	10.4.1	FINGER SUPPORT
9.3.3	WHOLE HAND SUPPORT	10.4.2	8.2.12
10.1.3	HALF HAND SUPPORT	10.4.3	$8.2.1^{30}$
	KNUCKLE SUPPORT	11.1.12	8.2.3
	FINGER TIP SUPPORT	11.1.3	$8.2.4^{30}$
	8.2.6	11.1.6	9.2.1
	8.3.6	11.0.1	10.2.1
	$8.1.1^{30}$		11.1.9

Fig. 1. Cluster analysis using 3 groups. The different postures are grouped following their time-development tendencies (RPE at 3 observation points, 15, 30 and 45 sec.). The postures included in each cluster are given after their code. The first number in each code relates to the functional unit, the second number to the stress level and the third to the position on a normal clock.

Lastly, the mean values for all postures after 30 seconds were filled in on the 8 position charts (fig. 2-9). Since the purpose was to assess "momentarily-adopted" postures, the 30 second rating was selected. The 15 second rating is regarded as being on the threshold of perception for the "light" postures, the threshold is probably passed at 30 seconds, and after 45 seconds there is a risk of static load, particularly in the case of extreme outer limit postures.

DISCUSSION

The present material shows that it is possible to evaluate different body postures by rated perceived exertion. New subjective-ratings should be obtained when using criteria of this nature on other homogeneous work-groups. The rating criteria which the authors feel is of general applicability is presented in a Guide for evaluation of body postures called Postures and loads (2).

The advantages are: Standardised, qualified ratings of different work-situations from the ergonomic point of view, without requiring the analyst to possess a qualified knowledge of anatomy, physiology and biomechanics.

The disadvantages are : A possible degree of inaccuracy in the ratings. For example, it is presumed, in analysing the posture of one extremity, that the other extremity is at rest: if this is not so, the stress is normally greater. It is further assumed that the body is standing upright. In other circumstances, bending forward for example, the stress on the head or the upper extremities is different. If the subject´s movement pattern is abnormal, for example as a result of diminished mobility in some part of the body or because the subject avoids certain postures as a result of injury or pain, errors may occur. Obviously there is also a possibility that a situation may be assessed incorrectly because the postures included cannot foresee every imaginable situation and the analyst has to select the picture that most closely resembles the posture.

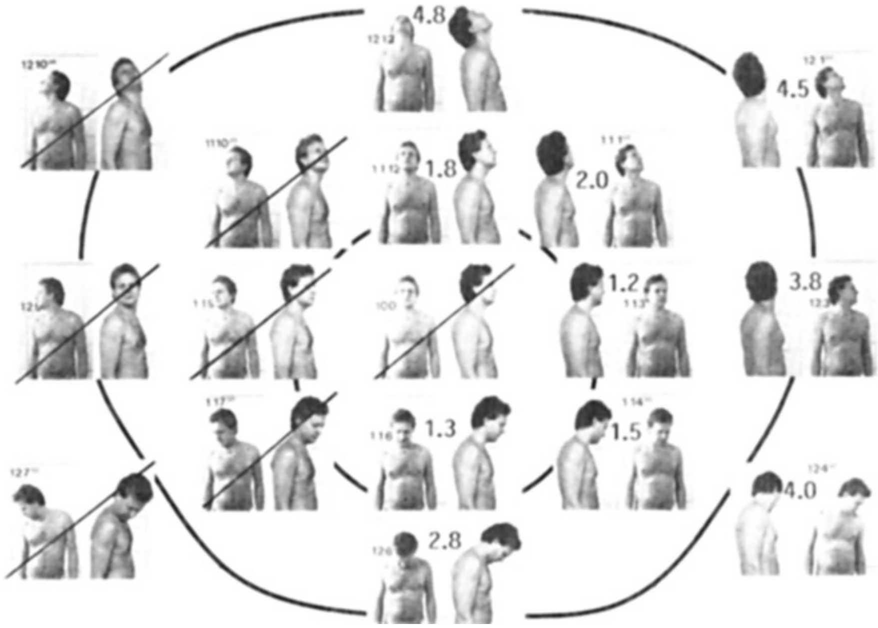


Fig. 2. Position chart showing the distribution of mean RPE on the head/neck. Each position is represented by a split picture showing the head from the front and from the side. Each picture has a code number, as well as a large number describing the mean RPE. The postures crossed out on the left, which are mirror-images of the ones on the right were not assessed. Neither was the normal position of rest.

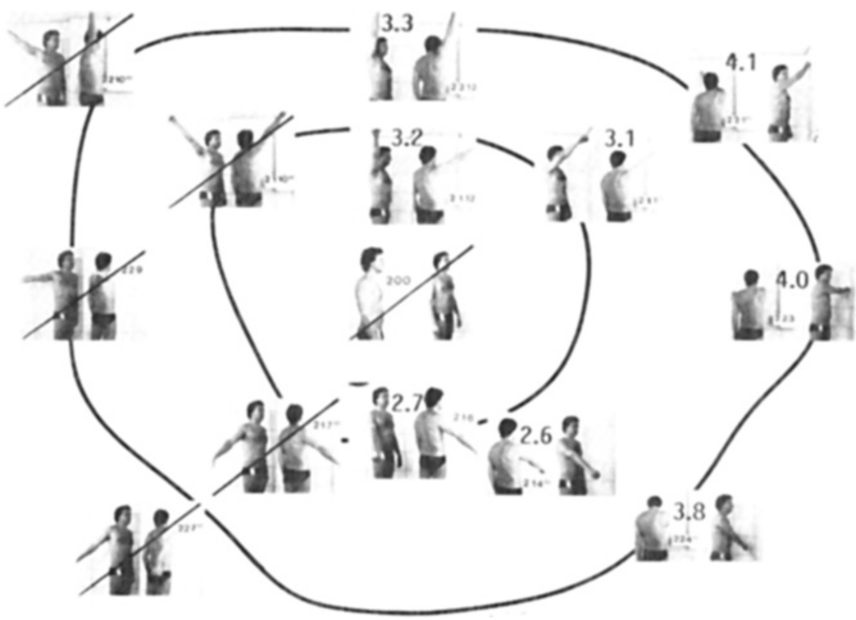


Fig. 3. Position chart showing the distribution of mean RPE on the shoulder/upper arm. The projections in each split picture are 45 of the frontal plane. The postures crossed out were not assessed for the same reasons as in figure 2.

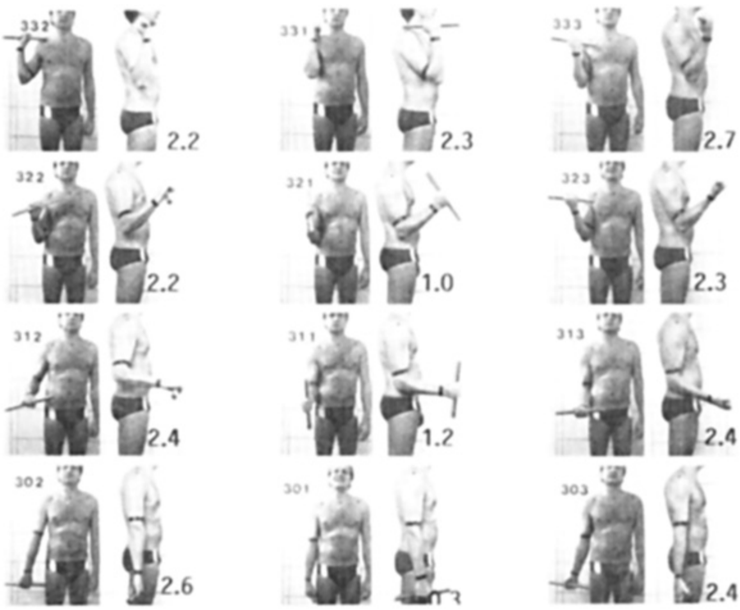


Fig. 4. Position chart showing the distribution of mean RPE on the elbow/forearm. The structure is the same as in figure 2, except for the movement pattern. The pictures on the left show pronation and on the right, supination. In each horizontal series of pictures the angle between the upper arm and forearm is the same. In the top series the arm is flexed maximally, while in the bottom series it is fully extended.

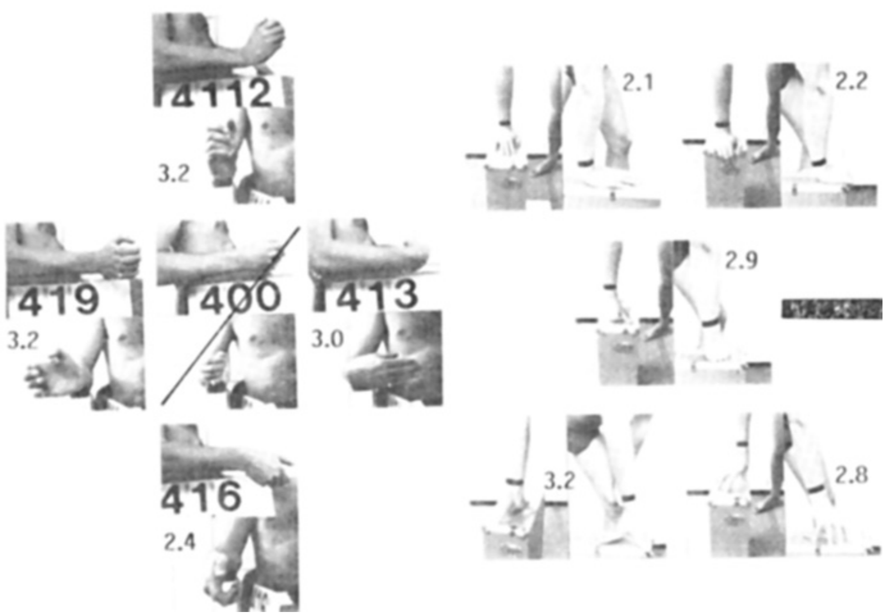


Fig. 5. Position chart showing the distribution of mean RPE on the wrist/hand. On the left the hand in a force grip is rotated showing different possible extreme position. On the right, five support postures, standing whilst supporting the body at waist level, are shown.

Fig. 6. Position chart showing the distribution of mean RPE on the back/trunk. The back is rotated around the normal rest position in the centre, starting from maximum flexion 8.2.12, around the clock to forward flexion demonstrating two special cases: 8.2.6 bent knees and 8.3.6 straight knees, and further back to 8.2.12. The postures crossed out were not assessed for the same reasons as in fig. 6.

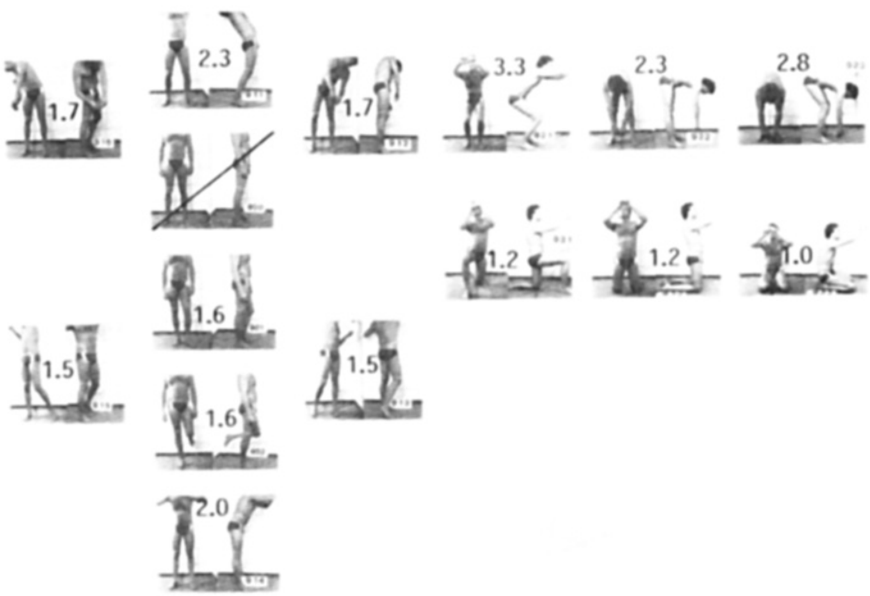


Fig. 7. Position chart showing the distribution of mean RPE on the hip/thigh. Left: the hip is rotated to left and right. Centre left: a few special cases. Top right: different flexions. Bottom right: three special cases.

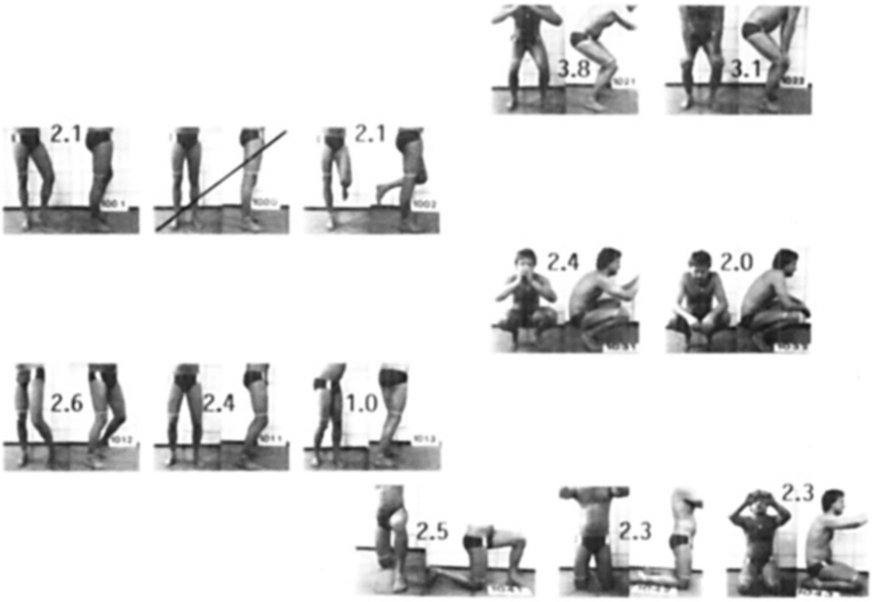


Fig. 8. Position chart showing the distribution of mean RPE on the knee/leg. Left: the hip is rotated left and right except for 10.0.2 demonstrating a person standing on one foot. Top right: two different flexions. The remaining five pictures demonstrate special cases.

Fig. 9. Position chart showing the distribution of mean RPE on the ankle/foot.

11.1.12, dorsiflexion 11.1.3, inversion
11.1.6, plantarflexion 11.1.9, eversion

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