REPORTS FROM THE DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF JYVÄSKYLÄ
FINLAND

THE RELATIONSHIP BETWEEN SOME COMPONENTS OF PHYSICAL FITNESS AND THE MODIFICATION BY MUSCULAR EXERCISE OF THE MOVEMENT PATTERN IN RISING FROM A SITTING POSITION AND STEPPING UP TO A PLATFORM.

JUHANI KIRJONEN

1970 101

THE RELATIONSHIP BETWEEN SOME COMPONENTS OF PHYSICAL FITNESS AND THE MODIFICATION BY MUSCULAR EXERCISE OF THE MOVEMENT PATTERN IN RISING FROM A SITTING POSITION AND STEPPING UP TO A PLATFORM

Juhani Kirjonen

N:o 101

URN:ISBN:978-951-39-8425-0
ISBN 978-951-39-8425-0
ISSN 0357-167X

CONTENTS

Abstract

The object of the study was to shed more light on the after-effects of muscular exertion on motor behavior. A group of 84 male teacher trainees were subjects in an experiment which consisted of a simple stepping movement (from a sitting position up to standing erect on a platform) repeated eight times. The starting position and the stepping foot were predetermined, otherwise the instructions emphasized a voluntary tempo and pattern. Between the seventh and eight recordings the subjects worked for 6 minutes on a bicycle ergometer with a moderately heavy load (working pulse rate of at least 130). The fifth, seventh and eight movements were recorded by means of a stroboscopic flashlight and photography apparatus. A number of fitness scores were also obtained for the subjects by appropriate tests. The score alterations between the three recordings were examined in several variables describing the movement pattern, such as 'time of motion', 'width of path' and 'arm swing'. The independent or fitness factors and the dependent or movement factors were computed by means of factor analysis. By dividing the subjects into fitness groups on the basis of their scores in each independent factor, and by using analyses of variance, the alterations could be studied in the means of the dependent variables at each level of fitness. The results indicated that the performance of the stepping movement speeded up significantly between the second and third measurements (seventh and eight recordings); in groups 3 and 4 (high score) of General strength-power and Endurance, and in groups 1 and 2 (low score) of Moving and Running power the increase was greater than in the opposite groups of the same factors. These results may be interpreted by differences between the subjects in specific components of physical fitness on one hand, and by specific requirements in the performance of the task on the other. The results may be interpreted by the co-effects of fatigue and arousal on the movement.

1. Purpose of the study

My aim in conducting this study was to obtain information on the quantitative aspects of the possible relationship between the physical performance ability - or physical fitness - of young men and the immediate effects of a single short exertion of muscular work with the legs on some simple variables describing the pattern of body movement in rising from a sitting position and taking one step up to standing erect on top of a knee-high platform.

2. Background of the study

We know from experience that when an untrained person who does sedentary work uses his muscles against an unusually great load, he will feel the after-effects of exertion as stiffness and numbness in the muscles involved. In order to produce these symptoms a loading of short duration must be rather high in relation to the working capacity of the muscles used. Running, climbing steps and cycling uphill are examples of such loading of the lower limbs. The intensity and quality of the after-effects evidently vary according to a person's fitness and to the magnitude of the load. We are faced by the question: what then are the after-effects caused by muscular exertion? In addition to what the subject himself feels, it is also possible for an outside observer to notice some stiffness and even some kind of disorganisation in his motor behavior after exercise. These effects could be caused, for example, either by fatigue of the muscles or by central excitation, i.e. increasing arousal, or by both (Darcus, 1953; Duffy, 1957; Welford, 1968).

Fatigue may manifest itself as a decrease in the velocity of sunbequent performance (Welford, 1968, 240-285), whereas an increase in arousal may accelerate the speed of performance. For example, Stennet (1957) and Klein (1961) have shown experimentally that at least in certain conditions heightened muscular tension simultaneously increases the velocity of a movement produced by other muscles, and decreases its accuracy. Physical fitness, especially those of its components which involve the performance of the legs, must be regarded here as an intervening variable. Hammerton

and Tickner (1968) studied the effects of physical fitness and heavy muscular exercise (step test of 200 2-step cycles in 400 sec.) on the performance of physically well trained military personnel in a skilled visual-motor control task. The results indicated that the performance of subjects with a lower physical fitness rating showed a marked decrement in a difficult task after exercise, while that of subjects with higher fitness showed no decrement in the same situation. The results of some recently published studies (Meyers et al., 1969; Welch, 1969), on the other hand, showed no significant alteration of reaction time after preceding muscular exercise.

The after-effects of muscular loading on motor performance may be examined by the methods of motion analysis. By recording and evaluating a simple pattern of gross motor response immediately before and after loading, and by comparing the respective scores, I have tried to shed some more light on the after-effects of muscular exercise on movement.

3. Hypotheses

My first assumption was that a single 6-minute exertion of moderately heavy muscular work increases the speed of movement, the variability of acceleration, and the expansion of paths of movement in performing an immediately following motor task. A further assumption was that the effects of muscular work depend on the subject's physical fitness in such a way that lower scores in the test items measuring endurance and power of the leg muscles are associated with smaller increments in speed and larger increments in variability and expansion measures than higher scores in the same items.

4. Methods

4.1. The task and recording

The motor task in the experiment had to be stereotypic and "overlearned", so that chance variations and repetition of the movement would not alter the mode of performance in a manner which could be difficult to account for (Takala, 1963). On the basis of previous studies (Jones et al., 1958;

Jones & Hanson, 1961) and preliminary experiments (Kirjonen, 1969), rising from a sitting position and stepping up to a platform at a voluntary tempo fulfilled these requirements (Figure 1). The subjects were instructed to perform the task in any way and at any speed they wanted. The starting signal and the general pattern of the movement were, however, explained in the instructions.

The movements of the subjects were recorded by means of a stroboscopic illumination and photography apparatus constructed at the Department of Psychology, University of Jyväskylä, after the model of Jones (Jones et al., 1958, a and b, Kirjonen, 1969). The apparatus included a small camera loaded with color film, and a stroboscopic flashlight with a flash-switch guided by a photocell. The timing of the flashes was regulated by a rotating perforated wheel between the photocell and a light source. The outer section of the wheel in front of the camera objective was divided into 10 filter sectors of 5 different colors. The wheel was rotated by a synchronous motor (2 rps.). Markers made of reflecting tape were fastened at predetermined positions on the subjects' skin with the aid of surgical tape. These facilitated the analysis of the photographs which recorded the successive positions of the four reflecting markers along their respective paths of movement (Fig. 1). The markers appeared in different colors at successive, identifiable moments of time, in accordance with the color of the filter sector in front of the objective at that moment; and phases of motion of the different parts of the body appeared as simultaneous alterations in the mutual relations of identically colored markers. The measurements of dependent variables were carried out on a white cardboard sheet on which the marker traces had been copied from projections produced by a micro-film reading device.

4.2. Study variables

4.2.1. Dependent variables

When choosing the variables I tried to take into consideration the basic dimensions in the study of the motion from the point of view of mechanics (movement time or velocity), psychomotor functions (coordination, steadiness/

variability, errors), and expressive movements (tempo, tension, areal factor, path angularity, intensity) (Contini & Drillis, 1966, 15-21; Fleishman, 1958; French, J.W., 1951; Jones & Hanson, 1961; Takala, 1962; Takala & Partanen, 1964).

1. Motion time (path of the head)

The score was the number of successive 1/10 s marker reflexions counted from the first perceptible marker reflexion following the starting point to the one highest on the path. The mean of the correlation coefficients between measurements was .76.

2. Mean velocity of the head

The score was the arithmetic mean of the linear distances between all the successive marker reflexions counted for the motion time. The mean r was .71.

3. Variability of motion velocity (head)

The score was the variance of the linear distances measured as above. The mean r was .49.

4. Width of path (head)

The score was the longest perpendicular distance of the path from a straight line connecting the starting point and the highest recorded point in the path of motion of the head. The mean r was .64.

5. Smoothness of the path (head)

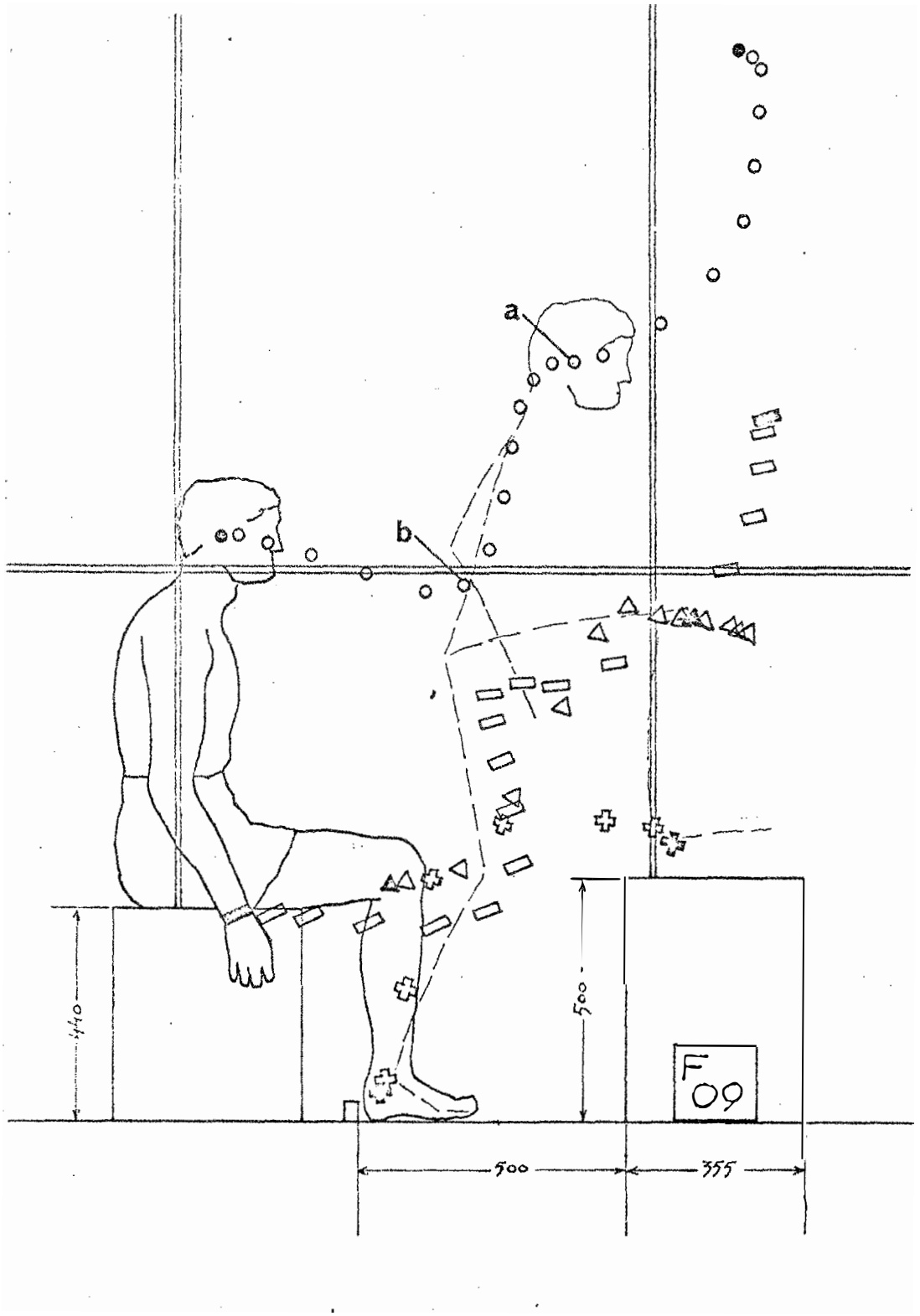
The score was the sum of 2 ratings (independent rating by two persons using rating graphically presented norms on a 5-point scale; r between raters .78, within rater .94) of the fluency or smoothness of the drawn path.

Criteria for determining rating norms:
a) Slight/strong deviation from the line connecting the starting point and the highest point.
b) Smoothness/angularity of path
c) Continual progress of the movement horizontally foreward and vertically upward/changes in direction backwards and downwards.

The mean r was .78

Figure 1

Diagram of the movement pattern and the paths of reflecting markers. Point a = marker of the head finishing its first ascent. Point b = marker of the head starting its first ascent.



6. Leg timing in relation to the movement of the head

The score was the number of ankle marker reflexions counted from the starting point to that corresponding to the marker of the head finishing its first ascent (see Fig. 1; point a). The mean r was .75.

7. Arm swing (wrist)

The score was the sum of the ratings (2 separate ratings by one person, see variable 5) made of the powerfulness of an arm swing. In this case the reflecting marker was fixed on the wrist on the side of the stepping foot. The movement of the arm represents a voluntary motor response and an auxiliary movement in the performance.

A 5-point scale based on graphically presented norms was used which covered the dimension of extensiveness of the foreward and/or upward path of the arm. The impulse from an effective swing of the arm through the shoulder joint brings about a force which moves the upper body and the centre of gravity of the whole body onwards. The mean r was .68.

8. Arm timing in relation to the movement of the head. The score was the perpendicular distance from the wrist marker corresponding to the first ascent of the head to a vertical line through the starting point of the ankle marker. (b, Fig. 1). The mean r was .71.

4.2.2. Independent variables

1. Age (in months)
2. Weight (in kilograms)
3. Height (in centimetres)
4. Height minus sitting height (in centimetres; Bayer & Bayley, 1959)
5. Hand grip (in kilopounds; the dominating hand, best in two trials; Nicks & Fleishman, Appendix A, 1962)
6. Standing broad jump (in centimetres; the longest jump in three trials; Larson & Yocom, 1951)
7. Bench press (the number of push-ups of the load of 31 kg in 20 s.; Nicks & Fleishman, App. A, 1962)
8. Agility run (time in 1/10 secs; "Loop the loop", McCloy & Young, 1954)

9. Chins (number of pulls in 20 s.; Nicks & Fleishman, App. A, 1962)
10. Knee bend (the number of bends in 60 s., Nicks & Fleishman, App. A, 1962)
11. Working heart rate (Åstrand, 1961)
12. An estimate of the maximum oxygen uptake (Åstrand, 1961)
13. School grade in gymnastics (Teacher rating, 7-point scale)
14. School grade in other sports (Teacher rating, 7-point scale)

4.3. Experimental procedures

The subjects were 84 male teacher trainees at the University of Jyväskylä with an age range of 254-429 months.

At first the following test items of motor fitness were measured[1]: hand grip, standing broad jump, bech press, agility run, chins, and knee bend. From two to fourteen days later the subjects' height, sitting height and weight were measured, and the experiment proper was carried out according to the following design.

Anthropometric measurements	Fixing reflecting markers	Instruction	Movement trials: 1 2 3 4 no recording; 5 6 7 recording	three jumps (warming-up exercise)	Ergometer test[2] (phys. exerc.)	Pause	8 Movement trial (recorded)
2	2		5-6	2	6	1	½
Approximate time in minutes							

[1] All measurements were carried out 22.4. - 6.5.1963

[2] The work load was 600 kpm/min. for 11 subjects, 900 for 72 subjects and 1200 for 3 subjects, adjusted in accordance with the physical appearance of each subject in order to obtain a working pulse rate of at least 130.

4.4. Data processing and statistical methods

The main method of statistical treatment was factor analysis. Most of the analyses were computed by using the programs of the "Statistical System" manual (IBM). Processing started from primary data and gave e.g. product-moment correlations, principal factor solution, varimax rotation, oblique rotation (Promax), and factor scores for each subject (IBM 1967; Harman, 1967). Communalities were estimated by means of the squared multiple correlation method (SMC) (Harman, 1967, 86-88). Analyses of variance were also computed by using the two-variate model with repeated measurements in one variate (Winer, 1962, 302-318).

For two dependent variables (smoothness of path and arm swing) the quantification was carried out at the level of classification scales which in general would not justify the use of product moment correlations as the basis of statistical analyses. In this estimation, however, the norm figures were composed in advance on the basis of the research material in order to reduce the inconvenient manual scoring, yet maintaining the linear relation to the physical scales. The classification indeed reduced standard deviation -and, unfortunately, information as well- and probably decreased the correlation coefficients. As a study of the normality of distributions and the linearity of regressions did not yield any exceptional cases, the variables could be accepted for analyses.

The design of the data analysis was to study the relations between the independent and dependent phenomena by starting from groups of independent variables at a general level of description (factor/factor) and by moving to more specific levels (factor/variable, variable/variable); this approach is particularly useful when the phenomenon is restricted in scope, or when its weak intensity prevents its appearance in complex contexts.

5. Results and interpretations

5.1. Factor analysis of independent variables

In this study factorizations and rotations were carried out separately on the independent and dependent variables. In addition, each subject was assigned factor scores (included also in the matrix of correlations, Table 1).

Table 1. Summary table of all intercorrelations. Coefficients representing variables 1-38 are based on primary scores and those representing 39-52 on factor scores

1. Age
2. Weight
3. Height
4. Height-Sitting height
5. Hand grip
6. Standing broad jump
7. Bench press
8. Agility run
9. Chins
10. Knee bend
11. Working heart rate
12. Max. oxygen up take
13. Grade in gymnastics
14. Grade in other sports
15. Motion time 1 (1.meas.)
16. Mean velocity 1
17. Variability of motion velocity 1
18. Width of path 1
19. Smoothness of path 1
20. Leg timing 1
21. Arm swing 1
22. Arm timing 1
23. Motion time 2 (2.meas.)
24. Mean velocity 2
25. Variability of motion velocity 2
26. Width of path 2
27. Smoothness of path 2
28. Leg timing 2
29. Arm swing 2
30. Arm timing 2
31. Motion time 3 (3.meas.)
32. Mean velocity 3
33. Variability of motion velocity 3
34. Width of path 3
35. Smoothness of path 3
36. Leg timing 3
37. Arm swing 3
38. Arm timing 3
39. General strength-power
40. Height
41. Endurance
42. Moving power
43. Running power
44. Tempo of motion 1 (1.meas.)
45. Auxiliary movements 1
46. Heaviness of motion 1
47. Tempo of motion 2 (2.meas.)
48. Auxiliary movements 2
49. Heaviness of motion 2
50. Tempo of motion 3 (3.meas.)
51. Auxiliary movements 3
52. Heaviness of motion 3

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.
1.																																							
2.		25																																				
3.	-10	51																																				
4.	-07	35	86																																			
5.	-04	34	31	19																																		
6.	-21	-09	15	16	34																																	
7.		19	42	-01	-12	31	34																															
8.	-02	-10	-02	-04	06	53	22																															
9.	-28	-35	-10	-11	16	60	42	39																														
10.		00	-08	-20	-20	07	42	42	37	47																												
11.		20	-14	-27	-23	-08	07	08	08	11	11																											
12.	-34	-31	00	00	07	27	-07	15	29	20	-67																											
13.	-13	-20	-21	-22	13	47	42	37	58	29	19	10																										
14.	-03	05	-01	-14	17	36	25	45	23	32	15	17	34																									
15.	-02	-04	10	03	01	-21	-20	-24	-05	-19	-10	08	00	-11																								
16.		01	15	20	28	-02	21	15	25	03	16	-06	-04	-11	05	-80																						
17.		05	06	23	27	-09	-13	-18	06	-15	-01	04	-20	-21	-10	07	25																					
18.		04	-04	34	34	-04	04	-13	-00	02	-01	-19	19	-14	-05	27	12	42																				
19.	-02	-08	-17	-16	-02	22	22	18	20	16	19	-07	21	09	-75	44	-36	-39																				
20.		06	-01	-11	-01	09	-04	03	-08	-08	-06	20	-13	-05	-01	-15	06	-04	-09	14																		
21.		16	-18	-12	-03	-15	-07	-06	-10	05	02	18	-06	-19	-28	-08	14	08	17	08	04																	
22.		15	-06	-11	-02	-16	-06	-08	-05	00	02	25	-17	-25	-18	-31	27	02	-04	24	-02	76																
23.	-05	-13	04	03	00	-08	-22	-19	-05	-23	-06	04	05	-15		86	-72	01	22	-63	-23	-05	-22															
24.		06	16	21	27	-02	10	12	18	-01	21	-05	00	-12	10	-63	78	30	20	32	10	03	13	-76														
25.	-10	08	18	24	-07	05	-09	13	01	09	-05	-02	-12	00		06	22	48	32	-26	-10	04	06	13	16													
26.		08	01	33	42	-06	04	-10	07	-04	-09	-13	10	01	-03	28	10	34	68	-34	03	04	-15	26	22	47												
27.		02	02	-04	-08	-05	18	24	15	12	16	04	02	08	09	-73	48	-28	-33	82	06	02	20	-73	43	-34	-35											
28.		07	00	-13	-12	07	-07	01	-10	-12	-04	19	-09	-07	08	-03	-10	-10	-16	11	78	02	-09	-15	00	-24	-02	10										
29.		23	-08	02	16	-11	-03	-08	-07	-02	-04	07	-08	-20	-26	-10	26	23	26	00	-02	80	62	-03	16	13	18	-02	-08									
30.		12	-07	-06	04	-16	-10	-10	-10	00	-10	11	-13	-25	-29	-21	25	13	-01	10	-09	70	84	-17	13	08	-13	12	-14	71								
31.	-13	-03	04	02	00	-22	-18	-28	-16	-26	-03	-03	-02	-06		72	-64	07	13	-62	-28	-17	-26	71	-56	02	07	-58	-26	-17	-21							
32.		10	00	16	26	-09	16	07	17	15	12	-03	01	-01	-02	-49	68	14	21	33	18	16	18	-52	67	20	28	29	10	23	19	-76						
33.		24	10	13	17	-10	-06	02	01	01	-03	23	-30	-17	-03	-05	24	49	34	-11	04	27	22	-14	33	50	38	-08	09	24	19	-16	43					
34.	-02	00	41	46	-09	-17	-19	-15	-09	-18	-13	02	-10	-10		19	14	33	61	-21	02	06	-10	12	18	28	64	-20	-05	08	-12	12	36	42				
35.		02	-01	-01	-01	01	28	19	26	18	17	08	-02	19	02	-63	46	-27	-27	78	20	12	25	-52	30	-23	-16	73	17	10	15	-73	39	-13	-20			
36.		05	09	01	07	20	00	-04	-03	-14	00	11	-08	-07	00	-14	08	00	-10	14	75	05	-03	-19	13	-05	10	-04	72	06	-09	-32	21	04	02	22		
37.		19	-12	00	14	-11	01	-05	11	09	-06	22	-15	-06	-10	-07	14	06	12	08	08	64	54	-04	09	04	14	05	11	61	53	-23	28	28	21	22	08	
38.		20	-05	00	10	-18	-06	-05	11	-01	-07	20	-16	-13	-04	-23	29	09	01	16	00	52	65	-20	20	03	07	14	-02	55	63	-34	31	25	07	31	02	79
39.	-31	-42	-16	-14	17	71	44	47	96	53	12	36	68	30	-10	05	-19	00	24	-06	02	-04	-06	00	-02	-03	15	-09	-05	-06	-17	13	-07	-13	22	-11	06	-04
40.	-09	48	96	96	27	13	-10	-07	-17	-25	-31	01	-27	-12		07	24	25	34	-19	-06	-09	-07	05	24	22	38	-08	-13	09	-01	04	20	14	43	-02	05	06	04
41.	-36	-10	20	17	11	14	-10	04	14	05	-91	90	-04	01		10	02	-11	22	-14	-19	-14	-24	06	03	03	13	-02	-17	-09	-14	00	03	-29	10	-05	-11	-20	-20
42.		31	80	28	11	42	18	87	10	07	24	-01	-24	17	23	-15	18	-07	-10	09	02	-15	-10	-21	16	-03	-05	16	01	-10	-12	-13	04	08	-11	12	02	-10	-06
43.	-06	-05	-05	-14	26	72	48	75	60	59	22	24	58	80	-21	15	-12	-04	22	-04	-17	-12	-20	13	02	-02	19	00	-18	-22	-22	09	-03	-21	22	-02	-02	-02
44.		01	07	-04	03	-01	22	21	25	07	19	08	-08	-00	10	-98	86	-06	-26	76	14	10	33	-86	66	-03	-23	73	02	14	23	-74	55	06	-15	66	14	10	26
45.		16	-13	-12	-02	-17	-05	-06	-06	03	03	23	-13	-23	-24	-27	27	07	06	22	01	93	94	-18	13	06	-06	16	-05	76	82	-27	22	27	-02	23	01	62	63
46.		04	12	44	47	-05	-02	-12	03	-07	-02	-22	07	-24	-10		23	35	67	78	-54	-14	17	00	16	32	50	64	-42	-22	34	12	10	31	42	56	-34	-10	15	12
47.		06	14	02	04	-01	10	21	18	04	23	04	-03	-07	13	-84	76	04	-15	61	18	04	22	-98	86	-12	-19	74	11	07	18	-70	57	16	-08	51	15	06	21
48.		18	-07	-02	12	-15	-06	-08	-08	00	-06	10	-11	-24	-28	-22	33	20	13	10	-06	80	79	-17	21	13	03	10	-13	92	93	-24	26	25	-02	17	-02	61	64
49.		03	08	37	47	-04	-03	-13	06	-07	-01	-14	04	-12	-05		19	26	54	67	-42	-08	06	-06	16	47	62	81	-43	-18	27	00	07	36	44	52	-29	02	12	08
50.		11	01	01	06	-03	24	16	27	18	23	02	03	04	03	-70	69	-05	-07	60	26	17	26	-69	61	-00	-00	55	21	20	23	-98	86	18	-02	72	30	26	36
51.		21	-08	00	13	-16	-02	-04	13	05	-06	22	-16	-10	-07	-20	26	08	07	16	05	61	63	-17	18	04	11	13	05	61	62	-35	36	30	15	32	06	94	95
52.		06	-01	31	41	-14	-08	-13	-08	00	-13	-04	-06	-11	-10		12	26	41	56	-29	-03	13	00	03	36	42	58	-28	-09	20	07	01	61	65	80	-34	-03	25	14

	40.	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.	51.	52.
40.													
41.	-22												
42.	16	20											
43.	05	20	-14										
44.	11	-01	-09	17									
45.	00	-08	-20	-12	-14								
46.	-11	47	18	-01	-10	-16							
47.	05	02	-04	20	18	85	18						
48.	05	-12	-10	-20	25	85	25	19					
49.	-08	43	12	-04	-05	-14	00	79	-04				
50.	19	02	01	11	20	74	27	-02	70	27			
51.	02	05	-21	-07	-01	23	67	14	18	67	11		
52.	-06	36	01	-08	-15	-07	08	66	04	15	67	13	

The independent variables yielded five factors (Table 2)

Factor 1. General strength-power. The most significant loadings fell on chins, grade in gymnastics, and standing broad jump.

Factor 2. Height. The factor received strong loadings on height and height minus sitting height, and a rather weak loading on weight.

Factor 3. Endurance. The factor showed loadings on the maximum oxygen uptake, working heart rate, and, partly on age. The technical correlation between the first two made a valid interpretation rather difficult, even though this factor was similar to the one presented in connection with earlier findings (Kirjonen & Pitkänen, 1964/1965).

Factor 4. The factor was characterized by loadings on weight, bench press, and hand grip. Thus we are obviously dealing with moving power (Kirjonen & Pitkänen, 1964/1965) which represents a short isotonic or isometric muscle contraction against an external load.

Factor 5. Running power. The factor was made up of variables measuring fast leg extensions in relation to the subject's weight, e.g. agility run, standing broad jump, and also the school grade in other sports.

These five factors extracted from the independent variables and the corresponding factor scores were used as the basis of classification in the analyses of variance concerning the treatment effects on dependent variables at the different levels of physical fitness.

5.2. Factor analyses of dependent variables

The analyses of the dependent variables were carried out as follows. Each of the three measurements for each subject was treated as a separate observation, the total number of subjects being thus 3 x 84 = 252. The procedure made it possible to deal with the results of the three separate measurements within the same factorization and rotation. It also yielded comparable factor scores. Three identified factors were extracted (Table 3).

Factor 6. Tempo of motion (TM). The factor was characterized by motion time, mean velocity and smoothness of path. The rotational solutions were rather clear and easy to interpret.

Factor 7. Auxiliary arm movements (AM). Only two variables yielded significant loadings on this factor: arm swing and arm timing, both

Table 2.

Rotated factor matrices: varimax and promax solution, independent variables.

	Varimax						Promax				
	1.	2.	3.	4.	5.	h^2	1.	2.	3.	4.	5.
Age	-31	12	-30	26	01	28	-38	18	-21	27	09
Weight	-38	40	-09	72	-02	84	-38	25	01	72	03
Height	-09	91	10	16	-02	88	-01	92	01	07	06
Height-Sitting height	-04	89	06	00	-09	80	08	93	-07	-08	-02
Hand grip	16	29	08	37	13	26	19	25	07	36	04
Standing broad jump	57	23	07	08	53	66	50	30	-01	-01	41
Bench press	34	-10	-09	77	22	78	38	-18	-01	81	-06
Agility run	25	01	00	00	64	46	02	05	-01	-11	70
Chins	82	-07	08	05	28	77	91	01	-01	05	-05
Knee bend	34	-21	05	20	43	38	22	-22	08	18	32
Working heart rate	14	-17	-83	-10	15	76	15	-04	-86	-15	15
Max. oxygen up take	20	-04	84	-14	20	81	08	-10	84	-14	18
Grade in gymnastics	57	-17	-06	12	34	48	56	-12	-10	11	13
Grade in other sports	08	-04	00	12	65	44	-20	-05	04	01	76
Eigenvalues	GSP 2.0	H 2.0	E 1.5	MP 1.4	RP 1.6	8.60	GSP (Starting communality: 8.28)	H	E	MP	RP
% of starting communality	24.2	24.2	18.1	16.9	19.4	102.8					

Factors:

1. General strength-power GSP
2. Height H
3. Endurance E
4. Moving power MP
5. Running power RP

Correlations between oblique Factors:

	GSP	H	E	MP
H	-22			
E	16	21		
MP	02	19	-14	
RP	63	-14	02	28

Table 3.

Rotated factor matrices: varimax and promax solution, dependent variables.

	Varimax				Promax		
	6.	7.	8.	h^2	6.	7.	8.
Motion time	-95	-15	-04	91	-96	01	-04
Mean velocity	78	14	-46	85	86	-03	-48
Motion variability	-02	11	-60	37	05	06	-60
Width of path	-17	03	-69	51	-08	-01	-70
Smoothness of path	71	16	35	65	67	07	36
Leg timing	17	-03	07	03	17	-06	06
Arm swing	01	82	-16	70	-06	83	-09
Arm timing	14	83	-01	71	05	84	06
	TM	AM	HM		TM	AM	HM
Eigenvalues	2.1	1.4	1.2	4.73	(Starting communality: 4.46)		
% of starting communality	47.1	31.4	26.9	105.4			

Factors:

6. Tempo of motion TM
7. Auxiliary arm movements AM
8. Heaviness of motion HM

Correlations between oblique factors:

	TM	AM
AM	26	
HM	12	14

of which describe the size and powerfulness of the forward swing of the arm. Because these variables represent the arm movements particularly during the starting phase the name 'auxiliary' (producing an aiding impulse) was chosen.

Factor 8. Heaviness of motion (HM). The factor was dominated by the loadings on width of path, on variability of motion velocity and on mean velocity. The factor describes primarily the forward tilt of the head and upper trunk with which the mean velocity is associated. In this solution it is only a partial reflection of the alterations along the "variability" (variability of acceleration and expansion of movement) dimension of the performance. Certain observable traits in flexing the big joints of the body might, however, be permanent individual characteristics of the gross motor functions.

5.3. Analyses of variance

On the basis of the analyses of the independent and dependent variables factor scores were computed for each subject, who thus received five scores from the independent and nine from the dependent variables (first, second and third measurement; three factors).

For the analyses of variance with repeated measurements of dependent variables, the Ss were divided into fitness groups (21 Ss each) on the basis of the size of the score in each independent factor. The dependent factor and variable scores were taken up successively for the analyses of the results of all measurements, i.e. for the analyses of the effects of treatment on the dependent phenomena at the different levels of physical fitness. The means of the three dependent factor scores and eight variable scores are given in table 4.

The analyses of variance (summarized in table 5) indicate that the main effects of measurement (treatment) were significant (at the 1 % level) in the factor Tempo of motion and in the variables loading it strongly (time and mean velocity). The tempo of performance (TM factor, time and velocity scores) had speeded up significantly between the second and third measurements.

The effect of treatment and the experimental situation at different levels of fitness can be observed in the dependent scores by computing the

Table 4.

The means of the dependent variables (factor scores and variable scores) at the different levels (groups 1 - 4) of each independent fitness factor. Dependent factors: Tempo of motion, TM; Auxiliary arm movements, AM; Heaviness of motion, HM. Independent factors: General strength-power, GSP; Height, H; Endurance, E; Moving power, MP; Running power, RP.

TM/GSP measurements

	1.	2.	3.
1.	-2.3	-0.5	0.4
2.	-2.3	-1.5	0.4
3.	-1.5	0.2	1.6
4.	0.0	0.0	5.5

AM/GSP measurements

	1.	2.	3.
1.	-0.3	0.6	0.7
2.	1.3	1.3	1.0
3.	0.2	0.5	-0.2
4.	-2.7	-1.5	-0.2

HM/GSP measurements

	1.	2.	3.
1.	-1.6	-0.3	-0.1
2.	0.2	2.6	1.3
3.	0.7	0.4	1.7
4.	-3.2	-0.2	-1.2

TIME/GSP measurements

	1.	2.	3.
1.	21.0	20.5	20.0
2.	21.0	20.6	19.9
3.	20.6	20.2	19.5
4.	20.0	20.3	18.5

VELOCITY/GSP measurements

	1.	2.	3.
1.	29.1	30.0	30.2
2.	29.4	30.4	30.5
3.	29.7	30.3	30.9
4.	29.7	29.7	31.8

VARIABILITY/GSP measurements

	1.	2.	3.
1.	12.8	12.8	13.6
2.	13.4	14.0	15.0
3.	13.4	13.2	15.0
4.	11.2	13.2	12.6

WIDTH/GSP measurements

	1.	2.	3.
1.	13.2	12.5	13.3
2.	13.7	13.6	13.2
3.	14.3	13.5	13.7
4.	12.7	12.8	12.1

SMOOTHNESS/GSP measurements

	1.	2.	3.
1.	-0.7	-0.5	-0.3
2.	-0.5	-0.3	-0.7
3.	-0.5	-0.1	-0.3
4.	0.5	-0.1	0.5

LEG TIMING/GSP measurements

	1.	2.	3.
1.	5.9	5.7	5.7
2.	6.0	6.2	6.0
3.	5.8	6.0	5.3
4.	5.4	5.4	5.3

ARM SWING/GSP measurements

	1.	2.	3.
1.	-0.0	0.1	0.0
2.	0.3	0.4	0.2
3.	0.0	0.1	0.1
4.	-0.2	-0.1	0.1

ARM TIMING/GSP measurements

	1.	2.	3.
1.	0.2	0.4	0.4
2.	0.4	0.1	0.2
3.	0.0	0.2	-0.3
4.	-0.7	-0.3	-0.2

TM/H measurements

	1.	2.	3.
1.	-0.9	0.9	2.7
2.	-4.3	-4.0	-0.2
3.	0.1	-1.0	2.4
4.	-1.1	2.4	3.0

AM/H measurements

	1.	2.	3.
1.	0.5	-1.4	0.5
2.	-2.3	0.0	-3.0
3.	1.7	1.6	1.1
4.	-1.4	0.7	2.5

HM/H measurements

	1.	2.	3.
1.	-5.3	-3.7	-3.0
2.	-3.3	-2.3	-2.5
3.	0.7	1.6	1.4
4.	4.0	6.8	5.7

TIME/H measurements

	1.	2.	3.
1.	20.0	19.3	18.7
2.	21.5	21.7	20.0
3.	20.1	20.5	19.3
4.	21.0	19.8	18.7

VELOCITY/H measurements

	1.	2.	3.
1.	28.8	29.7	30.3
2.	28.1	28.4	29.6
3.	30.2	30.0	31.2
4.	30.7	32.3	32.2

VARIABILITY/H measurements

	1.	2.	3.
1.	11.8	12.5	13.6
2.	12.6	13.4	13.7
3.	13.1	13.0	13.2
4.	13.4	14.5	15.7

WIDTH/H measurements

	1.	2.	3.
1.	12.3	12.5	12.4
2.	12.6	12.0	11.7
3.	14.1	13.2	13.3
4.	14.8	15.1	14.6

SMOOTHNESS/H measurements

	1.	2.	3.
1.	0.3	-0.1	0.0
2.	-0.6	-0.5	-0.6
3.	-0.3	-0.6	-0.3
4.	-0.6	-0.3	0.0

LEG TIMING/H measurements

	1.	2.	3.
1.	6.2	6.7	5.8
2.	5.2	5.4	4.8
3.	5.9	5.2	5.6
4.	6.0	5.8	6.0

ARM SWING/H measurements

	1.	2.	3.
1.	0.1	-0.1	0.0
2.	-0.1	0.0	-0.1
3.	0.3	0.4	0.2
4.	-0.2	0.2	0.4

ARM TIMING/H measurements

	1.	2.	3.
1.	0.3	-0.2	0.3
2.	-0.5	0.2	-1.0
3.	0.3	0.3	0.3
4.	-0.1	0.0	0.6

TM/E measurements

	1.	2.	3.
1.	-1.7	-0.8	1.1
2.	-2.5	-1.3	0.1
3.	1.8	1.5	5.2
4.	-3.8	-1.2	1.4

AM/E measurements

	1.	2.	3.
1.	1.1	0.2	2.3
2.	-1.4	-0.2	-1.6
3.	2.0	2.1	2.5
4.	-3.2	-1.2	-2.1

HM/E measurements

	1.	2.	3.
1.	-5.0	-2.5	-1.0
2.	-3.1	-1.2	-1.6
3.	5.5	5.7	6.0
4.	-1.3	0.6	-1.8

TIME/E measurements

	1.	2.	3.
1.	20.6	20.4	19.7
2.	21.0	20.7	19.9
3.	19.5	19.7	18.6
4.	21.5	20.5	19.3

VELOCITY/E measurements

	1.	2.	3.
1.	28.6	29.4	30.2
2.	28.7	29.0	29.8
3.	31.8	32.0	33.0
4.	28.8	30.0	30.4

VARIABILITY/E measurements

	1.	2.	3.
1.	12.6	12.8	15.0
2.	12.8	13.1	13.3
3.	14.2	14.6	16.4
4.	11.3	12.8	11.5

WIDTH/E measurements

	1.	2.	3.
1.	12.5	12.5	12.3
2.	13.2	12.5	12.8
3.	14.7	14.4	14.4
4.	13.5	13.4	12.8

SMOOTHNESS/E measurements

	1.	2.	3.
1.	-0.1	-0.4	-0.1
2.	-0.1	-0.3	-0.3
3.	-0.3	-0.4	-0.1
4.	-0.7	-0.3	-0.2

LEG TIMING/E measurements

	1.	2.	3.
1.	6.7	6.6	6.1
2.	5.9	5.7	5.2
3.	5.2	5.2	5.6
4.	5.6	5.8	5.4

ARM SWING/E measurements

	1.	2.	3.
1.	0.1	0.0	0.3
2.	-0.1	0.1	-0.0
3.	0.3	0.4	0.4
4.	-0.2	0.0	-0.2

ARM TIMING/E measurements

	1.	2.	3.
1.	0.6	0.3	0.7
2.	-0.1	-0.1	-0.6
3.	0.4	0.5	0.4
4.	-0.8	-0.3	-0.3

TM/MP measurements

	1.	2.	3.
1.	-5.1	-3.7	-0.7
2.	-1.0	-0.3	4.6
3.	-1.1	0.3	1.1
4.	1.0	1.8	2.9

AM/MP measurements

	1.	2.	3.
1.	1.1	1.8	1.2
2.	1.2	-0.3	0.5
3.	-4.8	-2.2	-1.4
4.	1.0	1.6	0.8

HM/MP measurements

	1.	2.	3.
1.	-0.3	1.1	-0.6
2.	-1.3	0.7	4.0
3.	-1.8	0.2	-0.3
4.	-0.5	0.4	-1.5

TIME/MP measurements

	1.	2.	3.
1.	21.9	21.7	20.4
2.	20.5	20.0	18.7
3.	20.2	19.9	19.7
4.	20.0	19.7	19.0

VELOCITY/MP measurements

	1.	2.	3.
1.	28.3	28.7	29.8
2.	29.6	30.4	32.4
3.	29.5	30.4	30.4
4.	30.4	30.8	30.8

VARIABILITY/MP measurements

	1.	2.	3.
1.	13.0	13.0	13.2
2.	12.8	13.3	14.4
3.	13.0	13.4	14.1
4.	12.3	13.6	14.4

WIDTH/MP measurements

	1.	2.	3.
1.	13.9	13.3	13.1
2.	13.6	13.3	13.7
3.	12.9	13.4	13.1
4.	13.5	12.8	12.4

SMOOTHNESS/MP measurements

	1.	2.	3.
1.	-0.8	-0.8	-0.3
2.	-0.2	-0.5	-0.4
3.	-0.3	-0.1	-0.3
4.	0.0	0.0	0.2

LEG TIMING/MP measurements

	1.	2.	3.
1.	5.9	6.0	5.6
2.	6.1	5.9	5.7
3.	6.1	5.8	5.6
4.	5.3	5.5	5.4

ARM SWING/MP measurements

	1.	2.	3.
1.	0.3	0.4	0.2
2.	0.3	0.1	0.3
3.	-0.7	-0.3	-0.2
4.	0.2	0.3	0.1

ARM TIMING/MP measurements

	1.	2.	3.
1.	0.3	0.6	0.4
2.	0.1	-0.2	-0.2
3.	-0.8	-0.3	-0.2
4.	0.4	0.3	0.2

TM/RP measurements

	1.	2.	3.
1.	-5.2	-2.9	-1.4
2.	-2.3	-2.0	2.2
3.	1.6	2.3	4.6
4.	-0.2	0.8	2.5

AM/RP measurements

	1.	2.	3.
1.	0.1	1.7	1.5
2.	1.1	1.0	1.2
3.	1.2	1.5	-1.0
4.	-3.9	-3.3	-0.6

HM/RP measurements

	1.	2.	3.
1.	0.8	1.8	0.8
2.	-2.4	-0.1	4.5
3.	0.4	0.8	-1.4
4.	-2.6	0.0	-2.3

TIME/RP measurements

	1.	2.	3.
1.	22.0	21.1	20.3
2.	21.0	20.7	19.6
3.	19.4	19.5	18.5
4.	20.2	20.0	19.1

VELOCITY/RP measurements

	1.	2.	3.
1.	28.6	29.6	29.7
2.	28.9	29.7	31.8
3.	30.7	30.6	31.3
4.	29.7	30.5	30.5

VARIABILITY/RP measurements

	1.	2.	3.
1.	13.8	13.0	14.1
2.	12.0	13.6	14.8
3.	12.7	13.3	13.9
4.	12.4	13.3	13.4

WIDTH/RP measurements

	1.	2.	3.
1.	13.7	13.3	13.7
2.	13.0	13.0	13.8
3.	14.1	13.2	12.7
4.	13.0	13.2	12.2

SMOOTHNESS/RP measurements

	1.	2.	3.
1.	-1.2	-1.0	-0.6
2.	-0.3	-0.4	-0.7
3.	0.4	0.2	0.5
4.	-0.0	-0.2	-0.0

LEG TIMING/RP measurements

	1.	2.	3.
1.	5.9	5.7	5.5
2.	6.0	5.8	5.6
3.	5.6	5.6	5.7
4.	6.0	6.1	5.5

ARM SWING/RP measurements

	1.	2.	3.
1.	0.1	0.3	0.3
2.	0.1	0.1	0.2
3.	0.3	0.3	0.0
4.	-0.4	-0.2	0.0

ARM TIMING/RP measurements

	1.	2.	3.
1.	0.1	0.6	0.4
2.	0.5	0.5	0.3
3.	0.2	0.3	-0.4
4.	-0.8	-1.0	-0.1

Table 5.
The significance of F-ratios in the analyses of variance by using the two variate model with repeated measurements in one variate

Independent, grouping factor	Dependent factors and variables							
	6. Factor (TM)	Motion time	Mean veloc.	7. Factor (AM)	Arm timing	8. Factor (HM)	Width of path	M.variability
1. General strength-power GSP								
measurement effect	1%	1%	1%	-	-	-	-	5%
simple main effect	5%	5%	5%	-	-	-	-	-
(groups)	(3,4)	(4)	(4)	-	-	-	-	-
2. Height H								
group effect	-	-	5%	-	-	1%	1%	-
measm. effect	1%	1%	1%	-	-	-	-	5%
interaction	-	-	-	5%	5%	-	-	-
simple main effect	5%	5%	5%	-	5%	-	-	-
(groups)	(2,4)	(1,2,4)	(1,2,4)	-	(2)	-	-	-
3. Endurance E								
group effect	-	-	1%	-	-	1%	5%	1%
measm. effect	1%	1%	1%	-	-	-	-	5%
interaction	-	-	-	-	-	-	-	5%
simple main effect	5%	5%	5%	-	-	5%	-	5%
(groups)	(3,4)	(4)	(1,4)	-	-	(1)	-	(1,3)
4. Moving power MP								
measm. effect	1%	1%	1%	-	-	-	-	5%
interaction	-	-	5%	-	-	-	-	-
simple main effect	5%	5%	5%	-	-	5%	-	-
(groups)	(1,2)	(1,2)	(1,2)	-	-	(2)	-	-
5. Running power RP								
measm. effect	1%	1%	1%	-	-	-	-	5%
interaction	-	-	5%	-	-	1%	1%	-
simple main effect	5%	5%	5%	-	-	-	5%	5%
(groups)	(1,2)	(1,2)	(2)	-	-	-	(3)	(2)

interactions and the simple main effect of measurement at each fitness level (Figure 2). The 5 % level of significance for F-ratios was used here.

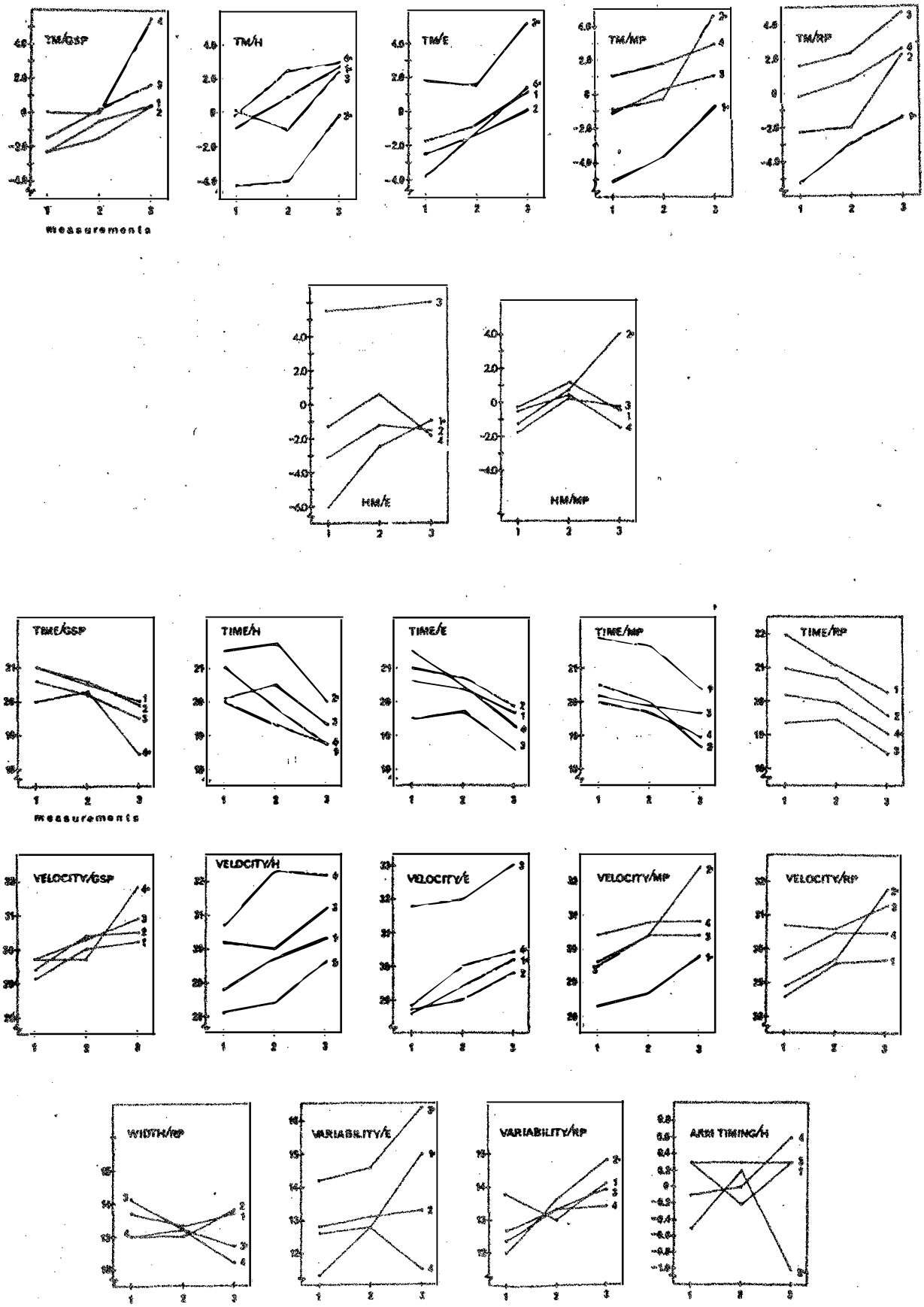
There were a few significant interactions, two of which were logically interpretable, viz. Moving power (MP)/measurement effect, and Running power (RP)/measurement effect, the former in the scores of mean velocity and the latter in the scores of width of path. Groups 1 and 2 (the lowest level) of MP speeded up their performance notably from the second to the third measurement, which indicated the treatment effect, while groups 3 and 4 remained much the same. In groups 1 and 2 of RP, width of path increased while in groups 3 and 4 the mean scores of this variable decreased. Analyses at the factor level reflected similar significant interactions, but the score alterations were not equally clear. The few interactions thus give partial support to the second hypothesis.

As to the simple main effects, the scores of Tempo factor increased significantly in groups 3 and 4 (the highest level) of General strength-power and Endurance, and in groups 1 and 2 of Moving power and Running power. The decrease in the performance time at the variable level is significant in group 4 of GSP and E, as well as in groups 1 and 2 of MP and RP. The changes in the velocity scores also support these results, because group 4 of GSP and groups 1 and 4 of E, as well as groups 1 and 2 of MP and group 2 of RP, increased the speed of their performance. The alteration in the score from the second to the third measurement is greatest in group 4 of the GSP factor. The change in the low group of E might be related with the increase in the score of velocity variability (there also appeared an increasingly negative correlation between the variables).

The most marked changes in the correlation coefficients (table 1) appeared as increases in those between motion velocity variability and the Endurance factor (negative) or working heart rate (positive), and in those between width of path and Running power (negative), from the first and second measurement to the third. These changes indicate the phenomenon described above in the analyses of variance.

Figure 2.

Profiles for repeated measurements at the levels of fitness factors. The graphical presentation includes significant main effects, simple main effects (o) and interactions obtained by means of analyses of variance. Symbols: TM = Tempo of motion, HM = heaviness of motion, GSP = General strength-power, H = Height, E = Endurance, MP = Moving power, RP = Running power. o = The level with significant simple main effect.



5.4. Summary and interpretation of results

The results indicate that

1. the performance of the stepping movement speeded up significantly between the second and third measurements, when the treatment by a short physical exertion occurred (main effects). This was true of each group representing different levels of physical fitness. The result supports the hypothesis. Nevertheless, the change was also very notable from the first to the second measurement in some cases, which might be due to 'the warm-up' effect observed many times in laboratory experiments;

2. in the groups with low scores in the power factors (MP and RP) the Tempo score, mean velocity and width of path increased, whereas in the groups with high scores in MP and RP the mean velocity remained at the same level while the width of path decreased (interactions and simple main effects). The alterations of scores representing tempo contradicted the second hypothesis. The increase (groups 1 and 2) and decrease (groups 3 and 4) in the scores of width of path were partly in accordance with the hypothesis;

3. groups 3 and 4 of GSP and E showed an increase in the scores of Tempo, and groups 4 of GSP and E a decrease in those of time of motion. The other groups showed no appreciable change in their means (interactions and simple main effects). In general, the results supported the hypothesis; yet groups 3 of GSP and 4 of E speeded up their mean performance to the same extent during the first and second period;

4. the variables representing more distincly the variability of acceleration were also affected by the experimental situation, but the changes were neither consistent nor interpretable.

In short, the low scores in power and the high scores in general fitness and endurance were related with great increases in the scores for tempo of movement, while the high scores on power and the low scores in general fitness and endurance were associated with small increments in the scores for tempo. This may be explained by the differences between the subjects in specific components of physical fitness on one hand, and, correspondingly, by specific requirements in the performance of the task on the other. The muscular exertion evidently increased the activation level of most of subjects in the higher groups of GSP and E, but not so much in the lower groups, owing to the co-effects of fatigue and arousal.

Power factors represented fitness characteristics needed, for example, in stepping movements, and they were loaded by such variables as weight, bench press, agility run, grade in other sports and standing broad jump. The subjects with low scores in power tended to speed up their performance considerably when affected by the load.

As regards the regularity of movement, it seems that either the treatment was not very effective in producing fatigue, or the variables representing it were not very sensitive. However, the score alterations of width of path in the groups 1 and 2 of RP may be tentatively interpreted as indications of fatigue. Groups 1 and 2 aided their performance by tilting the head and upper trunk forward noticeably during the starting phase of the task (after exertion), while in groups 3 and 4 the tilt was slighter after than before exertion.

The results described here may also be interpreted within the broad framework of general models which describe the relationship between the levels of activation and the characteristics of motor performance in an organism (Hebb, 1955; Duffy, 1957, 268; 1962, 17 and 140; Deese, 1962).

REFERENCES

1. BAYER, L. M. & BAYLEY, N. (1959) Growth diagnosis. Univ. of Chicago Press.
2. CONTINI, R. & DRILLIS, R. (1966) Kinematic and kinetic techniques in biomechanics. in Alt, F. (Ed.) (1966) Advances in bioengineering and instrumentation. Plenum Press, New York, 3-68.
3. DARCUS, H. D. (1953) Some effects of prolonged muscular exertion. in Floyd, W. F. & Welford, A. T. (Ed.) (1953) Symposium of fatigue. H. K. Lewis & Co. Ltd. London, 59-68.
4. DEESE, J. (1962) Skilled performance and conditions of stress. in Glaser, R. (Ed.) (1962) Training research and education. John Wiley & Sons Inc. New York, 199-222.
5. DUFFY, E. (1957) The psychological significance of the concept of "arousal" or "activation". Psychol. Rev. 64, 5: 265-275.
6. DUFFY, E. (1962) Activation and behavior. John Wiley & Sons, New York.
7. FLEISHMAN, E. A. (1958) Dimensional analysis of movement reactions. J. exp. Psychol. 55: 438-453.
8. FRENCH, J. W. (1951) The description of aptitude and achievement tests in terms of rotated factors. Psychol. Monogr. 5.
9. HAMMERTON, M. & TICKNER, A. H. (1968) Physical fitness and skilled work after exercise. Ergonomics, 11, 1: 41-45.
10. HARMAN, H. (1967) Modern Factor analysis. U. of Chicago Press, Chicago.
11. HEBB, D. O. (1955) Drives and the C.N.S. (Conceptual Nervous System). Psychol. Review, 62, 243-254.
12. IBM: Data acquisition system. p. 19-20. IBM Tech. Publ. Dept. White Plains, N. Y. 10601.
13. IBM (1967) 1130 Statistical System (1130-CA-06X) User's Manual. IBM Tech. Publ. Dept. White Plains, N. Y. 10601.
14. JONES, F. P. & O'CONNELL, D. N. (1958 a) Color-coding of stroboscopic multiple-image photographs. Science 127, 3306: 1119.
15. JONES, F. P., O'CONNELL, D. N. & HANSON, J. A. (1958 b) Color-coded multiple-image photography for studying related rates of movement. J. of Psychol. 45: 247-251.
16. JONES, F. P., GRAY, F. E., HANSON, J. A. & O'CONNELL, D. N. (1959) An experimental study of the effect of head balance on patterns of posture and movement in man. J. of Psychol. 47: 247-258.

17. JONES, F. P. & HANSON, J. A. (1961) Time space pattern in a gross body movement. Percept. Mot. Skills 12, 35-41.
18. KIRJONEN, J. & PITKÄNEN, P. (1964/65) Keskitetyn voimaharjoittelun vaikutus eräiden motorisen kunnon perustekijöiden ja niitä edustavien perussuoritusten kehittymiseen. (The effect of concentrated strength exercise on the development of some basic factors of motor fitness and on that of the basic test performances representing them.) Stadion 1964, 2: 21-26., 3: 12-20., 4: 31-43., and 1965, 2: 29-46., 4: 56-63.
19. KIRJONEN, J. (1969) Eräät fyysisen toimintakykyisyyden osatekijät istumasta korokkeelle nousu -liikesuorituksen ja lihastyön siinä aiheuttamien muutosten selittäjänä. (Some components of physical fitness in relation to the movement pattern in stepping from a sitting position up to a platform and to its alterations after muscular exercise.) Unpublished licentiate dissertation. Faculty of Educational and Social Sciences. University of Jyväskylä.
20. KLEIN, S. J. (1961) Relation of muscle action potentials variously induced to breakdown of work in task oriented subjects. Percept. Mot. Skills 12: 131-141.
21. LARSON, L. A. & YOCOM, R. O. (1951) Measurement and evaluation in physical, health and recreation education. The Mosby Co. St. Louis.
22. McCLOY, C.H. & YOUNG, N. D. (1954) Tests and measurements in health and physical education. Appleton Century Crofts, Inc. New York.
23. MEYERS, C. R., ZIMMERLI, W., FARR, S. D. & BASCHNAGEL, N. A. (1969) Effects of strenuous physical activity upon reaction time. Res. Quart. 40, 332-337.
24. NICKS, D. C. & FLEISHMAN, E. A. (1962) What do physical fitness tests measure? A review of factor analytic studies. Educ. Psychol. Measmt. 22: 77-96.
25. STENNETT, R. G. (1957) The relationship of performance level to level of arousal. J. exp. Psychol. 54, 1: 54-61.
26. TAKALA, M. (1962) Ilmaisuteorioiden perusmuuttujista. (On basic variables in expression theories). Kasvatus ja koulu, 6: 1-19. 380-398.
27. TAKALA, M. (1963) Psychomotor expression and personality study, I. Scand. J. Psychol. 4, 149-159.
28. TAKALA, M. & PARTANEN, N. (1964) Psychomotor expression and personality study, III. The problem of "personal tempo". Scand. J. Psychol. 5, 161-170.
29. WELCH, M. (1969) Specificity of heavy work fatigue: Absence of transfer from heavy leg work to coordination tasks using the arms. Res. Quart. 40, 402-406.

30. WELFORD, A. T. (1968) Fundamentals of skill. Methuen & Co. Ltd., London.

31. WINER, B. J. (1962) Statistical principles in experimental design. McGraw Hill Co., New York.

32. ÅSTRAND, P-O. (1961) Arbetsprov med ergometercykeln. Ab Cykelfabriken Monark, Varberg.