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PERFORMANCE EVALUATION OF BK AMPUTEES THROUGH GRADED LOAD CARRYING TESTS

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The ergonomic approach to performance evaluation in orthopaedic rehabilitation presents problems because of the cumbersome and time-consuming measurement and test procedures involved. This paper describes a method of performance evaluation through graded load carrying tests which makes it possible to set up regression equations which can be used in routine clinical practice for prediction of the performance of below-knee amputees.

Key words: performance evaluation; regression equation; ergonomic tests; biomechanical tests; energy expenditure; patellar-tendon-bearing prosthesis; graded load carrying; peak heart rate; resting heart rate

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The importance of an objective evaluation of a rehabilitee's performance at the terminal stage of any rehabilitation programme cannot be overemphasized. In the case of a lower extremity handicap, the technique of such objective evaluation has so far taken two basic forms: (i) *ergonomic,* where the rehabilitee is asked to perform a few standard tasks or work activities during which energy expenditure and other associated cardiorespiratory responses are measured; and (ii) *biomechanical,* where the mechanical aspects of performance such as range of motion at joints, muscular involvement, muscle power etc. are studied by mechanical, electrical or electronic means or a combination of these.

The ergonomic approach has an edge over the biomechanical approach in the sense that it produces information about the performance of the patient's body system as a whole whereas the latter only furnishes information about one or at best a few aspects of his body mechanics. However, the main disadvantage of the ergonomic method lies in the cumbersome measurement techniques that are normally used, and besides, the number of tasks that the subject has to perform in order to generate worthwhile data makes it an exhausting time-consuming procedure unsuitable for routine clinical application. In spite of such shortcomings, the basic superiority of the ergonomic approach must not be overlooked and having realised this fact, some of the present authors have evolved a suitable test battery which can be readily applied in the clinical setting.

Ganguli et al. (1973 and 1975), in their search for such a clinically acceptable technique, came up with a series of tests for unilateral below-knee amputees using

Table 1. Means and standard deviations of the data of control group and test group subjects.

	Control group (n = 6)			
	Age (years)	Height (cm)	Body weight (kg)	Body surface area (m^2)
Mean	31.5	163.4	51.8	1.54
S.D. ±	7.4	7.7	6.7	0.13

	Test group (n = 6)				
	Age (years)	Height (cm)	Body weight with prosthesis and shoe (kg)	Body weight without prosthesis and shoe (kg)	Body surface area (m^2)
Mean	24.2	161.2	45.65	43.47	1.41
S.D. ±	4.6	4.2	5.1	4.92	0.08

patellar-tendon-bearing (PTB) prostheses. The tests included four common activities of daily living and working, i.e., sitting upright in a chair, standing in the erect posture, walking on level ground at a convenient speed and ascending a staircase. Although otherwise quite pragmatic, the individual tasks and their respective energy expenditures had no definite relationship with each other, and therefore the method did not leave any scope for prediction of energy expenditure by extrapolation from regression curves, and each time evaluation of the performance of a new amputee was required it was necessary to repeat the whole test series.

This paper describes a series of tests involving a graded exercise, where it has been possible to establish a correlation between the tasks and thus set up regression equations for prediction of energy expenditure of other comparable subjects.

METHOD AND MATERIALS

The test battery included the following activities: (a) sitting upright in a chair as in a sedentary type of work; (b) walking a distance of 1 km on level ground at the rate of 3 km/h, this activity being a very common one for daily living and working; and (c) walking on level ground with a shoulder pack with loads of 5 kg, 10 kg, 15 kg and 20 kg. The rate and distance of the walk was the same in the graded load carrying tests as in the level walking test without any load.

These tests were administered to a *test group* made up of six below-knee amputees using PTB prostheses and a *control group* of six matching normal healthy able-bodied subjects. The means and standard deviations of the data of the subjects in both the groups are given in Table 1. Figure 1 shows an amputee test subject performing the graded load carrying test.

The tests were carried out between 1000 and 1200 h in the morning and only after the whole procedure and purpose of the study had been carefully explained to the subjects on their arrival at the laboratory in a post-absorptive state. For regulation of speed and timing over the measured distance, an investigator accompanied the subjects during the walks.

During each test, the parameters studied were: energy expenditure (kcal/min), oxygen consumption (l/min STPD), pulmonary ventilation (l/min BTPS) and peak heart rate (beats/min). Oxygen consumption and energy expenditure were determined by collecting the expired air in a Douglas Bag and subsequently analysing it in a Haldane gas analysis apparatus. The resting heart rate was recorded by timing 20 heart beats several times during the last 5 minutes of the rest period preceding the test and noting the lowest value; the peak heart rate was recorded

Figure 1. A below-knee amputee fitted with a PTB prosthesis and performing the graded load carrying test.

similarly, starting at the moment of the cessation of activity.

The energy expenditure, oxygen consumption and pulmonary ventilation values were expressed per unit body weight (kg) to eliminate differences between individuals as far as body build was concerned. For the test group, the weights of the prostheses and shoes were not considered since no energy was directly consumed by the prosthetic appliances and footwear; on the other hand, the body muscles had to expend extra energy to carry these external loads.

Student's t test was used for the various parameters to determine the differences, if any, between the two groups.

The investigation was carried out during winter and spring, when the thermal environment was generally pleasant and mild as is evident from the following data which were collected:

Dry bulb, range: 21.0–34.0° C (mean: 30.5° C).

Wet bulb, range: 12.0–28.0° C (mean: 25.0° C).

RESULTS AND DISCUSSION

The means and standard deviations of the energy expenditure, oxygen consumptions, pulmonary ventilations and peak heart rates observed in the control as well as the test group subjects are presented in Table 2.

Considering the mean values of Table 2, it was observed that while the resting energy expenditure of the below-knee amputees was around 25 per cent higher than those of the control subjects, walking without any load increased this difference markedly, the amputees expending 86.7 per cent more energy than the controls. In the load carrying (5, 10, 15 and 20 kg), the below-knee amputees displayed an increase in energy expenditure of 70 per cent compared with the control group for the first three loads and 82 per cent for the heaviest load. As far as oxygen consumption was concerned, the differences between the two groups were of a similar order. The difference in pulmonary ventilation was 33 per cent at rest, 71 per cent for walking without any load and 53.8, 51.7, 56.9 and 65.7 for carrying loads of 5, 10, 15 and 20 kg, respectively. As regards peak heart rate, the increments in the test group were lower, viz. 4.9 per cent at rest, 17.1 per cent for walking without any load and 16.1, 19.8, 21.2 and 22.4 per cent for walking with 5, 10, 15 and 20 kg, respectively. As expected, the values for all the parameters increased as the load became heavier in both the groups.

The relationships between energy expenditure (kcal/min/kg) and load carried (kg), as shown in Figure 2, can be expressed by the following equations:

$y = 0.0322 + 0.0018\,x$ for the control group subjects ($r = +0.84$) and $y = 0.0535 + 0.0032\,x$ for the test group subjects ($r = +0.77$) where x and y are the load carried in kg and energy expenditure in kcal/min/kg, respectively. The rise in energy expenditure with load carrying

Table 2. Means and standard deviations of physiological

	Control group					
	Rest	Walking without load	Walking with 5 kg	Walking with 10 kg	Walking with 15 kg	Walking with 20 kg
Energy expenditure	0.016	0.030	0.040	0.048	0.057	0.067
(kcal/min/kg)	± 0.03	± 0.008	± 0.009	± 0.007	± 0.010	± 0.012
Oxygen consumption	0.0033	0.0063	0.0086	0.0102	0.0121	0.0144
(l/min STPD/kg)	± 0.0008	± 0.0019	± 0.0018	± 0.0015	± 0.0015	± 0.0029
Pulmonary ventilation	0.12	0.21	0.26	0.29	0.32	0.35
(l/min BTPS/kg)	± 0.03	± 0.06	± 0.05	± 0.04	± 0.05	± 0.06
Peak heart rate	73.1	80.0	88.3	92.2	96.7	105.2
(beats/min)	± 6.4	± 6.8	± 9.2	± 10.8	± 10.2	± 11.7

was greater in the below-knee amputees than in the test group subjects.

Interpretations based on the application of the paired *t* test for comparison between the controls and the test group subjects are as follows:

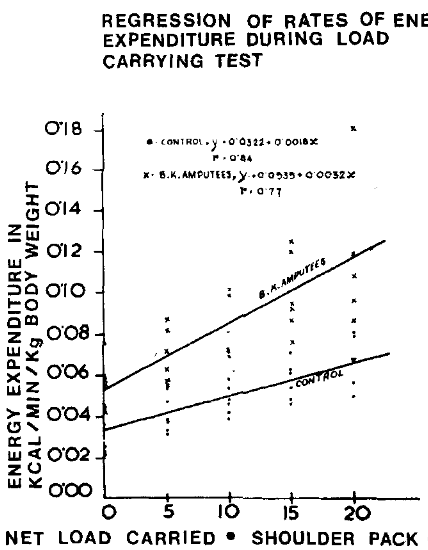

Figure 2. The relationship between energy expenditure (kcal/min/kg) and load (kg) in the control group and test group subjects.

(i) During rest, the differences between these two groups for all the parameters studied were not significant.

(ii) For walking on the level without any load, the differences in values of all parameters excepting oxygen consumption were highly significant.

(iii) For all denominations of load carrying, the differences were significant for all the parameters but were of a high order in the case of energy expenditure, oxygen consumption and pulmonary ventilation and of a low order for peak heart rate.

CONCLUSIONS

This investigation has shown that while the increase in the physiological effect on the below-knee amputees was much greater during level walking without any load than for load-carrying, the difference between the first three load conditions, viz., 5, 10 and 15 kg was, for all practical purposes, insignificant. Taking advantage of this finding one can safely *parameters of the control group and the test group subjects.*

Test group					
Rest	Walking without load	Walking with 5 kg	Walking with 10 kg	Walking with 15 kg	Walking with 20 kg
0.020	0.056	0.069	± 0.082	0.097	0.122
± 0.004	± 0.012	± 0.013	± 0.015	± 0.019	± 0.035
0.0043	0.0122	0.0148	0.0175	0.0209	0.0262
± 0.0008	± 0.0025	± 0.0028	± 0.0031	± 0.0038	± 0.0076
0.16	0.36	0.40	0.44	0.50	0.58
± 0.08	± 0.07	± 0.06	± 0.07	± 0.08	± 0.13
76.7	93.7	102.5	110.5	117.2	128.8
± 4.5	± 4.8	± 6.6	± 10.2	± 6.7	± 17.4

administer only one of the first three load carrying tests so that the test subject has only to carry 5 kg, 10 kg or 15 kg in the shoulder pack and the value of energy expenditure so obtained may be used for cross-checking the validity of the regression equation by substituting the value of the load carried and obtaining directly the energy expenditure in kcal/min/kg. This would simplify the evaluation procedure to a large extent thus making it suitable for routine clinical use. From this point of view, the method described in this paper is superior to the one earlier suggested by Ganguli et al. (1973, 1975) and offers much wider scope for clinical application.

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