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PHYSICAL WORKING CAPACITY IN A TROPICAL COUNTRY*)

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Summary

After an introduction, in which the theoretical background of working capacity measurements and some types of tests are reviewed, some results are presented from two types of (modified) Harvard step tests and a bicycle ergometer test applied mainly to Surinam forest labourers. Practical information is given especially with regard to experiences in a tropical country.
Finally a summary is presented of literature data on working capacity measurements for forest labourers from developed and developing countries. It appears that the working capacities of labourers in developing countries are lower, the main reason for this being their lower body weight.

Introduction

The physical working capacity of a subject or group is a physiological parameter indicating the capability to perform heavy physical work. Such work implies a high energy consumption. The only source for muscular energy that is of actual importance in professional work - which is characterized by a submaximal work load and long duration - is the one that delivers oxidation energy. The energy consumption is limited in the first place by the restricted capacity for oxygen intake by the human body. For this reason the working capacity is defined as the maximum oxygen intake of a subject [(Vo_2) max], with the dimensions l/min or l/min per kg body weight. The values measured usually vary from 2 to 5 O_2/min.

From the point of view of work science there are two important reasons why the physical working capacity is determined. In the first place it can be used as a reference standard in comparing subjects and in the second place as a criterion for the admissibility of specific activities.
The physical working capacity can be measured in various ways. To measure the working capacity a variety of tests have been developed during the years. They all have in common that people are subjected to a measurable work load. Two types of tests are distinguished, viz. (a) the recovery test,

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where measurements are taken after the exercise, during the recovery period and (b) the effort test, where the measurements are taken during the exercise. The effort tests can be classified according to the intensity of work load viz. (a) maximum tests, during which an exercise of increasing intensity is performed until oxygen intake does not further increase and (b) submaximum tests, performed at lower intensities of effort. In the latter case the (Vo_2) max is estimated from the submaximum load, or if available the oxygen consumption (Vo_2) and the heart rate (HR).
In the course of the last four years a variety of the above-mentioned tests were carried out. The experiences and results are discussed in this paper.
Most of the subjects under study were forestry labourers. Nevertheless, generally the results and conclusions are, as far as developing countries are concerned, also applicable to labourers of the timber industry.

Experimental methods

During the last years the methods gradually changed because of more accurate measuring equipment becoming available. In 1970 work was started with a Harvard step test (HST), a simple recovery test, which can be carried out with only a box, a metronome and a stopwatch. During the recovery period the heart rate (HR), as an index for the physical working capacity, is measured by means of palpation. Because the Surinam subjects were on average 10 cm shorter than the American (see Woodson and Conover, 1966) for which the test was developed, the original step height of 50 cm was reduced to 40 cm. In order to maintain the original work load the step rate should have been increased from 30 to 38 ascents per minute. This rate however is too fast (Shephard, 1969), so that the original rate of 30 ascents per minute was adhered to, changing the test from a maximum into a submaximum one; as a result the original index became useless. The duration of the test was 5 minutes. During the recovery period the number of heart beats was measured three times for half a minute, namely after the first, the second and the fourth minute. The sum of these three measurements was used as an index for the physical working capacity of the subjects.
During 1971 equipment suitable for measuring both the HR and the Vo_2 during the exercise was available and a change was made to a submaximum effort test, i.e. a test similar to the modified Harvard step test according to Ryhming (1953). Whereas Ryhming, like in the original HST, maintains the same step height and rhythm, a step height and rate depending on the body weight of the subject were used. The tests lasted 5 minutes. During the last minute HR and Vo_2 were measured. HR was measured wit a telemetric cardiotachometer (Hellige, one channel) and the Vo_2 was determined by means of a dry gasmeter according to Mueller-Franz and a microscholander O_2/CO_2-analyser. The maximum oxygen intake, which is a measure

for the working capacity of the subject, was estimated by combining HR and Vo_2 in the nomogram by Astrand (1960).
Since 1972 a Puch Tunturi bicycle ergometer is in use fitted with a mechanical brake and weighing only 34 kgs, which makes the bicycle very suitable for field studies. Moreover it is easy to adjust and to check, and not expensive. According to a test report (Bleeker, 1971) the bicycle is reliable up to a load of about 300 Watt. Unfortunately the moment of inertia of the mass as measured at the crank axle is on the low side, viz. 3.8 kg m^2 whereas normally it is at least 5.6 kg m^2
On this bicycle groups of labourers are tested in the forest. Each test consists of a submaximum discontinuous series of three increasing loads with intermediate rest periods. The exercise lasts for 5, the rest period for 10 minutes. During the fifth minute the HR is measured. The (Vo_2) max is determined according to Lange Andersen et al. (1971) from the given load and the measured HR by extrapolating to the maximum HR based on the age of the subject.

Results

The submaximum HST was applied to a group of Surinam agricultural labourers of Indian, Javanese, Amerindian and African origin and a group of Dutch students. The working capacity of the Surinam labourers, according to the index used, turned out to be higher than that of the Dutch students (table 1). The difference is highly significant (P = 0.001).

Table 1 Personal and (submaximum Harvard) step test data for Surinam agricultural labourers (A) and Dutch students (B). Index: sum of the heart beats taken from three half minutes during the recovery period: 1—1.5, 2—2.5 and 4—4.5 min.

category	number of subjects	age (years)	weight (kg)	length (m)	HR at rest (beats/min)	index
A	17	20—30	57 ± 1.5	1.65 ± 0.02	71	163 ± 3
B	13	20—30	74 ± 2.1	1.80 ± 0.02	71	176 ± 4

The difference in weight between the two categories is remarkable. The greater weight of the Dutch students is not responsible for their higher index. To test this supposition the weights and indices of the heaviest six labourers and the lightest six students were computed and compared with each other and with their original groups (table 2). It appears that the weights of the small groups draw near each other, whereas their indices remain the same. This shows that there is no effect of body weight on the HST-index. Ryhming (1953) arrived at similar conclusions. The lower weight of category A results in a lower work load on a HST which is not worked up in the appreciation of the HST. This means that a lighter group will score relatively higher in an HST than in a test based on the (V_{O_2}) max.

Table 2 Test results from two as to body weight comparable subgroups. For the original groups and their indices see table 1

category	number of subjects	weight (kg)	index
A	6	62.6 ± 0.6	162 ± 6
B	6	67.3 ± 1.8	177 ± 5

In another test applied to agricultural labourers, the influence of a light and heavy working day on the results of the modified HST was examined (table 3). For the individual subjects, except A, a small difference was found between the indices before and after a working day; no difference appeared between a light and a heavy working day.

Table 3 Comparison of the indices before and after a light and a heavy working day (for definition index see table 1)

subject	index		
		30 min after a	
	before a working day	light working day	heavy working day
A	156	142	125
B	127	134	147
C	135	143	140
D	183	185	184
E	157	163	157
F	159	165	160
G	154	155	170
average	153 ± 7	155 ± 7	155 ± 7

The modified HST similar to that of Ryhming (1953) was applied to a group of six forest labourers of African origin. The average estimated (V_{O_2}) max turned out to be 2.7 ± 0.2 l/min or 42 ± 3 ml/min per kg body weight (table 4).

Table 4 Personal data and (V_{O_2}) max calculations (according to the Astrand nomogram (1960) and corrected for age) of forest labourers tested with the modified HST

number of subjects	age (years)	weight (kg)	length (m)	(V_{O_2})max (l/min)	(V_{O_2})max (ml/min per kg)
6	28 (22—34)	64.5 (53.5—72.5)	1.66 (1.64—1.73)	2.7 ± 0.2	42 ± 3

The submaximum bicycle test was applied to another group of 10 forest labourers. Because some of the persons were not able to cycle, the pedals of the bicycle were fitted with tennis shoes which were fixed to the pedals. All persons were tested twice, i.e. for the first time in the afternoon after a (heavy) working day and secondly early next morning before their work. The average (V_{O_2}) max was estimated by extrapolation according to Lange Andersen et al. (1971). The afternoon tests did not differ significantly from the morning tests. Five subjects showed a higher and an equal number a lower (V_{O_2}) max. Thus no influence of psychological load nor previous heavy work could be shown and the hour of testing appeared of no importance. See table 5.

Table 5 Personal data and (V_{O_2})max calculations (according to the extrapolation method of Lange Andersen et al. (1971) based on bicycle tests

number of subjects	age (years)	weight (kg) (morning)	length (m)	(V_{O_2}) max l/min		(V_{O_2}) max ml/min/kg
				1st test (afternoon)	2nd test (morning)	body weight
10	22	54.6 ± 2.8	1.64 ± 0.01	2.27 ± 0.12	2.28 ± 0.12	42 ± 2

All tests discussed in this paper were applied in the open air. The average temperature and humidity during the tests are summarized in table 6.

Table 6 Average temperature, humidity and air velocity as measured during the various tests discussed in this paper

	type of test				
	HST		modified	bicycle	
	before working day	after working day	HST	afternoon	morning
temperature (°C)	25	28	28	28	24
humidity (%)	84	72	75	86	94
air velocity (m/sec)	0.1	0.7	0.8	0.8	1.1

At the end of this paper a table is presented which summarizes some results of working capacity tests carried out on forest labourers in other countries (table 7). There is a clear tendency that the (V_{O_2}) max values from studies carried out in developing countries are lower than those in developed countries. These differences in physical working capacity can be explained to a large extent by the differences in body weight and height.

Table 7 Literature data of working capacity tests of forest labourers from different countries, calculated from submaximum tests according to the Astrand (1960) — nomogram; for a comparison with Surinam figures see tables 4 and 5

country (author)	number of subjects	weight (kg)	length (m)	(Vo_2) max l/min	(Vo_2) max ml/min/kg body weight	age (years)
Venezuela (Mueller-Darss, 1971)	86	60	1.65	3.0	50	27
India (Hansson et al., 1966)	58	48	1.61	2.2	44	31
Greece (Vik, 1973)	3	60	1.62	2.6	44	27
Norway (Vik, 1973)	3	72	1.75	3.3	45	35
Norway (Hansson et al., 1966)	14	65	1.72	3.1	48	43
Sweden (Hansson et al., 1966)	50	73	1.74	3.5	49	38
Norway	76	74	—	3.5	47	<30
(Samset, 1969)		72	—	3.3	46	30—40
		71	—	3.2	45	40—50
		68	—	2.8	41	>50
The Netherlands	31	72	1.71	2.8	39	50—55
(Van Loon, 1969)	34	74	1.72	2.6	35	55—60
	38	76	1.70	2.5	33	60—65

The differences in length, weight and (Vo_2) max between populations of different countries have important consequences for research in work science and ergonomics. Apparently one cannot confine oneself to apply results from research in work science and ergonomics elsewhere but research in these disciplines has to be repeated on every population.

Conclusions and other remarks

1. The height of the Surinam people causes practical problems when the original HST is used, because of its step height of 50 cm (tables 1 and 7).
2. Our results confirm the findings by other authors (e.g. Ryhming, 1953) that in an HST no difference will exists in HR between a group of lighter and one of heavier subjects whereas the lighter group is loaded less (tables 1 and 2).
3. The consequence of the foregoing conclusion is that lighter subjects, as used in our experiments, show a better physical working capacity in an HST-type of test than in a test based on the (Vo_2) max.

4. One of the problems that occurred when carrying out bicycle tests is that not all persons were able to cycle. The mounting of footclips on the pedals does not always provide the best solution as not all persons wore suitable shoes. The problem was solved best with tennis shoes (largest size) fixed in the middle of the pedals.
5. In the HST a small effect from previous physical work was observed. In the bicycle tests no effect from psychological load (in the first test) nor any effect from previous heavy physical work (in the afternoon test) was found, so the hour of testing appeared of no importance.
6. The physical working capacity of forest labourers from Surinam and other developing countries, based on the (Vo_2) max, turns out to be lower than that from Western European countries (tables 4, 5 and 7).
7. In view of the differences in anthropometric and physiological data between populations of developing and some European countries, it is clear that with regard to work science and ergonomics Western European standards cannot be confined to. Research in these disciplines has to be repeated on every population.

References

Astrand, I., 1960. Aerobic work capacity in men and women with special reference to age. Acta Physiol. Scand. 49 Suppl. 169: 1—92.

Bleeker, J., 1971. IJkverslag Puch Tunturi ergometer NRTP 12789. NIPG-TNO report nov. 1971. Leiden.

Hansson, J.E. et al., 1966. Men and tools in Indian logging operations. Research notes, nr. 29. Royal College of Forestry, Stockholm.

Lange Andersen, K. et al., 1971. Fundamentals of exercise testing. WHO, Geneva.

Loon, J.H. van, 1969. Physica work load in tree felling and the working capacity of older forest workers. FAO/ECE/LOG/243 Vol II, 1971.

Mueller-Darss, H., 1971. Personal communication.

Mueller-Darss, H., 1974. Some aspects for the determination of work capacity in tropical regions by way of field studies. Paper presented at the IUFRO-symposium 'Ergonomics in Sawmills...' Jönköping, August 26—30.

Ryhming, I., 1953. A modified Harvard step test for the evaluation of physical fitness. Arbeitsphysiologie 15: 235—250.

Samset, I. et al., 1969. Cutting studies in Norwegian spruce and pine forests. Meddr norkske SkogsforsVes. 95; Vollebekk.

Shephard, R.J., 1969. Endurance fitness. University of Toronto Press. Toronto.

Vik, T., 1973. Workload on Greek and Norwegian cutters in hot and cold climates. IUFRO News 3 : 9.

Woodson, W.E. and D.W. Conover, 1966. Human enginering guide for equipment designess. University of California Press, Los Angeles.