Assessment of the 2,4 km run as a predictor of aerobic capacity

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Summary

Since the 2,4 km run time test is routinely used in military training programmes as an indicator of aerobic capacity and its possible improvement, an attempt was made to: (*i*) establish a regression equation of VO_{2max} v. 2,4 km run time in a group of 20 young military volunteers; and (*ii*) determine whether this equation could be used to predict VO_{2max} reliably from the 2,4 km time obtained from another group. Before and after training, VO_{2max} was measured in all subjects using a treadmill test, and 2,4 km run time was determined in the field. Linear regression equations using the 2,4 km run time as the independent variable accounted for 76 - 92% of the variance in VO_{2max}, while the standard error of the estimate varied from 2,24 - 2,91 ml/kg/min. In the second test group, the directly measured VO_{2max} was 59,89 ± 0,99 ml/kg/min, while the mean value estimated from the regression equation of the first group was 59,61 ± 1,16 ml/kg/min ($P < 0,001$). It was concluded that, in the population studied, the 2,4 km run time in the field reliably predicts VO_{2max} measured during treadmill exercise in the laboratory.

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Maximal oxygen uptake (VO_{2max}) is an expression of the cardiorespiratory capacity for oxygen transport to active tissues as well as the ability of these tissues to utilise oxygen. Direct measurement of maximal oxygen uptake is now universally accepted as a standard of reference for assessment of aerobic power.[1,2]

However, laboratory determination of VO_{2max} is both time-consuming and expensive in terms of expertise and equipment, and is impractical for the evaluation of large groups of people. Consequently, indirect submaximal tests for predicting VO_{2max} have been developed. Of these, the Astrand-Rhyming nomogram[3] and the Cooper 12-minute walk-run test[4] are the most widely used. Divergent correlations have been reported between direct VO_{2max} and predicted values based on the Cooper test[5] and the Astrand-Rhyming nomogram.[6-9] Since measurement of the 12-minute distances of a large number of subjects is laborious and inaccurate, modifications of the original Cooper 12-minute test are at present being used, especially in the armed forces.[10-12] In the South African Defence Force, the 2,4 km run has been the standard basic fitness test since the early 1970s. The most practical form of this test is a 'reversed' Cooper test in which a distance of 1,5 miles (2,4 km) is run by the subjects and the run time (approximately 12 minutes in fit subjects) is recorded. O'Donnell *et al.*[10] reported a significantly higher correlation between the 2,4 km run time and the VO_{2max} than between the 12-minute distance and VO_{2max}. This relationship established, the question of whether or not the 2,4 km run time could be used as a reliable predictor of aerobic capacity in national servicemen was addressed.

The objects of this study were thus: (*i*) to establish a regression equation that expressed the relationship between directly measured VO_{2max} values obtained on the treadmill and the 2,4 km time values of a military population before and after 12 weeks of intensive basic military training; and (*ii*) to assess the accuracy of this original regression equation in predicting VO_{2max} from the 2,4 km time in a new intake of national servicemen.

Subjects and methods

A randomly selected sample of 20 male volunteers for military training from the February intake of an infantry training unit was briefed on the objectives of the study. Participation in the study was voluntary and informed consent was obtained from each individual. Baseline measurements were made over 10 days between the arrival of the recruits and the start of basic training (pre-BT). All measurements were repeated over the last 10 days of their 12-week period of basic training (post-BT). Observations on 18 of the original group were completed. The data obtained from the 2 subjects who were unable to complete the study were not included in the statistical analysis of results.

The experiment was repeated in 1988 on a new group of recruits. Due to illness and scheduling conflicts, only 18 of the initial 20 subjects of this group could be followed up. Physical characteristics of all subjects are shown in Table I.

TABLE I. PHYSICAL CHARACTERISTICS (MEAN ± SE)

			Pre-BT		Post-BT	
Year	*N*	Age (yrs)	Height (cm)	Mass (kg)	Height (cm)	Mass (kg)
1987	**18**	**20,3 ± 1,3**	**163 ± 3**	**55,3 ± 1,0**	**166 ± 7**	**57,8 ± 1,1**
1988	**18**	**20,1 ± 1,5**	**167 ± 1**	**57,2 ± 1,1**	**167 ± 2**	**58,9 ± 1,2**

Direct measurement of VO_{2max}

VO_{2max} was determined for each subject using a continuous graded treadmill test. The test consisted of running on a calibrated Jaeger Laufergotest motor-driven treadmill at an initial speed of 8 km/h and a constant gradient of 5%, with speed being increased by 2 km/h every 3 minutes[13] until VO_{2max} was reached. Although a plateau of VO_2 was used as the main criterion of maximum, the test was terminated if the subject was unable to continue due to exhaustion; in this case, the peak VO_2 achieved over any 6-second period was recorded for analysis. All treadmill tests were completed within 10 minutes.[14]

Minute ventilation, heart rate and mixed expired concentrations of oxygen and carbon dioxide were measured continuously and the average value was recorded every 6 seconds

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by means of a computerised exercise system (PK Morgan). Subjects breathed through a low-resistance non-return T valve and the expired gas was directed to a 5 l mixing chamber. The inspired gas volume was measured using a calibrated Morgan MK2 vane ventilometer and corrected to standard temperature and pressure dry (STPD) conditions. Mixed expired concentrations of oxygen and carbon dioxide were measured at a constant sample flow of 0,5 l/min aspirated from the distal end of the mixing chamber using a Morgan paramagnetic oxygen analyser and a Morgan 901-MK2 carbon dioxide analyser. The sampled gas was dried using calcium chloride before analysis, and VO_{2max} was expressed in ml/kg/min under STPD conditions.

2,4 km run test

In accordance with the regulations of the infantry unit, subjects were dressed in combat clothing with light webbing, and each individual carried his own rifle. All runs were executed at 08h00 and on the same level road over an accurately measured distance of 1 200 m. An out-and-back route was used, and subjects were motivated to complete the distance in the shortest possible time. Individual values for the 2,4 km run were recorded to the nearest second.

Training procedures

All subjects completed the standardised South African Defence Force basic training period as previously described by Gordon *et al.*[15]

Statistics and calculations

Data are represented as mean ± standard error. Statistical analysis of before-and-after data were performed using Student's paired *t*-test. Standard linear regression was performed in order to derive the prediction equations.[16] Regression equations obtained in 1987 (Table II) were used to predict individual VO_{2max} values from the 2,4 km run time for all volunteers in the 1988 group.

TABLE II. REGRESSION EQUATIONS

	Predicted VO_{2max}	r	P value	SEE
1987				
Pre-BT	125,4 (0,098 × s)	−0,93	< 0,001	2,76
Post-BT	125,0 (0,096 × s)	−0,88	< 0,001	2,79
1988				
Pre-BT	99,9 (0,059 × s)	−0,74	< 0,001	2,91
Post-BT	107,7 (0,072 × s)	−0,76	< 0,001	2,24

SEE = standard error of the estimate.

Results

Table II and Fig 1 show the significant negative correlations that exist between direct VO_{2max} and 2,4 km run times. The direct VO_{2max} of both groups and the predicted VO_{2max} of the 1988 group are given in Table III.

The 1988 estimates of VO_{2max}, as predicted from the time taken to complete the 2,4 km field run and applied to the 1987 regression equations, did not differ significantly from the measured VO_{2max} values determined directly in 1988 during exercise on the treadmill. The post-BT predicted VO_{2max} values of the 1988 group were 9% higher than the corresponding pre-BT figure, and again were not significantly different from the VO_{2max} values measured directly.

On intake into the army, both groups completed the 2,4 km run test in a time faster than the 12 minutes suggested by Cooper.[4] On completion of basic training, the run time of the 1987 group was not significantly improved, whereas the 1988 group showed a significant decrease in run time. This result was significantly different from the average post-BT time of the 1987 intake.

TABLE III. DIRECT AND PREDICTED VO_{2max} VALUES (MEAN ± SEM) — 1988 TIME PREDICTED FROM 2,4 km RUN USING 1987 FORMULAS

Test	Pre-BT	Post-BT	P value
1987			
Direct VO_{2max} (ml/kg/min)	57,12 ± 1,60	60,43 ± 1,30	> 0,05
1988			
Direct VO_{2max} (ml/kg/min)	59,89 ± 0,99	62,50 ± 0,77	> 0,05
Predicted VO_{2max} (ml/kg/min)	59,61 ± 1,16 (r = 0,74*)	64,71 ± 0,78 (r = 0,76*)	< 0,01

*Correlation between direct and predicted VO_{2max}; $P < 0,05$.

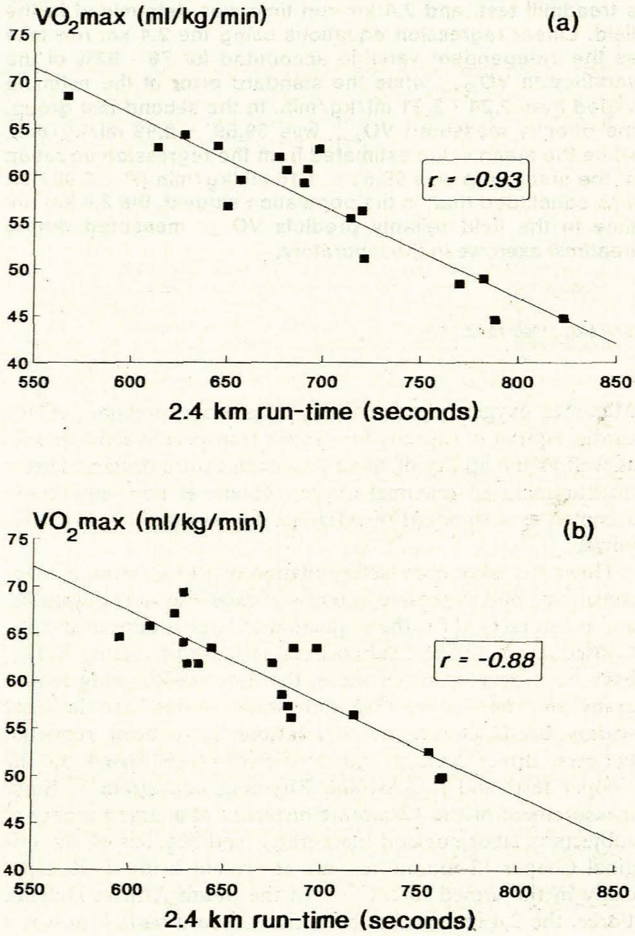

Fig. 1. Data and regression lines from subjects of the 1987 intake: (a) before basic training; (b) after basic training (see Table II for equations).

TABLE IV. 2,4 km RUN TIMES (MEAN ± SEM)

Year	Pr-Bt	Post-BT	Change (%)
1987	**695,5 ± 15,5**	**671,5 ± 12,3**	**−3,1 ± 1,3**
1988	**670,8 ± 8,3**	**628,0 ± 8,3*†**	**−6,1 ± 1,2**

*Pre-BT 1988:post-BT 1988; $P < 0,05$.
†Post-BT 1987:post-BT 1988; $P < 0,05$.

Discussion

The major findings of this study establish the practical application of a 'reversed Cooper test' on a military population, and are as follows: (*i*) that a statistically significant negative correlation exists between direct VO_{2max} and 2,4 km run time; and (*ii*) that VO_{2max} can be accurately predicted from the 2,4 km run time in a group of soldiers using the regression equation obtained from another group. As far as could be established, this is the first time that predictive values have been tested against direct VO_{2max} values on a totally different group of subjects.

Since the 2,4 km run-time test is routinely conducted by the army as an indication of aerobic capacity and improvement, and since it was our intention to ascertain the validity of this assumption, military recruits were selected for this study. Subjects were dressed in combat clothing and light webbing, and were required to carry a rifle in an attempt to duplicate as accurately as possible the conditions under which they were routinely tested. An advantage of the selected population was the identical training programmes and lifestyles followed by all recruits: this restricted the effect of extraneous factors on the fitness changes. However, in order to widen the application of this test as a predictor of VO_{2max} in other non-military groups, it will be both necessary and valuable to repeat this study using participants in ordinary running gear and without rifles.

No training effect was observed for direct VO_{2max} values since they did not increase significantly over the period of rigorous physical training. Larsson *et al.*[17] and Pollock *et al.*[18] have shown increases in VO_{2max} of approximately 20% when initial VO_{2max} values were 40 ml/kg/min or less, while Wilmore *et al.*[19] observed increases of 10% or less when initial VO_{2max} was in excess of 40 ml/kg/min. Vogel *et al.*[20] state that persons having an initial VO_{2max} value of 50 ml/kg/min or more have achieved their physiological potential for aerobic power and would show little or no further response despite the level of training intensity. Since the mean pre-training VO_{2max} levels obtained in this study exceeded this value (57,12 and 59,89 ml/kg/min), increases following a training programme were unlikely. These high values may be the consequence of rigorous selection criteria applied to military volunteers in the infantry unit. Since it is clear that the recruits were already fit on admission to the army, it was not possible to demonstrate a significant change in either VO_{2max} or 2,4 km time in *all* subjects of this study. Previous work on healthy, non-obese males[8] suggests that the changes in 2,4 km time will reflect that of the VO_{2max}. However, the significant improvement in 2,4 km run time after training in 1988 was not associated with a similar increase in VO_{2max}, but may be ascribed to an improvement in stamina and economy of submaximal running.[8] It is not clear why the 1988 group differed from the 1987 group.

Given the necessary equipment and expertise, the direct measurement of VO_{2max} on the treadmill is the method of choice for estimating aerobic capacity in relatively small numbers of subjects. Furthermore, VO_{2max} is a highly reproducible measurement.[13,21] However, the complexity and time required to perform this test make it impractical for application to a large population such as military recruits. As a solution, the validity and reliability of the Cooper test have been investigated in several studies,[5,22] with correlations between direct VO_{2max} and the 12-minute run distance ranging from 0,22 to 0,90. In the present study, *r*-values ranging from −0,74 to −0,93 (Table II) are lower than that obtained for trained subjects by Thiart *et al.*,[8] but compare favourably with those of Myles and Toft,[11] who evaluated the 2,4 km run — performed in boots and trousers — in the British Army and reported a correlation coefficient of −0,675. In addition, when we applied their prediction formula of $[VO_{2max} = 85,95 - 3,079 \times \text{run time (min)}]$ to our study group, the predicted VO_{2max} values were similar to the actual measured values. Furthermore, since the predictive value of the VO_{2max} for running performance is favoured by large variation in performance, the fact that the 2,4 run times differed by up to 30% in our study enhances the predictive value of this test.

It is concluded that in the population of military personnel studied, a 2,4 km timed out-and-back run test correlates significantly with, and reliably predicts, the directly measured VO_{2max}, and is therefore a reliable alternative measure of aerobic capacity.

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