W. L. Kenney

J. L. Hodgson

VARIABLES PREDICTIVE OF PERFORMANCE IN ELITE MIDDLE-DISTANCE RUNNERS

W. L. KENNEY, PhD and J. L. HODGSON, PhD

Laboratory for Human Performance Research, The Pennsylvania State University, University Park, PA 16802, USA

ABSTRACT

The purpose of this study was to investigate possible factors which may account for differences in performance times within a closely-matched group (in terms of performance) of elite distance runners. The runners were training for competition in the 1984 Olympic Games in either the 5000 m or the 3000 m steeplechase events. Each runner's best performance time (BPT) was obtained and a stepwise regression analysis was performed with the following independent variables: age, weight, % body fat, VO_2 max, aerobic threshold (AerT), and anaerobic threshold (AnT). For the 5000 m-runners, a multiple correlation of age and AnT accounted for 77% of the variance ($p < 0.02$); for the 3000 m steeplechase runners, body weight alone and body weight and AnT accounted for 94% ($p < .01$) and 98% ($p < .05$) of the variance, respectively. The results suggest that, among elite middle-distance runners, these parameters deserve attention as potential predictors of performance.

Key words: Elite distance runners, Prediction, Age, VO_2 max, Aerobic threshold, Anaerobic threshold, Body weight, % body fat.

INTRODUCTION

Physical and physiological characteristics of distance runners have received considerable attention in recent literature. Variables which have been associated with performance in distance running competition include maximal aerobic power (Costill, 1967; Davies and Thompson, 1979; Wyndham et al, 1969; Saltin and Åstrand, 1967), body composition (Costill et al, 1970; Novak et al, 1977; Sprynarova and Parizkova, 1971), various training indices (Hagan et al, 1981; Murray et al, 1980; Slovic, 1977), and running economy (Conley and Krahenbuhl, 1981). However prediction of performance times based on these and other parameters is often nebulous. For example, contrary to the traditional view that VO_2 max is the criterion on which to base cardiovascular endurance, LaFontaine (1981) pointed out recently that published correlations between VO_2 max and performance range from 0.08 to 0.91. An attempt to predict subtle performance differences in a homogeneous group of elite athletes is even more difficult. In the present study, possible predictors of best performance times for an elite group of 5000 m and 3000 m steeplechase (3000 s) runners were examined.

METHOD

Subjects

A total of 13 athletes was tested, eight 5000 m-runners and five 3000 m steeplechase runners. At the time of testing, all 13 were actively in training for these respective events for the 1984 Olympic Games, as part of the USOC Olympic-development programme. Each was given a complete physical examination and gave informed consent to participate

in the subsequent testing. Physical and physiological characteristics are given in Table I.

TABLE I
Physical and physiological characteristics of runners (mean $\pm$ SEM)

Event	n	Age (yrs)	Weight (kg)	% Body Fat	(ml.kg ⁻¹ min ⁻¹)		Best performance time (BPT) (min:sec)
					VO_2 max	Anaerobic Threshold	
5000 m	8	21.4 ± 1.0	64.5 ± 2.4	8.8 ± 0.8	74.4 ± 1.3	62.2 ± 2.1	14:05 $\pm 0:05$
3000 m Steeplechase	5	22.0 ± 1.5	71.9 ± 1.0	9.2 ± 0.5	72.4 ± 1.2	58.0 ± 2.1	8:38 $\pm 0:06$

Procedures

Each subject was weighed under water to determine % body fat and given a continuous running graded exercise test to determine VO_2 max. On a separate day, another graded exercise test was administered to determine both the aerobic (AerT) and anaerobic (AnT) thresholds (according to the definitions of Skinner and McLellan, 1980). The protocol of that test was as follows: After an initial warm-up period, treadmill speed was increased from 5.5 to 10 mph at a rate of 0.5 mph min⁻¹. Thereafter, the grade was increased at a rate of 1% min⁻¹ until approximate maximum heart rate was reached. Data were recorded breath-by-breath by an on-line computer system and VE vs VO_2 and VCO_2 vs VO_2

Dr. Kenney (right) and Dr. D. Kiser collecting breath-by-breath ventilatory data for AerT and AnT. The computerised system was developed at Noll Laboratory for Human Performance Research.

were plotted by computer for analysis. AerT and AnT were determined as the two points of inflection in these plots (Skinner and McLellan, 1980). Each runner's best performance time in seconds, in his best event (BPT 5000 or BPT 3000 s) was obtained and verified.

Statistics

A multiple linear regression analysis was performed which yielded the correlations seen in Table II. A correlation coefficient was considered significant if $p < 0.05$.

TABLE II
Relationships of best performance times to measured variables

Independent Variable	R ²	Significance	
		5000 m	3000 m
Age (years)	0.14	NS	0.50 NS
Weight (kg)	0.15	NS	0.94 $p < 0.02$
% Body Fat	0.29	NS	0.03 NS
VO ₂ max (ml.kg ⁻¹ min ⁻¹)	0.08	NS	0.16 NS
An Threshold (ml.kg ⁻¹ min ⁻¹)	0.12	NS	0.35 NS
Age and An Threshold	0.98	$p < 0.02$	0.98 $p < 0.05$

RESULTS AND DISCUSSION

As seen in Table I, the athletes in this study represented a fairly homogenous group in terms of physical and physiological characteristics. They were also closely matched in terms of best times in 5000 m (SEM = 5 seconds) and 3000 m steeplechase events (SEM = 6 seconds). As a group, they can be characterised as having ectomorphomorphic body builds, high maximal aerobic capacities, and slightly below average body weights. Their ages ranged from 19 to 26, with a high age indicative of greater competitive running experience (personal observation).

The relationships between performance time and the independent variables studied are shown in Table II. None of the correlations for the 5000 m group was significant and only the relationship between total body weight and BPT 3000 s was significant ($p < 0.01$). The correlations between VO₂ max and performance ($r = 0.28$ and 0.40) were much lower than earlier investigators who used less homogeneous groups over distances from 7.5 km (4.7 mi) to 15 km (9.4 mi) (Costill, 1967; Costill et al, 1973; Foster et al, 1977; Foster et al, 1978). However, Conley and Krahenbuhl (1981) recently obtained a correlation of $r = -0.12$ with a subject population which was similar in homogeneity (for

performance and VO₂ max) to the present group. Our correlation carried a positive sign, indicated that there was a small, albeit insignificant, inverse relationship between VO₂ and performance. *This does not argue that VO₂ max is unimportant, as evidenced by the high levels exhibited by all members of the group, but that a given elite level of competition, a higher VO₂ max does not determine success in a race of this distance.*

The best prediction equation of BPT 5000 contains the independent variables of age and AnT (BPT 5000 = $1155 - 5.4$ (age) $- 2.9$ (AnT)). The older runners had been training longer and had a greater advantage in terms of both years and level of competition. Thus, it appears that, within the age span of these runners, older (more experienced) runners who could delay onset of lactate formation (as evidenced by high AnT) did better in competitive 5000 m races.

In the 3000 m steeplechase group, body weight alone accounted for 94% of the variation in performance time (BPT 3000 s = $93.4 + 5.9$ (wt), $p < 0.01$). Addition of AnT to the equation (BPT 3000 s = $99 + 5.4$ (wt) + 0.6 (AnT)) increased the R² value to 98%. (However, due to the small sample size, the extra variable decreased the significance level somewhat).

Thus, it appears that for the small, homogeneous group of runners studied, age, AnT and body weight are important variables in predicting best performance time in competitive 5000 m and 3000 m steeplechase races. Other variables not studied here, e.g., running economy (Conley and Krahenbuhl, 1981), and training indices (Hagen et al, 1981) have shown similar predictive usefulness.

CONCLUSIONS

The present study merits the following conclusions:

1. A high aerobic capacity is a prerequisite for entry into an "elite" class of distance runners. However, among these runners, VO₂ max does not determine success in a competitive running event.
2. Within a highly-trained, homogeneous population of 5000 m runners, age (within the range of the present study) and anaerobic threshold accounted for a large and significant amount of variation (77%) in peak performance. In 3000 m steeplechasers, low total body weight alone accounted for 94% of the variation; body weight and AnT accounted for 98%.
3. It is recommended that, within such a group of athletes possessing equally-high aerobic capacities, age (experience), low body weight, and high anaerobic threshold are important attributes for successful performance.

References

- Conley, D. L. and Krahenbuhl, G. S., 1981 "Running economy and distance running performance of highly trained athletes". *Medicine and Science in Sports and Exercise* 12: 357-360.
- Costill, D. L., 1967 "The relationship between selected physiological variables and distance running performance". *Journal of Sports Medicine and Phys. Fitness* 7: 61-66.
- Costill, D. L., Bowers, R. and Kammer, W. F., 1970 "Skinfold estimates of body fat among marathon runners". *Medicine and Science in Sports* 2: 93-95.
- Costill, D. L., Thomason, H. and Roberts, E., 1973 "Fractional utilization of the aerobic capacity during distance running". *Medicine and Science in Sports* 5: 248-252.
- Davies, C. T. M. and Thompson, M. W., 1979 "Aerobic performance of female marathon and male ultramarathon athletes". *European Journal of Applied Physiology* 41: 233-252.
- Foster, C., Costill, D. L., Daniels, J. T. and Fink, W. J., 1978 "Skeletal muscle enzyme activity, fibre composition and VO₂ max in relation to distance running performance". *European Journal of Applied Physiology* 29: 73-80.
- Foster, C., Daniels, J. T. and Yarbrough, R. A., 1977 "Physiological and training correlates of marathon running performance". *Aust. Journal of Sports Medicine* 8: 14-17.
- Hagen, R. D., Smith, M. G. and Gettman, L. R., 1981 "Marathon performance in relation to maximal aerobic power and training indices". *Medicine and Science in Sports Exercise* 13: 185-189.

LaFontaine, J. P., Londeree, B. R. and Spath, W. K., 1981 "The maximal steady state versus selected running events". *Medicine and Science in Sports and Exercise* 13: 190-193.

Murray, T. D., Zinkgraf, S. A. and Shea, C., 1980 "The relationship of selected training variables on performance in marathon running". *Medicine and Science in Sports and Exercise* 12: 81 (abstract).

Novak, L. P., Woodward, W. A., Bestit, C. and Mellerwicz, H., 1977 "Working capacity, body composition, and anthropometry of Olympic female athletes". *Journal of Sports Medicine and Physical Fitness* 17: 275-283.

Saltin, B. and Åstrand, P. O., 1967 "Maximal oxygen uptake in athletes". *Journal of Applied Physiology* 23: 353-358.

Skinner, J. and McLellan, T., 1980 "The transition from aerobic to anaerobic metabolism". *Research Quarterly for Exercise and Sport* 51: 234-248.

Slovic, P., 1977 "Empirical study of training and performance in the marathon". *Research Quarterly for Exercise and Sport* 48: 769-777.

Sprynarova, S. and Parizkova, J., 1971 "Functional capacity and body composition in top weight-lifters, swimmers, runners, and skiers". *International Zeitschrift für angewandte Physiologie*, 24: 184-194.

Wyndham, D. H., Strydom, N. B., Von Rensburg, A. J. and Borade, A. J. S., 1969 "Physiological requirements for world-class performance in endurance running". *South African Medical Journal* 43: 996-1002.

BOOK REVIEW

Title: RACE HORSE TRAINING AND FEEDING

Author: Dr. Philip Swann   1984   ISBN 0-9590433-0-6

Publisher: Race Horse Sportsmedicine and Scientific Conditioning, PO Box 12, DOREEN, Victoria 3754, Australia

Price: \$Aust. 20 + 5 p. & p.   145 pages   Soft cover   Illustrated with half-tone photographs

This book is written essentially for the trainer of Australian and American flat race and trotting race horses, but the information given could be of value to the British trainer, point-to-point or hunter owner, and to those in European centres of trotting such as Austria.

The author applies the technique of modern human athletic training, based on muscle and cardio-respiratory physiology, to the training of the elite equine "athlete", an approach long overdue. He compares the 7%-15% improvement in human athletics in the past 25 years with only 1%-3% in equine performance. Anaerobic training is described using heart rate monitoring to aim at increasing speed with a heart rate of around 150 beats a minute (from a pre-exercise level of 35) and heart-rate meters are now available. The 150/min HR reaches the anaerobic threshold. More specific schedules are given to develop slow-twitch muscle fibres by distance work, then strenuous pace work to increase speed and stamina at steady state, developing fast-twitch fibres, and finally speed work, largely anaerobic, at HR > 150, by interval training. Horses, however, unlike humans, should not be trained to exhaustion. Special types of training, such as swimming, especially in rehabilitation after injury, are mentioned. The physiological reasons for the schedules are given in terms that should easily be understood by the layman.

Diet is discussed in detail, but the hundredweight of grain each eight to ten days needed for the race horse is beyond the pocket of the recreational rider, nor is it really necessary in this quantity. The chapter on drugs has several weaknesses, or rather missed opportunities. The author, although mentioning adverse effects of doping, fails to state that in international rules of racing even a trace of a prohibited drug is enough to have the horse banned, and the presence of theobromine from a chocolate tit-bit or from cattle cake made from chocolate-bean husks fed to point-to-pointers has led to heavy penalties.

This book is recommended to the owner of a competition horse, whether a point-to-point hunter or a child's gymkhana pony, as few doctors or physiotherapists own a race horse, though many are concerned with horses and ponies in some sort of training. To the non-horse owner the action photographs include some of dramatic accidents, illustrating the aetiology of human injuries. The need for better head protection is stressed. I am only sorry that this book was not written before my stable and paddock were empty. My daughter would have found it of considerable value.

H. E. Robson

BOOK REVIEW

Title: MANUAL MEDICINE 1984

Editors: J. Dvorak, V. Dvorak and W. Schneider

Publisher: Springer-Verlag, Berlin

Price: £28.80

This book contains the results of a seminar held in Fischingen, Switzerland, attended by 32 international specialists in Manual Medicine (in this context a combination of osteopathic medical practice and the latest American concept of muscle energy treatment techniques as propounded by Philip Greenman, D.O. Michigan State University).

It attempts to define treatment terminology such as 'mobilisation' and 'manipulation', and offer a multinational view, at times not only at variance but also at opposite extremes to each other, of a large number of examination and 'manipulative' procedures directed to the spine. A basic knowledge and groundwork in osteopathic practice is, in my view, essential before tackling this book, which is in danger of convincing the uninitiated of the requirement for "peaceful co-existence" in this branch of medicine as well as in East-West political confrontation in the 1980's.

For those with basic grounding in Manual Medicine the wide range of techniques demonstrated will add an interesting dimension though strictly in an osteopathic sense, without any direction towards other managements such as traction or injections.

M. A. Hutson