SUB MAXIMAL OXYGEN UPTAKE RELATED TO FAT FREE MASS AND LEAN LEG VOLUME IN TRAINED RUNNERS

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ABSTRACT

The sub maximal oxygen uptake (VO_2) of 32 trained male middle and long distance runners aged 19.5-36.0 years was determined at five treadmill speeds. There was a significant linear relationship ($p < 0.01$) between VO_2 at each of the treadmill speeds and Fat-Free Mass (FFM) and Lean Leg Volume (LLV). To explain the relationship other factors are considered, the most important of which may be the mechanical configuration of muscle and mitochondrial function.

INTRODUCTION

Physiological anthropometry has provided a means whereby an understanding, as opposed to a description, of the structure and function of physiological processes may be obtained. Parameters concerned with limb volumes, especially the Fat-Free Mass of a limb have been used and related to the rate of oxygen uptake. Davies (1968), Cotes *et al* (1969), Jones *et al* (1969) and Hamley and Watson (1969) have demonstrated the relationships between particular anthropometric indices and maximal rate of oxygen uptake (VO_2 max) and sub maximal rate of oxygen uptake (VO_2). However there are other points to consider. VO_2 is less trying on both the observer and the victim and satisfies the suggestion by Shephard (1972) who says that while haemoglobin levels rise with training an excessive increase in Hb can result in polycythaemia and the resulting increase in circulation resistance negates any theoretical advantages gained. Yet Cotes *et al* (1971) claim that O_2 transport is the limiting factor in work capacity and thus prefer to study VO_2 max.

Apart from the work by Cotes *et al* 1971 on cyclists, relatively little work has been conducted on the physiological anthropometry of trained athletes, and the relationship between anthropometric parameters and specific athletic skills has not been studied in detail.

SUBJECTS AND METHODS:

The group studied comprised 32 male athletes who were participating in daily running in their preparation for top level competition. These were students from Loughborough Colleges' Athletics Club, Loughborough University of Technology Athletics Club and local athletes. Details of the subjects are given in Table I.

Anthropometric Measures: Body density was predicted from the log of the sum of 4 caliper skinfold

TABLE I
Details of the 32 subjects

	Mean	S.D.
Age	23.8 years	± 5.0
Height	1.78 metres	± 0.08
Weight	66.6 kg	± 7.46
FFM	61.6 kg	± 6.23
Total Body Fat	7.43%	± 2.45
LLV	7.10 litres	± 1.10

thicknesses (Durnin and Rahaman 1967) where the error has been estimated to be $\pm 3.5\%$ of body wt., measurements were made on the left side of the body over the biceps, triceps, sub-scapula and supra-iliac regions. The percentage of fat in the body was calculated from the formula of Siri (1961):

$$\% \text{fat} = \left(\frac{4.95}{D} - 4.5 \right) \times 100 - \text{where } D \text{ is body density in } 10^3 \text{ kg.m}^{-3}$$

Fat-free mass in kg. was calculated by:

$$\text{FFM} = (100 - \% \text{fat}) \times W / 100 - \text{where } W \text{ is weight in kg.}$$

LLV was measured by the method of Jones and Pearson (1969) which partitions the leg into 6 segments which are similar to truncated cones.

Exercise Procedure: It was important from a consideration of the specificity of endurance performers that the subjects under test were examined in an exercise procedure as close as possible to their skill. The subjects were studied at five different work rates on a motor driven treadmill, these were: standing erect, walking at 2 mph., walking at 4 mph., jogging at 6 mph. and running at 8 mph. The subjects exercised for 6 min. at each level allowing 4 min. for equilibration and the last 2 min. providing the actual sample periods.

VO₂ was measured using a Douglas bag which was suspended vertically to reduce resistance. The subjects breathed through a low dead space face mask connected to 2 bags by lightweight 40 mm dacron tubing. Previously calibrated automatic gas analysers (Servomex ICA and Hartman Braun) were used to determine the O₂ and CO₂ contents of the expired air. The expiratory volume was measured by a Parkinson Cowan CD4 gas meter. The calculated VO₂ was corrected to STPD.

RESULTS AND DISCUSSION: There was a significant linear relationship between VO₂ and FFM, and VO₂ and LLV at all the treadmill speeds, $p < 0.01$. Figures 1 and 2 show the regression equations, correlation coefficients, coefficients of variation and the standard errors of the estimates (SEE). It can be seen that there is good relationship between the structural parameters and function as measured by VO₂. However, two main points arise:

- the relationships are not constant for different rates of work i.e. there are different slopes.
- If VO₂ was entirely dependent on the amount of muscle, the relationship should approach unity. Anything removed from this value implies that the relationship has been distorted by other variables. This becomes clearer when specificity and generality i.e.

$1-r^2$ and r^2 respectively, are computed and expressed as a percentage. At best only a third of the variance of VO₂ is attributable to its relationship with LLV and two-thirds of the variance of VO₂ is attributable to its relationship with FFM.

Graham and Andrew (1973) demonstrated that trained subjects had a higher VO₂ max than their untrained peers. If one considers the different results of Glassford *et al* (1965), DeVries (1968), Shephard *et al* (1968), Åstrand and Rodahl (1970), McArdle and Magel (1970) and of Wyndham (1974) one finds that among highly trained individuals VO₂ max differs markedly with the physical skill employed for the work task. Certainly we cannot suggest that the differences are solely dependent on O₂ transport and with our own results with highly trained performers giving different slopes for different work rates we suggest we might look at two aspects of muscle function.

First is *mechanical configuration of muscle*; unfortunately when determining FFM the mechanical configuration of muscle is not taken into account as the calculation is essentially volumetric. Thus utilization of the 'Units' of contraction, which will vary in their action between individuals and skills, may contribute to different effective forces being produced. In endurance

type performances as in these work tasks the cumulative effect could be considerable.

Second is *mitochondrial function*; Holloszy (1967) demonstrated that the mitochondria in striated muscle undergo adaptive changes both in number and composition as a result of training. He also showed that the pertinent enzyme systems develop most in the most active muscles. This will have considerable bearing on the efficiency of energy production and shows that O₂ utilisation at a specific cell site may be more important than previously thought.

If we take both these arguments it may be possible to explain why an international class performer in one skill is not seen to be as effective in another. Thus to perfect a given pattern of muscular activity to its ultimate capability, the training rates must be intense and must be specifically related to the muscular systems involved in the skill. However, considerably more work in this area is needed.

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