Specific Ergometric Test for Determination $VO_{2\,max}$ of Competitors in Underwater Orientation and Swimming With Fins

G. Mateev*

SUMMARY

There were investigated 20 top-class competitors in underwater orientation and swimming with fins during two tests:

1. Bicyle ergometer test with increasing intensity till exhaustion.

2. Swimming test with increasing resistance till exhaustion. A water ergometer was constructed, permiting the subject to swim with fins against gradual increasing resistance. During the both tests the next parameters were followed up: heart rate, blood pressure, lung ventilation, O_2 consumption, CO_2 expiration, lactate and acid-base balance of the blood. The comparison of the data, received from test 1 and 2 show, that the results from test 2 are more informative about the underwater swimming performance.

The special features of the swimming with fins, underwater or on the surface, require excellent swimming technique and give the possibility for considerable faster forward motion compared with the classical swimming, despite the fact that the muscle effort is perfomed only by the legs.

A lack of correspondance is very often observed between the data from bicycle ergometer performance tests and sport results in fin-swimming competition events. Perharps this is due to a complex of factors like: inherent features of the swimming with fins, improved hydrodynamic position of the swimmer and reduced frontal resistance, snorkel or SCUBA breathing use of neoprene suit, underwater environment isolation, considerable mental concentration, etc.

The aim of this study was to compare the physiological data in resonse to a maximal progressive ergometer test with these, reseived from maximal tethered swimming test and if it is possible, to es-

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tablish which of them is more informative with regard to the prediction of the competitors' sport results.

METHODS

Subjects of the investigation was 20 top-class sportsmen in underwater orientting and swimming with fins with mean age 21 ± 3.8 years and body weight 74 ± 5.3 kg, all of them in a very good sport condition.

The maximal oxygen consumption (VO_2max) was measured twice in random: 1. By means of progressive bicycle ergometer test (BET) with initial resistance of 60 wats (60 rpm). Every 90 s the resistance was increased with 30 wats till exhaustion. Mechanical ergometer «Monarch» was used. 2. By means of water ergometer test (WET), similar to the tethered swimming test, described by Magel a. Faulkner (1967). The difference was, that the subjects were swimming with fins with hands stretched ahead and breathing with snorkel.The swimmer had to support a definite weight while working with legs with adequate power. The initial load was 5 kg and every 90 s there was added 1 kg more till the swimmer was not able to sustain the weight.

In both cases (BET and WET) the subjects were connected to an open - circuit spirometer for measuring lung ventilation (VE). Expired air samples were analysed for O_2 with «Godart» gas analyser. Vo_2max was established as the highest VO_2 reached during the exhaustive swimm or cycling. In the same minute the heart rate (HR) was followed up by palpation and arterial blood pressure (BP) was measured with sphygmomanometer (in WET with specially constructed device).

RESULTS

The physiological data, obtained in the same minute when VO_2max was determined, are presented in table 1.

DISCUSSION

The significant lower HR at the end of WET is due to the prone position of the body and to the immersion in water, which lelds to intrathoracic blood pooling and increased heart stroke volume (Arborelius et al., 1972). Lower HR during maximal efforts in water than in air is reported by Dressendorfer et al. (1976), McArdle et al. (1978), Magel et al (1967) and others and is explained also with the improved venous return, water pressure, position of the body and state of hypogravitation of the body immersed in water. In present study it was not found any correlation between HR, Vo_2max and sport result.

There are no significant differences in the values of BP (either systolic or diastolic) during exhaustive cycling and swimming. Some changes were expected due to «diving reflex», which causes a rise of the diastolic BP with about 20 % (Heistad et al., 1968). It is obvious, that the muscle exercise is more powerful stimulus for vasodilation, than «diving reflex» is for vasoconstriction.

Maximal effort in water is accomplished with lower VE, which is not statistically significant. In classical swimming the breathing is restricted in connection with the swimming cycles (with the exception of back-stroke) and the reduced ventilation is compensated by increased O_2 utilization. In the presented investigation the swimmers used snorkel and the breathing was not limited, the diminished VE in

WET with 17 l is probably a result of the lower VO_2max.

It is found a significant decrease in VO_2max during WET and this is in a close agreement with other studies in classical swimming (McArdle et al., 1971; McArdle et ai., 1978). Loomis et al. (1972) found out that swimming with fins resulted in VO_2 max which is 74 % of the value found for land work on a bicycle ergometer, However, Magel a. Faulkner (1967) reported, that elite swimmers generate a similar VO_2max in both running and swimming. In our investigation the reduction of VO_2 max in WET compared with BET is probably due to the fact, that less muscle groups are involved than in the classical swimming. That's why VO_2max in WET is lower, despite of the subjects were top-class sportsmen. Because of low motivation it is possible to refuse exercising before the exhaustion is complete. But since in all instances maximal respiratory quotient exeed 1.00 and the heart rates are close to these reported by McArdle et al. (1978) and Magal et al. (1969) during exhaustive swimming tests, we make the conclusion that the refusal is objective.

The relationship between the data of the two tests performed with the sport results was evaluated by means of the Spearman coefficient of rank correlation. Every subject was ranked in accordance to: VO_2 max from BET; VO_2 max from WET; the position of the person in the classification of the National championship held 10 days after the experiment was carried out. The rank correlation coefficient between VO_2max from BET and sport result is 0.39, while between VO_2max from WET and sport result is 0.89. This high coefficient shows that WET is considerably more informative for the prediction of the sport results in swimming with fins competitors.

Irrespective of this advantage of the water ergometer test we have some objections - the most important one is that during this test the swimmer loses one of the most important features of the fin-swimming - the improved hydrodynamics, especially when using monofin.

Table-1. Maximal oxygen uptake (VO_2max), lung ventilation (VE). heart rate (HR) and arterial blood pressure (BP) in response to two maximal test. The data are presented in means ± standart deviation

	HR (beats per min)	BP (mm Hg) syst.	BP (mm Hg) diast.	VE (l STPD)	VO_2max ml/min/kg
BET	196.5 ±14.4	175.0 ±14.2	64.0 ±23.9	118.6 ±20.3	57.7 ± 7.3
WET	187.6 ± 8.9	170.0 ± 5.3	64.2 ±19.8	101.3 ±18.3	53.2 ± 8.2
P	<0.05	>0.10	>0.50	>0.10	<0.01

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Physiological Characteristics of Top Class Women Athletes

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SUMMARY

Physiological data of top class women athletes some of them Olympic Games and World Championships medal winners are presented.

The maximal aerobic power (VO_2max), the oxygen extraction from respired air ($Vo_2.Ve^{-1}$), the oxygen to heartrate ratio ($VO_2.HR^{-1}$), the PWC_{170}, the maximal ergometric power (W max) and similar physiological parameters of the women competitors in rowing, canoe-kayak ,and some track and field events are very high not only in comparison to normal men's population, but also to mean standarts for men athletes.

Women athletes undergo standart exercise loads with less energy expenditure than men and often with smaller disruption of homeostasis. Some of the women teams have a higher efficiency compared to men practicing the same kind of sport. For some elite women athletes an efficiency higher than 30 % has been established during moderate exercise.

An indirect confirmation of the above mentioned high efficiency of women athletes are sport performances. While women athletes are 20-25 % smaller and lighter than men of the same kind of sport and have correspondingly lower absolute values of important physiological parameters the differences of measurable performances in most of track and field and swimming event are no more than 7-10 %.

Except for maximal muscle strength, women athletes do not give in to men and in some respect even surpass them as to the level of some major physiological functions. The authors advance therefore the viewpoint that in most kind of sports there is no reason for major differences in the system of training for men and women athletes.

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The number of the women involved in sport activitiy is making a continuous prog ress. Women athletes' participation in the Balkan Games, in World Championships and Olympic Games is permanently increasing. Only in the last Olympics more than 1200 women had participated in over 40 sport disciplines. Such a large penetration of women in world sports as well as in the sport of Balkan countries pose before the sport medicine some special questions to be resolved.

One of them, which is not yet sufficiently elucidated, concerns the level of functional capacity, the general and special work capacity of sports women. In the present communication some data on that problem are presented which touch on the training of top sports women too.

The significance of the sex differences concerning absolute and relative muscle mass and muscle strength, as well as sport results especially in disciplines where the body mass is of a great importance is leading to a generalized transfer of these differences to almost all of the other physiological functions and sports abilities. Such generalization occurs mainly on the basis of the comparison of absolute values of the estimates of the functional capacity and potentials of the body.

For example, comparing the vital capaicty of elite sports women (4 200 ml) and sportsmen (5800 ml) a difference of 25 % in favour of men will be established. We have found up to 25-30 % lower absolute oxygen capacity in women than in men in the national teams of rowing, track and field, kayak. The data obtained by many other authors, including our Roumanian collegues are in agreement with our data.

The PWC_{170} values of sports women of the national teams in kayak, rowing, basketball, volleyball, skiing etc. are 16 to 32 % lower than the values of sporstmen of the same sports. 12 to 41 % lower in women than in men are the absolute values of the parameters of breathing efficiency, obtained in the same sample, excluding the rowing team, where minimal differences of about 4 % were found.

Nevertheless, the results of women in the measurable sport disciplines, such as track and field, running events, swimming, cycling, speed skating etc. are significantly nearer to sportsmen's results. The comparison of the world records in the respective sports disciplines shows that sports women's speed is only 5 to 10 % lower than the speed of sportsmen. As it may be seen from the next figures the differences between men and women are decreasing with the increasing of distance. Such findings disagree with the common opinion that women have a lower physical endurance than men (fig 1 to 4).

The discrepancy between sex differences of physiological parameters and the sport results is mainly due to the fact that generally absolute values are being compared instead of the relative values of the parameters investigated. In fact when relative values of the physiological parameters are compared a high correlation between them and sport results is established.

For example, the absolute aerobic capacity of women competitors in kayak are 30 % lower than the sportsmen's ones. The oxygen pulse values are 29 % lower respectively. If related to body weight, however, these differences decrease almost three times-up to 11 %. Similar dependences were found in competitive rowing.

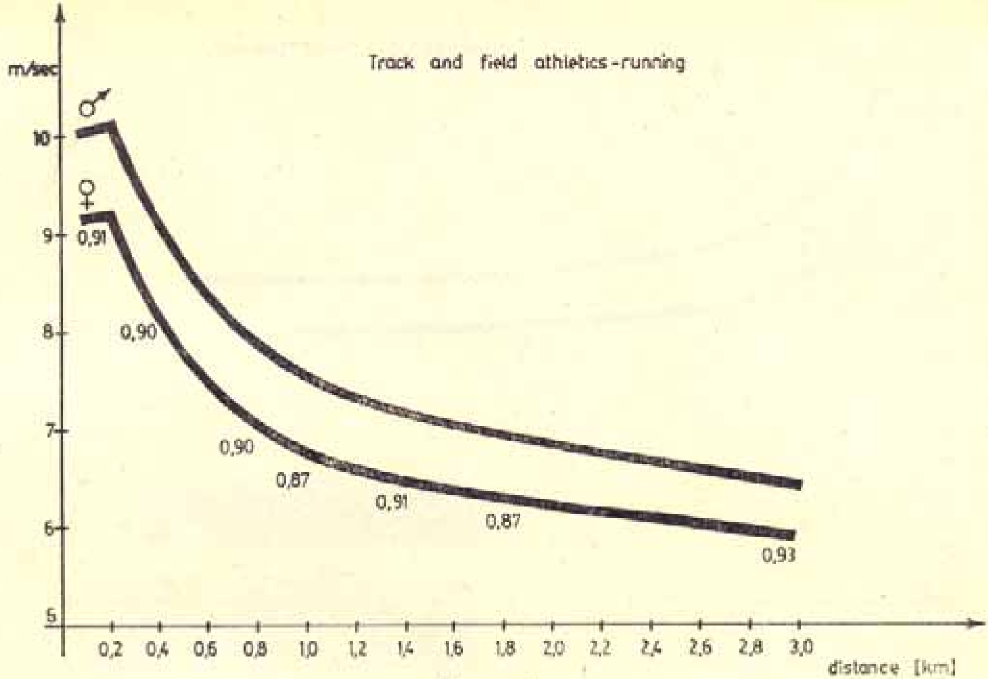


Figure — 1

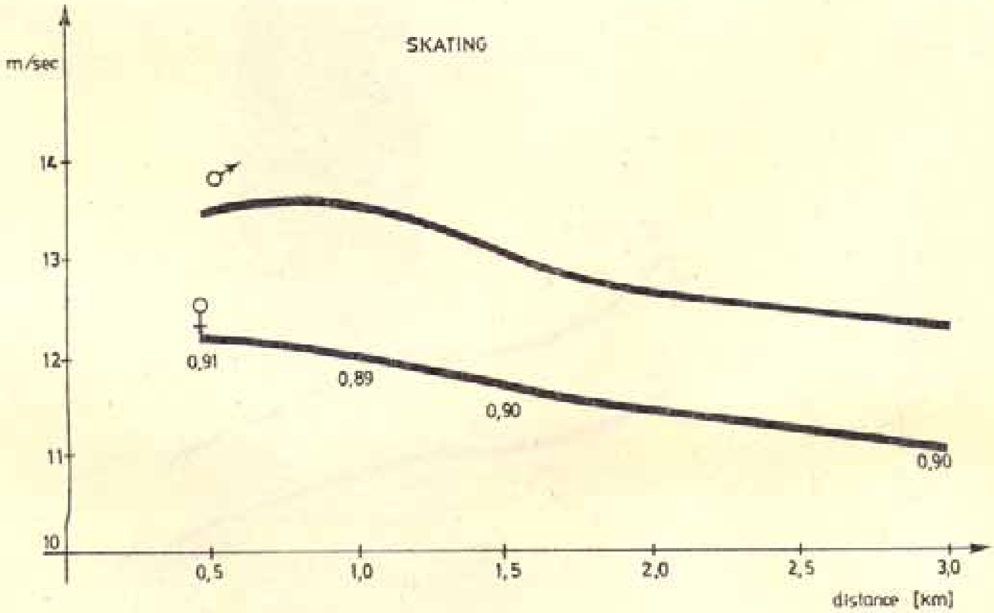
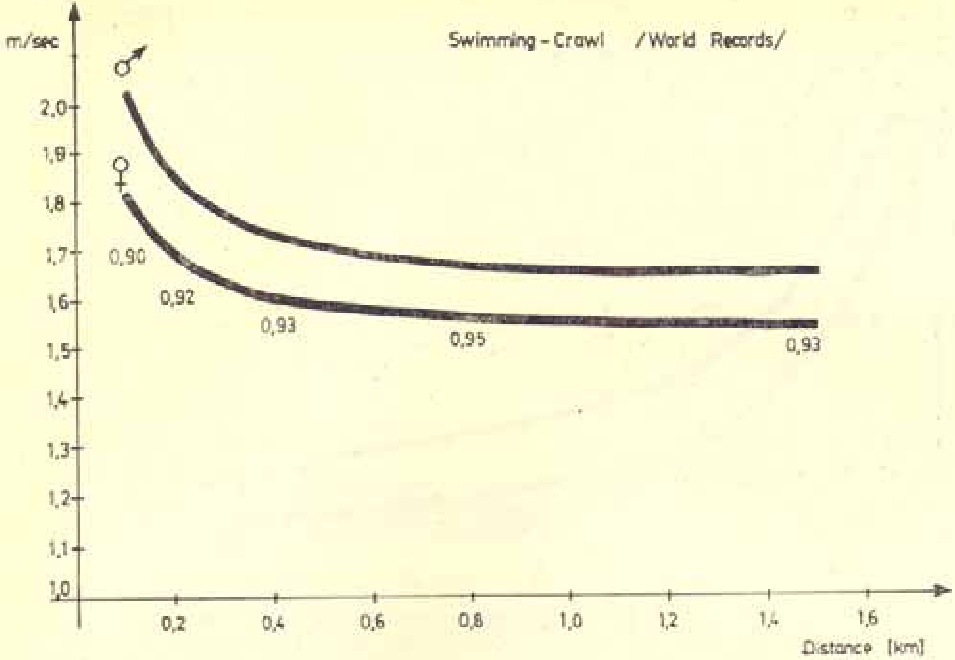


Figure — 2



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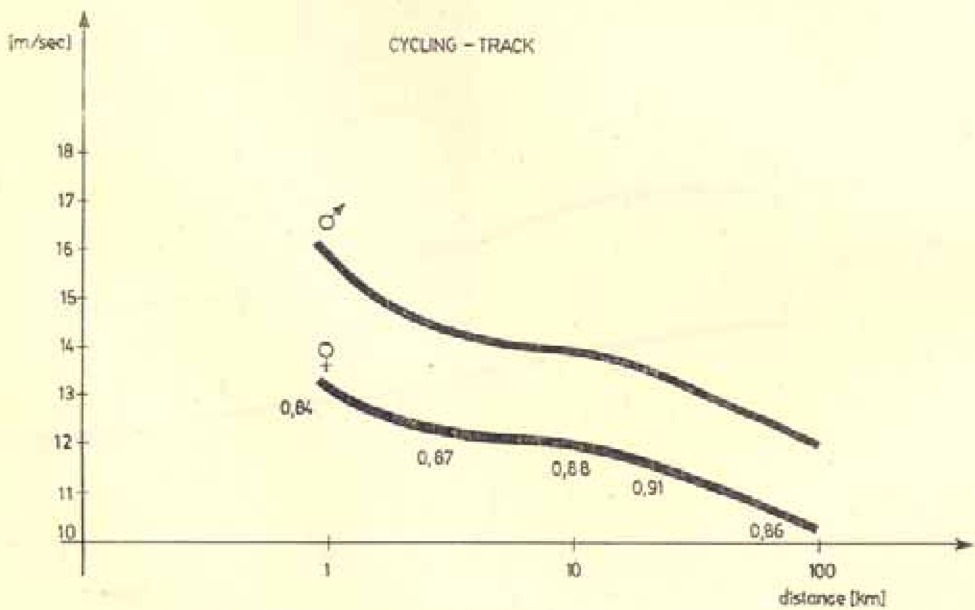


Figure — 4

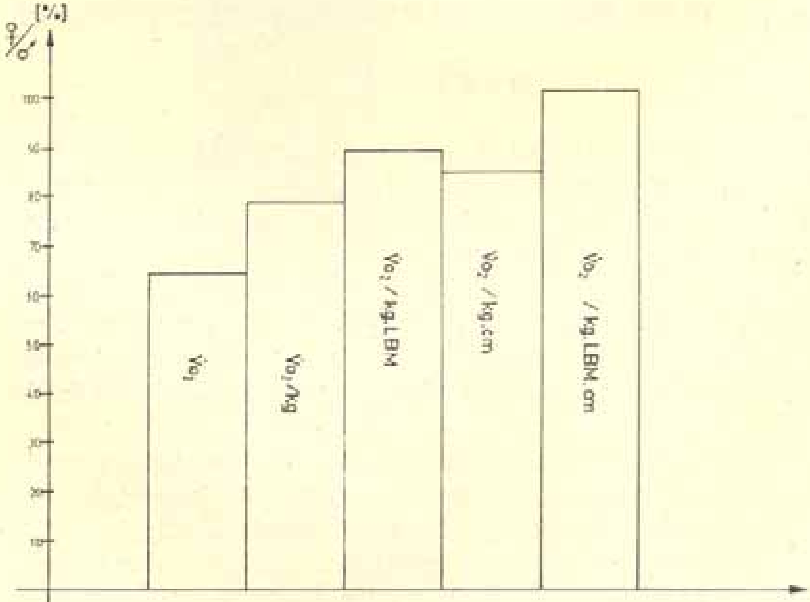
The next figure represents the mean values of data published in the literature in the last several years (Fig 5).

The differences between VO_2 max absolute values of sports women and sportsmen are as usually - 35 %. But the relative values (VO_2/kg) differences for the same parameters decrease to 21 %. If related to lean body mass and height (VO_2 max/LBM/cm) the men-women differences almost disappear - they are 3 %. Some women athletes demonstrate very high work efficiency. The highest individual values of this parameter (over 30 %) among all our top sportsmen and sports women were found in 4 women champions of Montreal Games 1976 in rowing.

As it may be seen from Fig. 6 at same maximal work power (W max) the VO_2 max of sports women is lower than VO_2 max of sportsmen in competitive rowing. That is an indirect evidence of the higher efficiency of the oxydative processes in sports women.

According to many criteria the adaptive capacity toward physical exercise of women athletes surpass the sportsmen's ones. The values obtained in our studies of many physiological parameters of basic importance in women show increasing rates which was never observed in sportsmen. For example in the course of the Olympic preparation of the women rowing teams we have found an increase of VO_2 max and of ergometric work capacity up to 50 % and more.

This and other data give us the reason to support the thesis that in many kinds of sport there should not be fundamental differences between the training systems for men and women.



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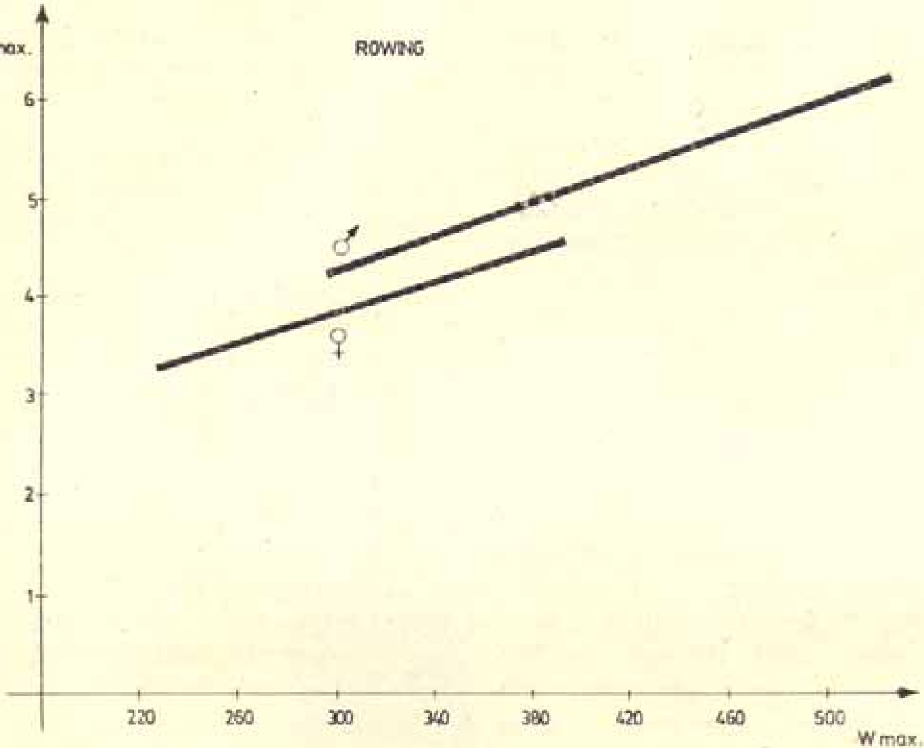

Figure — 6

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The Role of The General Practitioner in Sports Medicine

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The increasing interest in sport throughout the world will lead inevitably to an increase in the total number of injuries. «Sport for All = Sports Injuries for All». (P.N. Sperryn).

In any country, for example Turkey, with a population of 35.000.000 it is likely that some 10 %, 3.500.000 will participate in sport, in clubs or at school, and every year a significant proportion will sustain injury whilst engaged in sport, so obviously no specialised sports injury clinics could cope with the vast numbers at risk. One might expect some 3.500 of these club athletes to attain local or provincial standard, 350 National or International standard, and only perhaps 35 to qualify for the Olympics; 1 : 1 million (Fig.1).

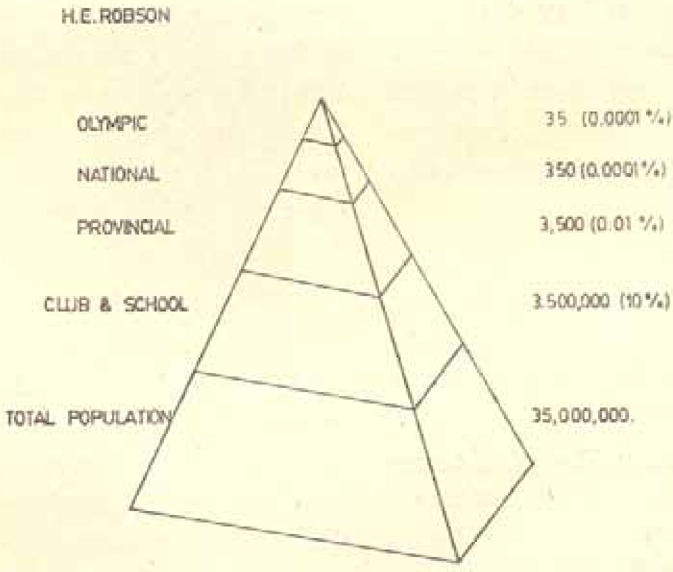

FIG.1.
POSSIBLE DISTRIBUTION OF CLASSES OF ATHLETES IN A COUNTRY'S POPULATION

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These latter three groups will need some medical and physiological supervision of their training, and highly skilled treatment of some of their injuries (though it is hoped that ALL sports injuries to Every class of athlete will have adequate treatment at all times).

In a similar way, the vast majority of injuries sustained in sport can be dealt with by anyone who has had some training in First Aid; it is to be hoped that most coaches, trainers and other team officials will have had some such training, and the services of the voluntary services such as the Red Cross or Red Crescent are often available for sports fixtures. Physiotherapists and nurses can play a very important part in the immediate treatment of injuries, even very severe damage. It should, however, be the responsibility of the doctor to see that voluntary helpers are properly trained in first aid. Even if only to prevent further trauma to an injured person, especially when spinal damage could be suspected.

Those injuries beyond simple first aid measures should be seen by a doctor, and most could, and should be the responsibility of the general practitioner or junior hospital casualty doctor.

A small proportion will need to be referred for specialist investigation or treatment in a geenral hospital; an orthopaedic surgeon for fractures, meniscus lesions and ligamentous lesions that might require surgery; to physicians for cardiological conditions; to gynaecologists for severe menstrual disorders and water skiiers, pyometra etc.

Only very few injuries are specific to sport, and need the attention of the highly specialised sports injuries expert, and his limited services should not be swamped by trivia or by conditions that others can handle, even though the patient be an Olympic athlete. (Fig.2).

During a weekend in any small town there are likely to be many sporting events taking place simultaneously, in widely separated locations. Of the dozen doctors such a town may have, it is unlikely that more than one will be available for the treatment of sports injuries; if boxing is included, by international rules a doctor must be present for the whole duration of the contest, so he will not be available elsewhere. The best place for the doctor doing his turn of duty is in his home or his clinic, where everyone knows where to find him, where patients can be brought to him, and from whence they can be evaculated to hospital. Much as he may enjoy watching football, horse racing or any other sport, he will not be performing his duties conscientiously unless he is accessible to everyone that needs him.

Apart from training coaches and other personnel in first aid, the general practitioner can help with the physiological basis of training, especially for the middle aged. The value of routine screening for the young and healthy is rather doubtful, but the doctor should be available to advise on choice of suitable sports for the disabled, and give guidance on when an injured athlete will be able to resume training and competition.

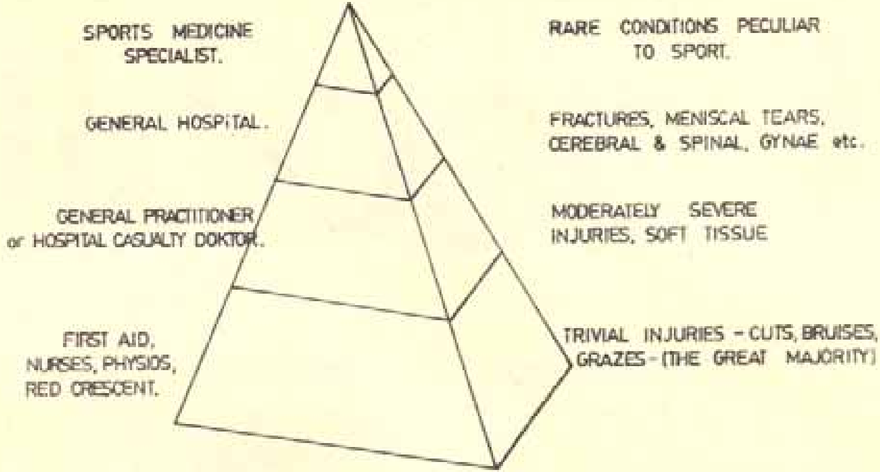

FIG 2. RESPONSIBILITY FOR TREATING SPORTS INJURIES.

As a respected member of the community, the doctor should be able to exert some influence with local authority for the establishment of training facilities. In Rio de Janeiro, Brazil, the local sports medicine group have been able to pursuade the City Council to mark out measured jogging tracks along the paths in the parks and along the beaches. They have laid down inexpensive football pitches and beach gymnasia. In Sweden there are jogging tracks through the forests, used also for cross country skiing in winter, and augmented by inexpensive improvised outdoor gymnasia.

Although it is pleasant, and good for national prestige to have sports facilities of Olympic standard, much can be done at little cost, but with the expenditure of time and hard work for those who have the health and wellfare of their community at heart.

Blood Lactic Acid Levels of Judo - Karate Trained and Nontrained Children in Maximal and Supramaximal Exercises

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SUMMARY

The blood lactic acid levels of judo-karate trained children and non-trained children in maximal and supramaximal exercises was investigated. In the present work we have established that there is typical and significant increases in blood lactic acid levels between the children (11-13 years old) who were trained continuously in judo-karate groups and the others who were not taking part in any sportive activity, in rest maximal and supramaximal exercises.

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Sports Injuries in Women and Its Basic Problems

SUMMARY

Some results of athletic injuries in men and women are compared. the main causes of injuries show differences in both sex. Other differences according to sex are shortly discussed. It is concluded that girls may begin swimming at 5 years of age and tennis at 8 years, track and field 9 years, hand ball, volleyball at liest 10 years of age.

Triiodothyronine, Thyroxine and Thyrotropin Changes During Bicycle Training and ergometer endurance Test

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SUMMARY

The levels of triiodothyronine (T_3), thyroxine (T_4) and thyrotropin (TSH) in serum were measured in two groups of top-class bicyclists: 1. After a 125 km (3 1/2 h) road training - 6 subjects. 2. After an ergometric endurance test with variable intensity - 50 min cycling with changing the intensity every 5 min alternately with 50% W max or 75% W max - 7 subjects. It was found a significant elevation of T_3 and T_4 after the training and nonsignificant increase after the laboratory test. 22 hours later the values of T_3 and T_4 returned to the preexercise concentrations in both groups. TSH was not changed after the physical exercise in groups 1 and 2, but there was a significant fall of TSH 22 hours after training and not after the ergometric test. It is concluded, that the increase of the concentrations of T_3 and T_4 depends on the energy production needs, connected with the duration and intensity of the physical work. This elevation is due to the sympathetic stimulation of the thyroid gland, not via TSH. The higher concentrations of T_3 and T_4 after the training in group 1 caused the fall of TSH in blood plasma and hence - normalization of the levels of T_3 and T_4 22 hours later. The less elevation of T_3 and T_4 after laboratory test in group 2 did not cause such effect.

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The regulatory effects of thyroid hormones (TH) on metabolic rate and energy supply during exercise still are not cleared. Changes in plasma thyroid hormones levels and the sensitivity of the target tissues are observed during muscular work. According to Sawin, C.T., 1969 exercise lowers the plasma free thyroxine (T_4) probably by increasing peripheral utilization of T_4. An elevated T_4 plasma level after prolonged efforts is reported by Stromme, S.B., et al. 1975. Roti, S., et al. 1979 and Dessypris, A., et al. 1980 found no changes of TH secretion during physical exercise. The data are obviously very contradictory.

Changes in T_4 levels are generally paralled by similar changes in triiodothyronine (T_3), but in some circumstances the changes are independent and the measurement of both levels and also thyrotropine (TSH) level is therefore an important part of the investigation of the function of hypothalamic-pituitary- thyroid axis during muscular exercise.

The purpose of the present investigation was to examine the T_3, T_4 and TSH changes: I) during bicycle training and 2) during bicycle ergometer endurance test with variable intensity in laboratory conditions.

METHODS

Two groups of top-class cyclists aged 16-21 years were investigated. All subjects were submitted to a progressive exercise test until exhaustion for determination of maximal oxygen consumption (VO_2 max) and maximal ergometric performance (W max).

Bicycle training. Group I (6 persons) was investigated during 125 km road training with duration of 3 1/2 hours.

Bicycle ergometer endurance test in laboratory conditions. The subjects of group II (7 persons) performed an endurance test of 50 min duration with variable insensity alternating 5-min bouts of 55 % and 75 % of W max.

Blood, samples for determination of T_3 T_4 and TSH were taken at rest before the experiment, immediately after ceasing of the effort and 22 hours later. T_3, T_4 and TSH were evaluated by Amersham radioimmunoassay kits.

RESULTS

The data for T_3, T_4 and TSH concentrations are presented in table 1. After the bicycle training T_3 increases by 23.5% ($p < 0.05$) and exceeds the upper limit of the normal values. After the endurance test T_3 is less, but also significantly elevated by 14.4 % ($p < 0.001$). T_3 returnes to the initial values ($p < 0.001$) 21 hours later in both cases.

T_4 is increased by 21.6% ($p < 0.05$) only after the road training. T_4 indicates a tendency of lowering 22 hours after the two types of exercise.

TSH level does not change immediately after both kinds of physical effort. After a period of recovery of 22 hours following the laboratory endurance test no changes are observed in TSH concentration. However, there is a significant Fall in TSH ($p < 0.05$) 22 hours after the road training.

DISCUSSION

The observed changes in T_3 and T_4 levels are obviously related to the intensity and duration of the exercise. Energy production during the applied physical efforts proceeds mainly at the expence of carbohydrate and fat oxidation. Thyroid hormones stimulate an increased glycogen breakdown and enhanced peripheral utilization of glucose. They increase the mobilization and oxidation of free fatty acids, particulary when there is a relative lack of carbohydrate. This may occur during prolonged and intensive exercise. Thyroid hormones increase the O_2 consumption in the liver and skeletal muscle. The well known uncoupling of oxidative phosphorilation occurs in liver mitochondria, but it is not seen in skeletal muscle mitochondria. Physiological doses of T_4 does not change P/O ratio and may actually cause an increase in available energy supply (Sawin, C.T., 1969).

Elevation of T_3 is more significant after the bicycle road training, where the intensity and duration of the effort are greater, compared to the laboratory endurance test. These data correspond to those obtained by Demeter, A., et al. 1975. They have established an increase of thyroid function proportional to the amount and intensity of the effort.

During the laboratory endurance test the increase of T_3 is probably sufficient for realisation of its biological effect on the metabolism, because of the lower energy requirements. During the bicycle training we find not only a more significant increase of T_3, but also a simultaneous elevation of T_4, which intensifies the biological effect mainly in respect to the utilization of FFA in energy supply.

Table I

T_3, T_4, TSH concentrations in serum of cyclists submited to endurance test and bicycle training

		Endurance test			Bicycle training		
		initial	after	22^h recovery	initial	after	22^h recovery
T_3 ng/ml	$\bar{x}$	0.93	1.07$^+$	0.91^{++}	1.66	2.05	1.59^{++}
	s	0.10	0.11	0.10	0.45	0.14	0.30
T_4 g/100 ml	$\bar{x}$	7.32	7.54	6.47	7.68	9.34$^+$	8.10
	s	1.32	1.02	0.92	0.96	1.21	1.50
TSH μU/ml	$\bar{x}$	4.80	4.40	4.50	4.36	4.24	3.17^{++}
	s	1.70	1.09	0.95	0.81	1.70	0.64

$^+$ $p < 0.05$ compared with initial data

$^{++}$ $p < 0.05$ compared with data after effort

The changes in T_3 and T_4 concentration are not associated with changes in TSH level. It is well known, that thyroid gland has a direct sympathetic innervation (Samson Wright, 1965, Melander, A., et al. 1975, Hommel, E., et al. 1981). During the applied exercises there is a prolonged and intensive sympathetic tone, which may call forth an enhanced release of thyroid hormones without involving the negative feedback control via the hypothalamic-pituitary axis. On the other hand the elevated T_3 and T_4 concentrations after the bicycle training are probably sufficient to put in action the feedback control mechanism and cause the TSH decrease and an adequate normalization of T_3 and T_4 levels, found 22 hours after the training.

After the laboratory endurance test the increase in T_3 is of a lower extent, the T_4 concentration is unchanged, hence TSH level remains the same.

In conclusion changes in T_3 and T_4 levels during exercise are associated with duration and intensity of effort and are caused by the sympathetic stimulation of the thyroid gland. The extent of these changes determines the involving of feedback control mechanism from the hypothalamo-pituitary axis.

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