

Physical fitness of young belgian swimmers

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INTRODUCTION

The aim of this study is to analyze the physiologic parameters obtained during bicycle ergometer tests for top level swimmers of adolescent age group from best Belgian clubs issuing from the French speaking population. Many authors have already measured the maximal oxygen uptake ($\max \dot{V}O_2$) values of swimmers; thus the $\max \dot{V}O_2$ of trained subjects have been found to lie between 58 and 67 $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for boys and 52-58 $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for girls [Saltin and Åstrand (1967), Holmer (1972), Shepard (1974) and Cazorla (1978)]. Further the mean of $\max \dot{V}O_2$ values are quite similar for breast-stroke, backstroke and butterflystroke, while that obtained for crawl is slightly lower (Holmer, 1972).

In the realm of swimming, various methods have been used to determine the $\max \dot{V}O_2$: Myashita (1971) and Cazorla (1978) have utilized the treadmill, Åstrand *et al.* (1978) the bicycle ergometer. In 1966 Costill had proposed a system whereby the $\max \dot{V}O_2$ could be determined in the swimming pool; this method has been further elaborated by Holmer who in 1974 came to a highly sophisticated ergometer called the "swimming flume". Numura in 1978 and Cazorla in 1982 adopted methods

which were intermediate between those proposed by Costill and Holmer. Whatever the various advantages and difficulties of those different methods, Holmer (1972) and Nomura (1978) found a very high coefficient of correlation ($r=0.97$) between the values of $\max \dot{V}O_2$ obtained for respective swimmers using either their ergometer or the bicycle ergometer.

It is on the basis of these studies that we felt it was more expedient to maintain the bicycle ergometer method for the physiological evaluation of young swimmers. Indeed this study aims at assessing the level of adaptation reached by these adolescents rather than their actual metabolic performance in the swimming-pool.

SUBJECTS AND METHODS

(A) Subjects

The subjects were 130 boys (male) and 98 girls (female) engaged in swimming at the rate of 8-14 hours per week and belonging to the best Belgian clubs from the French speaking population. Prior medical examination did not reveal any pathology likely to falsify the results. None of these swimmers were taking any drug.

(B) Methods

The physiological evaluation is made from bicycle ergometer test with progressively increasing work load starting from

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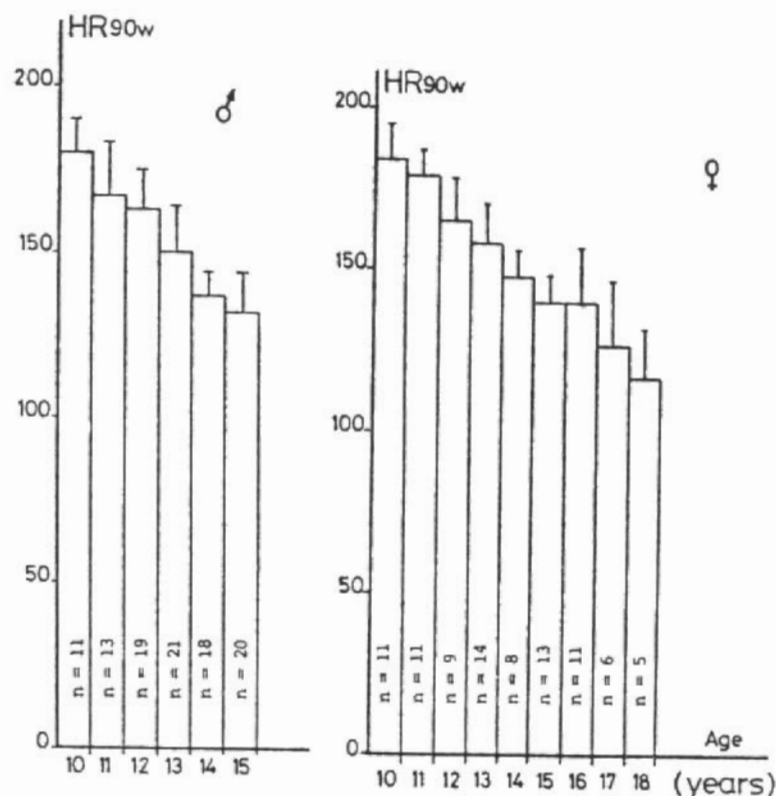


Fig. 1.—Evolution, with respect to age, of the Heart Rate (HR) corresponding to work load of 90 watts.

30 watts, with increments of 30 watts every 3 minutes till the heart rate reaches about 180 beats min^{-1} . At the end of each 3 minutes, the following values, which are monitored continuously, are noted: the ventilation (VE), the oxygen consumption ($\dot{V}\text{O}_2$), the CO_2 excretion ($\dot{V}\text{CO}_2$), the heart rate (HR) and the load (W). The following parameters are then calculated by linear regression: max $\dot{V}\text{O}_2$, i.e. the $\dot{V}\text{O}_2$ corresponding to the theoretical maximum for the heart rate ($220 - \text{age}$ in years); $\dot{V}\text{O}_2$ 170 for the boys, i.e. the $\dot{V}\text{O}_2$ value obtained by intrapolation corresponding to HR of 170 min^{-1} ; PWC 170 for male or the physical work capacity that can be tolerated when the HR is 170 min^{-1} ; and corresponding by the $\dot{V}\text{O}_2$ 180 and PWC 180 for female. Further these parameters are expressed per kg body weight. Finally the

respiratory quotient (RQ) ($\dot{V}\text{CO}_2/\dot{V}\text{O}_2$) is calculated for each work load level.

The apparatus (Siemens) is of open circuit type and consists of a pneumotachograph, a rapid analyzer of the respiratory gases O_2 and CO_2 , a multitracer with an incorporated calculator, an 8-channel graph recorder and an ECG. The calculations are carried out on a microcomputer (Apple IIe). The bicycle ergometer (Siemens) can be adapted to fit the height of the subjects. Cycling speed is fixed at 60 rpm.

RESULTS

1. The heart rate at a given work load is considered an index of adaptation of cardiac function. Figure 1 shows the evolution, with respect to age, of the HR90 (at a work load of 90 watts) in these

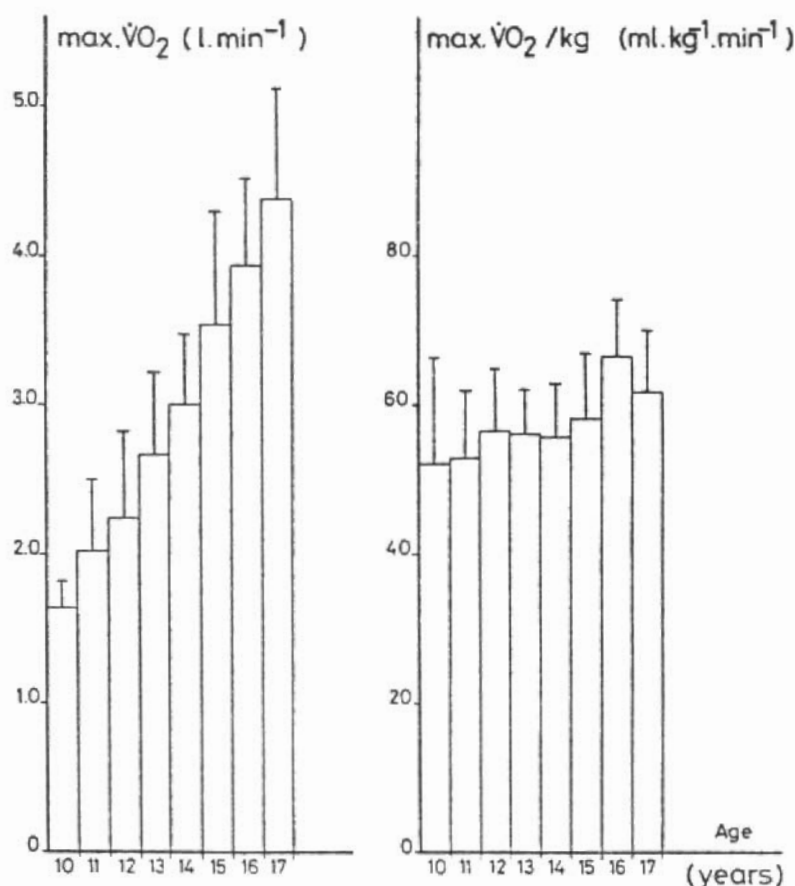


Fig. 2.—Evolution, with respect to age, of the max $\dot{V}O_2$ and max $\dot{V}O_2/kg$ for the male swimmers.

young swimmers: an almost linear reduction in HR is seen, virtually identical for both the sexes.

2. The max $\dot{V}O_2$ increases progressively with age, for all the swimmers. In the boys (Fig. 2), it increases from a mean of 1.65 l·min⁻¹ at 10 years up to a mean of 4.4 l·min⁻¹ at 17 years; similarly for the girls (Fig. 3) it increases from 1.5 l·min⁻¹ to 3.6 l·min⁻¹.

The max $\dot{V}O_2/kg$ is more or less constant for the boys between 10 and 14 years (± 53 ml·kg⁻¹·min⁻¹) and thereafter increases appreciably to ± 63 ml·kg⁻¹·min⁻¹ at 16-17 years. This phenomenon is less obvious in the girls; the corresponding max $\dot{V}O_2/kg$ values being ± 50 ml·kg⁻¹·min⁻¹ and ± 54 ml·kg⁻¹·min⁻¹.

The results for $\dot{V}O_2$ 170 (male) and $\dot{V}O_2$ 180 (female) reveal a course of evolution similar to the max $\dot{V}O_2$ and those for $\dot{V}O_2$ 170/kg (male) and $\dot{V}O_2$ 180/kg (female) similar to that of the max $\dot{V}O_2/kg$.

3. When the Respiratory Quotient (RQ) exceeds unity, it indicates that the anaerobic threshold has been crossed and translates the impossibility to maintain the work in aerobic conditions. On an average, it is only at the age of 13 that the boys are found to acquire the capacity to tolerate a work load of 90 W while maintaining their RQ below unity, while for a work load of 150 W, aerobic conditions can be maintained only when they reach 16 years.

On the other hand, the girls acquire the

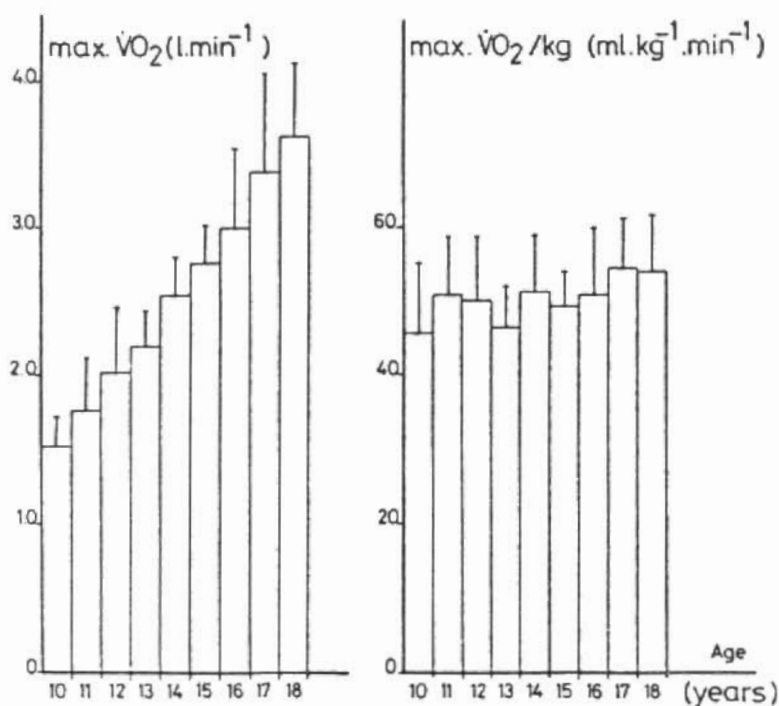


Fig. 3.—Evolution, with respect to age, of the $\text{max } \dot{V}O_2$ and $\text{max } \dot{V}O_2/\text{kg}$ for the female swimmers.

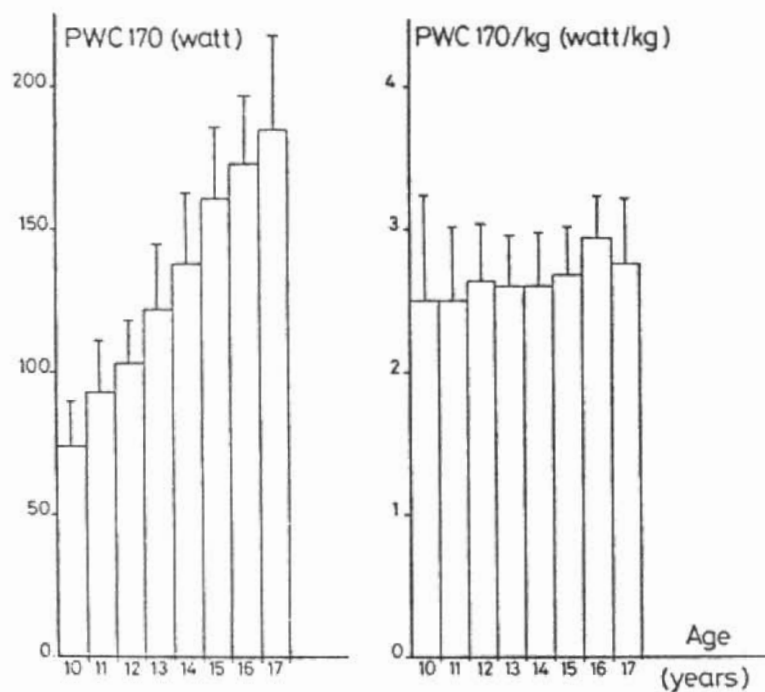


Fig. 4.—Evolution, with respect to age, of the PWC 170 and PWC 170/kg for the male swimmers.
Note: PWC 170=physical work capacity at heart rate 170 $\text{beats}.\text{min}^{-1}$.

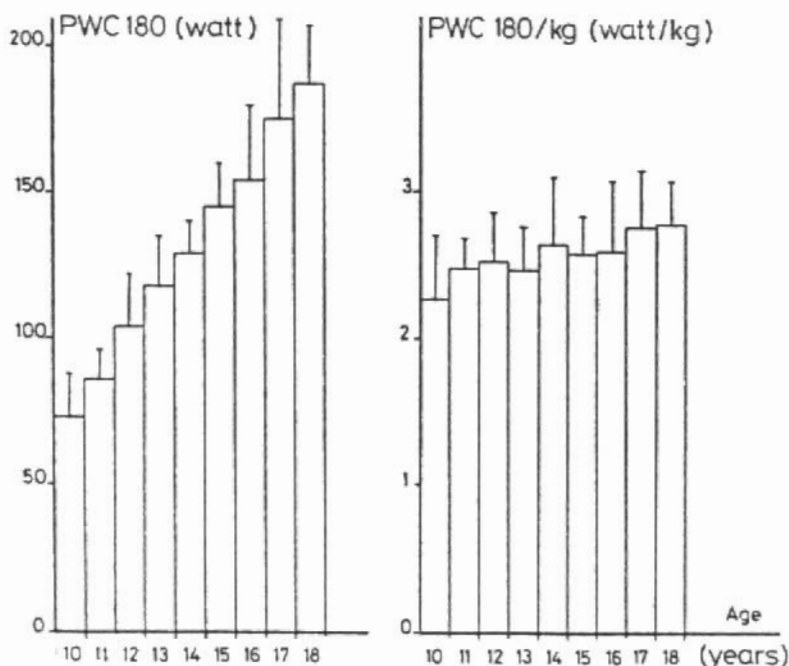


Fig. 5.—Evolution, with respect to age, of the PWC 180 and PWC 180/kg for the female swimmers. Note: PWC 180=physical work capacity at heart rate 180 beats·min⁻¹.

capacity to tolerate a work load of 90 watts with the $RQ < 1$ only at 15 years, while for a work load of 150 watts, on an average the RQ is > 1 even when they have reached 18 years.

4. The PWC 170 (male) (Fig. 4) and PWC 180 (female) (Fig. 5) increase in a practically linear fashion with age and the results show a doubling of the PWC from 10 to 15 years for both sexes at the respective heart rates considered (male: 170 beats min⁻¹, female: 180 beats min⁻¹). When expressed per kg, B.W., this increase is far less obvious, especially in boys.

5. We can compare the degree of adaptation to aerobic work of young swimmers to that of other groups of young athletes having about the same training intensity. Our comparison is based on the $\dot{V}O_2$ 170 actually measured and show that all these groups exhibit similar values; the same is found for $\dot{V}O_2$ 170/kg B.W.

6. For all the age groups and for both sexes, a highly significant correlation ($p < 0.01$) has been found between heart rate (HR) and work load (W), as well as between HR and the oxygen consumption ($\dot{V}O_2$). It has been found useful to obtain multiple regression equations (Table 1) expressing the max $\dot{V}O_2$ in terms of the HR and the corresponding W as well as in terms of the HR and the corresponding $\dot{V}O_2$ for each age group and for the two sexes.

All these equations have a very high level of significance except for girls of 10-11 years. Thus these prediction equations provide a reliable indirect determination of the max $\dot{V}O_2$ provided measurements are made for an exercise which brings the HR to at least 150 min⁻¹.

DISCUSSION

The adaptation of the HR with age for a given work load is highly significant

TABLE 1.

Multiple regressions (♂ swimmers)

Age	Equation	Standard error	Corr. coef.	Probab. ratio
10-11	Max $\dot{V}O_2 = 19.09 W - 12.56 HR + 2430$	297.4	0.77	0.001
12-13	Max $\dot{V}O_2 = 22.88 W - 24.08 HR + 3943$	396.0	0.66	0.001
14-15	Max $\dot{V}O_2 = 16.63 W - 23.89 HR + 4798$	403.1	0.70	0.001
16-17	Max $\dot{V}O_2 = 18.83 W - 41.39 HR + 7597$	507.4	0.69	0.001
10-11	Max $\dot{V}O_2 = -17.7 HR + 1.43 \dot{V}O_2 + 2792$	198.8	0.90	0.001
12-13	Max $\dot{V}O_2 = -16.3 HR + 1.29 \dot{V}O_2 + 2879$	357.5	0.73	0.001
14-15	Max $\dot{V}O_2 = -29.8 HR + 1.35 \dot{V}O_2 + 5004$	247.5	0.90	0.001
16-17	Max $\dot{V}O_2 = -38.8 HR + 1.32 \dot{V}O_2 + 6623$	335.8	0.88	0.001

Multiple regressions (♀ swimmers)

Age	Equation	Standard error	Corr. coef.	Probab. ratio
10-11	Max $\dot{V}O_2 = 7.02 W - 5.58 HR + 2099$	169.7	0.42	0.1
12-13	Max $\dot{V}O_2 = 19.56 W - 20.44 HR + 3636$	304.9	0.58	0.001
14-15	Max $\dot{V}O_2 = 23.64 W - 21.69 HR + 3528$	246.2	0.82	0.001
16-17-18	Max $\dot{V}O_2 = 18.76 W - 29.66 HR + 5462$	348.1	0.80	0.001
10-11	Max $\dot{V}O_2 = -14.8 HR + 1.46 \dot{V}O_2 + 2437$	209.6	0.86	0.001
12-13	Max $\dot{V}O_2 = -21.7 HR + 1.53 \dot{V}O_2 + 3356$	256.3	0.73	0.001
14-15	Max $\dot{V}O_2 = -26.7 HR + 1.49 \dot{V}O_2 + 4164$	174.4	0.92	0.001
16-17-18	Max $\dot{V}O_2 = -28.6 HR + 1.08 \dot{V}O_2 + 5395$	274.8	0.88	0.001

for both sexes. However the interpretation of this result should be made not only with respect to the physical growth of these athletes but also with respect to their training as well. The comparison of the HR for a given work load between these athletes and other non-athletic students of corresponding age shows a marked difference in favour of the former. The same comparison is obtained concerning PWC 170 (male), or PWC 180 (female) and PWC 170/kg (male) or PWC 180/kg (female).

The max $\dot{V}O_2$ increases markedly and reaches on an average nearly 160% of mean values obtained in the non-athletic

Belgian population (Van Fraechem *et al.*, 1979).

The max $\dot{V}O_2$ /kg B.W. are initially (age group 10-11 years) already relatively high before showing a very significant further increase between 16 and 18 years. These values (extrapolated for the theoretically maximum heart rate, i.e. 220-age in years) are comparable to those reported in the introduction. We think it is more realistic to focus on the $\dot{V}O_2$ 170 ($\dot{V}O_2$ 180 for female) which is a measurable value and does not entail high medical risks especially where group testing is involved. $\dot{V}O_2$ 170 ($\dot{V}O_2$ 180 for female) increases with age in parallel with the max $\dot{V}O_2$ and is

related to the PWC 170 (male) (PWC 180 for female) which shows a uniform increase between 10 and 17 years. A similar evolution has been described by Macek *et al.* (1971) in a study on a school population of Prague as well as by Andersen *et al.* (1978) on a population of Norwegian children. Moreover, one must note that at the work load level taking the HR to 170 beats min^{-1} (male) or 180 beats min^{-1} (female), the $\text{RQ} > 1$. The last work load level carried out with an $\text{RQ} = 1$ is, for the boys 60 watts at 10, 11, and 12 years, 90 watts at 13 years, 120 watts at 14 and 15 years, 150 watts at 16 and 17 years; for the girls: 60 watts at 10, 11, 12, 13 and 14 years, 90 watts at 15 years, 120 watts at 16, 17 and 18 years. This means that the anaerobic threshold is reached at a relatively low HR and at a $\dot{V}\text{O}_2$ value rarely exceeding 70% of the $\text{max } \dot{V}\text{O}_2$. Since most of the swimmers in the group of our study compete on short distances, this metabolic profile is not very surprising even though endurance remains an important component of the effort required during swimming practice.

On the other hand, the brief comparison made between well-trained young male Belgian Athletes from various disciplines and the young swimmers in our study shows that the latter have a good metabolic profile which is well adapted to effort. No doubt progressive selection at club level adds up to the effects of training.

Multiple regression equations have been proposed in order to enable simple submaximal tests to be carried out at the swimming pool complex itself. They can be utilized for young trained swimmers for whom they are more suitable than the regressions of Astrand. These multiple regressions yield more reliable results of submaximal $\dot{V}\text{O}_2$ is introduced rather than submaximal work load. The standard error is in fact smaller when the indepen-

dent variables are the HR and the corresponding $\dot{V}\text{O}_2$.

CONCLUSION

This study on young competition swimmers reveals that the energy demand at any age is quite high and is naturally bound to increase progressively with age. The importance of the increase in submaximal $\dot{V}\text{O}_2$ for HR of 170 beats min^{-1} for boys and 180 beats min^{-1} for girls leads us to deduce that the heart itself reacts to the intense training of these swimmers. On the other hand, the high levels of $\dot{V}\text{O}_2$ are accompanied by a relatively low RQ , the result of mixed endurance resistance training programmes of these athletes.

Finally, we must remember that the physical condition of these young athletes is the result of their growth, their training and of the selection process according to the requirements of the clubs.

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SUMMARY

The young swimmers were rarely investigated in Belgium in spite of the growing importance for this sport. At high level, the training includes a daily physical practice as far as 25 km/week. The aim of this study is to analyse the physiologic response obtained during bicycle ergometer tests from 130 boys and 98 girls engaged in swimming at the rate of 8-14 hours/week and between the ages of 10-15 (male) and 10-18 (female). The results show a progressive and important adaptation of heart rate for a given work load, aerobic capacity and mechanical power output. Multiple regression equations are proposed in order to enable simple submaximal tests to be carried out for routine examination. If the literature is in accordance with these results, we must remember that the physical condition of these swimmers is the result of their growth, of their training and of the selection process.

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