ORIGINAL ARTICLE

Effects of dominant somatotype on aerobic capacity trainability

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Br J Sports Med 2005;**39**:954–959. doi: 10.1136/bjsm.2005.019943

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Accepted 9 May 2005

Purpose: This study examined the association between dominant somatotype and the effect on aerobic capacity variables of individualised aerobic interval training.
Methods: Forty one white North African subjects (age 21.4±1.3 years; $\dot{V}o_{2max}$ = 52.8±5.7 ml kg^{-1} min^{-1}) performed three exercise tests 1 week apart (i) an incremental test on a cycle ergometer to determine $\dot{V}o_{2max}$ and $\dot{V}o_2$ at the second ventilatory threshold (VT2); (ii) a VAM-EVAL track test to determine maximal aerobic speed ($v\dot{V}o_{2max}$); and (iii) an exhaustive constant velocity test to determine time limit performed at 100% $v\dot{V}o_{2max}$ (tlim100). Subjects were divided into four somatometric groups: endomorphs-mesomorphs (Endo-meso; n = 9), mesomorphs (Meso; n = 11), mesomorphs-ectomorphs (Meso-ecto; n = 12), and ectomorphs (Ecto; n = 9). Subjects followed a 12 week training program (two sessions/week). Each endurance training session consisted of the maximal number of successive fractions for each subject. Each fraction consisted of one period of exercise at 100% of $v\dot{V}o_{2max}$ and one of active recovery at 60% of $v\dot{V}o_{2max}$. The duration of each period was equal to half the individual tlim100 duration (153.6±39.7 s). After the training program, all subjects were re-evaluated for comparison with pre-test results.
Results: Pre- and post-training data were grouped by dominant somatotype. Two way ANOVA revealed significant somatotype-aerobic training interaction effects ($p<0.001$) for improvements in $v\dot{V}o_{2max}$, $\dot{V}o_{2max}$ expressed classically and according to allometric scaling, and $\dot{V}o_2$ at VT2. There were significant differences among groups post-training: the Meso-ecto and the Meso groups showed the greatest improvements in aerobic capacity.
Conclusion: The significant somatotype-aerobic training interaction suggests different trainability with intermittent and individualised aerobic training according to somatotype.

There is great interest in systematically studying the factors that can influence fitness development for better sporting performance.[1] Most available methods of measuring endurance training efficacy use maximal oxygen uptake ($\dot{V}o_{2max}$) as the main outcome variable. However, it has been shown that $\dot{V}o_{2max}$ is not the only indicator of cardiorespiratory fitness for endurance events.[1] $\dot{V}o_{2max}$ must be associated with other factors such as ventilatory threshold (VT), velocity at $\dot{V}o_{2max}$, and exercise economy to explain differences in endurance performance.[2]

Several studies relating to the effect of interval training on aerobic fitness indicate that cardiorespiratory adaptation depends mainly on the initial fitness level of the subjects, the training intensity, the frequency of training sessions, and the duration of the training sessions and programs.[3] Genetic factors explain part of the variability in adaptation to a given training program and should be considered.[4] The contribution of morphological factors, such as somatotype, to athletic performance has also been studied. Indeed, anthropological studies of Olympic athletes characterised the typical somatotype associated with performance in specific athletic events.[5] However, few have explored physiological adaptation to training in relation to morphological factors. Some authors have shown that the dominant somatotype influences functional responses at peak exercise.[6 7] Ergen *et al*[8] found no correlation between somatotype components and maximal alactic anaerobic power in trained subjects. Nevertheless, it is still questioned whether dominant somatotype is directly related to improvements in aerobic capacity variables.

Investigations by Berg *et al*[9] to determine the best predictors of 10 km running time, have shown that the somatotype and anthropometric traits of athletes contribute significantly to variance in endurance performance. However, the main physiological determinants of running endurance performance, that is $\dot{V}o_{2max}$, the second VT, exercise economy, and velocity at $\dot{V}o_{2max}$, were not included in the study's stepwise multiple regression analysis. Furthermore, the influence of somatotype on aerobic fitness trainability was not considered.

The aim of the present study was therefore to investigate the interaction between somatotype and the adaptation of the key aerobic capacity variables to individualised intermittent aerobic training in male white North African students.

METHODS

Subjects

Forty one fit physical education students volunteered to participate in this study. They did not practice any sport but undertook ~10 h per week of various physical activities as part of their university course. Aged 21.4±1.3 years, they were divided into four somatometric groups (fig 1). Body composition was estimated from skinfold thickness.[10] The anthropometric characteristics are presented in table 1. The study was approved by the University Ethics Committee. After receiving a detailed explanation of the potential benefits and risks associated with participation in the study,

Abbreviations: ACE, angiotensin converting enzyme; ANCOVA, analysis of covariance; ANOVA, analysis of variance; HR, heart rate; RER, respiratory exchange ratio; $\dot{V}o_{2max}$, maximal oxygen uptake; VT, ventilatory threshold

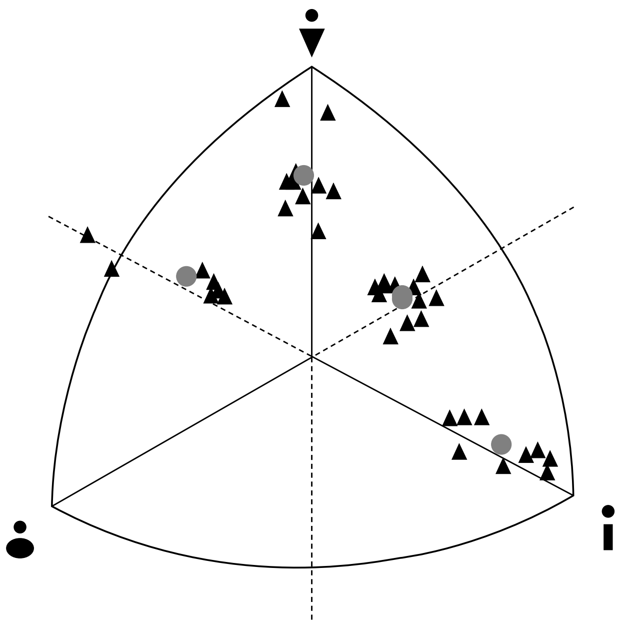

Figure 1 Individual somatoplots (triangles) with mean somatotype for each category (circles).

each student gave his informed consent. All subjects were white North Africans from Tunisia.

Protocol

All subjects underwent an identical battery of tests before and after the 12 week training program. The pre- and post-tests included anthropometric measurements, and laboratory and field tests.

Individual somatotypes were assessed according to the Heath-Carter anthropometric method rounded to the nearest half-unit rating.[11] This method provides an anthropometric rating of physique and shows the relative dominance of the three following components: (i) endomorphy (component I) refers to relative fatness and is derived from the sum of three skinfolds: triceps, subscapular, and supraspinal; (ii) mesomorphy (component II) relates to relative robustness development, and is derived from bi-epicondylar femur and humerus widths, and arm and calf circumferences corrected for the site specific skinfold thickness; and (iii) ectomorphy (component III) refers to relative linearity and is based on the stature-body mass ratio (stature divided by the cube root of body mass or kg $m^{-1/3}$). All skinfolds and girths were recorded by the same examiner. Each skinfold was measured three times with a skinfold calliper (Lange, Cambridge, MA, USA). The average of the three measurements for each site was considered in the calculation. The right side values for skinfolds, girths, and diameters were included in the calculations according to the method described by Ross *et al*.[12]

Each subject performed three preliminary tests 1 week apart. The first test measured $\dot{V}O_{2max}$ and was performed in the laboratory. The second test, that is the VAM-EVAL track test,[13] measured maximal aerobic speed ($v\dot{V}O_{2max}$), and the third test assessed the time to exhaustion at 100% $v\dot{V}O_{2max}$ on the running track (tlim100).

$\dot{V}O_{2max}$ measurement

Individual $\dot{V}O_{2max}$ was measured during a continuous, incremental test to exhaustion[14] on an electronically braked cycle ergometer (Monark Ergometrics 800, Bitz, Germany). Prior to the test, the subjects underwent clinical examination to check their health status. Respiratory parameters ($\dot{V}O_2$, CO_2) and respiratory exchange ratio (RER) were measured continuously (ZAN 680, Oberthulba, Germany) during the initial resting period and throughout the test until exhaustion. The gas analysers were calibrated before each test with gases of known concentrations. Heart rate (HR) was recorded with an ECG monitoring system. The following criteria[15] indicated $\dot{V}O_{2max}$ had been attained: (i) a plateau or slight drop in $\dot{V}O_2$ despite an increase in workload; (ii) exhaustion; (iii) an RER above 1.1; and (iv) an HR above 95% of predicted maximal HR. The second ventilatory threshold (VT2)[16] and maximal oxygen pulse (O_2 pulse) were then quantified. VT2 was assessed independently by two experienced individuals who then compared their results and reached a consensus. VT2 was expressed in $\dot{V}O_2$ (ml kg^{-1} min^{-1}) and as a fraction of $\dot{V}O_{2max}$ (%$\dot{V}O_{2max}$). Maximal O_2 pulse (ml $beats^{-1}$) was calculated by dividing $\dot{V}O_{2max}$ (ml min^{-1}) by maximal HR (HR_{max}), the highest HR attained at exhaustion. $\dot{V}O_{2max}$ was expressed classically and according to allometric scaling to avoid underestimation in heavy and overestimation in light individuals.[17]

VAM-EVAL track test

The VAM-EVAL track test[13] took place on a 400 m track with cones placed every 20 m. A pre-recorded soundtrack indicated with brief sounds the instant when the subject had to pass near a cone to maintain the imposed speed. A longer sound marked a change of stage. The first stage was set at 8 km h^{-1} with subsequent increments of 0.5 km h^{-1} per 1 min stages. The test was finished when the subject was unable to maintain the imposed running speed. The speed corresponding to the last completed stage was recorded as $v\dot{V}O_{2max}$ (km h^{-1}).

Time to exhaustion at 100% $v\dot{V}O_{2max}$ (tlim100)

The purpose of the third field session was to estimate the individual running performance at 100% $v\dot{V}O_{2max}$ (tlim100).[18] The test took place on the same track described above. After a

Table 1 Physical characteristics of each group separated according to somatotype

Somatotype characteristics	Endo-meso, n = 9	Meso, n = 11	Meso-ecto, n = 12	Ecto, n = 9
Body mass (kg)	77.7±6.1	72.3±4.7	66.4±2.0	65.5±3.6
Height (cm)	178.9±5.6	175.3±4.3	176.0±2.3	184.8±6.1
Body fat (%)	20.6±2.2	14.0±1.4	11.8±1.6	11.4±0.5
Fat mass (kg)	16.0±2.1	10.1±1.2	7.8±1.1	7.5±0.5
Lean mass (kg)	61.7±5.2	62.2±4.1	58.6±2.3	58.0±3.1
BMI (kg m^{-2})	24.2±1.0	23.5±0.5	21.4±0.4	19.2±0.4
Endomorphy	4.1±0.5	2.3±0.2	1.8±0.2	1.7±0.2
Mesomorphy	4.1±0.3	4.8±0.6	3.3±0.2	2.0±0.2
Ectomorphy	2.1±0.5	2.2±0.2	3.2±0.2	5.0±0.5

BMI, body mass index; Ecto, ectomorph; Endo-meso, endomorph-mesomorph; Meso, mesomorph; Meso-ecto, mesomorph-ectomorph. Values are expressed as mean±SD.

15 min warm up at 60% $v\dot{V}o_{2max}$, the subjects had to run for as long as possible at a pace corresponding to their $v\dot{V}o_{2max}$. The post-training tlim100 was performed at the pre-training $v\dot{V}o_{2max}$.

Training

The training program lasted 12 weeks with two sessions per week, and consisted of individualised intermittent running. Each training session began with a 20 min warm up at 60% of each subject's $v\dot{V}o_{2max}$. The session itself was composed of the maximal number of running fractions that each subject was able to perform. Each fraction consisted of one period of running at 100% of $v\dot{V}o_{2max}$ and one period of active recovery at 60% of $v\dot{V}o_{2max}$. The duration of each period was equal to half the individual tlim100 duration.[19] To establish the maximal number of fractions that each subject could perform during a session, an individualised test was performed before the start of the training program. Thus, the training program was individualised both for the running speed for intervals and for the number of fractions.[20] The intensities of the periods of exercise and recovery were readjusted after 6 weeks by way of a VAM-EVAL test (intermediate $v\dot{V}o_{2max}$). After training, $\dot{V}o_{2max}$, $v\dot{V}o_{2max}$, and tlim100 (performed at the pre-training $v\dot{V}o_{2max}$) were measured for each subject.

Statistical analysis

A somatochart was developed with Somatotype 1.0 software to determine the somatotypes (fig 1). Four distinct groups emerged with nine endomorph-mesomorph (Endo-meso), 11 mesomorph (Meso), 12 mesomorph-ectomorph (Meso-ecto), and nine ectomorph subjects (Ecto). The data were grouped by dominant somatotype and descriptive statistics were expressed as mean $\pm$ SD. The hypothesis that somatotype impacts improvements in aerobic fitness variables was tested for significance at an $\alpha = 0.05$ level by two way analysis of variance (ANOVA) for repeated measures. An analysis of covariance (ANCOVA) was used post hoc to compare means for each variable in the presence of significant somatotype-aerobic training period interaction effects. Differences between pre- and post-training mean values were evaluated for significant ($p<0.05$) changes from 0 by the paired Wilcoxon test (SPSS 10.0).

RESULTS

ANOVA indicated significant training effects for all physiological variables from pre- to post-training within groups ($p<0.001$) except for maximal HR (table 2). A significant (somatotype×pre- and post-training) interaction effect ($p<0.001$) was observed. This interaction mainly concerned $v\dot{V}o_{2max}$, $\dot{V}o_{2max}$ expressed in ml kg^{-1} min^{-1} and ml kg$^{-0.75}$ min^{-1}, and $\dot{V}o_2$ at VT2 (fig 2).

$v\dot{V}o_{2max}$ and tlim100

$v\dot{V}o_{2max}$ increased significantly in the four groups after the training period (table 2). Significant (somatotype×pre- and post-training) interaction effects ($F = 9.70$ (df 1, 37); $p<0.001$) were also observed. Meso-ecto subjects showed the greatest increment in $v\dot{V}o_{2max}$. Significant elevation of tlim100 (performed at the pre-test $v\dot{V}o_{2max}$) was evident for all somatotype groups (table 2), but the mean increases were not significantly different between groups.

$\dot{V}o_{2max}$

Both absolute (l min^{-1}) and relative $\dot{V}o_{2max}$ (ml kg^{-1} min^{-1} and ml kg$^{-0.75}$ min^{-1}) increased significantly in the four groups except for absolute $\dot{V}o_{2max}$ in Endo-meso subjects which only showed a trend towards significance ($p = 0.08$, table 2). However, interaction effects (somatotype×pre- and post-training) were significant ($F = 22.7$ (df 1, 37); $p<0.001$) only for relative $\dot{V}o_{2max}$ (ml kg^{-1} min^{-1} and ml kg$^{-0.75}$ min^{-1}). The Meso-ecto and Meso groups experienced significantly greater improvements than the other groups (fig 2B1,B2).

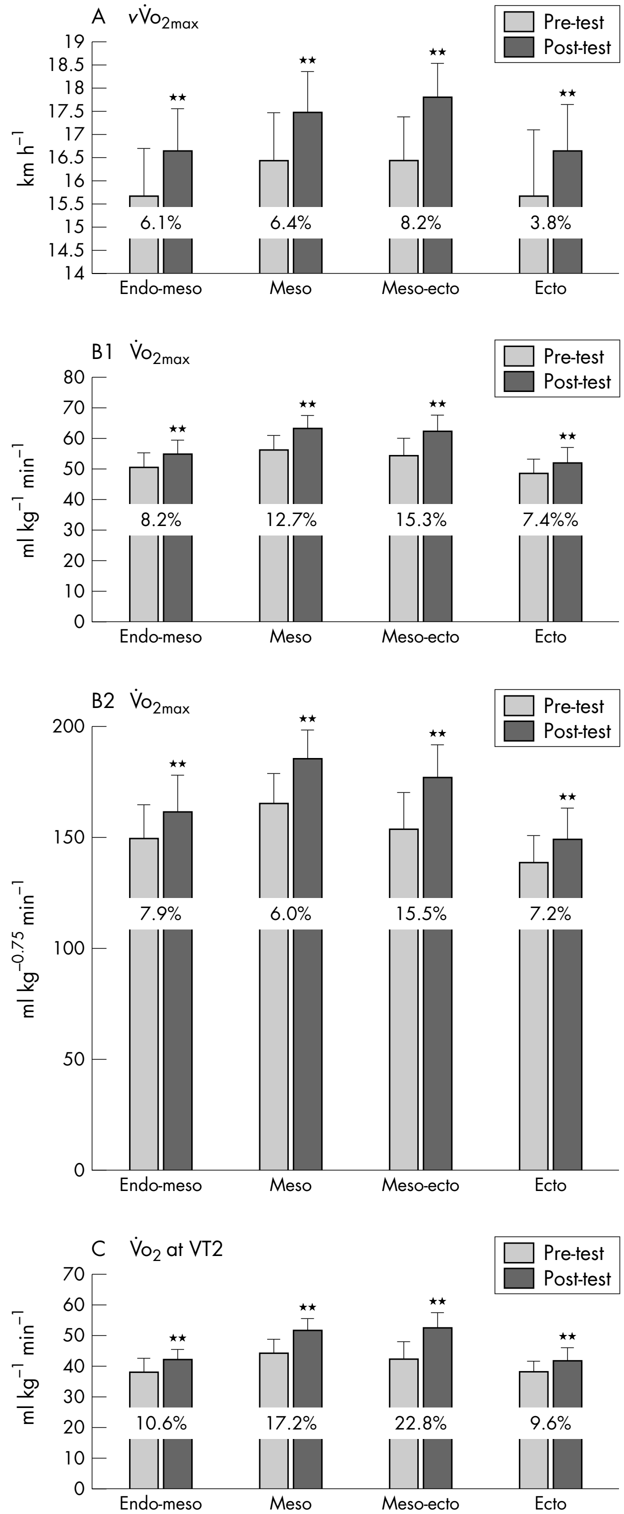

Figure 2 Somatotype-aerobic training interaction effects on cardiorespiratory parameters. The numbers on the columns represent the percentage of change from test to retest; **p<0.01. For legends, see table 1.

Table 2 Effects of 12 week training program on components of aerobic capacity in somatotype groups

		Endo-meso, n=9	Meso, n=11	Meso-ecto, n=12	Ecto, n=9	Total, n=41	Interaction, df 1, 37
$v\dot{V}o_{2max}$ (km h^{-1})	Pre-test	15.7±1.0	16.4±1.0	16.4±0.9	16.2±0.9	16.2±1.0	F=9.7
	Post-test	16.6**±0.9	17.5**±0.9	17.8**±0.7	16.9**±0.8	17.2**±0.9	**
tlim100 (s)	Pre-test	345.6±70.0	306.8±64.5	298.4±103.8	280.9±64.1	307.2±79.5	F=1.5
	Post-test	443.6**±73.6	410.2**±52.4	407.4**±84.8	344.7**±54.0	402.3**±74.0	NS
$\dot{V}o_{2max}$ (l min^{-1})	Pre-test	3.9±0.5	4.2±0.5	3.5±0.5	3.3±0.2	3.7±0.6	F=1.5
	Post-test	4.2±0.6	4.7**±0.6	4.1**±0.4	3.5**±0.2	4.1**±0.6	NS
$\dot{V}o_{2max}$	Pre-test	50.7±4.6	56.4±4.7	54.2±5.7	48.5±4.8	52.8±5.7	F=22.6
(ml kg^{-1} min^{-1})	Post-test	54.9**±4.9	63.6**±4.2	62.5**±5.2	52.1**±5.3	58.8**±6.8	**
$\dot{V}o_{2max}$	Pre-test	150.0±14.8	165.3±13.5	153.8±17.1	138.9±12.2	152.8±17.0	F=13.4
(ml kg$^{-0.75}$ min^{-1})	Post-test	161.9**±16.3	186.1**±13.1	177.8**±14.6	149.0**±13.3	170.2**±20.0	**
VT2	Pre-test	38.1±4.7	44.2±4.3	42.7±5.7	38.1±3.7	41.1±5.3	F=16.32
(ml kg^{-1} min^{-1})	Post-test	42.2**±3.7	51.8**±4.0	52.4**±5.2	41.8**±4.4	47.7**±6.6	**
$\%\dot{V}o_{2max}$	Pre-test	75.1±4.5	78.4±4.6	78.7±6.7	78.6±2.1	77.8±5.0	F=1.8
	Post-test	76.9±3.4	81.4**±3.2	83.8**±2.8	80.1**±1.5	80.9**±3.7	NS
HR max	Pre-test	184.7±9.2	190.7±6.5	187.3±7.5	191.1±7.7	188.5±7.8	F=2.07
(beats min^{-1})	Post-test	187.4±9.8	191.4±5.6	187.7±7.0	190.1±5.7	189.1±7.0	NS
Maximal O_2 pulse	Pre-test	21.1±2.7	22.0±3.2	18.8±3.0	17.1±1.7	19.8±3.3	F=1.5
(ml beat^{-1})	Post-test	22.3±3.4	24.5**±2.8	21.8**±2.5	18.3 **±1.6	21.9**±3.4	NS

NS, not significant; **p<0.01. For legends, see table 1.

$\dot{V}o_2$ at VT2

Oxygen uptake at VT2 expressed in ml kg^{-1} min^{-1} and in percentage of $\dot{V}o_{2max}$ ($\%\dot{V}o_{2max}$) showed a significant increase pre- to post-training for all groups except for $\%\dot{V}o_{2max}$ in the Endo-meso group (table 2). However, interaction effects (somatotype×pre- and post-training) were significant ($F = 16.3$ (df 1, 37); $p<0.001$) only in VT2 expressed in ml min^{-1} kg^{-1}; the Meso-ecto group presented a significantly higher mean of increases compared to the other groups.

Maximal O_2 pulse

No significant interaction effects (somatotype×pre- and post-training) were noted. However, there was a significant improvement in all somatotype subjects from pre- to post-training (table 2) except for the Endo-meso group.

DISCUSSION

The results of this study showed the effects of somatotype on adaptation of aerobic capacity to individualised aerobic interval training in white North African male students. The variations in aerobic capacity variables demonstrated a significant interaction effect with somatotype over a period of aerobic training. The magnitude of increase in these parameters varied according to somatotype group. Indeed, as a result of training, $v\dot{V}o_{2max}$, $\dot{V}o_{2max}$ (ml kg^{-1} min^{-1} and ml kg$^{-0.75}$ min^{-1}), and $\dot{V}o_2$ at VT2 improved in all training groups, with the Meso-ecto and Meso groups showing the highest training gains.

The objective of the interval training program was mainly to elicit optimal improvements in aerobic capacity variables. The frequency, intensity, and duration of the training program were established as essential components in promoting adaptive responses to training.[21] Individual $v\dot{V}o_{2max}$ was considered as a relevant criterion to set training intensities. In the present study, $v\dot{V}o_{2max}$ measurement in the field, for training purposes, was preferred to laboratory measurements.[22] The time for which exercise at $v\dot{V}o_{2max}$ could be sustained (tlim100) was used to individualise the duration of interval training at $v\dot{V}o_{2max}$ according to the method of Billat *et al*.[19] The number of repetitions performed by subjects in the previously individualised intermittent protocols varied from 2 to 5. The mean values recorded by Billat *et al*[19] in long distance runners were 5.5±2.0 repetitions. This is the reason why the number of repetitions in training sessions was individualised and not standardised.

The post-training improvements in relative $\dot{V}o_{2max}$ (ml kg^{-1} min^{-1}) were significantly higher for the Meso-ecto and Meso groups (15.3% and 12.7%, respectively) than for the other groups (fig 2B1,B2). These mean gains are consistent with values found in other training studies which have reported increases ranging from 10% to 23%.[20 23 24] Increments in $\dot{V}o_{2max}$ could be explained by augmented stroke volume, and by enhanced potential for widening the arterial-venous oxygen difference during exercise and/or by both factors.[25] The improvements in relative $\dot{V}o_{2max}$ (ml kg^{-1} min^{-1} and ml kg$^{-0.75}$ min^{-1}) in the present study could be due to improved capacity of the cardiorespiratory system and not to any change in body mass. The rise in O_2 pulse following the training period may reflect the extent of cardiac and peripheral adaptation to training.[26] The highest increases were observed in the Meso (11.4%) and Meso-ecto groups (15.9%) in comparison to the Endo-meso (5.6%) and Ecto (7.3%) groups.

The training program also induced a significant improvement in $v\dot{V}o_{2max}$ (fig 2B). The magnitude of these increases (from 6.1% to 8.2%) differed among somatotype groups. The Meso-ecto group showed the highest mean gains (8.2%). This improvement in $v\dot{V}o_{2max}$ indicates that a certain percentage of $\dot{V}o_{2max}$ will be associated with higher speed after training.[27 28] Several studies have reported increased $v\dot{V}o_{2max}$ of between 2.9% and 8.5% in well trained athletes following endurance training.[20 29 30] They found that this increase in $v\dot{V}o_{2max}$ resulted from significant improvements in both $\dot{V}o_{2max}$ and running economy. In the present study, improvements in the former were shown while the latter variable was not measured.

$\dot{V}o_2$ at VT2 ($\dot{V}o_2$ threshold) increased after training (fig 2C). However, there was a wide variation in the mean changes between groups (9.6% to 22.8%). Again, the Meso-ecto group achieved the highest increase. Similar results were obtained for $\dot{V}o_2$ at the second VT expressed in $\%\dot{V}o_{2max}$. The highest values recorded in this somatotype group reached 83.8±2.8% of $\dot{V}o_{2max}$, with a significant gain of 6.4%. Several studies have demonstrated the sensitivity of the VT to endurance training.[31 32] The significant improvements in this parameter could be explained by better enzymatic adaptation due to high intensity training, allowing subjects to exercise at a high percentage of $\dot{V}o_{2max}$ for prolonged periods.[32 33]

The main findings of our study showed that the most significant improvements in aerobic capacity components following the training program varied among the dominant somatotype groups. Indeed, mean gains in $v\dot{V}O_{2max}$, relative $\dot{V}O_{2max}$ (expressed per ml kg^{-1} min^{-1} and per ml kg$^{-0.75}$ min^{-1}), and $\dot{V}O_2$ at VT2 were higher when the Meso and Ecto components were balanced as is the case in the Ecto-meso group. Improvements were slightly lower in subjects exhibiting a Meso dominance. Thus, a morphological type favouring cardiorespiratory adaptation to aerobic training seems to exist. Quantification of the contribution of the dominant somatotype to improvement in aerobic fitness is difficult. However, studies of monozygote and heterozygote twins and other subjects with familial similarities have shown appreciable genetic effects on somatotype, especially at the level of the Ecto component.[34] On the other hand, $\dot{V}O_{2max}$, an index of aerobic fitness, is influenced by genetic and environmental factors.[35] Genetic factors indeed impact the development of $\dot{V}O_{2max}$, but training allows its improvement. The same author showed that heredity largely influences the trainability of $\dot{V}O_{2max}$. Depending on genotype, the same training program can have different effects, ranging from 0% to 30%.[35] According to these studies, there is a potential association between genetic variables, such as muscular enzymes (that is mitochondrial DNA), and changes in $\dot{V}O_{2max}$ following training. Nevertheless, in contrast to somatotype determination, which is quite easy, studying the genetic type of an athlete is, at present, somewhat problematic. A new issue, which has recently been raised and could help explain differences in responses to endurance training, is the role played by the angiotensin converting enzyme gene (ACE) especially its I allele variant.[36] One possible explanation for the great improvement in aerobic capacity in the Meso-ecto and Meso groups is the higher prevalence of the ACE gene insertion polymorphism in these groups.

In addition, somatotype-aerobic training interaction effects on improvement in aerobic capacity are also influenced by the relationship between $\dot{V}O_{2max}$ and biometric data, such as body size, body mass, and body surface. Thus, the allometric approach is used to compare individuals of various dimensions and sizes.[37 38] Many studies have shown that relative $\dot{V}O_{2max}$ is negatively correlated to body mass.[39] However, it also appears important to consider how segments are distributed. As indicated by Cavanagh and Kram as regards running,[40] a higher energy cost was recorded when the lower limbs were heavier. Body dimensions also influence running energy cost, but a relatively conflicting report has been presented on this topic.[41] These factors should be considered by researchers attempting to further explain the interaction between somatotype and the effect of aerobic training. Fat mass also may have influenced aerobic capacity. Most studies have reported that high levels of adiposity reduce aerobic capacity expressed relative to body mass.[42] Finally, differences in ethnic/racial origins should also be taken into account when interpreting the results of subjects differing in racial origin. This point is not addressed in the present study because all subjects were of the same background. Moreover, somatotype measurement is based on several criteria which are independent of ethnic origin. To the best of our knowledge and according to the literature, there are no differences in trainability between black and white subjects of the same somatotype group.

The results of our investigation suggest that somatotype may partly explain the variance in physiological adaptive responses to aerobic interval training. Anthropometric traits which characterise the Meso-ecto and Meso somatotype subjects may explain these differences. However, it seems that genetic factors play a considerable role in the expression of physiological adaptation to which the somatotype-training association may make an important contribution.

In conclusion, the results of the present study indicate significant somatotype-aerobic training interaction effects that may make an important contribution to the establishment of an adaptive response to intermittent and individualised aerobic training. Somatotype mainly influenced gains in aerobic capacity, particularly $v\dot{V}O_{2max}$, relative $\dot{V}O_{2max}$, and relative $\dot{V}O_2$ at the second VT. Significant post-training differences among groups were observed; Meso-ecto and Meso subjects seemed to be particularly predisposed to benefit from aerobic training. The relationship of aerobic fitness trainability to somatotype and genetic factors warrants further investigation.

What is already known on the topic

The contribution of morphological factors, such as somatotype, to athletic performance has been widely studied. Some authors have shown the influence of dominant somatotype on functional responses at peak exercise. However, few have explored the influence of morphological factors on physiological adaptation to training.

What this study adds

The results suggest that somatotype may partly explain the variance in physiological adaptive reponses to interval training. Aerobic capacity variables demonstrated significant interaction effects with somatotype over a period of aerobic training. The mesomorph and the mesomorph-ectomorph subjects demonstrated greater improvements in aerobic capacity following aerobic training.

Conclusions

This study demonstrates that somatotype is a structural factor in aerobic fitness trainability and could be helpful when identifying talented individuals for endurance events. Nevertheless, it is not easy to establish with precision the contribution of somatotype-training interaction effects to aerobic capacity determinants. Many factors, including genetic contribution, may be determinants of both somatotype and the capacity to adapt to training; this could be further investigated.

ACKNOWLEDGEMENTS

This study was financially supported by the Ministère de la Recherche Scientifique, de la Technologie et du Développement des Compétences, Tunisia.

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Competing interests: none declared

REFERENCES

1 **Myburgh KH**. What makes an endurance athlete world-class? Not simply a physiological conundrum. *Comp Biochem Physiol A Mol Integr Physiol* 2003;**136**:171–90.
2 **Whipp BJ**, Ward SA, Lamarra N, *et al*. Parameters of ventilatory and gas exchange dynamics during exercise. *J Appl Physiol* 1982;**52**:1506–13.
3 **Mikesell KA**, Gary AD. Influence of intense endurance training on aerobic power of competitive distance runners. *Med Sci Sports Exerc* 1984;**16**(4):371–5.
4 **Bouchard C**, Dionne FT, Simoneau JA, *et al*. Genetics of aerobic and anaerobic performance. *Exerc Sport Sci Rev* 1992;**20**:27–58.

5 **Carter JEL**, Aubrey SP, Sleet DA. Somatotypes of Montreal Olympic athletes. *Med Sport* 1982;**16**:53–80.
6 **Schreiber ML**. Anaerobic capacity as a function of somatotype and participation in varsity athletics. *Res Q* 1973;**44**(2):197–205.
7 **Bolonchuk WW**, Siders WW, Lykken GI, *et al.* Association of dominant somatotype of men with body structure, function during exercise and nutritional assessment. *Am J Hum Biol* 2000;**12**:167–80.
8 **Ergen E**, Sardella F, Dal-Monte A. The relationship of maximal alactacid anaerobic power to somatotype in trained subjects. *Br J Sports Med* 1985;**19**:221–3.
9 **Berg K**, Latin RW, Coffey CH. Relationship of somatotype and physical characteristics to distance running performance in middle age runners. *J Sports Med Phys Fitness* 1998;**38**:253–7.
10 **Durnin JVA**, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr* 1974;**32**:77–92.
11 **Carter JEL**, Heath BH. *Somatotyping: development and applications*. Cambridge: Cambridge University Press, 1990.
12 **Ross WD**, Hebbelink M, Brown SR, *et al.* Kinanthropometric landmarks and terminology. In: Shephard RJ, Lavallée H, eds. *Fitness assessment*. Charles C. Thomas: Springfield IL, 1978:44–50.
13 **Cazorla G**, Léger L. *Comment évaluer et développer vos capacités aérobies. Épreuve de course navette et épreuve Vam-éval*. Bordeaux: AREAPS, 1993:1–23.
14 **Hansen JE**, Sue DY, Oren A, *et al.* Relation of oxygen uptake to work rate in normal men and men with circulatory disorders. *Am J Cardiol* 1987;**59**(6):669–74.
15 **Vandewalle H**. Oxygen uptake and maximal oxygen uptake: interests and limits of their measurements. *Ann Readapt Med Phys* 2004;**47**(6):243–57.
16 **Beaver WL**, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. *J Appl Physiol* 1986;**60**(6):2020–7.
17 **Chamari K**, Hachana Y, Ben Ahmed Y, *et al.* Field and laboratory testing in young elite soccer players. *Br J Sports Med* 2004;**38**(2):191–6.
18 **Billat V**, Renoux JC, Pinoteau J, *et al.* Reproducibility of running time to exhaustion at $\dot{V}o_{2max}$ in sub-elite runners. *Med Sci Sports Exerc* 1994;**26**(2):254–7.
19 **Billat V**, Pinoteau J, Petit B, *et al.* Calibration de la durée des répétitions d'une séance d'interval training à la vitesse associée à $\dot{V}o_{2max}$ en référence au temps limite continu. *Sci Motricité* 1996;**28**:13–20.
20 **Billat V**, Flechet B, Petit B, *et al.* Interval training at $\dot{V}o_{2max}$: effects on aerobic performance and overtraining markers in endurance athletes. *Med Sci Sports Exerc* 1999;**31**:156–63.
21 **Galy O**, Manetta J, Coste O, *et al.* Maximal oxygen uptake and power of lower limbs during a competitive season in triathletes. *Scand J Med Sci Sports* 2003;**13**:185–93.
22 **Lacour JR**, Padilla-Magunacelaya S, Chatard JC, *et al.* Assessment of running velocity at maximal oxygen uptake. *Eur J Appl Physiol Occup Physiol* 1991;**62**:77–82.
23 **Gibbons E**, Jessup G, Wells T. Effects of various training intensity levels on anaerobic threshold and aerobic capacity in females. *J Sports Med Phys Fitness* 1983;**23**:315–8.
24 **Hickson RC**, Hagberg JM, Ehsani AA. Time course of the adaptive responses of aerobic power and heart rate to training. *Med Sci Sports Exerc* 1981;**13**:17–20.
25 **Åstrand PO**, Rodahl K. *Textbook of work physiology: physiological bases of exercise*, 3rd ed. New York: McGraw-Hill, 2003.
26 **Clausen JP**. Effects of physical training on cardiovascular adjustments to exercise in man. *Physiol Rev* 1977;**57**:779–815.
27 **Daniels J**, Scardina N, Hayes J, *et al.* Elite and subelite female middle- and long-distance runners. In: Landers DM, ed. *Sport and elite performers*. Champaign, IL: Human Kinetics, 1986:57–72.
28 **Léger L**, Mercier D, Gauvin L. The relationship between % $\dot{V}o_{2max}$ and running performance time. In: Landers DM, ed. *Sport and elite performers*. Champaign, IL: Human Kinetics, 1986:113–20.
29 **Berthoin S**, Mantéca F, Lensel-Corbeil G, *et al.* Effect of a 12 week training program on maximal aerobic speed (MAS) and running time to exhaustion at 100% of MAS in school students aged 14 to 17 years. *J Sports Med Phys Fitness* 1995;**35**:251–6.
30 **Jones AM**, McConnell AM. Effect of exercise modality on oxygen uptake kinetics during heavy exercise. *Eur J Appl Physiol* 1999;**80**:213–19.
31 **Carter H**, Jones AM, Doust JH. Effect of six weeks endurance training on the lactate minimum speed. *J Sports Sci* 1999;**17**:957–67.
32 **Weltman A**, Seip RL, Snead D, *et al.* Exercise training at and above the lactate threshold in previously un-trained women. *Int J Sports Med* 1992;**13**:257–63.
33 **Weston AR**, Karamizrak O, Smith A, *et al.* African runners exhibit greater fatigue resistance, lower lactate accumulation, and higher oxidative enzyme activity. *J Appl Physiol* 1999;**86**:915–23.
34 **Skibinska A**, Sklad M. Genetic determination of Heath and Carter somatotype. *Biol Sport* 1984;**1**:37–53.
35 **Bouchard C**. Genetics of aerobic power and capacity. In: Malina RM, Bouchard C, eds. *Sports and human genetics*. Champaign. IL: Human Kinetics, 1986:59–88.
36 **Montgomery HE**, Marshall R, Hemingway H, *et al.* Human gene for physical performance. *Nature* 1998;**393**(6682):221–2.
37 **Léger L**, Bosquet L, Folch N. Évaluation et développement des aptitudes aérobies au cours de la croissance. In: Cazorla G, Robert G, eds. *Actes du quatrième Colloque International de la Guadeloupe*. Bordeaux: AREAPS, 1997:70–94.
38 **Winter EM**. Scaling partitioning out difference in size. *Pediatr Exer Sci* 1992;**4**:296–301.
39 **Bergh V**, Sjödin B, Forsberg A, *et al.* The relationship between body mass and oxygen uptake during running in humans. *Med Sci Sports Exerc* 1991;**23**:205–11.
40 **Cavanagh P**, Kram R. Mechanical and muscular factors affecting the efficiency of human movement. *Med Sci Sports Exerc* 1985;**17**:326–31.
41 **Pate R**, Macera C, Bailey S, *et al.* Physiological, anthropometric, and training correlates of running economy. *Med Sci Sports Exerc* 1992;**24**:1128–33.
42 **Cureton KJ**, Sparling PB, Evans BW, *et al.* Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. *Med Sci Sports* 1978;**10**:194–9.