Effects of dominant somatotype on aerobic capacity trainability

M Chaouachi, A Chaouachi, K Chamari, M Chtara, Y Feki, M Amri, F Trudeau

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; Vo2max = 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 Vo2max and Vo2 at the second ventilatory threshold (VT2); (ii) a VAM-EVAL track test to determine maximal aerobic speed (Vo2max); and (iii) an exhaustive constant velocity test to determine time limit performed at 100% Vo2max (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 Vo2max, and one of active recovery at 60% of Vo2max. 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 Vo2max, Vo2max expressed classically and according to allometric scaling, and Vo2 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.

T here is great interest in systematically studying the factors that can influence fitness development for better sporting performance. Most available methods of measuring endurance training efficacy use maximal oxygen uptake (Vo2max) as the main outcome variable. However, it has been shown that Vo2max is not the only indicator of cardiorespiratory fitness for endurance events. Vo2max must be associated with other factors such as ventilatory threshold (VT), velocity at Vo2max, and exercise economy to explain differences in endurance performance.

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. Genetic factors explain part of the variability in adaptation to a given training program and should be considered. 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. 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. Ergen et al 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 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 Vo2max, the second VT, exercise economy, and velocity at Vo2max, 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 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. 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, all subjects provided their written informed consent.

Abbreviations: ACE, angiotensin converting enzyme; ANCOVA, analysis of covariance; ANOVA, analysis of variance; HR, heart rate; RER, respiratory exchange ratio; Vo2max, maximal oxygen uptake; VT, ventilatory threshold.
USA. The average of the three measurements for each site recorded by the same examiner. Each skinfold was measured in mm.

Body mass or kg, stature-body mass ratio (stature divided by the cube root of body mass or kg $^{1/3}$), all skinfolds and girths were included in the calculations according to the method described by Ross et al. Each subject performed three preliminary tests 1 week apart. The first test measured $V_{\text{o}2\text{max}}$, and was performed in the laboratory. The second test, that is the VAM-EVAL track test, measured maximal aerobic speed ($vV_{\text{o}2\text{max}}$), and the third test assessed the time to exhaustion at 100% $vV_{\text{o}2\text{max}}$ on the running track (tlim100).

### $V_{\text{o}2\text{max}}$ measurement

Individual $V_{\text{o}2\text{max}}$ was measured during a continuous, incremental test to exhaustion$^{18}$ 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 ($V_{\text{CO}2}$, $V_{\text{CO}2}$) 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 $V_{\text{o}2\text{max}}$ had been attained: (i) a plateau or slight drop in $V_{\text{o}2}$ 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. $V_{\text{o}2\text{max}}$ 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$^{14}$ 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 $vV_{\text{o}2\text{max}}$ (km h$^{-1}$).

### Time to exhaustion at 100% $vV_{\text{o}2\text{max}}$ (tlim100)

The purpose of the third field session was to estimate the individual running performance at 100% $vV_{\text{o}2\text{max}}$ (tlim100). The test took place on the same track described above. After a 1 min stage, 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 $vV_{\text{o}2\text{max}}$ (km h$^{-1}$).
15 min warm up at 60% \(v\text{VO}_2\text{max}\) the subjects had to run for as long as possible at a pace corresponding to their \(v\text{VO}_2\text{max}\). The post-training \(t\text{lim}100\) was performed at the pre-training \(v\text{VO}_2\text{max}\).

**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 \(v\text{VO}_2\text{max}\). 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 \(v\text{VO}_2\text{max}\) and one period of active recovery at 60% of \(v\text{VO}_2\text{max}\). The duration of each period was equal to half the individual \(t\text{lim}100\) duration. 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. The intensities of the periods of exercise and recovery were readjusted after 6 weeks by way of a VAM-EVAL test (intermediate \(v\text{VO}_2\text{max}\)). After training, \(v\text{VO}_2\text{max}\), \(V\text{O}_2\text{max}\), and \(t\text{lim}100\) (performed at the pre-training \(v\text{VO}_2\text{max}\)) 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 four 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\times pre- and post-training) interaction effect (\(p<0.001\)) was observed. This interaction mainly concerned \(v\text{VO}_2\text{max}\), \(V\text{O}_2\text{max}\) expressed in ml kg\(^{-1}\) min\(^{-1}\) and ml kg\(^{-0.75}\) min\(^{-1}\), and \(V\text{O}_2\) at VT2 (fig 2).

**\(v\text{VO}_2\text{max}\) and \(t\text{lim}100\)**

\(v\text{VO}_2\text{max}\) increased significantly in the four groups after the training period (table 2). Significant (somatotype\times 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 \(v\text{VO}_2\text{max}\). Significant elevation of \(t\text{lim}100\) (performed at the pre-test \(v\text{VO}_2\text{max}\)) was evident for all somatotype groups (table 2), but the mean increases were not significantly different between groups.

\(V\text{O}_2\text{max}\)

Both absolute (l min\(^{-1}\)) and relative \(V\text{O}_2\text{max}\) (ml kg\(^{-1}\) min\(^{-1}\) and ml kg\(^{-0.75}\) min\(^{-1}\)) increased significantly in the four groups except for absolute \(V\text{O}_2\text{max}\) in Endo-meso subjects which only showed a trend towards significance (\(p = 0.08\), table 2). However, interaction effects (somatotype\times pre- and post-training) were significant (\(F = 22.7\) (df 1, 37); \(p<0.001\)) only for relative \(V\text{O}_2\text{max}\) (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).
The post-training improvements in relative $V\dot{O}_2\text{max}$ (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 2B,2). These mean gains are consistent with values found in other training studies which have reported increases ranging from 10% to 23%.20–24 Increments in $V\dot{O}_2\text{max}$ 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.29 The improvements in relative $V\dot{O}_2\text{max}$ (ml kg$^{-1}$ min$^{-1}$ and ml kg$^{-0.75}$ min$^{-1}$) in the present study could be due to improved cardiac output and systemic oxygen delivery and not to any change in muscle mass. The rise in O$_2$ pulse following the training period may reflect the extent of cardiac and peripheral adaptation to training.28 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 $V\dot{O}_2\text{max}$ (fig 2B). The magnitude of these increases (from 6.1% to 8.2%) differed among somatotype groups. The Meso-ecto group showed the highest improvements (7.3%) for the Endo-meso group (15.9%) in comparison to the Endo-meso (5.6%) and Ecto (7.3%) groups.

DISCUSSION

The results of this study showed the effects of somatotype on aerobic performance in trained individuals, and in particular, the effects of somatotypes on $V\dot{O}_2\text{max}$ in trained athletes. The variations in aerobic capacity variables demonstrated a significant interaction effect with somatotype over a period of training. The magnitude of increase in these parameters varied according to somatotype group. Indeed, as a result of training, $V\dot{O}_2\text{max}$, $V\dot{O}_2\text{max}$ (ml kg$^{-1}$ min$^{-1}$ and ml kg$^{-0.75}$ min$^{-1}$), and $V\dot{O}_2$ 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 $V\dot{O}_2\text{max}$ was considered as a relevant criterion to set training intensities. In the present study, $V\dot{O}_2\text{max}$ measurement in the field, for training purposes, was preferred to laboratory measurements.22 The time for which exercise at $V\dot{O}_2\text{max}$ could be sustained (trim100) was used to individualise the duration of interval training at $V\dot{O}_2\text{max}$ according to the method of Billat et al.23 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.24 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 main findings of our study showed that the most significant improvements in aerobic capacity components following the training program varied among the dominant

| Table 2: Effects of 12 week training program on components of aerobic capacity in somatotype groups
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<tr>
<td></td>
<td>Endo-meso,</td>
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<td>Meso-ecto,</td>
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<td>$V\dot{O}_2\text{max}$ (ml kg$^{-1}$ min$^{-1}$)</td>
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<td>$V\dot{O}_2\text{max}$ (ml kg$^{-0.75}$ min$^{-1}$)</td>
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<td>%V$\dot{O}_2$ (V$\dot{O}_2$ at VT2)</td>
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<td>Post-test</td>
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<td>HR max</td>
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<td>(beats min$^{-1}$)</td>
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<td>(ml breath$^{-1}$)</td>
<td>Pre-test</td>
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NS, not significant; *p<0.01. For legends, see table 1.
somatotype groups. Indeed, mean gains in \( \dot{V}O_{2\max} \), relative \( V_{O2max} \) (expressed per ml kg\(^{-1} \) min\(^{-1} \)), and \( V_O2 \) 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. On the other hand, \( V_O2 \), an index of aerobic fitness, is influenced by genetic and environmental factors. Genetic factors indeed impact the development of somatotype-aerobic training interaction effects. These factors should be considered when interpreting the results of subjects differing in ethnic/racial origins. 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 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 \( \dot{V}O_{2\max} \), relative \( V_{O2max} \) and \( V_O2 \) at 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.

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.

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