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; V\textsuperscript{o}2\textsubscript{max} = 52.8±5.7 ml kg\textsuperscript{-1} min\textsuperscript{-1}) performed three exercise tests 1 week apart (i) an incremental test on a cycle ergometer to determine V\textsubscript{o}2\textsubscript{max} and V\textsubscript{o}2 at the second ventilatory threshold (VT2); (ii) a VAM-EVAL track test to determine maximal aerobic speed (V\textsubscript{\textsuperscript{o}2\textsubscript{max}}); and (iii) an exhaustive constant velocity test to determine time limit performed at 100% V\textsubscript{o}2\textsubscript{max} (lim100). 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\textsubscript{o}2\textsubscript{max} and one of active recovery at 60% of V\textsubscript{o}2\textsubscript{max}. The duration of each period was equal to half the individual final100 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\textsubscript{o}2\textsubscript{max}, V\textsubscript{o}2\textsubscript{max}, expressed classically and according to allometric scaling, and V\textsubscript{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. Most available methods of measuring endurance training efficacy use maximal oxygen uptake (V\textsubscript{o}2\textsubscript{max}) as the main outcome variable. However, it has been shown that V\textsubscript{o}2\textsubscript{max} is not the only indicator of cardiorespiratory fitness for endurance events. V\textsubscript{o}2\textsubscript{max} must be associated with other factors such as ventilatory threshold (VT), velocity at V\textsubscript{o}2\textsubscript{max}, 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\textsuperscript{7} 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\textsuperscript{7} 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 V\textsubscript{o}2\textsubscript{max}, the second VT, exercise economy, and velocity at V\textsubscript{o}2\textsubscript{max}, 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.\textsuperscript{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; V\textsubscript{o}2\textsubscript{max}, maximal oxygen uptake; VT, ventilatory threshold
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.\textsuperscript{12}

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

\textbf{VO\textsubscript{2max} measurement}

Individual VO\textsubscript{2max} was measured during a continuous, incremental test to exhaustion\textsuperscript{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 (VO\textsubscript{2}, CO\textsubscript{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\textsuperscript{15} indicated VO\textsubscript{2max} had been attained: (i) a plateau or slight drop in VO\textsubscript{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)\textsuperscript{16} and maximal oxygen pulse (O\textsubscript{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 VO\textsubscript{2} (ml kg\textsuperscript{-1} min\textsuperscript{-1}) and as a fraction of VO\textsubscript{2max} (%VO\textsubscript{2max}). Maximal O\textsubscript{2} pulse (ml beats\textsuperscript{-1}) was calculated by dividing VO\textsubscript{2max} (ml min\textsuperscript{-1}) by maximal HR (HR\textsubscript{max}), the highest HR attained at exhaustion. VO\textsubscript{2max} was expressed classically and according to allometric scaling to avoid underestimation in heavy and overestimation in light individuals.\textsuperscript{17}

\textbf{VAM-EVAL track test}

The VAM-EVAL track test\textsuperscript{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\textsuperscript{-1} with subsequent increments of 0.5 km h\textsuperscript{-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 \(v\text{VO}_{2\text{max}}\) (km h\textsuperscript{-1}).

\textbf{Time to exhaustion at 100% \(v\text{VO}_{2\text{max}}\) (tlim100)}

The purpose of the third field session was to estimate the individual running performance at 100% \(v\text{VO}_{2\text{max}}\) (tlim100).\textsuperscript{14} The test took place on the same track described above. After a

<table>
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<th>Physical characteristics of each group separated according to somatotype</th>
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<tr>
<td>Somatotype characteristics</td>
<td>Endo-meso, n = 9</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>77.7 ± 6.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.9 ± 5.4</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>20.6 ± 2.2</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>16.0 ± 2.1</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>61.7 ± 5.2</td>
</tr>
<tr>
<td>BMI (kg m\textsuperscript{-2})</td>
<td>24.2 ± 10.0</td>
</tr>
<tr>
<td>Endomorphy</td>
<td>4.1 ± 0.5</td>
</tr>
<tr>
<td>Mesomorphy</td>
<td>2.1 ± 0.3</td>
</tr>
<tr>
<td>Ectomorphy</td>
<td>2.1 ± 0.5</td>
</tr>
</tbody>
</table>

BMI, body mass index; Ecto, ectomorph; Endo-meso, endomorph-mesomorph; Meso, mesomorph; Meso-ecto, mesomorph-ectomorph. Values are expressed as mean ± SD.
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 \( V_\text{O2max} \). 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 \( V_\text{O2max} \) and one period of active recovery at 60% of \( V_\text{O2max} \). The duration of each period was equal to half the individual \( t\text{lim100} \) 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 \( V_\text{O2max} \)). After training, \( V_\text{O2max} \), \( V_\text{O2max} \) and \( t\text{lim100} \) (performed at the pre-training \( V_\text{O2max} \)) were measured for each subject.

Statistical analysis

A somatochart was developed with Somatype 1.0 software to determine the somatypes (fig 1). Four distinct groups emerged with three somatotypes (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 \( V_\text{O2max} \), \( V_\text{O2max} \) expressed in ml kg\(^{-1} \) min\(^{-1} \) and ml kg\(^{-0.75} \) min\(^{-1} \), and \( V_\text{O2} \) at VT2 (fig 2).

\( V_\text{O2max} \) and \( t\text{lim100} \)

\( V_\text{O2max} \) 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 \( V_\text{O2max} \). Significant elevation of \( t\text{lim100} \) (performed at the pre-test \( V_\text{O2max} \)) was evident for all somatotype groups (table 2), but the mean increases were not significantly different between groups.

\( V_\text{O2max} \)

Both absolute (l min\(^{-1} \)) and relative \( V_\text{O2max} \) (ml kg\(^{-1} \) min\(^{-1} \) and ml kg\(^{-0.75} \) min\(^{-1} \)) increased significantly in the four groups except for absolute \( V_\text{O2max} \) 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 \( V_\text{O2max} \) (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).
Effects of 12 week training program on components of aerobic capacity in somatotype groups

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Effects of 12 week training program on components of aerobic capacity in somatotype groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endo-meso, n=9</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>VT2 (ml kg (^{-1}) min (^{-1}))</td>
<td>Pre-test</td>
</tr>
<tr>
<td>16.4 ± 1.0</td>
<td>16.6 ± 0.9</td>
</tr>
<tr>
<td>54.7 ± 6.4</td>
<td>54.2 ± 5.7</td>
</tr>
<tr>
<td>1.7 ± 1.0</td>
<td>1.6 ± 0.9</td>
</tr>
<tr>
<td>2%</td>
<td>2%</td>
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<tr>
<td><strong>NS</strong></td>
<td><strong>NS</strong></td>
</tr>
</tbody>
</table>

\( \text{VO}_2 \) at VT2

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

Maximal \( \text{O}_2 \) pulse

No significant interaction effects (somatotype \( x \)-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, \( \text{VVO}_{2\text{max}}, \text{VO}_{2\text{max}} \) (ml kg \(^{-1}\) min \(^{-1}\) and ml kg \(^{-0.75}\) min \(^{-1}\)), and \( \text{VO}_{2} \) 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. \(^{11}\) Individual \( \text{VVO}_{2\text{max}} \) was considered as a relevant criterion to set training intensities. In the present study, \( \text{VVO}_{2\text{max}} \) measurement in the field, for training purposes, was preferred to laboratory measurements. \(^{22}\) The time for which exercise at \( \text{VVO}_{2\text{max}} \) could be sustained (\( \text{tim}100 \)) was used to individualise the duration of interval training at \( \text{VVO}_{2\text{max}} \) according to the method of Billat et al. \(^{11}\) 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. \(^{26}\) 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 \( \text{VO}_{2\text{max}} \) (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,23). These mean gains are consistent with values found in other training studies which have reported increases ranging from 10% to 23%. \(^{21,23,24}\) Increments in \( \text{VO}_{2\text{max}} \) 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. \(^{25}\) The improvements in relative \( \text{VO}_{2\text{max}} \) (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 \( \text{O}_2 \) 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 \( \text{VVO}_{2\text{max}} \) (fig 2B). The magnitude of these increases (from 6.1% to 8.2%) differed among somatotype groups. The Meso-ecto group showed the highest mean gains (8.2%). This improvement in \( \text{VVO}_{2\text{max}} \) indicates that a certain percentage of \( \text{VO}_{2\text{max}} \) will be associated with higher speed after training. \(^{27,28}\) Several studies have reported increased \( \text{VVO}_{2\text{max}} \) of between 2.9% and 8.5% in well trained athletes following endurance training. \(^{29,30}\) They found that this increase in \( \text{VVO}_{2\text{max}} \) resulted from significant improvements in both \( \text{VO}_{2\text{max}} \) and running economy. In the present study, improvements in the former were shown while the latter variable was not measured.

\( \text{VO}_{2} \) at VT2 (\( \text{VO}_{2} \) 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 \( \text{VO}_{2} \) at the second VT expressed in % \( \text{VO}_{2\text{max}} \). The highest values recorded in this somatotype group ranged from 83.8 ± 28% of \( \text{VO}_{2\text{max}} \), 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 \( \text{VO}_{2\text{max}} \) for prolonged periods. \(^{20,31}\)

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 \( \dot{V}O_2_{\text{max}} \), relative \( \dot{V}O_2_{\text{max}} \) (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. On the other hand, \( \dot{V}O_2 \), an index of aerobic fitness, is influenced by genetic and environmental factors. Genetic factors indeed impact the development of somatotype, but training allows its improvement. The same author showed that heredity largely influences the trainability of \( \dot{V}O_2_{\text{max}} \). Depending on genotype, the same training program can have different effects, ranging from 0% to 30%. According to these studies, there is a potential association between genetic variables, such as muscular enzymes (that is mitochondrial DNA), and changes in \( \dot{V}O_2_{\text{max}} \) 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) insertion polymorphism in these groups. 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 \( \dot{V}O_2_{\text{max}} \) 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. Many studies have shown that relative \( \dot{V}O_2_{\text{max}} \) is negatively correlated to body mass. However, it also appears important to consider how segments are distributed. As indicated by Cavanagh and Kram as regards running, 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. 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. 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 \( \dot{V}O_2_{\text{max}} \), relative \( \dot{V}O_2_{\text{max}} \) 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.

**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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**Authors’ affiliations**

M Chaouachi, M Chitara, Y Feki, M Amri, Laboratoire de Physiologie de la Nutrition, Faculté des Sciences de Tunis, El Manar 1060 Tunis, Tunisia

A Chaouachi, K Chamari, Centre National de la Médecine et des Sciences du Sport, Unité de Recherche “Évaluation, Sport, Santé”, CNMSS, El Menzah, Tunisia

F Trudeau, Département des Sciences de l’Activité Physique, Université du Québec à Trois-Rivières, Québec, Canada

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**REFERENCES**


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