Topics in Functional and Ecological Vertebrate Morphology, pp. 125-138.
P. Aerts, K. D'Août, A. Herrel & R. Van Damme, Eds.
 ISBN 90-423-0204-6

Running Economy in Early and Late Mature Youth Soccer Players

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Abstract

The aim of this study was to investigate whether maturity is a performance related physiological parameter in competitive youth soccer.
This study investigated the influence of maturity on running economy in a population of young soccer players with different maturity status. 13 boys (mean age = 14.3 years) active in soccer were divided in two groups: 6 early and 7 late maturers. Anthropometric characteristics, respiratory exchange ratio (RER), heart rate, ventilatory equivalent (VE) and maximal oxygen uptake were measured. Running economy was assessed at three submaximal running speeds (8, 9.5 and 11 $km.h^{-1}$). Allometric coefficients were calculated and used to take into account differences in body mass. In addition, running style was analysed biomechanically (stride length, inertia and meaningful kinematic values). There was no significant difference in the running economy of early and late mature soccer players. With exception of the VE/VO_2 ratio at 8 $km.h^{-1}$ there were no significant differences in physiological values. Physiological differences can not explain why late maturers succeed in keeping up with early maturers. Late mature boys take relatively longer strides, have a smaller knee-angle during the swing-phase and more anteversion of the thigh. Running style seems to be an important determinant of running economy in children. More flexion at the knee during the swing-phase leads to a smaller mass moment of inertia of the swinging leg in late maturers. This allows more anteversion of the thigh and probably diminishes the rotational energy required to swing the leg to the front, thus allowing late maturers to keep up with early maturers.

Key words: running economy, youth soccer, submaximal exercise, maturity.

Introduction

Early mature children have advantages over late mature children in physiological and anthropometric characteristics (e.g. absolute strength, height, body mass, sprinting capacities and anaerobic components; Rowland, 1990; Malina, 1994; Beunen and Malina, 1996; Williams and Reilly, 2000). Generally, in sports in which "performance" depends on the mentioned characteristics, for instance in team sports like basketball, volleyball or soccer, early maturers get more chances (Malina and Beunen, 1996; Malina et al, 2000; Williams and Reilly, 2000). Even when physiological parameters are scaled to body dimensions (relative strength; Malina and Bouchard, 1991; Beunen and Malina, 1996 and relative maximal oxygen uptake, in $ml.kg^{-1}.min^{-1}$; Rowland, 1996) early maturers score better.
Another important physiological determinant in sports is running economy, defined as the steady-state oxygen uptake (VO_2) at a submaximal running speed. Good running economy is an

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important parameter in endurance sports. In adult soccer players for instance, it enables the active recuperation after game phases of maximal intensity (Reilly et al, 1997; Drust et al , 2000). However, running economy among children with a different maturity status and participating in competitive youth soccer has not yet been examined before. Still, this is important when profiling the young soccer players, when adapting the training to their abilities, and when identifying the highly talented youngsters.

Children demonstrate a poorer running economy when compared to adolescents or adults, although the underlying reasons are not exactly known (Rowland et al, 1987; Rowland and Green, 1988; Maliszweksi and Freedson, 1996). The latter finding, together with the better scores on other physiological parameters leads to the hypothesis that early maturers (more close to adults) should have a better running economy when comparing them to late maturers. Indeed, Kemper et al (1987) found a better running economy for early mature youngsters. But in a recent study of Armstrong et al (1999) late maturers appear to have an equal running economy when compared to early maturers. As running economy relates to submaximal VO_2 scaled to the body mass it is clear that the scaling factor plays an important role in the determination of running economy. Where Kemper et al (1987) used a simple ratio standard (ml kg^{-1} min^{-1}), Bergh et al proposed to express VO_2 relative to the body mass to the 0,75 power (ml.$kg^{-0,75}min^{-1}$). More recently allometric or log-linear scaling was adopted (Armstrong et al, 1994; Nevill and Holder, 1995; Welsmann et al, 1996; Nevill et al, 1998). Armstrong and coworkers (1999) found for a large school population (97 boys and 97 girls, 12.2 ± 0.4 years of age) a scaling factor varying between 0,89 and 0,93, but stated in the discussion the specificity of the mass exponents for the sample. Unfortunately, these results are not applicable to early and late maturers in youth soccer because of the the highlighted specificity and the non-equivocal results.

Furthermore, the underlying mechanisms explaining how maturity status affects running economy are not yet known (Armstrong, 1999). Although there is no evidence for a causal physiological factor, the running aspect (i.e. the running movement itself) has not yet received attention. Therefore, our hypothesis is that running style is an important variable in explaining the difference in running economy between early and late mature boys.

The purpose of the present study is thus to investigate the influence of maturity on running economy (submaximal VO_2) in a selective sport-specific sample of the Ghent Youth Soccer Project (GYSP). The early mature boys have the same chronical age as the late mature boys but they differ at least 2 years in biological (skeletal) age. The effect of maturity on submaximal VO_2 adjusted for body size using allometric scaling (a power function model to explain the relationship between a physiological variable and a body size variable) is examined (see Welsman et al,1996; Armstrong and Welsman, 1997; Nevill et al, 1998; Armstrong et al, 1999). Running style of the early mature and late mature boys is studied using biomechanical analyses of stride length and frequency (Cavanagh et al, 1982; Brisswalter et al, 1996), and lower limb kinematics and inertia (Williams et al, 1987).

Materials and methods

<u>Subjects</u>

The subjects are all participants in the Ghent Youth Soccer Project (GYSP), a longitudinal study on growth and performance of soccer players between 12 and 16 years of age. In this study, longitudinal data are available for 50 subjects observed annually.

Fourteen male subjects were selected from the GYSP based on the following criteria: (1) practising at least 4.5 h/week during the last 2 years (2) 13 or 14 years old (3) experience in treadmill running

(4) difference in maturity status: 7 boys were early maturers (EM), 7 were late maturers (LM) 1 year and 2 years before testing. Skeletal age (SA) was assessed using the TW2 system derived by Tanner et al. (Malina and Beunen, 1996). SA is expressed relative to the child's chronological age (CA) and children are often classified as having an SA that is advanced, average or delayed. The criteria that define the categories are: a) advanced: SA is one year or more ahead of CA (early maturer), b) average: SA is within plus or minus one year of CA (average maturer), c) delayed: SA is one year or more behind CA (late maturer) (see Malina, 1994).
Tanner stadia of sexual maturation (Pubic Hair development (PH) and Genital development (G)) were also assessed. All the data concerning SA, PH and G were collected by an experienced researcher at the Ghent University Hospital.
Prior to the start of the GYSP, all the children and their legal guardians were fully informed of the procedures of the experiment, and they gave their written consent to participate in the project. The local ethical committee approved the experiment.

Procedures

Stature, sitting height, body mass, leg length and shank length were measured using the following procedures described by Lohman (1988). Thigh length was calculated using the next formula: leg length - shank length. Circumferences of thigh and calf and skinfold measurements were obtained following the procedures described by Parizkova (1977). Subsequently partial masses of the leg were calculated according to the method proposed by Jensen (1986). The position of the centre of gravity (CG) of the body was determined according to the balance method (Hall, 1995).
Subjects were asked not to participate in strenuous exercise the day before the exercise test to determine maximal oxygen uptake, as well as the day before the test to determine running economy. Both tests were performed in the afternoon.
Values of maximal rate of oxygen uptake (VO_2peak) were obtained for each subject. One early maturer was eliminated for further research for being an outlier in VO_2peak value. His training status seemed to differ from that of the other 13 subjects. His results were not taken into account for statistical analysis.
VO_2peak was measured on a Technogym treadmill (Runrace, Electronic Competition, HC 1200). The test began with a walk at 1% grade at 7 km/h and progressed each minute in speed until ventilatory threshold was reached. After reaching ventilatory threshold running grade was augmented with 1% each minute until subjects reached exhaustion. Expired air was analysed throughout the test using an open breath-by-breath system (Oxycon Champion Version 3.10, Mynhardt) with ventilatory rate, rate of carbon dioxide production and oxygen uptake and respiratory exchange ratios (RER) calculated as 30-s averages. RER was calculated by dividing V_{CO2} by VO_2 (RER>1 = anaerobic; RER<1 = aerobic) Oxygen and carbondioxide analysers were calibrated with gases of known concentrations before each test. Expired air was analysed throughout the test using a MedGraphics CPX/D. Heart rates (HR) were monitored with a Polar Accurex Plus telemetric HR monitor. VO_2peak was judged to be achieved when two of the three following criteria were fulfilled (Unnithan, 1995): (1) the maximal heart rate within 10 bpm of 200 bpm (2) a heart rate increase less than a 5 bpm from the penultimate to the final stage (3) a respiratory gas exchange ratio of greater than 1.0 (RER > 1)
Running economy was quantified by having each subject perform three 6-min. treadmill runs at 1% grade. Each subject wore the same type of shoes and similar clothing during the test session. Treadmill speed was calibrated prior to the test sessions. Subjects ran at 8 $km.h^{-1}$ (= 2.2 m/s^{-1}), 9.5 $km.h^{-1}$ (= 2.5 m/s^{-1}) and 11 $km.h^{-1}$ (= 3.06 m/s^{-1}). Rest periods of 5 min. separated each running bout. Heart rates obtained during the last minute of each running bout, along with ventilation and submaximal oxygen consumption values averaged over three consecutive 30-s collection periods

during the last 90s of each running bout were used in statistical analyses. Expired air was analysed throughout the test using a MedGraphics CPX/D. During this test running economy was recorded as the submaximal VO_2. In this study, VO_2 was adjusted for body mass using allometric or log-linear scaling. This means that the following power function model is used to explain the relationship between a physiological variable and a body size variable

$$VO_2 = a \cdot mass^{k}$$

All data were stored and analysed using the SPSS-PC package (SPSS inc., Chicago, IL). Oxygen uptake was examined by computing analysis of covariance (ANCOVA) on log-transformed data with body mass as the covariate. Besides producing adjusted means for VO_2, the analysis of covariance also enables the identification of the parameters a and k in the allometric equation (Armstrong et al, 1999). The fit was made using a 95% confidence interval with r^2-values varying between 0.815 and 0.856 with the restriction $k<1$ (Welsman et al., 1996). Running economy is the opposite of VO_2: high submaximal VO_2 means bad running economy and vice a versa.
Prior to each test, eleven landmarks were placed on the lateral part of the body (ear, neck, shoulder, elbow, wrist, hip, knee, ankle, heel, metatarsal V and thoracal XII) (figure 1). Running was filmed laterally at a frequency of 50 Hz. The following kinematic variables, as proposed by Williams (1987), were calculated in one stride: shank angle at contact, trunk angle, maximal plantar flexion angle, maximal knee flexion in support, minimum knee velocity, wrist excursion, vertical oscillation and minimal knee angle during swing-phase (figure 1). Segment mass and position of the centres of gravity of the segments were corrected for age (Jensen, 1986) and used to calculate the mass moment of inertia. Stride frequency and stride length were derived of the video recordings. Stride length, the length from one foot contact to the next contact of the same foot, was calculated using the following formula: SL = treadmill speed / SF.
Descriptive statistics (mean ± SD) were calculated for subject characteristics and submaximal responses to exercise. Significant differences between two groups were tested with a non-parametric Mann-Whitney U test. Repeated measures ANOVA and ANCOVA were used to examine maturational differences in the pattern of increase in VO_2 across the 3 submaximal running speeds. Correlations were calculated with a Pearson product moment correlation method. Significance probability levels of 0.05 and 0.01 were used.

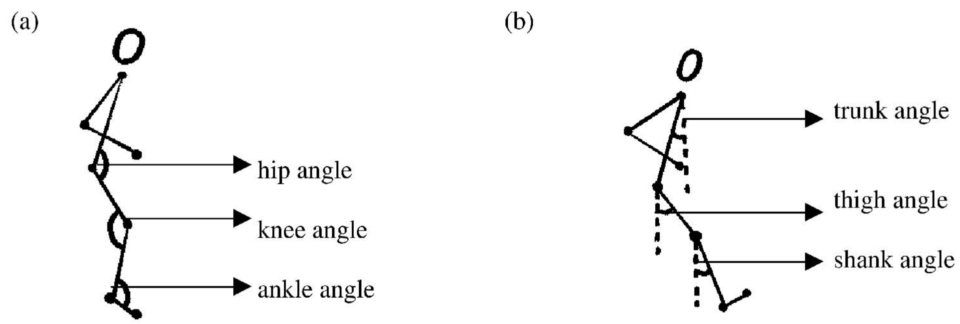

Figure 1. *Joint angles (a) and segment angles (b) used for biomechanical analysis.*

Results

Subject characteristics, maximal performance and scaling factor

Subject characteristics and variables describing maximal performance are summarised in table 1. Sports performance related variables of the young soccer players are summarized in table 2.

Variables	Early maturers (n = 6)	Late maturers (n = 7)	p [1]
Age (years)	14.3 (0.6)	14.4 (0.5)	NS [2]
Skeletal age (years)	16.0 (1.1)	13.2 (1.0)	.01
Height (cm)	175.7 (6.6)	154.6 (8.1)	.01
Weight (kg)	65.2 (7.6)	43.3 (4.9)	.01
Shoesize (european)	43.50(1.38)	39.29 (1.38)	.01
Body fat (%)	17.1 (5.2)	14.8 (3.8)	NS [2]
Tanner PH	3.7 (0.8)	2.4 (0.5)	.01
Tanner G	3.7 (0.8)	2.4 (0.5)	.01
Thigh length (cm)	46.8 (1.4)	40.0 (1.6)	.01
Shank length (cm)	45.3 (3.5)	40.9 (2.6)	.05
Thigh outline (cm)	54.7 (3.4)	45.4 (2.3)	.01
Shank outline (cm)	36.3 (2.4)	30.9 (1.4)	.01
VO_2peak			
($l.min^{-1}$)	3.84 (0.5)	2.57 (0.4)	.01
($ml.kg^{-0.91}.min^{-1}$)	177.0 (12.1)	159.9 (16.9)	NS [2]
HR max [3] ($beats.min^{-1}$)	195 (7)	195 (6)	NS [2]
VE [4] at VO_2peak			
($l.min^{-1}$)	131.2 (12.1)	88.0 (11.4)	.01
($ml.kg^{-0.91}.min^{-1}$)	5.7 (0.4)	5.2 (0.5)	NS [2]

Table 1. *Subjects characteristics (mean (SD)). [1] p= Significance level, [2] NS= Not Significant, [3] HR max = maximal heart rate, [4] VE = ventilatory equivalent for oxygen.*

	Highest level of competition [1]	Intermediate level of competition [2]	Low level of competition [3]
Early maturers (n=6)	1	5	0
Late maturers (n=7)	1	4	2

Table 2. *Level of sports performance of the young soccer players. [1] Highest level of competition = national level, [2] Intermediate level of competition = provincial level, [3] Low level of competition = regional level.*

There were no significant differences between the two groups of boys for age and body fat distribution. Skeletal age and Tanner's indices showed significant differences, confirming the difference in maturity status of the 2 groups. Early matures were significantly taller and heavier than late maturers.

Scaling factors were found using the described allometric scaling method: for maximal oxygen uptake and submaximal opxygen uptake a scaling factor of -0.91 resp. -0.98 was found ($p<0.05$ and r^2 varying between 0.815 and 0.856).

Comparisons of the two groups at maximal exercise intensity demonstrated that significant differences existed in VO_2peak ($l.min^{-1}$) and VE at VO_2peak ($l.min^{-1}$). No significant differences in relative VO_2peak ($ml.kg^{-0.91}.min^{-1}$) were found.

Running economy

Figure 2 shows the adjusted VO_2 using allometric scaling for early maturers and late maturers running at a constant speed of 8 $km.h^{-1}$, 9.5 $km.h^{-1}$ and 11 $km.h^{-1}$ respectively.

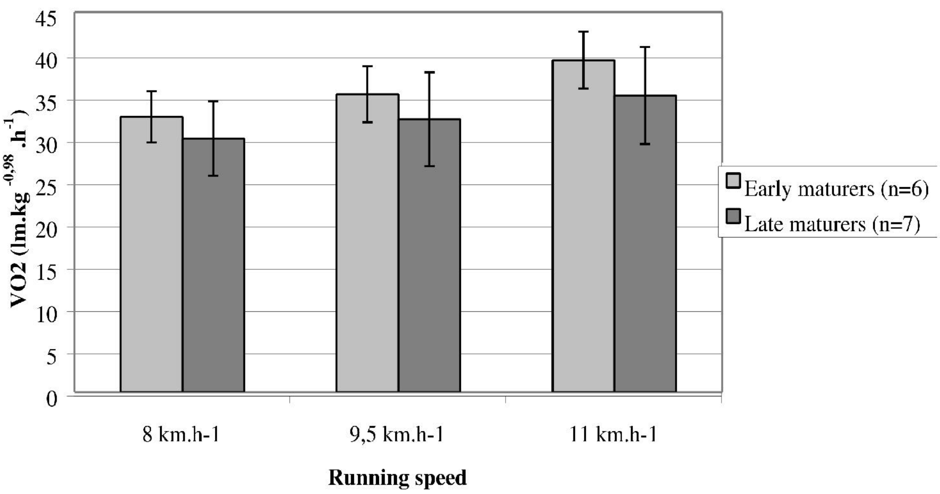

Figure 2. *Submaximal VO_2 adjusted using allometric scaling for early maturers and late maturers during running at a constant speed of 8 $km.h^{-1}$, 9.5 $km.h^{-1}$ and 11 $km.h^{-1}$ respectively. No significant differences were found.*

VO_2 values for early maturers running at 8, 9.5 and 11 $km.h^{-1}$ were 32.56 ± 3.03 $ml.kg^{-0.98}.min^{-1}$, 35.27 ± 3.32 $ml.kg^{-0.98}.min^{-1}$, and 39.31 ± 3.35 $ml.kg^{-0.98}.min^{-1}$ respectively. The aerobic demands for late maturers at the same running speeds were 30.02 ± 4.41 $ml.kg^{-0.98}.min^{-1}$, 32.30 ± 5.56 $ml.kg^{-0.98}.min^{-1}$, and 35.12 ± 5.73 $ml.kg^{-0.98}.min^{-1}$ respectively.

	Early maturers (n=6)	Late maturers (n=7)	p [1]
% VO_2peak at 8 km. h^{-1}	51.2 (7.1)	47.0 (5.7)	NS [2]
% VO_2peak at 9.5 km. h^{-1}	55.4 (8.0)	50.6 (7.1)	NS [2]
% VO_2peak at 11 km. h^{-1}	61.8 (8.5)	55.0 (7.8)	NS [2]

Table 3. *Percentage VO_2peak used at all running speeds (8 km. h^{-1}, 9.5 km. h^{-1} and 11 km. h^{-1}) for early maturers and late maturers.[1] p= Significance level, [2] NS= Not Significant.*

The fractional utilization of VO_2max (percentage VO_2peak) showed no significant differences between early maturers and late maturers at all speeds, indicating the same relative effort (table 3).

Physiological variables

No significant differences could be found between the two groups for the following variables: RER, HR, and relative HR (% HRmax) at the three running speeds. At the running speed of 8 km.h-1 the ventilatory equivalent (VE/VO_2) was higher ($p < .05$) for late maturers. No significant differences could be found at 9.5 and 11 km.h^{-1}, although late maturers showed exhibited higher VE/VO_2 values (table 4).

	Early maturers (n= 6)	Late maturers (n=7)	p [1]
RER [3] at 8 km.h^{-1}	0.95 (0.05)	0.92 (0.05)	NS [2]
RER [3] at 9.5 km.h^{-1}	0.95 (0.05)	0.93 (0.05)	NS [2]
RER [3] at 11 km.h^{-1}	0.96 (0.06)	0.93 (0.05)	NS [2]
HR [4] at 8 km.h^{-1}	143 (11)	145 (9)	NS [2]
HR [4] at 9.5 km.h^{-1}	154 (15)	158 (10)	NS [2]
HR [4] at 11 km.h^{-1}	168 (17)	170 (10)	NS [2]
% HR [4] at 8 km.h^{-1}	73.6 (5.5)	74.7 (6.6)	NS [2]
% HR [4] at 9.5 km.h^{-1}	79.4 (7.4)	81.4 (7.0)	NS [2]
% HR [4] at 11 km.h^{-1}	86.7 (8.0)	87.7 (6.9)	NS [2]
VE[5]/VO_2 at 8 km.h^{-1}	26.7 (2.0)	30.6 (3.2)	.05
VE[5]/VO_2 at 9.5 km.h^{-1}	27.9 (1.8)	30.8 (3.6)	NS [2]
VE[5]/VO_2 at 11 km.h^{-1}	28.7 (2.7)	32.0 (3.6)	NS [2]

Table 4. *RER, HF, % HF and VE/VO_2 values for EM and LM at all running speeds (8 km.h^{-1}, 9.5 km.h^{-1} and 11 km.h^{-1}).[1] p= Significance level, [2] NS = Not Significant, [3] RER = Respiratory Exchange Ratio, [4] HR = Heart Rate (beats per minute), [5] VE= Ventilatory Equivalent for oxygen.*

Biomechanical variables

Stride length - stride frequency

No significant differences could be found in absolute stride length (m) or stride frequency (strides.min^{-1}) between the two groups at 8, 9.5 and 11 km.h^{-1}. The relative stride length (% of leg length) however showed a significant difference at all running speeds (table 5). LM exhibit significantly larger relative stride lengths at all running speeds.

Variables	Early maturers (n = 6)	Late maturers (n = 7)	p [1]
SL [3] (m) at 8 km.h^{-1}	1.6 (0.1)	1.6 (0.1)	NS [2]
Relative SL [3] (%) at 8 km.h^{-1}	174.3 (11.9)	192.6 (11.5)	.01
SL [3] (m) at 9.5 km.h^{-1}	1.9 (0.1)	1.8 (0.1)	NS [2]
Relative SL [3] (%) at 9,5 km.h^{-1}	203.2 (10.4)	226.8 (12.4)	.01
SL [3] (m) at 11 km.h^{-1}	2.1 (0.1)	2.1 (0.2)	NS [2]
Relative SL [3] (%) at 11 km.h^{-1}	230.4 (15.3)	259.5 (14.2)	.01

Table 5. *Relative stride length (% of leg length) in early and late maturers (mean (SD)).*
[1] p= Significance level, [2] NS = Not Significant, [3] SL = Stride Length .

Other biomechanical variables

Shank angle at contact, trunk angle, maximal plantar flexion angle, maximal knee flexion in support, minimum knee velocity, wrist excursion and vertical oscillation (Williams et al, 1987) showed no significant difference between early maturers and late maturers with exception of the maximal thigh angle at the running speed of 9.5 $km.h^{-1}$. At touch down, more anteversion of the thigh is found in late maturers. When comparing all other meaningful kinematic variables, in terms of running style, between early and late maturers, only the minimal knee-angle during swing-phase was found to be smaller in late mature boys (more flexion). There was a significant difference between early mature boys and late mature boys in minimal knee-angle during swing-phase. Values of maximal thigh angle and minimal knee-angle during swing-phase are included in table 6.

Biomechanical variable	**Early maturers (n=6)**	**Late maturers (n=7)**	**p [1]**
Max thigh angle at 8 $km.h^{-1}$ (dg)	19.5 (3.0)	28.6 (5.8)	NS [2]
Max thigh angle at 9.5 $km.h^{-1}$ (dg)	20.8 (3.1)	26.5 (4.6)	.05
Max thigh angle at 11 $km.h^{-1}$ (dg)	23.7 (5.8)	28.6 (4.6)	NS [2]
Min knee-angle swing-phase at 8 $km.h^{-1}$ (dg)	105.1 (6.1)	96.6 (7.0)	.05
Min knee-angle swing-phase at 9.5 $km.h^{-1}$ (dg)	97.3 (4.1)	88.6 (8.8)	.05
Min knee-angle swing-phase at 11 $km.h^{-1}$ (dg)	91.5 (9.1)	78.1 (10.3)	.05

Table 6. *Maximal thigh angle and minimal knee-angle at all running speeds (8 $km.h^{-1}$, 9.5 $km.h^{-1}$, 11 $km.h^{-1}$). Angles are expressed in degrees (dg). [1] p= Significance level, [2] NS = Not Significant.*

Discussion

Since the 'Bosman Ruling' by the European Court of Human Rights in 1995, clubs need to retain their most talented players on a long-term basis and balance the inflow and outflow of players (Williams and Reilly, 2000). Professional soccer clubs invest a large amount of money to identify and nurture potentially elite soccer players. In this respect soccer players are often profiled at early age. By profiling children, professional clubs have the intention to adapt the training to the player's capacities and to select the 'future' for their A-team.

Typically in children there is a large difference in maturity status (Beunen and Malina, 1996). Scaling physiological performance parameters to body dimensions has the potential to reduce maturity status effects, but even then early maturers score better on most maximal performance criteria. Based upon literature data, it was argued that running economy (submaximal VO_2) is very important in sports, and it was thus questioned whether early maturers have a better running economy than late maturers. In the current study, conducted with young soccer players, this was not found to be the case. On the contrary, the relative submaximal VO_2 values are on the average lower for the late mature boys (see figure 2). So, late maturers run at least as economical as the early maturers. However, due to the small number of test subjects, the latter could not be demonstrated statistically. The findings agree with the results of Armstrong et al (1999) who also found no effect of maturational status on running economy.

How do late maturers manage to keep up with, or even score better than, the early maturers at submaximal level? Both, in the current study and in Armstrong et al (1999), early and late maturers do not differ in their peak aerobic capacity independent of body weight (see relative VO2peak in table 1) and therefore a trend towards a better running economy in late maturers (see VO_2submax in figure 2) can not be explained by differences in maximal cardiovascular capacity. Calculating the percentage VO_2peak at all tested running speeds (range from 47% to 61.8%, see table 3) demonstrates that the subjects indeed performed submaximally. When looking at the other physiological parameters (see table 4) it can be noticed that there is almost no difference between early and late maturers. In other words, the "physiological motor" is nearly the same for early and late mature boys at the age of 14. So the question remains: "How do late maturers indeed succeed in competing with early maturers at submaximal level?".

Because in adult runners, a relationship between running style and running economy was found (Williams et al, 1987; Morgan et al, 1989), we investigated if a difference in running style could be detected. First, stride length was examined. There was no significant difference in absolute stride length (table 5). Because of the significantly shorter leg length of the late maturers (table 1) it is logical that late maturers have a greater relative stride length than early maturers (table 5). Additionally the correlations between stride length and relative VO_2 were calculated for the 3 submaximal running speeds (table 7).

Variables	**VO_2 (ml.kg$^{-0.98}$.min^{-1}) at 8 km.h^{-1}**	**VO_2 (ml.kg$^{-0.98}$.min^{-1}) at 9.5 km.h^{-1}**	**VO_2 (ml.kg$^{-0.98}$.min^{-1}) at 11 km.h^{-1}**
Stride length	-.40	-.21	-.24
Relative stride length	-.67*	-.57*	-.56*

Table 7. *Correlations between absolute and relative stride length (see table 5) and running economy (VO_2 in ml.kg$^{-0.98}$.min^{-1}) at three running velocities (8 km.h^{-1}, 9.5 km.h^{-1}, and 11 km.h^{-1}). Correlations are significant for $p < .05$ (*).*

There is a significant negative correlation between relative stride length and relative VO_2 enabling the less mature players who generally take relative larger strides, to run with the same running economy as the early mature players (see figure 3).

But how do late matures accomplish the relative larger strides? From all the variables that Williams et al (1987) found to differentiate between "cheap" and "expensive" adult male runners, in our population of young soccer players, only the amount of anteversion of the thigh at foot strike was significantly larger for the late maturers. This points already in the direction of taking larger steps. Stride length consists of a stance and a flight phase. Step length during stance equals the horizontal travelling distance of the body centre of mass relative to the heel at contact and on the other hand to the forward position of the centre of mass relative to contact at push-off. Despite the fact that no significant differences could be found, there is a remarkable difference between early and late maturers in relative distance covered during contact. Late maturers tend to put their foot further away and their push-off is somewhat further in the running direction. As a stride consists of two steps it is suggested that the latter observation accomplishes the relative larger strides of late mature players. Of course, length of flight phase should also be considered but the latter was not measured in a direct way.

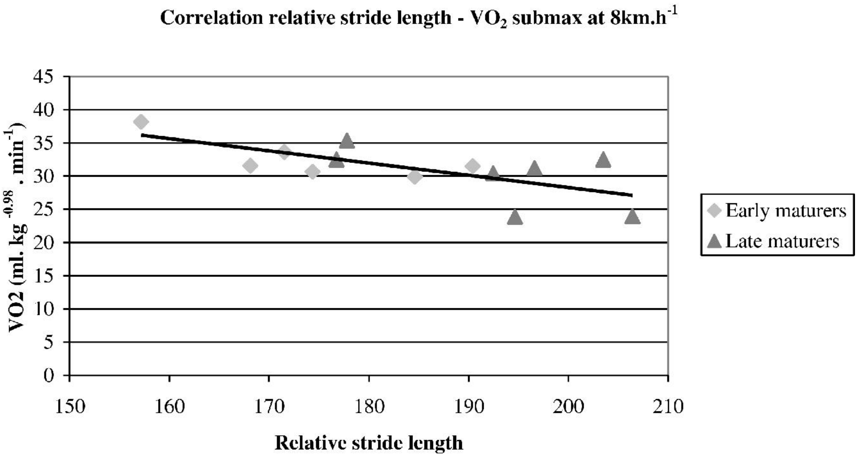

Figure 3. *Correlation between submaximal VO_2 and relative stride length at 8 $km.h^{-1}$.*

	Early maturers (n=6)	Late maturers (n=7)	p [1]
Distance heel contact [3] at 8 $km.h^{-1}$ (%)	13.36 (4.0)	20.81 (3.0)	0.05
Distance heel contact [3] at 9.5 $km.h^{-1}$(%)	14.29 (3.4)	17.54 (4.7)	NS [2]
Distance heel contact [3] at 11 $km.h^{-1}$(%)	17.62 (4.4)	20.00 (2.8)	NS [2]
Distance push-off [4] at 8 $km.h^{-1}$(%)	35.52 (11.52)	37.16 (4.2)	NS [2]
Distance push-off [4] at 9.5 $km.h^{-1}$(%)	41.34 (6.1)	40.22 (6.0)	NS [2]
Distance push-off [4] at 11 $km.h^{-1}$(%)	36.77 (8.2)	40.47 (3.8)	NS [2]
Total distance contact [5] at 8 $km.h^{-1}$(%)	48.88 (8.8)	57.98 (4.6)	.05
Total distance contact [5] at 9.5 $km.h^{-1}$(%)	55.63 (7.3)	59.58 (5.4)	NS [2]
Total distance contact [5] at 11 $km.h^{-1}$(%)	54.38 (8.1)	60.47 (4.7)	NS [2]

Table 8. *Fractionated step length during stance (definition paragraph above) expressed in percentage of the leg length (mean (SD)) at all running speeds. [1] p= Significance level, [2] NS = Not Significant, [3] Distance heel contact = Placement of the heel at first contact , [4] Distance push-off = Placement of metatarsal 5 at push-off, [5] Total distance contact = Total distance covered during stance.*

Besides the variables proposed by Williams et al (1987), the minimal knee-angle during the forward swing of the leg, was found to be smaller (i.e. more flexion) in late mature players, at all running speeds (see table 6). By doing this they diminish the mass moment of inertia of the swinging leg. When comparing the mass moment of inertia of early and late mature boys, there is a significant difference at all running speeds (table 9).

Variables	**Early maturers (n=6)**	**Late maturers (n=7)**	**p**	**r with VO_2**
Mass moment of inertia during swing-phase at 8 $km.h^{-1}$ ($kg.m^2$)	2.87 (0.45)	1.39 (0.24)	.01	+ .64*
Mass moment of inertia during swing-phase at 9.5 $km.h^{-1}$ ($kg.m^2$)	2.82 (0.46)	1.31 (0.21)	.01	+ .62*
Mass moment of inertia during swing-phase at 11 $km.h^{-1}$ ($kg.m^2$)	2.77 (0.48)	1.27 (0.21)	.01	+ .70*

Table 9. *Average mass moment of inertia of the swinging leg at the 3 running speeds (mean (SD)) in $kg.m^2$ for early maturers and late maturers and the correlation coefficient with VO_2. Correlations are significant for $p < .05$ (*).*

The mass moment of inertia during swing-phase is lower for late mature boys and correlates positively with oxygen consumption (the inverse of running economy), which points in the direction of an energy-saving mechanism. Firstly, it could be that less inertia in the swing leg enables the runner to put the foot further in front of the body, and secondly, it would require less rotational energy to swing the leg forward. On the other hand these beneficial effects could be offset by lifting the lower leg against gravity, thus increasing its potential energy.

But the negative correlations between total leg inertia and the running economy demonstrate that running style seems to be an important determinant of running economy in children. Since the meaningful parameters are influenced by maturational status, it is important to conduct further research aiming at a full biomechanical analysis including the calculation of the segmental energies.

As the current study started four years ago and still continues on a longitudinal basis, we can state that the players that participated in this study are still active in competitive youth soccer. There is no drop out, which implies that they are highly motivated to play soccer and to push through to the highest regions of soccer competition. Nowadays the early maturers are divided equally over the two highest regions in the soccer competition (3 in highest level of competition, 3 in intermediate level of competition), the late mature boys on the other hand are mainly active in the intermediate level (n=5), one late maturer is active in the highest level of competition and one in the lowest. Compared to four years ago (see table 2) there is a notable difference in longitudinal evolution in competition level between early and late mature boys. Early matures continue on average to higher regions of the soccer competition. Indeed, research indicates that most successful youth soccer players have a greater biological age (Malina et al, 2000). Moreover, there is a trend favouring the children born early in the selection year. This remarkable finding persists in adult elite squads (Williams and Reilly, 2000).

Children are not miniature adults and need another approach! At a young age it is important to develop good running economy, and to practise skills, especially those related to soccer. The emphasis for selection of talented soccer players should not be put solely on maximal, and thus maturity related, performance. In our study late mature soccer players have at least an equal running economy. Since submaximal VO_2 is important for soccer performance (Helgerud et al, 2001; Wisløff et al, 1998), the profiling criteria for young soccer players should include running economy.

Although not subject of the current study, technical and tactical skills should receive enough attention in profiling, which should not favour early maturers. This prejudice could result in a drop out of the late mature and potentially talented young child and in a lack of high-quality coaching (Malina and Beunen, 1996; Williams and Reilly, 2000).

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