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ORIGINAL ARTICLE

Does living in urban or rural settings affect aspects of physical fitness in children? An allometric approach

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Objective: The aim of this study was to investigate physical fitness in relation to fatness in urban and rural Greek children by means of allometric scaling.**Methods:** The sample consisted of 360 (189 urban and 171 rural; age 12.3 ± 0.42 years) boys and 247 (125 urban and 122 rural; age 12.3 ± 0.43 years) girls. The sample was highly representative (32–64%) of all 12 year old children registered in the prefecture of Trikala, Greece. All volunteers were assessed for BMI and % body fat, as well as sit and reach, basketball throw (BT), vertical jump (VJ), handgrip strength (HG), 40 m sprint, agility run, and 20 m shuttle run. To correct for possible associations between fatness and fitness, a single cause allometric scaling was employed using the natural logarithms (ln) of fitness parameters that were significantly correlated with the ln body fat.**Results:** Independent-samples *t* tests revealed that VJ ($p < 0.05$) was significantly higher in boys living in urban settings compared to their rural counterparts. Similarly, BT was found to be significantly better ($p < 0.05$) in urban girls, whereas HG was significantly higher ($p < 0.05$) in rural girls.**Conclusion:** Considering that (a) only three out of the 14 possible cases (seven fitness parameters for boys and seven for girls) were significantly different between urban and rural children, and (b) these differences were not uniformly distributed in children living in either urban or rural environments, it is concluded that the place of residence has no clear impact on physical fitness as studied herein.

Increased body fatness is a global epidemic.¹ In adults, ample epidemiological evidence demonstrates a positive association between body fat levels and a greater health risk of all-cause mortality.² Similarly, children with increased body fat are more likely to display aberrant CHD risk factor profiles,³ demonstrate orthopaedic complications, and develop a distorted self image that appears to persist into adulthood.⁴

Body composition in general and body fatness in particular may also affect physical fitness components. For instance, a cross-sectional study has shown that obese Hungarian children have lower aerobic fitness⁵ than their non-obese counterparts. On a similar note, Greek children demonstrate increased prevalence of obesity⁶ and, compared to their counterparts from other countries, low aerobic fitness levels.⁷

Living in areas distinguished by population size can be associated with differences in, inter alia, eating habits, access to sports facilities, and opportunities for physical fitness activities.^{8–9} However, it is not entirely clear whether such factors can affect aspects of body composition and, therefore, physical fitness.

While some data indicated that urban children have more body fat than their rural counterparts,¹⁰ other data are in strong disagreement.¹¹ Contradictory reports have also been published in relation to physical fitness parameters in children living in urban and rural settings.^{12–15} In some cases, no differences have been identified in a range of fitness and motor skill measures between children from urban and rural areas.¹⁶

It has been suggested that the distribution of children's health related fitness across geographic boundaries needs to be studied in different climatic, economic, and cultural contexts.¹⁷ Furthermore, several studies have used an allometric approach to study fitness in children.^{18–19} This technique provides a truly dimensionless expression of data which can be used in subsequent comparisons between groups that differ in body characteristics,²⁰ such as body fat.

To our knowledge, there is a dearth of such data on Greek children. Therefore, the aim of this study was to investigate physical fitness in relation to fatness in urban and rural Greek children by means of allometric scaling.

METHODS

This study is part of a larger investigation on aspects of fitness in European children. We present a cross-sectional analysis of the effects of geographical area of residence on a variety of physical fitness determinants corrected for body fat.

Geographical area of residence (urban v small towns or rural areas)

Definitions of urban and rural areas are inconsistent. They are based on variables such as distance from trading centres and cut off population sizes of 100 000, 50 000, and 10 000 inhabitants.²¹ The latter criterion was used in this study to describe an urban area (>10 000 inhabitants) and a rural area (<10 000 inhabitants).

Subjects

The sample consisted of 360 (189 urban and 171 rural; age 12.3 ± 0.42 years) boys and 247 (125 urban and 122 rural; age 12.3 ± 0.43 years) girls with no medical history of disease. Volunteers were recruited from four randomly selected schools in the town of Trikala, Greece (population ~70 000) and from four randomly selected schools in the surrounding villages (population <2000 in each village). Urban volunteers represented approximately 40% and 32% of all 12 year old boys and girls, respectively, while their rural counterparts represented approximately 64% and 53% of all 12 year old boys and girls in the prefecture of Trikala.

Abbreviations: 20 mSR, 20 m shuttle run; AR, agility run; BT, basketball throw; HG, handgrip strength; ln, natural logarithms; SR, sit and reach; VJ, vertical jump

respectively. The participation rates for first grade pupils from all eight schools were 96% and 90% for boys and girls, respectively. The Research Ethics Committee of the University of Thessaly approved the investigation and permission was granted by the Greek Ministry of Education. Written informed consent was obtained from all volunteers and their parents after full explanation of the procedures involved.

Data collection

Procedures took place during morning school visits from September to December 2001, 2002, and 2003. Demonstrations of each test were given to children prior to testing. All measurements were conducted by the same investigating team, following the same order of testing, and allowing 5–10 min rest intervals between tests. These measurements and tests will be presented in the order in which they were conducted.

Anthropometry

Standing height was measured to the nearest 0.5 cm using a Seca Stadiometer 208 (Seca, Hamburg, Germany), with the subject's shoes off and head in the Frankfurt horizontal plane. Body mass was assessed to the nearest 0.5 kg (Seca Beam Balance 710). BMI was calculated as $\text{weight}/\text{height}^2$. Percentage body fat was calculated from two skinfolds, that is, triceps and subscapular (average of two measurements) with a Harpenden calliper (British Indicators, St Albans, UK) using an established formula.²²

Physical fitness tests

Physical fitness was assessed using seven field tests which have been previously validated for use in paediatric populations.²³ For all but the last test, two trials were allowed and the best score was recorded for further analyses. These tests are described below.

Sit and reach (SR)

The sit and reach test was used to assess flexibility of the spine and posterior leg muscles. Each subject was asked to sit on the gymnasium floor, with knees straight and resting their bare feet vertically against a box 30 cm in height. To perform the test, the subject leaned forward with straight arms and knees and reached over the top surface of the box. The distance between toes and finger was measured. Positive values were recorded if the subject was able to reach further than his/her toes, negative values were recorded if the subject was unable to reach his/her toes, and a zero value was given when subjects just touched their toes.

Basketball throw (BT)

The test involved throwing a standard size and weight senior basketball in the horizontal direction as far as possible, from a sitting position. The participant was asked to sit on the gymnasium floor with straight legs, while buttocks, back, and head were resting against a wall. The participant uses a two-handed chest pass to push the ball.

Handgrip (HG)

Subjects had to squeeze a calibrated hand dynamometer as forcefully as possible with the preferred hand. The handle length was adjusted to account for variations in hand size.

Vertical jump test (VJ)

Following a short familiarisation period, volunteers performed the required jumps from a squatting position (90° knee angle with hands on hips). A jump meter with a digital display (T.K.K. 5106 JUMP MD; Takei Scientific Instruments,

Tokyo, Japan) was used. The jump height was recorded in centimetres.

40 m sprint (40 m)

The volunteer started the test from a standing position with one foot on the starting line. The timer stood at the finish line, called ready, and signalled the start of the sprint. Timing was initiated by the first movement of the subject. Time was recorded to the nearest 0.1 s.

Agility 10×5 m run (AR)

Two lines 5 m apart were drawn on the gymnasium floor. On the command of "go", the pupil had to run forward as quickly as possible, pivot on the far line, and return to the starting line. This had to be repeated five times in total. The time required to complete the test was recorded to the nearest 0.1 s.

20 m shuttle run (20 mSR)

Subjects performed the test individually and were instructed to run between two lines 20 m apart in synchrony with a sound signal emitted from an audiocassette. The frequency of signals increased by 0.5 km/h each minute from a starting speed of 8.5 km/h. The test was terminated when subjects were unable to maintain the prescribed pace for three consecutive signals. The equivalent shuttle running speed was used as an endurance performance indicator.²⁴

Statistical analyses

The Kolmogorov-Smirnov test of normality revealed that none of the studied variables required logarithmic transformation. Correlation coefficients were calculated between the natural logarithm (ln) of body fat and the seven ln physical fitness tests for boys and girls separately. Significantly correlated parameters were then used to calculate power function ratios by means of allometric scaling.²⁵ The Kolmogorov-Smirnov test was again used to ensure that the calculated power function ratios were also normally distributed. The independent samples *t* test was utilised to assess for differences between urban and rural settings. The significance level was set at $p < 0.05$.

RESULTS

Although body fat was found to be higher than that which is universally regarded as acceptable for boys and girls of this age, no statistical differences were found between our urban and rural children (tables 1 and 2). Independent-samples *t* tests revealed that VJ ($p < 0.05$) was significantly higher in boys living in urban settings compared to their rural counterparts. In girls, BT was found to be significantly better ($p < 0.05$) in the urban children, whereas HG was significantly higher ($p < 0.05$) in the rural subjects (tables 1 and 2). No further statistical differences were established.

Table 1 Fatness and fitness parameters in urban and rural Greek boys

Parameters	Urban	Rural
BMI (kg/m^2)	21.0 ± 3.4	20.5 ± 3.4
Body fat (%)	21.0 ± 7.8	19.4 ± 7.9
SR (cm)	14.3 ± 6.1	14.5 ± 6.0
BT (m)	4.7 ± 0.9	4.6 ± 0.8
VJ (cm)	48.6 ± 7.7†	46.9 ± 7.5† *
HG (kg)	26.7 ± 5.4†	27.3 ± 5.5†
40 m (s)	5.2 ± 0.5†	5.2 ± 0.4†
AR (s)	17.0 ± 1.5†	17.0 ± 1.0†
20 mSR (km/h)	15.1 ± 1.3†	15.1 ± 1.0†

* $p < 0.05$, †test; ‡power function ratio.
Data are means ± SD.

Table 2 Fatness and fitness parameters in urban and rural Greek girls

Parameters	Urban	Rural
BMI (kg/m ²)	20.9±3.3	20.5±3.3
Body fat (%)	25.6±6.7	24.8±6.8
SR (cm)	19.3±6.5	18.6±6.4
BT (m)	4.0±0.7	3.8±0.6*
VJ (cm)	59.0±7.7†	58.0±9.0†
HG (kg)	20.0±4.0	21.1±4.2*
40 m (s)	4.9±0.4†	5.0±0.4†
AR (s)	16.9±1.3†	16.7±1.0†
20 mSR (km/h)	13.9±0.9†	13.9±0.8†

* $p < 0.05$, †test; ‡power function ratio.
Data are means ± SD.

Table 3 shows the b exponents derived from the allometric equation $\text{fitness parameter} = \alpha \times \text{body fat}^b$, where α is constant. It is noteworthy that these equations were employed to adjust for body fatness, mainly in relation to running and jumping test parameters.

DISCUSSION

In line with previously published reports on Greek children,^{6, 26} the present data have demonstrated that Greek children from both urban and rural areas have higher body fat levels than considered healthy for boys ($\leq 15\%$ body fat) and girls ($\leq 20\%$ body fat) of this age group.²⁷ Given that body fat negatively affects various aspects of physical fitness,^{7, 28} adjustment of the studied fitness parameters for body fat would better serve the aims of this study.

The principal aim of the current study was to examine potential differences in aspects of physical fitness in Greek children living in either urban or rural settings. To correct for possible associations between fatness and fitness, a single cause allometric scaling was employed using the natural logarithms of fitness parameters that were significantly correlated with the ln body fat. The main findings were that only three out of the 14 possible cases (seven fitness parameters for boys and seven for girls) were significant different between urban and rural children and that these differences were not uniformly distributed in children living in either urban or rural environments. It is, therefore, tempting to suggest that, for Greek children, the place of residence has no clear impact on physical fitness as studied herein.

The advantages of allometric scaling over other procedures for examining size-independent performance scores have been detailed elsewhere.²⁹ To our knowledge, this is the first study which examined selected physical fitness components in urban and rural children using the above method. Nevertheless, the present data do not agree with published reports advocating that the place of residence indeed has an impact on children's fitness. Specifically, it has been found

Table 3 Derived exponents for b in the formula: $\text{fitness} = \alpha \times \text{body fat}^b$ for boys and girls

Parameters	Boys, b_b ($\pm 95\%$ CI)	Girls, b_g ($\pm 95\%$ CI)
VJ	-0.14±0.04	-0.22±0.06
HG	0.06±0.05	-
40 m	0.11±0.02	0.13±0.04
AR	0.07±0.02	0.09±0.03
20 mSR	-0.12±0.02	-0.11±0.03

α , constant; b_b , common b exponent for urban and rural areas for boys; b_g , common b exponent for urban and rural areas for girls.

What is already known on this topic

Contradictory reports exist in relation to children living in urban and rural settings and selected physical fitness parameters. The latter can be affected by body fatness. Allometric scaling provides a truly dimensionless expression of data which can be used in subsequent comparisons between groups that differ in body characteristics, such as body fat.

What this study adds

This study examines physical fitness in relation to fatness, between urban and rural Greek children by means of allometric scaling. This is the first study that utilises allometric procedures to compare fitness parameters between paediatric samples living in areas distinguished by population size. The place of residence (urban v rural areas) has no clear impact on physical fitness in 12 year old Greek school children.

that US¹¹ urban children have superior fitness levels compare to those living in rural areas, whereas a report from Poland proposed that rural children were fitter than their urban counterparts.³⁰ Methodological differences, such as the criterion used to define rural versus urban areas, variability in tests used to assess fitness levels, and statistical analyses may account for the discrepancies in the literature.

One potentially important factor behind the lack of statistical differences in physical fitness in boys and girls living in urban and rural environments may be the national Greek physical education (PE) programmes. Irrespective of schools' size or location, state secondary school PE programmes are common and compulsory throughout Greece. However, it has been recently found that these programmes are insufficient to bring about beneficial adaptations in selected health related fitness parameters, such as maximal oxygen intake.³¹ These findings are also in line with existing data from other countries questioning the validity of school PE classes³² and partly contradict the assertion that school PE lessons should fulfil most of the fitness needs of children.³³ The emerging trend towards urbanisation of Greek rural life³⁴ may be an additional explanation for the present findings.

The lack of statistical differences between children living in urban and rural environments may be supported by the well established genetic basis of certain fitness components.³⁵ It has been suggested, for instance, that aerobic fitness in children serves just as a proxy indicator of physical activity participation.³⁶ However, low aerobic fitness reduces muscular fat oxidation capacity, which may decrease tolerance of dietary fat and increase adiposity.³⁷ On the other hand, adequate body fat in young females is necessary for menarche to occur and this can be partly achieved through reduced physical activity levels, suggesting the existence of an energy conserving mechanism in favour of fat accumulation.³⁸

The results of this study confirm the importance of body fatness as a negative influence on performance in running and jumping tests. It is noteworthy that all running and jumping parameters tested were negatively associated with body fat. This finding is in accordance with previous published reports whereby body fat negatively affects jumping and running performance in both children³⁹ and adults.⁴⁰

In conclusion, and within this study's limitations, including data collection from a single geographical region, it is suggested that the place of residence has no clear impact on physical fitness in 12 year old Greek school children. Further research is required involving allometric scaling to study aspects of health and fitness in paediatric populations from different countries.

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