The Process of Human Growth at the End of the 20th Century and Prospects for the New Millennium: An Italian Study of the Effects of Moderate Physical Exercise on Pre-pubertal Children

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An increasing number of case reports, follow-ups and other studies have greatly expanded our knowledge of processes of growth and development in the latter part of the 20th century (see, for instance, numerous references cited in Eveleth and Tanner, 1990; Ulijaszek et al.,1998). There is unanimous acknowledgement that environmental conditions can interfere with the genetic programming of individual growth. It is also evident that there is a multitude of interacting environmental factors in different populations. The great diffusion of new technologies and the evolution of lifestyles are the principal causes of increasingly sedentary habits in developed countries. This and the tendency to over-nutrition are thought to be related to the increasing incidence of some pathologies or illnesses, like obesity and cardiovascular disease (Cureton et al., 1991; Beunen et al., 1993; Malina, 1995; Gualdi Russo et al., 1998). These diseases, generally affecting adults or the elderly, usually evolve over a long time and result in high social costs. Today, prevention is considered the best, or the only, way to reduce the risk of developing these pathologies.

Non-competitive sports are believed to have a preventive effect, as shown by the positive effects on general health status, the cardiovascular apparatus and weight control (Blair et al., 1989; Pate et al., 1989, 1990; Gutin and Owens, 1999). For these reasons, in the next few decades, sport education and practice during childhood may become an important investment for the well-being and improved health status of the populations of developed countries. This will prevent the exposure of children to risk factors related to sedentary habits and over-nutrition or dietary imbalances.

The positive effects of physical activity are well known in adults (Krahembul et al., 1985; Gualdi Russo et al., 1994; Malina, 1994; Bar-Or and Malina, 1995), but they are not so clear in children (Livingstone, 1994; Morrow and Freedson, 1994). However, positive influences of sport on motor performances and skills, aerobic fitness and reduction of fatness have been observed in children from different ethnic and socio-economic groups (Radusepp and Jurimae, 1997; Benefice, 1998), although the differences between sporting and non-sporting sub-samples were not always significant (Bordin et al., 1996). Moreover, some longitudinal studies have shown better and faster growth in sporting children (Gualdi Russo and Toselli, 1997; Farello et al., 1997), supporting the hypothesis of a positive auxological role of physical activity (Bar-Or, 1983; Malina, 1993).

The purpose of this study was to provide information on patterns of growth and motor performance, on the basis of a large set of somatometric and physiometric traits and physical performance parameters collected in a large cross-sectional sample of pre-pubertal boys and girls (9-11 years old) living in a well-off area of northern Italy. This study reports on the effects of various physical activities, through a comparison of sub-samples practising different sports.

SUBJECTS AND METHODS

Sampling: The cross-sectional study was carried out on 849 children (9-11 yrs old), attending primary school in Ravenna province (northern Italy) during the 1997-98 school year. Personal data and information about the subjects were collected in a questionnaire completed by the children, with the permission and supervision of their families. Permission to approach the children in the schools for the anthropometric survey was obtained from the local education authority («Provveditorato agli studi di Ravenna») and from the headmasters of the schools.

Children with developmental pathologies (i.e. GH deficit) or abnormalities that might hamper their ability to perform the tests correctly were excluded from the study. Moreover, in agreement with the research aim, seven girls with precocious maturation were also excluded.

The composition of the sample by age and sex is shown in table 1.

Anthropometry: The traits examined in this report are: weight, height and sitting height, Body Mass

Table 1: Composition of the sample desegregated for sex and age

Age (yrs)	*Males*	*Females*	*Total*
9	127	118	245
10	228	214	442
11	91	71	162
Total	446	403	849

Index (BMI), bicristal and biacromial diameter, skinfold thicknesses at four sites (biceps, triceps, subscapular and suprailiac), percent body fat (%F), vital capacity (VC), forced vital capacity (FVC) and forced expiratory volume in one second (FEV^1), left and right hand grip strength, squat and counter movement jump elevation and 20 m dash time.

Children were measured according to the prescriptions of the International Biological Program (Weiner and Lourie, 1981).

Weight was measured to the nearest 0.1 kg, while height, sitting height, bicristal and biacromial diameter were all recorded to the nearest 0.1 cm. Skinfold thicknesses were measured to the nearest 0.1 cm by the same trained observer using a Lange caliper. VC, FVC and FEV^1 were determined with a Vitalograph Compact spirometer to the nearest 0.01 litre. Muscle strength of both hands was assessed to the nearest 1 kg by a Grip A Takey dynamometer; the higher value of two trials was recorded for each hand.

Squat and counter movement jumps were executed with a Bosco's springboard. Elevation was computed (±0.1 cm) from the jump flight time as follows: elevation = flight $time^2$ x 1.226. The squat jump (measure of explosive leg strength) was performed in vertical; the starting position was knees bent at 90°, feet on the floor and hands on the hips. For the counter movement jump (measure of elastic leg strength), the subject started in a standing position, bent and jumped with the help of a leg counter movement.

The motor performance tests included a 20 m dash. The time was measured by pairs of photocells at the start and finish of the dash distance; when the child ran past the photocells, they started and then stopped an electric chronograph (±0.01 sec). The subject was told to run as fast as possible.

The BMI was computed from weight and height (kg/m^2).

Percent body fat was estimated from body density, predicted from anthropometric equations using the skinfold thickness measurements at four sites:

D (g/ml) = 1.1690 – 0.0788 log (T+B+S+I) (pre-pubertal males) (Brook, 1971)

D (g/ml)= 1.2063 – 0.0999 log (T+B+S+I) (pre-pubertal females) (Brook, 1971)

%fat = ((4.950 / D) – 4.500) . 100. (Siri , 1961)

where: D = body density; T = triceps skinfold; B = biceps skinfold; S = subscapular skinfold; I = suprailiac skinfold.

Statistical Analysis: Descriptive statistics were calculated according to age, gender and sport activity. Data were analysed with BMDP statistical software (Dixon et al., 1988). The mean, standard deviation, and values of Student's t-test (after the normal distribution of the trait was verified), ANOVA, Levene's test and Welch's test were computed; $p < 0.05$ was accepted as statistically significant.

All variables had a normal distribution except the skinfold thicknesses, which were transformed using the decimal logarithm for comparison tests among groups.

RESULTS

Sample Description: Descriptive statistics by sex and age are reported in table 2. In males, all the traits increase regularly from 9 to 11 years. In females, weight, height, sitting height, diameters, hand strength and pulmonary function increase with age; the values of female skinfolds, BMI and %fat are maximal at 10 years of age. The motor performance parameters improve with age in both sexes.

Differences among the three age classes (ANOVA) are always significant, except for the skinfolds, BMI and %fat in both sexes and the motor tests in females.

Sex differences (t-test) are greatest (statistically significant) at 10 years of age, especially for skinfold thicknesses, hand strength, vital capacity and motor abilities. However, significant differences are also seen at 9 years, for skinfolds, physiometric traits (hand strength, breathing parameters) and 20 m dash. At 11 years, males and females differ significantly in physiometric traits (hand strength, VC, FVC) and motor abilities (squat jump, 20 m dash).

During the growth process, 10 year-old girls are larger than boys of the same age, but the latter catch up to and surpass the former one year later. Skinfolds are thicker in females at all ages, while physiometric traits and performance parameters are higher in males.

A comparison of our results with Italian standards (Nicoletti, 1992) or international standards (Maaser et al., 1972; Tanner and Whitehouse, 1976; Hamil, 1979; Hall et al., 1989) confirms the tendency to overweight, with greater mean values of weight, BMI and skinfold thicknesses. However, comparison of our results with data collected in Central Italy more recently than the data of Nicoletti (which are from surveys conducted in 1965-67 and 1970-77) and by means of the same methodology (Toselli et al., 1997) show very similar values of BMI, skinfold thicknesses

Table 2: Mean values (above) and standard deviations (below) for anthropometric traits and motor performance tests in both sexes.

	Males			*Females*		
Age (yrs)	*9*	*10*	*11*	*9*	*10*	*11*
Weight (Kg)	35.2	36.9	40.4	35.2	38.2	40.3
	7.4	8.3	8.5	7.1	8.8	10.8
Height (cm)	135.9	138.9	144.6	136.4	140.2	143.9
	6.1	6.3	6.3	6.4	7.0	8.3
Sitting height(cm)	72.5	73.3	75.9	72.3	73.8	75.3
	3.0	3.2	2.8	3.2	3.5	4.0
Bicristal diameter	21.9	22.2	23.1	21.9	22.6	22.9
(cm)	1.7	1.8	1.8	1.8	1.9	2.1
Biacromial	30.3	30.8	31.6	30.2	30.9	31.6
diameter (cm)	1.3	1.7	1.7	1.6	2.1	2.0
Biceps skinfold	6.5	6.6	7.2	7.4	7.9	7.7
(mm)	3.2	3.6	3.7	2.7	3.7	3.5
Triceps skinfold	11.7	12.0	13.1	13.7	14.0	13.5
(mm)	5.0	5.5	5.6	4.4	5.1	5.5
Subscapular	8.5	8.4	9.5	9.5	10.1	10.0
skinfold (mm)	5.0	5.3	5.8	4.3	5.9	5.3
Suprailiac	9.3	9.6	11.0	11.3	11.0	11.0
skinfold (mm)	6.2	6.7	7.2	5.6	6.1	6.2
BMI	18.97	19.05	19.15	18.81	19.29	19.18
	3.23	3.39	3.09	2.71	3.43	3.68
% fat	21.38	21.41	23.08	22.67	22.70	22.28
	7.53	7.83	8.17	7.77	8.71	9.08
Right hand	17.2	18.3	20.0	15.3	16.7	17.9
strength (kg)	3.3	3.6	3.6	3.2	3.2	4.1
Left hand strength	16.3	17.7	19.3	14.8	16.2	17.4
(kg)	3.2	3.8	3.3	3.1	3.3	4.2
VC (l)	2.00	2.15	2.30	1.82	2.02	2.09
	0.32	0.42	0.38	0.34	0.43	0.46
FVC (l)	2.06	2.15	2.31	1.85	2.04	2.15
	0.39	0.46	0.44	0.42	0.43	0.48
FEV^1 (l)	1.74	1.80	1.90	1.61	1.73	1.86
	0.35	0.39	0.35	0.36	0.42	0.49
20 m dash (sec)	4.10	3.99	3.91	4.26	4.21	4.15
	0.31	0.31	0.25	0.29	0.32	0.41
Squat jump (cm)	21.3	22.8	23.2	20.6	20.8	21.6
	3.8	4.2	3.7	3.1	3.6	4.5
Counter	22.4	23.6	23.9	21.8	21.7	22.8
movement j. (cm)	3.8	4.4	4.0	3.1	3.8	4.6

and %fat. Finally, the values of height, weight and BMI of our sample of Italian children are always higher (on average) than the 50th percentile values of the NCHS growth charts (Kuczmarski et al., 2000). In particular, the BMI average line is above the 75th percentile, with the exclusion of 11 year-old females.

Comparison of Sporting and Non-Sporting subsamples: On the basis of the information from the questionnaire, the sample was divided into sporting and non-sporting groups. Table 3 reports the descriptive statistics, by sex and age, of the two subsamples.

In the anthropometric traits, the sporting children differ slightly (and seldom significantly) from the non-sporting children.

Generally, the age trend in the differences between sporting and non-sporting children cannot be easily interpreted. However, the differences in %fat between the two groups (albeit not significant) show that the sporting children have a lower tendency to develop fatness with age. The same trend is observable for the BMI.

Physical performance seems to be better in sporting children: sporting males and females of all ages jump higher and run faster than their non-sporting counterparts. Nevertheless, these differences are significant only in the 20 m dash for 9 and 10 year-old males.

DISCUSSION

Adverse socio-economic, dietary and sanitary conditions in Italy during the second half of the 1950's (Frontali, 1950; Bacchetta, 1951; Cresta and Fiorentini, 1956; Ferro-Luzzi, 1962) exerted strong negative pressure on the genetic potential for growth. However, the situation changed profoundly, with a revolutionary improvement in the more deprived areas and a general attenuation of the environmental pressure on the genetic potential for growth of the average Italian child (Cresta et al., 1982; Cresta et al., 1998; Ferro-Luzzi, 1984). Since nutritional deficiencies are no longer the main influence on growth performance in Italy, the contribution of other factors must be carefully evaluated.

The developmental and growth situation in Italy evolved greatly during the second half of the 20th century. Indeed, there is a current tendency (also demonstrated by the data reported in the present study) toward increasing adiposity, as in other European and extra-European countries. These changes, probably due to lifestyle modifications, highlight new problems for public health, particularly that of overweight subjects (WHO, 1994; Violante et al., 1998), and underline the necessity for appropriate measures of prevention in order to face the emergency and its associated risk factors also in Italy.

In the present paper, we consider the effects of physical activity, which is believed to have a positive influence on growth and particularly on overweight. Although our results indicate generally small differences for most traits (with unclear age trends), they do indicate a certain trend in body fat percentage and physical performances in relation to moderate physical exercise. There is a tendency for sporting boys and girls to develop lower body fat percentage with age and to achieve better jumping and running performances, even though in most cases the difference from non-sporting children does not reach

Table 3: Mean values (above) and standard deviation (below) for anthropometric traits and motor performance tests in sporting and non sporting children of Italian sample

	Males			*Females*		

significance.

Therefore, it appears that a moderate level of physical activity during childhood may have little effect on most anthropometric traits. Nevertheless, it can definitely help to control fat development and to improve motor abilities. Moreover, sport appears to act equally on males and females.

In conclusion, although it is difficult to make predictions, we believe that a process of standardization of the lifestyle is in progress in the U.S.A. and Europe. In Italy, the diffusion of new cultural models and different behaviours may lead to a tendency to renounce the typical Mediterranean diet. This is already suggested by the fact that, among highly-developed countries, Italy has experienced the greatest increase in meat consumption (which has trebled) (De Garine, 1998). This, plus increasingly sedentary habits, may induce an increased diffusion of obesity, an important predisposing factor to many pathologies (from hypertension to ischemic heart disease).

A careful evaluation of the significance, rhythm and intensity of physical exercise in childhood is

important; for example, strong specialization in one sport is thought to be imprudent before 12 years of age (Kruger, 1993). However, adequate physical training in childhood may be an important future resource to control and prevent the onset of pathologies linked to nutritional imbalances.

If the health of a population is most accurately reflected in the growth of its children (Eveleth and Tanner, 1990), the prospects for the new millennium must include continuous and accurate sanitary monitoring and preventive measures, in order to create the ideal environmental conditions for improved growth and development.

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KEY WORDS Childhood . Growth . Anthropometry . Motor-performance . Physical Activity. Over-weight.

ABSTRACT The research was carried out by way of a cross sectional study on a sample of 849 pre-pubertal subjects, 9 – 11 aged, living in Ravenna province (northern Italy). Aim of this study was to investigate the possible relationships of anthropometric traits and physical performances with physical activity and lifestyle. Examination records consisted of weight, height , bicristal and biacromial diameter, skinfold thicknesses, functional and physical performance parameters. Estimated means were compared with national and international standards, showing a tendency of North Italian children showed to overweight. The influence of a moderate physical exercise was evaluated on sub-samples of sporting and non-sporting children. The results show that moderate levels of physical activity have limited effects on anthropometric traits, before puberty. Nevertheless physical activities contribute to slightly improve motor performance and to keep the body weight under control. The observed Italian trend is discussed in relation to actual tendencies to a progressive uniformisation process in the lifestyle of populations of developed countries.

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