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Secular changes in human biological variables in Western Countries: an updated review and synthesis

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Summary - *This paper provides a review of the recent literature on some aspects of secular trends in Western countries. In particular, we discuss height variation, mainly on the basis of conscript data. There are still large height differences between European countries, and there is a marked trend for the tallest conscripts to be in northern Europe and the shortest ones in the southern part of the continent. The secular trend in adult height has come to a halt in northern Europe and Italy, while it is still in progress in Belgium, Spain and Portugal. The secular trend in height mainly depends on the increase of lower limb length. Obesity is now epidemic in Western countries, the USA population being the most affected. There is also a progressive anticipation of all the signs of puberty, namely age at menarche, appearance and development of the breasts, genitals and pubic and axillary hair, although there is ethnic/population variability in this regard. A tendency to later onset of menopause has also been recorded. Regarding secular trends in sport, there has been a progressive selection of athletes with larger body dimensions. Finally, the authors provide suggestions for future fruitful directions of the research of the secular trend in human biology.*

Key words - *Secular trend, Anthropometry, Puberty, Menopause, Sport.*

Introduction

The term *secular trend* traditionally indicates the attainment of larger adult body dimensions than in previous generations and the progressively earlier onset of menarche in adolescents in industrialized countries during the last 150 years. According to van Wieringen (1979, 1986), the term *secular changes* would be more appropriate: in contrast to *secular trend*, which suggests a unidirectional course, *secular changes* implies the sense of temporal variations among generations or between populations with different geographical and socio-economic backgrounds. However, *secular trends* and *secular changes* are used synonymously in the literature.

Secular trend is one of the major topics of physical anthropology. At first, studies were limited to the increase of height and the progressive decrease of the mean age at menarche through at least 6 generations, approx. from the mid-1800s to the 1980s/1990s in industrialized countries (Floud, 1994; Hermanussen *et al.*, 1995; Cavelaars *et al.*, 2000; Fubini *et al.*, 2001; Thomas *et al.*, 2001; Ulijaszek, 2001). Since the 1990s, there have also been analyses of the relative increase of different body segments (Ali *et al.*, 2000; Kromeyer-Hauschild & Jaeger, 2000; Sanna & Soro, 2000; Sanna & Palmas, 2003) and the onset of puberty, namely the progressively earlier appearance of secondary sexual characteristics in both boys and girls (Lindgren,

1996; Bodzsar, 2000; Herman-Giddens, 2006; Herman-Giddens *et al.*, 1997; 2001; Kaplowitz, 2006). More recently, research on secular changes has extended both to the development of motor performance, physical fitness and attitudes to sports in children and adolescents, because of the association with the increasing incidence of overweight and obesity (Mészáros *et al.*, 1999; Westerstahl *et al.*, 2003a; 2003b; Wedderkopp *et al.*, 2004; Matton *et al.*, 2007), and to the field of professional sports because of the possible implications of such changes in the evolution of physical performance of elite athletes (Norton & Olds, 2001; Olds, 2001; Westerstahl *et al.*, 2003a; Lozovina & Pavicic, 2004). In addition, many long-term studies of the secular trend have highlighted a progressive decrease of the intensity and speed of the phenomenon among the more industrialized countries over the last few decades, suggesting that it is coming to a halt in some of these countries, e.g. Denmark, Norway, and Sweden (Larnkjær *et al.*, 2006).

This paper is intended to be a review paper on the above fields of anthropological research aimed at defining and clarifying the current questions still debated for each biological topic, thus providing suggestions for future fruitful directions of the research in human biology.

Secular changes of height and weight

Adult height, sitting height and leg length

The most visible expression of the secular trend is the increase in adult height in many parts of the world, with grown-up children being taller on average than their same-sex parents. This has been documented since at least the mid-19th century, mainly on the basis of male conscript data (Cole, 2003).

Studies on secular trend of height are generally investigated through "means" and "medians", less attention has been devoted to the possible modifications of height distribution characteristics (variance, skewness, and kurtosis) during the period in which the secular trend was observed. From an explanatory stand-point, the secular increase of the mean, the modifications of the height distribution characteristics are interesting as well (Terrenato & Ulizzi, 1983; Ulizzi & Terrenato, 1985).

Adult height depends by genetic and environmental factors, and by the interaction between them. Socio-economic conditions, such as social class, income, parental education, crowding, hygiene and war, have been suggested as factors affecting conscript height. Socio-economic and environmental factors do not influence growth directly, but act through biological factors such as nutrition and infection, both of which may affect adult height (Floud *et al.*, 1990; Schmidt *et al.*, 1995). All the socio-economic factors suggested as determinants of adult height influence the availability and provision of an adequate diet and the risk of acquiring infections through crowding and poor hygiene. Therefore, the improved nutrition and reduced prevalence of infections can be considered important determinants of the secular trend toward increasing adult height (Schmidt *et al.*, 1995).

In Europe and North America, the estimated secular height increase in the period 1880-1980 was about 1-2 cm per decade during infancy, 2-3 cm per decade during adolescence, 1 cm per decade in adulthood (Eveleth & Tanner, 1990**;** Malina, 1990; Hauspie *et al.*, 1997). However, human height has both risen and fallen in recent history, and even over several millennia. For example, height decreased in several European countries at the beginning of the 19th century, probably due to the effects of the industrial revolution or wars (Floud *et al.*, 1990).

Information on adult height in the past comes mainly from conscript data available for several European countries since the 19th century or even earlier. In some countries, there were minimum height requirements, so that short recruits were excluded, but in countries where conscription was complete, the data provide an unbiased estimate of height over time at one particular age. Height has increased since the mid-19th century (except for a slight slowing down in the 1890s). This increase is for example particularly noticeable in Italian conscripts when the series of height

measured during medical check-up is considered for all the call-up years (Hermanussen *et al.*, 1995; Arcaleni, 2006) (Fig. 1). The secular trend in height accelerated after the Second World War (Cole, 2000) and there was still evidence of a trend in the 1980s (Gerver *et al.*, 1994; Cole, 2000) (Figures 1, 2).

Recent data for 18-year-old conscripts demonstrate rising trends in height between 1960 and 1990 in eleven European countries (Schmidt *et al.*, 1995). There are still large differences between the countries, and there is a marked trend for the tallest conscripts to be in northern Europe and the shortest ones in the southern part of the continent. Norwegians are the tallest (179.7 cm in 1990) and Portuguese the shortest (171.3 cm). The trend tends to be greater in the shorter groups, e.g. 23 mm/decade in Spain vs. 2.5 mm/decade in Norway from 1980 to 2000, and the taller northern European groups show some evidence of slowing during the period. Based on population surveys, rates up to 10 mm/decade are typical for western European countries in recent years, while eastern Europe and Japan have achieved about 30 mm/decade (Schmidt *et al.*, 1995; Hauspie *et al.*, 1997; Cole, 2000).

Data arising from compulsory military service have shown that there were no increases after 1990 in the Scandinavian countries and Denmark, whereas the secular trend continued in Spain and Portugal. The Italian data differ from this pattern. While the increase was close to 2.5 cm/decade from 1960 to 1990, the increase from 1990 to 1998 was only 6 mm in 8 years, with substantially no increase from 1994 to 1998 (Fig. 1). Therefore, it can be inferred that secular changes in adult height may have come to a halt in northern Europe and Italy, while they are still in progress in Belgium, Spain and Portugal (Padez, 2003, 2007; Larnkjær *et al.*, 2006).

The reason why some countries have reached a plateau in adult height and others are still increasing is an interesting matter of discussion. One interpretation of this pattern is that secular increase continues until the genetic potential of a given population is reached (Larnkjær *et al.*, 2006). However, considering that height is a sensitive indicator of the quality of life, namely

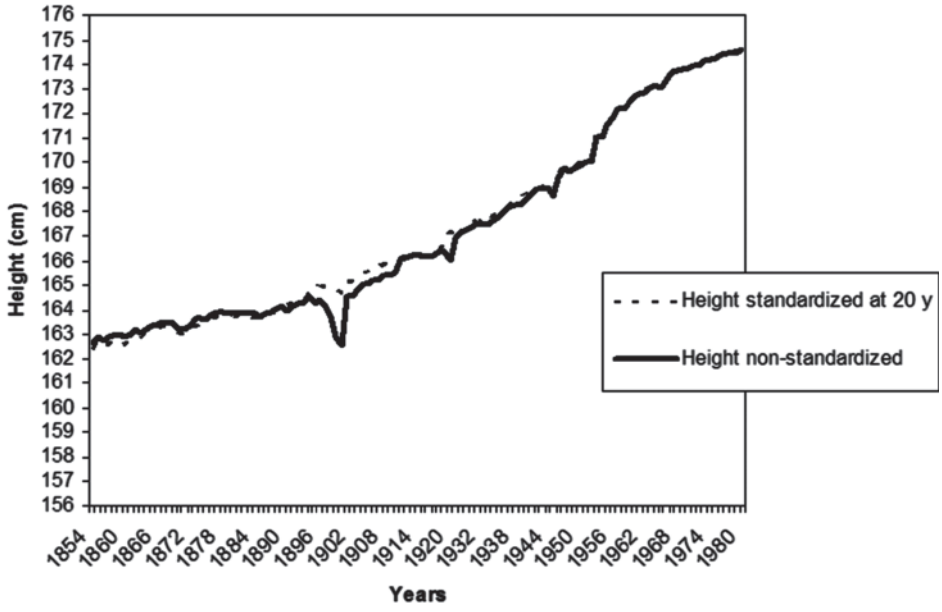

Fig. 1 – Average height measured during medical check-up and average height standardized at age of 20 years of Italian conscript birth cohorts from 1854 to 1980. Data from: Istat, 1958, 2003.

of the socio-economic environment, if the secular trend is stopped or still in act it could depend from socio-economic differences within and among countries (Schmidt *et al.*, 1995; Arcaleni, 2006; Larnkjær *et al.*, 2006).

The Euro-American population of the USA constitutes an enigmatic case with regard to the secular trend in height. The US height advantage over western and northern Europeans was 3 and 9 cm, respectively, in the mid-19th century, and Americans were very far from being overweight. In 1860, the mean height of US whites was 174.1 cm, compared with 168.6 cm in Norway and Sweden in 1855 and 1880, respectively, 165.6 cm in England in 1860 and 165.3 in Denmark in 1850 (Komlos & Baur, 2004). In contrast, Americans are now 2-6 cm shorter than western and northern Europeans. For example, US whites whose first language is English are shorter than West Germans by about 2 cm for the men and 3 cm for the women (Komlos & Baur, 2004). Moreover, among western and northern Europeans, the Danes, Dutch, Swedes and Norwegians are the tallest (Fig. 2). A possible explanation of this enigma is the greater social inequality, inferior health care system and fewer social safety nets in the USA than in western and northern European countries, in spite of the higher per capita income. The western and northern European welfare states seem to provide a higher biological standard of living than the United States (Komlos & Baur, 2004). Not only has the average physical stature of the US population not kept pace with European trends, but there is some indication that height has been stagnating in men and might actually have decreased in females of the youngest birth cohort. The decrease in height appears even more pronounced when income and education are controlled for (Komlos & Baur, 2004). In 1993, the height of white American-born women (speaking English in the family – not considering Hispanics) born in the late 1950s and early 1960s was 164.3 cm. In contrast, those born in the late 1960s and early 1970s were 163.5 cm tall (Komlos & Baur, 2004). The only groups that made steady gains in height in recent decades are low-income Afro-Americans

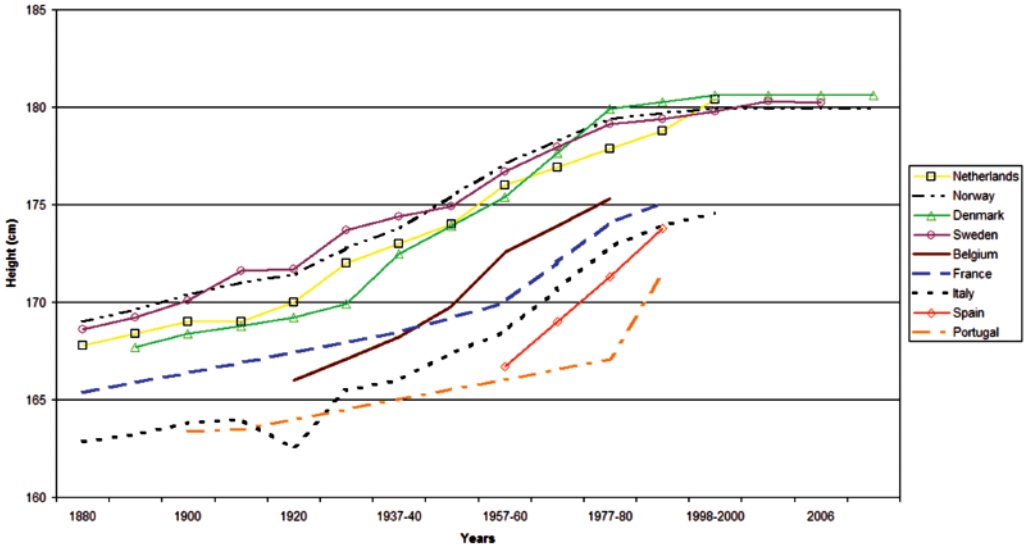

Fig. 2 - Average height (cm) at time for conscription per country from 1880 to 2006. Data from: Chamla, 1964, 1983; Lindgren, 1998; Rebato, 1998; Padez, 2003, 2007; de Beer, 2004; Komlos & Baur, 2004; Statistics Norway, 2006; Werner, 2007; Statistics Denmark, 2007; Statistics Netherlands, 2007. The colour version is available online at the JASs web site.

males, low- and middle-income Euro-Americans men, Euro-Americans men with an elementary education, and Afro-American males with elementary and college education. In contrast, all the female groups, as well as upper-income and better educated Euro-Americans men, tended not to do as well in this respect (Komlos & Baur, 2004).

Apart from the conscript data, there is a dearth of long-term information on adult height, particularly for women (Cole, 2000). Indeed, the secular trend in women is much less documented because they were not conscripted. However, the secular trend has been weaker in women than in men in the 20th century, so that the sex difference in adult height has increased in time (Cole, 2003). British cohort studies by sex and birth-year from 1892 to 1958 have shown a mean trend over the period of 10.9 mm/decade for men and 3.6 mm/decade for women, i.e. only one-third the rate and very significantly smaller ($P<0.001$). This sexual dimorphism in the height trend is striking, and has not been observed elsewhere. It was greater before 1940 than after and was still present when expressed in percentage terms. Among parents born before 1905, fathers were 6.9% taller than mothers, whereas in the 1958 cohort the men were 9.3% taller than the women (Cole, 2000). The smaller increase in height with increasing birth-year among women than among men indicates that the secular trend has been slower in females than in males in most countries. An explanation arising from several studies is that growth in males is more susceptible to adverse living conditions in childhood than growth in females and that males respond more dramatically to improvements in living conditions (Cavelaars *et al.*, 2000).

Secular height trends in children mirror those in adults but they vary with the child's age, so the apparent trend may be smaller or larger than that seen in adults. At each age, the height has increased steadily with time, but the height curve also shifts to the left, as seen clearly in puberty. This is the combined effect of a secular trend toward increasing height and a secular trend toward faster development. The net effect is that the height trend appears to be greater in puberty than earlier or later (Cole, 2003).

Among researchers on secular changes, it is still debated whether the secular height increase is due to a proportional increase of both sitting height and lower limb length (Tanner, 1962; Charzewski & Bielicki, 1978; Bodzar & Papai, 1994; Bodzar, 1998) or a greater increase of lower limb length than of sitting height (Moore, 1970; Himes, 1979; Tanner *et al.*, 1982; Zhang & Huang, 1988; Tanner, 1990; Susanne, 1993; Leung *et al.*, 1996; Demoulin, 1998; Vercauteren *et al.*, 1998; Sanna & Soro 2000; Alì *et al.*, 2000; Sanna & Palmas, 2003). In addition, the height increase in 18-19 year-old Polish males from 1962 to 1992 has been attributed to a lengthening of the trunk and a shortening of the lower limbs (Ziólkowska, 1997). Greulich (1957) compared Japanese and American-born Japanese children and found that the latter had longer legs than the former at younger ages, but the difference rapidly decreased with age and disappeared in both sexes in late adolescence. The two groups ended up with the same trunk-to-leg ratio even though the American-born individuals were much taller. According to Cole (2000), however, there is greater evidence in the literature for the argument that the secular trend in adult height, both in men and women, is chiefly a trend in lower limb length.

Weight, BMI and obesity

Along with secular changes in height, there are concomitant changes in weight, both in adults and children (Elrick *et al.*, 2002). These trends arise from two distinct sources, increases in body size (height) and changes in body shape, corresponding to adiposity as measured by weight-for-height or indices of regional body composition, e.g. skin-fold thickness or circumferences. Hence, the secular trend in weight is a combination of the trend in height and the trend in adiposity (Cole, 2003).

Although height has largely silized since the 1990s, weight has continued to increase, reflecting the growing epidemic of obesity throughout the Western world (Cole, 2000). Developed

countries show alarming increases in obesity and the epidemic now seems unstoppable. Over 55% of Americans are now overweight or obese and obesity has increased by 30% over the last 50 years, while most of Europe has seen a 10-40% increase in obesity over the last 10 years (Molarius *et al.*, 2000; Elrick *et al.*, 2002). Thus, the increase in obesity has been most marked in North America (Troiano *et al.*, 1995) but has also affected countries throughout Europe. The timing and pattern of the obesity epidemic has been quite different from the secular trend in height, and this difference reflects its different etiology (Cole, 2000).

The body mass index (BMI; kg/m^2) is the most commonly used indicator of overweight and obesity, as it provides useful estimates of weight-for-height at the population level. Using the criteria for the classification of obesity recommended by the World Health Organization (WHO) Expert Consultation on Obesity (BMI≥30), it is estimated that the prevalence of obesity in European countries is 10-20% in men and 10-25% in women (Komlos & Baur, 2004). In Canada, the estimates of obesity for the period 1986-92 are 13% of men and 14% of women (Torrance *et al.*, 2002).

The worldwide obesity epidemic (linked to fat mass) started in the 1960s in adults and in the 1980s in adolescents and children (Cole, 2003). The BMI values of the US population have been consistently increasing since the 1980s (Komlos & Baur, 2004; Baskin *et al.*, 2005) and as many as 30% of adults (≥20 years) are now considered obese (BMI≥30) (Baskin *et al.*, 2005). Although this is part of a general "Western" trend, the American obesity rates are the highest. At the same time, the life-expectancy of the US population lags 3.2 years behind that of Japan and has fallen behind the levels in western Europe. Moreover, the US infant mortality rate (7.2 per 1000) was higher than that of Sweden (3.4), Finland (3.6) and Norway (3.8) in 2000 (Komlos & Baur, 2004). In the USA and in European countries, obesity is prevalent among all ages and both sexes, and seems to be conditioned by the socio-economic status, since men and especially women with higher education are leaner than those with lower education (Molarius *et al.*, 2000). For example, in the USA, non-Hispanic Afro-Americans and Mexican American women have higher BMI values than non-Hispanic Euro-Americans women, even when matched by income and education (Baskin *et al.*, 2005). In Italy, both boys and girls show an increasing prevalence of overweight and obesity as the socio-economic status decreases (Sanna *et al.*, 2006).

There does not seem to be an unequivocal sex difference in the prevalence of obesity (Mascie-Taylor & Goto, 2007), although females seem to have a higher incidence than males of the same country (Fig. 3). For example, women have higher obesity rates than men in all ethnic groups in the USA (Hedley *et al.*, 2004).

Although obesity in children started after 1980, it has increased as rapidly as in adults since then. Indeed, it is now seen at younger and younger ages (Bundred *et al.*, 2001).

BMI is actually a less than ideal measure of obesity, as it fails to distinguish between fat mass and muscle mass. When the incidence of obesity first started rising, the increase in fat mass was probably masked by a corresponding reduction in muscle mass. This is particularly true for children, in whom reduced physical activity is an important risk factor for obesity. Thus, the rise in childhood obesity probably started earlier than 1980, even though BMI did not reflect it until later (Cole, 2003).

Secular changes in puberty

The onset of puberty is an important moment of the growth process because of the complex physiological changes that occur and their relevance to the development of the adolescent personality (Nicoletti, 1994). Analysis of the times and modes of the onset of puberty are also of anthropological interest because of the well-known influence of genetic, environmental and socio-economic factors, which produce significant differences between populations.

Menarche

Most studies on the onset of puberty have focused on analyses of the mean/median age at first menstruation. The terms mean and median are commonly considered synonymous in studies on menarche and menopause: most authors use the two terms without distinction and many authors do not explain if they refer to the arithmetic mean or to the median. This is why we will use the double definition in this paper. Mean age at menarche is considered the most important indicator of female puberty because of the ease and reliability of its determination. From 1830 to 1980, the mean age at menarche decreased in Western Europe by about 3-4 months per decade, settling at ca. 12.5-13.0 years in all these countries (Eveleth & Tanner, 1990; Ulijaszek, 1998). Table 1 is drawn from the paper by Thomas *et al.* (2001) who reported the mean and/or median ages at menarche in 66 countries worldwide. The data were grouped by geographical macro-areas (the five continents and the Middle East) for easier interpretation. In general, mean ages at menarche ≤13.0 years are recorded in central-southern Europe, Russia, China and Japan, in many countries of the Americas, in Australia and New Zealand, while higher mean menarcheal ages are in Africa, many Asian countries and many developing and geographically disadvantaged countries, i.e. those at high altitudes. It will be very interesting to compare the data from Thomas (2001) in the future, after a period of time, adequate for estimates of the secular trend. There is also high variability, due to the multiple factors acting synergistically on the onset of menstruation. The age at menarche depends on the genetic component (Eveleth & Tanner, 1990; Sanchez-Andres, 1997; Salces *et al.*, 2001), but certain environmental characteristics are also very important: a hot climate causes greater precocity, whereas high altitude, isolation and a rural environment are responsible for delayed menarcheal age (Barnes-Josiah & Augustin, 1995; Gonzales & Villena, 1996;

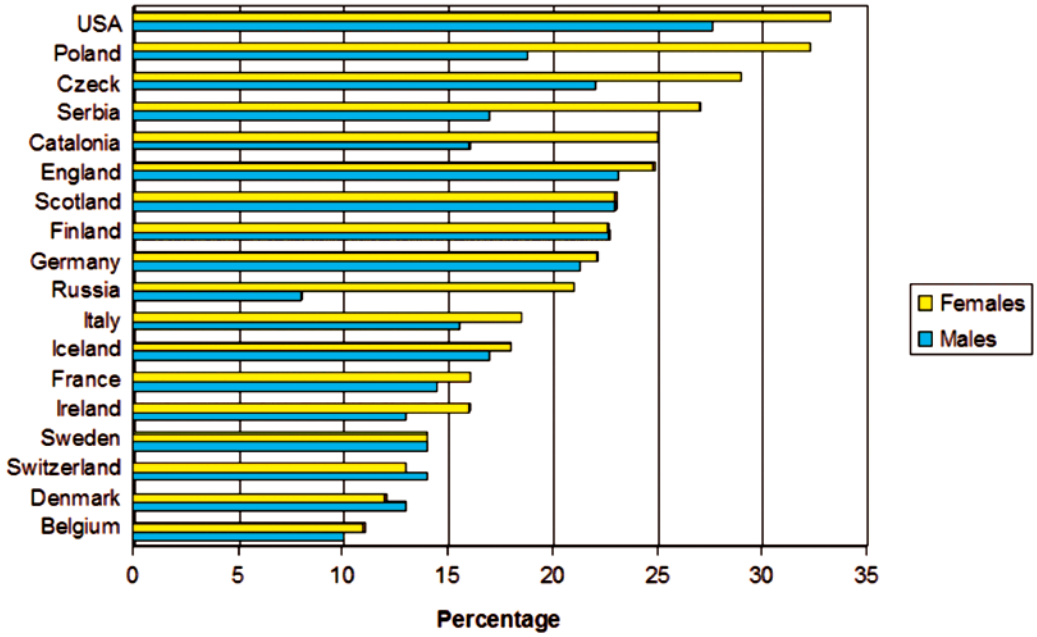

Fig. 3 – Prevalence of obesity in 16 European countries and USA. Data from: Molarius et al., 2000; Baskin et al., 2005; NHS, 2007. The colour version is available online at the JASs web site.

Tab. 1 – Mean (or median) age at menarche in different countries. Data from: Thomas* et al.*, 2001.

Country	Age at menarche	Country	Age at menarche	Country	Age at menarche	Country	Age at menarche
Europe		**America**		**Middle East**		**Africa**	
Greece	12.0	Mexico	12.4	Israel	13.3	Congo-Brazza	12.0
Spain	12.3	Argentina	12.6	Yemen	14.4	Egypt	13.2
Italy	12.5	Dominican Rep.	12.6			Zimbabwe	13.5
Hungary	12.9	Venezuela	12.7	**Asia**		Zambia	13.7
Belgium	13.0	Usa	12.8	Thailand	12.3	Congo-Kinshasa	13.8
Denmark	13.0	Colombia	12.8	Cina	12.4	Morocco	13.8
Russia	13.0	Chile	13.0	Japan	12.5	Sudan	13.8
Switzerland	13.0	Cuba	13.0	Indonesia	13.0	Ghana	14.0
France	13.1	Jamaica	13.1	Sri Lanka	13.5	Algeria	14.3
Iceland	13.1	Peru	13.2	Philippines	13.6	Kenya	14.4
Poland	13.1	Guatemala	13.8	Taiwan	13.6	Cameroon	14.6
Sweden	13.1	Nicaragua	14.0	South. Korea	13.9	Somalia	14.8
Finland	13.2	Haiti	15.4	Malaysia	14.2	Nigeria	15.0
Norway	13.2			India (Punjab)	14.3	Tanzania	15.2
Britain	13.3	**Oceania**		Bangladesh	15.8	Senegal	16.1
Turkey	13.3	Thaiti	12.8	Nepal (high altitude)	16.2		
Ireland	13.5	New-Zealand	12.9				
Roumania	13.5	Australia	13.0				
East Germany	14.0	Papua NG	15.8				
Czechoslovkia	14.6						

Pasquet *et al.*, 1999; Marrodan *et al.*, 2000). No less important are the girl's general living conditions: nutrition and health status; physical activity; sibship size and birth order; educational level, income and profession of the parents (Ulijaszek *et al.*, 1991; Wellens *et al.*, 1992; Martuzzi Veronesi & Gueresi, 1994; Cameron & Nagdee, 1996; Malina *et al.*,1997; Graham *et al.*, 1999; Artaria & Henneberg, 2000; Ayatollahi *et al.*, 2002; Vadocz *et al.*, 2002). In general, it can be concluded that the secular trend in age at menarche is lower in children from higher socioeconomic classes (Bielicki *et al.*, 1986; Ulijaszek *et al.*, 1991; Henneberg & Louw, 1995; Macias-Tomei *et al.*, 2000).

In the 1990s, it was reported that the secular trend in menarcheal age had ended or slowed down in some European countries: Great Britain, Iceland, Norway, Denmark, ex DDR, Hungary, Belgium, Poland (Hulanicka & Waliszko, 1991; Roberts, 1994; Tryggvadottir *et al.*, 1994; Juul *et al.*, 2006). Moreover, Prebeg *et al.* (1994) recorded a slight inversion of the trend in Croatia: from 12.87 to 12.95 at Split (1977-1982) and from 12.7 to 12.82 at Zagreb (1982-1991). Wyshak (1983) also observed a substantial stasis of the mean age at menarche for the USA, which was confirmed by Malina (1990) in samples referring to 1940, 1950 and 1960, in which the value remained firmly around 12.8 years. Herman-

Giddens *et al.* (1997) also reported that the mean age at menarche (12.6 years for Euro-Americans and 12.1 years for Afro-Americans) had not shown a significant decrease in the last 40 years. Recent reports also suggest that the decline in the age of onset of menses may be slowing in US females. McDowell *et al.* (2007) reported a decline of approximately 2.5 months in the mean age of menarche for US females between 1963-70 and 1988-1994 and a further decline of approximately 2.3 months (from 12.53 to 12.34 years) between 1988-94 and 1999-2002. However, there are conflicting indications, such as those of Nichols *et al.* (2006) who confirmed a decrease of the mean menarcheal age for women born between 1919 and 1949 (13.1 vs. 12.7 years) in three American states but also a subsequent increase to 13.0 years for those born between 1960 and 1969.

A similar situation seems to have occurred in Italy. Table 2 shows an alignment of all the Italian regions around mean values of age at menarche of about 12.5 years. The delay of southern Italy with respect to the northern part also seems to have disappeared, even though the menarcheal age continues to decrease in some regions, e.g. Sardinia: Floris (2003) recently reported a median age at menarche of 11.7 years, lower than the 12.7 years recorded in the period 1987-1990 (Floris *et al.*, 1991). In contrast, some zones, e.g. the province of Bologna in Emilia-Romagna, have shown a slight inversion of the secular trend toward a lower menarcheal age in the last few decades: from 12.5 years for the 1930-39 cohort to 12.2 years for the 1950-59 one, but back to 12.5 years for girls born in 1960-69 and in 1970-73 (Martuzzi Veronesi & Gueresi, 1994).

Secondary sexual characteristics

The pilot study by Herman-Giddens *et al.* (1997) turned the attention of researchers to another aspect of puberty that seems to show a secular change in the USA and should be verified in other industrialized countries. Despite a stable or even slightly increasing mean age at menarche and an unchanged overall duration of puberty, signs of puberty such as breast development

Tab. 2 - Mean (or median) age at menarche in several samples from Italian towns, provinces and regions listed from North to South.

Place	Age at menarche	Source
Northern Italy		
Pordenone	12.2	Antonini Canterin *et al.*, 1977
Veneto	12.8	Grassivaro Gallo & Boscolo Moro, 1980
Turin	12.6	Benso *et al.*, 1989
Lombardy	13.0	Grassivaro Gallo & Savoia, 1978 (in Floris *et al.*, 1987)
Milan	12.3	Kehyayan *et al.*, 1980 (in Calò *et al.*, 1996)
Bologna	12.5	Martuzzi Veronesi & Gueresi, 1994
Mantova	12.6	Gueresi, 1996
Parma	12.4	Gueresi, 1996
Reggio Emilia	12.5	Gueresi, 1996
Central Italy		
Marche	12.7	Grassivaro Gallo, 1984
Marche	12.7	Grassivaro Gallo, 1991
Ancona	12.5	Grassivaro Gallo, 1991
Ascoli	12.4	Grassivaro Gallo, 1991
Fabriano	12.9	Grassivaro Gallo, 1991
Fermo	12.6	Grassivaro Gallo, 1991
Florence	11.9	Marianelli et al., 1977 (in Calò *et al.*, 1996)
Jesi	12.8	Grassivaro Gallo, 1991 (in Calò *et al.*, 1996)
S. Benedetto T.	12.7	Grassivaro Gallo, 1991 (in Calò *et al.*, 1996)
Rome (Prov.)	12.4	Vienna & Capucci, 1994
Southern Italy		
Molise	12.5	Vienna & Capucci, 1994
L'Aquila (Prov.)	12.6	Danubio *et al.*, 2004
Naples	12.5	Carfagna *et al.*, 1972
Puglia	12.7	Grassivaro Gallo & Parnigotto, 1982
Sardinia	12.8	Floris *et al.*, 1987
Sardinia	12.7	Floris *et al.*, 1990
Cagliari	12.3	Floris, 1984 (in Calò *et al.*, 1996)

and pubic and axillary hair are appearing at a progressively earlier age. The authors surveyed more than 17,000 girls in the US in 1992-1993 and found that 21.4% of 7-8-year-old Euro-Americans girls already exhibited one or more pubertal signs, while the percentage was significantly higher in Afro-American girls (over 50%). The median age of breast development in the Euro-Americans girls was 10.0 years vs. 8.9 years in the Afro-Americans, while the respective median ages of pubic hair growth were 10.5 years vs. 8.8 years. These values are slightly lower than those reported in the National USA surveys for the preceding years (Herman-Giddens, 2006). A similar trend towards earlier development seems to have occurred in boys, with the same difference between Euro-Americans and Afro-Americans: 10 years in Euro-Americans vs. 9.5 years in Afro-Americans for the onset of genital growth and 12 years vs. 11.2 years for the onset of pubic hair growth (Herman-Giddens *et al.*, 2001). In a review of studies on pubertal precocity in the US, Herman-Giddens (2006) confirmed this tendency in females and perhaps in males, as well as the greater precocity of Afro-Americans than Euro-Americans; based on the results of Sun *et al.* (2002) and Chumlea *et al.* (2003), she underlined a gradient of significant ethnic differences, with Mexican-Americans intermediate between the other two groups. However, she recommended caution in comparing data obtained with different survey methods and emphasized the necessity of more studies on boys using reliable methodologies. Indeed, one of the main problems in surveying secondary sexual characteristics is the assessment of pubertal development. This is evaluated by visual inspection according to the five stages of breast, genital, and pubic and axillary hair development defined by Tanner (1962). Standardized methodologies, conventional criteria, and training of operators should thus be defined in order to avoid and/or reduce individual evaluation errors.

Finally, Herman-Giddens (2006) speculated on the possible causes of this secular trend in secondary sexual characteristics that include genetic differences, increased incidence of overweight and obesity, nutritional factors, namely the effects of the different types of diet, reduced physical activity and the improvement of socio-economic conditions. Moreover, hormones introduced by diet and exposure to several chemical compounds from the environment is also being considered. Some insecticides, plastic materials and hair-care products deteriorate into substances with estrogenic effects able to modify endocrine activities; thus they could play a significant role in the observed trend (Blanck *et al.*, 2000). However, Kaplowitz (2006) was of a different opinion in this regard. In a critical review of the topic, he concluded that the relationship of earlier puberty with obesity is stronger than that with endocrine disrupters present at various times, places and degrees in the surrounding environment; he also called attention to the possible role of leptin, a protein known for its regulatory effect on weight and for its relationship to normal gonadotropin secretion. Both authors concluded that it is necessary to extend the research on this topic to the population level and to investigate the real-life effects of multiple cumulative environmental exposures over time.

In Europe and in industrialized countries and/or countries in which the demographic transition is in an advanced phase, it is difficult to acquire similar data from longitudinal studies because of the lack of standardized national surveys. However, it is possible to make synchronous comparisons among different countries and with the US data. Table 3 shows the substantial similarity of data for both sexes, with a slight delay in the age of appearance of stage 2 of all the secondary sexual characteristics, especially in northern European boys: between 12.0 and 11.0 years for G2 in males, 10.9 and 10.0 years for B2 in females. Although at the lower limits of the table, the Italian values do not equal those reported for the USA.

Finally, despite a progressive anticipation of all signs of puberty (age at menarche, appearance and development of the breasts, genitals, pubic and axillary hair) and the existence of ethnic/population variability, the secular trend toward a progressive anticipation of some of these signs is

Tab. 3 - Median age of entry into stages 2 and 3 of pubertal development (G=Genital, PH=Pubic Hair, B=Breast) in samples from other countries.

	Boys				Girls				Source
Place	**G2**	**G3**	**PH2**	**PH3**	**B2**	**B3**	**PH2**	**PH3**	
Stockholm	11.6	13.5	12.7	13.5	10.8	11.7	11.2	12.3	Lindgren, 1996
Copenhagen	11.8	13.3	11.9	13.5	10.9	12.4	11.3	12.4	Juul *et al.*, 2006
Lithuania	-	-	-	-	10.2	11.3	11.0	-	Žukuskaité *et al.*, 2005
Russia									
Chapaevsk	11.9	13.3	12.7	14.1	-	-	-	-	Lee *at al.*, 2003
Hungary									
Székesfhérvàr	11.6	13.0	11.7	13.2	10.1	11.2	10.3	11.6	Bodzsar, 2000
Pécs	12.0	13.1	11.8	13.3	10.0	11.3	10.1	11.6	Bodzsar, 2000 ; Dober & Kiralyfalvi, 1993
Jàszberény	11.7	12.7	12.0	12.8	10.4	11.4	10.7	11.5	Bodzsar, 2000
Wroclaw *	12.4	-	13.2	-	-	-	-	-	Bielicki *et al.*, 1984
Italy	12.3	13.0	12.3	13.3	10.9	11.9	11.0	12.2	Nicoletti, 1994
L'Aquila	11.2	12.6	11.5	12.7	10.3	12.4	10.4	12.1	Danubio *et al.,* 2004; De Simone *et al.,* 2004
Piedmont	11.0	-	11.2	-	10.5	-	10.6	-	Bona *et al.*, 2002
United States **	10.1	12.4	12.0	12.6	10.0	11.3	10.5	11.5	Herman-Giddens *et al.,* 1997; 2001; Karpati et al., 2002
Caracas ***	11.6	12.6	11.8	12.6	10.4	11.0	10.5	11.4	Macias-Tomei *et al.*, 2000
Hong Kong	11.4	12.6	12.7	13.5	9.8	11.1	11.6	12.8	Huen *et al.*, 1997

* born in 1953; ** white; ***upper-middle-class

still a controversial topic requiring further investigation, especially regarding the psychological and social implications of precocious development on both children and adults.

Secular changes in menopause

In contrast to the ample research on the onset of puberty in both sexes (mean age at first menstruation, appearance of pubertal signs), little attention has been given to the variability of the age at menopause among populations. This is largely for two reasons. The first is the supposed low interest in analyzing a process that marks the end of the reproductive period and the second is the difficulty in investigating a parameter whose nature is often altered by pharmacological and surgical interventions. Thomas *et al.* (2001) dealt broadly with the variability of menopausal age by investigating the underlying causes and correlating them to the factors determining the variability of menarcheal age (Tab. 4). They reported the mean age at menopause in 26 countries and concluded that, while factors related to living conditions have a great influence on the

Tab. 4 – Mean (or median) age at menopause in different countries.

Country	Age at menopause	Country	Age at menopause
Indonesia	54.5	Japan	49.3
France	52.0	South Africa (black)	49.2
Czechoslovkia	51.2	Cina	49.0
Usa	51.3	Russia	49.0
Finland	51.0	Canary Islands	48.6
Sweden	50.9	Nigeria	48.4
Malaysia	50.7	Philippines	48.0
Australia	50.4	Ghana	48.1
Thailand	50.3	Turkey	47.8
Chile	50.0	Unit. Arab Emir.	47.3
Colombia	50.0	Nepal (high altitude)	46.8
Switzerland	50.0	Mexico	46.5
Taiwan	49.5	India (Punjab)	44.6

Data from: Thomas *et al.*, 2001.

variability of menarcheal age, the determinant factor of menopausal age seems to be exclusively intrinsic, namely the reproductive history of the individual, although they underlined the necessity of further research of this type.

The existence of a secular trend toward the postponement of menopause is controversial. An extensive critical review of studies that have reported an increase in the menopausal age failed to confirm the hypothesis that there has been a delay of 4 years in the onset of menopause in the last 100 years; instead, the age at menopause appears to have been constant in time, namely at about 50 years of age (Pavelka & Fedigan, 1991). Recently, however, Rödström *et al.* (2003) reported the results of a survey of over 1400 Swedish women born between 1908 and 1930 and followed at regular intervals for 35 years. They found a progressive and significant increase of the mean age at natural menopause of ca. 1 month/birth-year: 48.5 years for those born in 1908 and 51 years for those born in 1930. Differences in the menopausal age in various subgroups were examined in relation to several factors, and one of the most influential seemed to be smoking. They also showed a probable positive relationship between menarcheal age and menopausal age. Similar results were reported by Nichols *et al.* (2006) for 22,774 American women born between 1910 and 1969: the mean age at natural menopause passed from 49.1 years for those born in 1915-1919 to 50.5 years for those born in 1935-1939, i.e. an increase of 17 months. Their comparison of these results with data reported by various authors for women born in the periods preceding and following the ones they investigated strengthened the hypothesis of a secular trend in the mean menopausal age: from 47.1-47.9 years at the beginning of the 20th century to 48.8-51.0 years during the last 30 years. These authors also observed an increase of the mean reproductive period, from 36.1 years for those born in 1915-1919 to 37.7 years for those born in 1935-1939, and they confirmed the negative association between smoking and age at natural menopause, which reduces the mean menopausal age by ca. 1.5-2.0 years.

All researchers who have studied the secular trend in age at natural menopause agree on the need to carry out further research on its effects on the onset of cancer, osteoporosis and heart diseases, as well as on the increased risk of female mortality in general.

Large, long-term studies on this topic are lacking in Italy. Recent preliminary results of a national study (EPIC-Italy) of correlates of age at natural menopause (Celentano *et al.*, 2003) confirmed the influence of lifestyle and educational level, and identified smoking as a major correlate. In his review of 2002, Sanna reported a secular trend in menopausal age in Sardinian samples of different generations and compared the results to those for a Bolognese sample of women studied by Martuzzi Veronesi & Gualdi Russo (1982-83). For Sardinia, Floris *et al.* (1992) recorded a mean age at menopause of 49.1 years, higher than the 48.0 years reported by Maxia *et al.* (1975) and the 46.8 years of a large sample of married women in 1928 (Gini & De

Orchi, 1939). A retrospective study of Bolognese women born in 1846-55 and in 1916-25 showed an increase of the mean menopausal age from 47.5 to 50.0 years (Martuzzi Veronesi & Gualdi Russo, 1982-83). The authors attributed the trend to the socio-economic status and occupational activity, since menopause appeared later in women with advantageous economic conditions and non-manual activities. Nevertheless, the small sample sizes and the lack of both a comparison among a large number of cohorts and a detailed analysis of the determinants and their association with the onset of menopause exclude the possibility of a thorough nationwide investigation of changes in the menopausal age and the causes underlying the process.

Secular changes and sport

At the end of the 1990s, the progressive involvement of an ever larger number of young people in various competitive and recreational sports allowed investigations of secular changes in the field of sport science and/or kinesiology. Indeed, the increasing diffusion of sporting activities in children, the growing body of morpho-functional knowledge, and the recruitment by sporting bodies of talented youngsters to be trained for professional sports will provide large series of data (including anthropological data) in different disciplines.

In 1984, Borms & Hebbenlinck reviewed the heights and weights of athletes who participated in the Olympic Games between 1928 and 1976 to investigate the possible presence of a secular increase of these dimensions. Although aware of the sampling dishomogeneity (including the different ethnic backgrounds of athletes in the various sports), they showed that there was a general increase of the size of the athletes in the 50-year period. However, Borms (2003) cautioned that the binomial 'large size/success in sport' is not necessarily valid for all specialties. For example, Norton *et al.* (1996) showed that the height and weight of soccer players do not differ from those of the general population (except for goalkeepers); moreover, although being tall may be advantageous in tennis, other characteristics like speed, technique and strategic skills are necessary to be successful. Instead, body dimensions are crucial for success in other specialties, e.g. height in basketball, high jumping, Australian rules football and heavyweight rowing, and body mass in super-heavyweight lifting, rugby and American football. In fact, these are the sports in which there has been a progressive selection of larger athletes.

The Australian anthropological school, heavily involved in the motor and sport sciences, has been the leader in analyzing the secular trend in this field. Norton *et al.* (1996) adopted a purely anthropological approach for the study of sports performance, considering the changes of body shape and proportionality in time and across levels of sports activity (recreational or elite competitive). The main question the authors posed was if body size and shape are important for success in a particular sport and, if so, how can this be determined. The analysis involved three steps. Firstly, ascertain if the mean value and standard deviation of a certain physical characteristic differ between the sporting population and the general reference population. Secondly, check for a trend of changing physical characteristics from recreational to regional and/or international competitions. Lastly, examine the possible changes in the physical characteristics of elite athletes over time. To quantify the differences between athletic and non-athletic populations, they introduced the concept of *overlap zone* (OZ) and *bivariate overlap zone* (BOZ) when considering one or two anthropological parameters, respectively. The OZ and BOZ are calculated and visualized as the degree of overlap of the frequency distributions of the analyzed parameters between the sporting population and the general population from which the athletes are recruited.

The results of the study showed that there were significant differences in the mean heights of athletes in various team sports with respect to the general population, significant differences of the athletes relative to the position they played

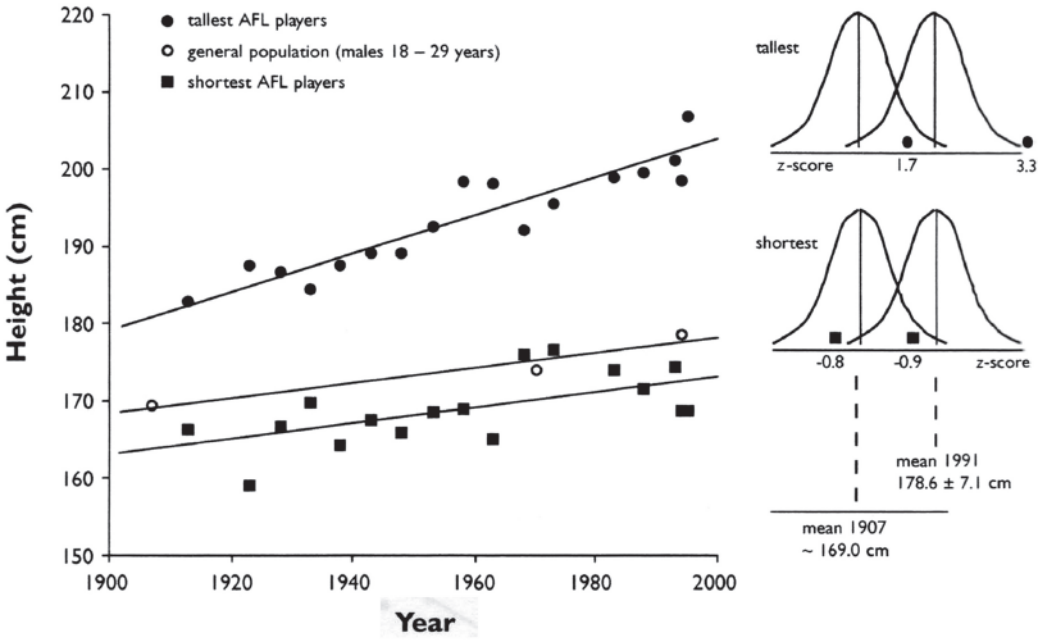

Fig. 4 - Secular trend of height of tallest and shortest Australian football players compared to that of the general population (source: Norton* et al.*, 1996, courtesy of the author).

within the team, and an evident secular trend in height during 100 years (Fig. 4) (Norton *et al.*, 1996). In addition, the rate of change in mean height of all players in the National Basketball Association was significantly greater than that of the general population (2.25 cm/decade since 1945); this value was almost twice that of the mean increase for the taller players and about 4 times that of the general population. There were similar results for the weight and BMI of elite rugby players: over the last 25 years, the values of the two parameters increased at twice the average rate for the entire century and at rates up to 5 times higher than in the source population (Olds, 2001).

These results prompted Norton & Olds (2001) to extend the study of secular trend in sport by contemporaneously considering two related characteristics, i.e. height and mass, to calculate the probability that a young adult male from the general population possessed the required height and mass to be a successful elite athlete. Figure 5 refers to National Football League inside linemen for the period 1920 to 1999. The point cloud represents the general population and the ellipse the football players. The secular trend in height in the general population (the progressive rightward shift of the point cloud) and the increasingly evident shift of the ellipses (the players) for both height and weight away from the general population can be observed. Similar results were also obtained for other sporting disciplines. Therefore, the athletes became taller and more massive over time, at a rate that outstripped that of the secular trend. These changes, likely related to greater selectivity in international recruitment following the globalization of sport, to the greater financial and social incentives in professional sports, and to the use of special training methods (unfortunately including artificial stimulants), will probably continue in the future.

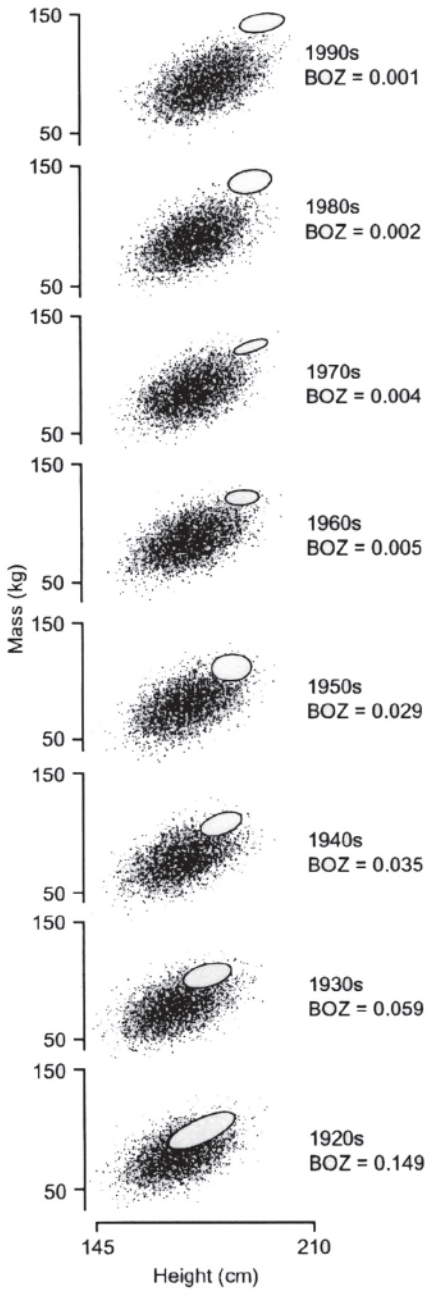

Fig. 5 - Secular trend of height and mass (BOZ) of the general population and of the National Football players from the 1920s to the 1990s (source: Norton & Olds, 2001, courtesy of the authors).

Conclusions

Adult height and weight have been increasing more or less linearly since the 19th century. Increases in adult height slowed in the late 20th century and approached a plateau in northern Europe and Italy, while weight continued to increase as part of the worldwide obesity epidemic. Similar trends occurred in children over the same period; the changes are amplified in mid-childhood by the increased developmental tempo and earlier maturation. The increase in adult height from one generation to the next is due to increased lower limb length (Cole, 2003). The worldwide obesity epidemic, linked to fat mass, started in adults in the 1960s and in adolescents and children in the 1980s. It is due to an imbalance between energy intake and energy expenditure, so that both diet and exercise are involved. Physiologically, it seems that once energy expenditure falls below a certain level, the body's natural ability to regulate energy intake breaks down and fat stores accumulate. The way to avoid or cure obesity is to increase activity and to control energy intake. Watching television has probably played an important role in the obesity epidemic and the Western emphasis on a labor-saving lifestyle almost guarantees increasing levels of obesity (Cole, 2003).

Secular trends toward greater height and earlier maturation are mainly linked to improvements in nutrition and health (Tanner, 1986; Hauspie *et al.*, 1997). Parallels have been observed between secular trends and indices of well-being, such as the level of survival to adulthood (Ulizzi & Terrenato, 1982; Hauspie *et al.*, 1997), daily per capita intake of animal protein and per capita income and gross national product (Hauspie *et al.*, 1997).

Obesity appears to be associated with earlier maturation of girls and boys, even though many other factors have contributed to the change (Herman-Giddens, 2006). However, the secular trend toward a progressively lower age at menarche seems to have stalled (with some episodes of inversion) in industrialized countries, while the trend toward earlier onset of signs of puberty is

still controversial and requires further verification, especially for boys (Herman-Giddens, 2006; Kaplowitz, 2006). Analysis of the secular trend in mean age at natural menopause is interesting, as it shows a postponement of menopause to after 50 years of age. The onset of menopause, which appears to be influenced by exogenous factors (primarily smoking, which reduces it) seems to show a positive correlation with the menarcheal age and with the individual reproductive history (Thomas *et al.*, 2001; Rödström *et al.*, 2003). These topics should be investigated further to evaluate their repercussions on the mean duration of the reproductive period; for instance, a tendency to an increased duration has been shown in a sample of American women (Nichols, 2006). Moreover, it is important to analyze in more detail the timing of menopause because of its effects on the onset of various age-related pathologies and the increased risks of female mortality in general.

Finally, research by the Australian anthropological school on the secular trend in sport has revealed a progressively greater difference in height and weight between athletes in team sports and the general population; moreover, there has been an evident secular trend in height and weight of the athletes over 100 years (irrespective of the position they play), and the rate of the changes has been significantly greater than that of the general population (Norton *et al.* 1996; Norton & Olds, 2001; Olds, 2001). These authors interpret the results as effects of the globalization of sport, of the greater financial and social incentives in professional sports, and of the use of special training methods (including the growing use of drugs). They emphasize that this trend will probably persist in the future and they foresee the possibility of 'gene-farming' through assortative mating and athlete gamete banks. In the latter case, the concept of natural selection of potential elite athletes from the general population would be definitively superceded and new ethical questions would be raised.

In conclusion, we highlight the need of continuing the research on secular trend in Western societies, specially aimed at evaluating the following main points:

- if it has reached a halt in height and if menarche's secular trend is going back
- if earlier maturation is occurring in boys too;
- the factors that play a role in it, their relative contribution and their interrelation;
- to understand better the real-life effects of multiple cumulative environmental exposures over time on earlier maturation, both in girls and boys;
- to analyze in more detail the timing of menopause because of its effects on the onset of various age-related pathologies and the increased risks of female mortality in general;
- to further investigate the possible positive correlation between the onset of menopause, the menarcheal age and with the individual reproductive history to evaluate their repercussions on the mean duration of the reproductive period;
- finally, it will be very important to give attention to anthropological aspects in sport, especially nowadays in view of the developing interest of the genetic of sport and its related ethical problems.

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