SECULAR CHANGES IN SPORT

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Introduction

The concept of secular changes (better known as secular trends) is of classic interest in human biology, auxology and, as we shall see further, also in sport science or kinesiology. Secular trends refer, in general, to changes in body size and other somatic characteristics, indicators of maturity, and motor performance over one or usually several decades. These changes may be positive, i.e. increases or accelerations, or they may be negative, i.e. decreases. A positive change is not necessarily favorable, e.g. increase of fatness. The issue is not new as some investigators discussed the possibility of these changes as early as the beginning of the 19th century, before the phenomenon had actually been observed (Van Wieringen, 1986).

The literature on secular changes, especially in height and weight during growth and early adulthood, is extensive and covers large parts of the world, developed and less developed regions, male and female populations, low and higher social-economic strata, but is less extensive as far as special populations such as world class athletes are concerned. Height and weight have been studied most among all somatic characteristics.

Based on a synthesis of the literature, the following generalizations on secular changes in size seem warranted: secular differences in birth length and weight are slight; secular increases in height and weight are apparent by the end of the first year of life and become progressively larger with age until about 12-13 years in girls and about 14-15 years in boys. The largest secular differences in height and weight are apparent during puberty while there is a progressive reduction in the magnitude of secular increases in size from puberty until young adulthood. This increase in height up until puberty may be proportional, however, to the attained height in the age group. If a ratio between the increase in height per decade and the mean stature of the first measurement period is taken into consideration, the secular changes in height with increasing age become somewhat less evident around puberty.

Secular changes have occurred in all socio-economic groups in Europe, USA and Japan, but these changes are not universal. Indeed, populations in underdeveloped areas of Asia, Africa and Latin America show little, none or a negative secular trend in adult stature.

Size differences between children of different generations in part reflect maturity differences. Children today mature earlier than those of 100 years ago. Age at menarche, the most commonly reported indicator of maturity status, has decreased over the last 150 years in European populations by 3-4 years. The estimated rate at which age at menarche has diminished in Europe is about 4 months per decade from 1830 until now (Roche, 1979). The percentage of adult height achieved at the age of menarche has remained, however, quite constant over several decades, i.e. at 95%, although height, weight and age of menarche varied significantly.

Meta-analysis of 136 reports of changes in height and of 142 reports on weight reveals that over the past century the median increase in the height of children aged 5-16 years has been 1.23 cm and 0.80 kg respectively per decade. This rate of secular changes in height varies according to age and the level of health and well-being of a certain population. We would expect that the trend in weight would be proportional to the relationship with height. This is, however, not always the case as weight is more sensitive to the availability of food, and depends greatly on the individual's response.

There is evidence that the positive secular changes in height and weight, and the decrease in the age of menarche is slowing down or stopped in developed countries, during the 60s and the 70s. Nevertheless, an increase in height of British

children between 1982 and 1990 was reported in the study of China and Rona (1994) This was attributed to decreased family size. In a follow up study on growth and fitness of Flemish children (Lefevre, Bouckaert & Duquet, 1997), it was shown that the rate of secular changes in height and weight has slowed down but has not stopped yet. Also in the Netherlands secular growth has not ended yet although the Dutch belong to the tallest populations in the world (Fredriks, Van Buuren, Burgmeijer et al., 2000).

What is causing the secular change in size?

The underlying causes of secular changes are not known, but several hypotheses have been proposed. Two hypotheses relate to the elimination of growth-inhibiting factors and the introduction of growth-stimulating factors. It is generally thought that the secular increase in height and weight over the past century is most probably due to improved living conditions, improvement in housing and sanitation (a very important factor for good health), immunization, urbanization, industrialization, improved medical technology, better nutrition and environmental quality, dietary changes, changing patterns of infant nutrition; increased availability of food, improved awareness of health issues, increased population mobility (heterosis), reduction in child labor and reduction in family size. The improved health conditions are reflected in, for example, a remarkable drop between 1896 and 1996 of infant mortality, a sensitive indicator of a population's social and economic well-being. Death rates from infectious diseases also declined between 1921 and 1995 from 185 to 5.5 per 100 000. Evidence for all this is that the rate of change in height and mass has fluctuated over the past century and was likely influenced by changes in the environment and in the political climate.

Better nutrition has very likely been an influential factor for the secular changes. Most epidemiologists and nutritionists have assumed that the Western diet has been associated with improved life expectancy (e.g. Popkin, 1994). But a number of nutritionists and growth experts have challenged this approach (e.g. Hauspie, Vercounteren & Susanne, 1997), claiming among other things that excessive nutrition during child- and adulthood can lead to increases of cancer and other chronic diseases in middle age.

Both recently and in the past, societies have favored tall stature, and tallness has characterized upper social classes (Keyes, 1980) although numerous exceptions exist as well. Human biologists, but economists as well, support the thesis that a taller stature is a correlate of productivity, standard of living in a country and superior health. But not everyone idolizes tall people. Charles H. Townes, for example, the Nobel laureate in physics, proposed in 1996 a reduction of human size as the most effective means for improving the world because of the resources that would be conserved. In a very recent article Samaras and Storms (2002) presented an astonishing summary of the potential impact of a 20% taller US population on biodiversity and fiscal expenditures. Assuming that the variety of body types is maintained and that buildings, transport vehicles, roads etc. are scaled to the average height and body size of the population, extraordinary quantities of more food, water, farmland, natural resources and energy and so on would be needed. An enormous amount of extra garbage and industrial waste would be produced and there would be more pollution with the substantial impact on biodiversity.

The amazing review of Samaras and Storms has provided a new view and a discussion forum on secular changes and particularly on the (relative) importance that is given to height. But height is only one factor out of many that determine health, well-being or longevity of any person. Therefore, exercise, diet, stress management, personal happiness, avoidance of smoking, obesity, and drugs, all combined, exert a much longer influence on any one person's length and quality of life than height on its own.

Secular changes in sport

Specific populations, such as top athletes, have also shown secular increases in size, although these phenomena have been studied less, at least compared to other groups. Comparisons of heights and weights of athletes studied at several Olympic games between 1928 and 1976 have been reviewed by Borms and Hebbelinck (1984). In spite of the variation in sampling and the different ethnic composition of the athletic groups, it can be generalized that a considerable increase in size took place in this period. It remains of course difficult to partition the trends into separate estimates for secular effects per se and for those effects that might be attributed to selection or changes in rules and style of play, favoring larger athletes.

Studying changes in the physical characteristics of athletes over time is one way to find out if size and shape are determinants for success in a particular sport. It is hereby assumed that physique is an important but not the only factor determining sporting success. In certain sports, such as soccer, there is hardly a difference to note between soccer

players and the general population in terms of height and weight. In other sports though, such as tennis, a great variety of physique types among the players can be noted (although the advantage in tennis of being tall is recognized here), meaning that other characteristics (speed, technique, strategic skills, motor control…) play a great if not a greater role in success.

In several sports the rates of increases in height and weight have been higher than what could be expected from secular trend alone and therefore the changes point to the importance of changing physical attributes. Norton, Olds, Olive & Craig (1996) and Norton and Olds (2001) reviewed the secular trend in some sports where it is assumed that height and weight play an important role. To quantify the differences between athletic and non-athletic populations in terms of, e.g., height and weight, they designed the concept of the *overlap zone* (OZ). It is a mathematical method for calculating an overlapping zone, in percentage of the normal probability curve, between two bivariate distributions. It can best be visualized as the degree of superimposition of the frequency distributions of the two populations and can be quantified in a statistic called OZ or BOZ (bivariate overlap zone). The simple principle is that the sporting subpopulation is compared to the so-called 'source population' to recruit athletes from. The further the populations are apart, the more difficult it will become to recruit athletes with the desired physical attributes.

Anthropometric and other characteristics tend to be optimized and it is similar among elite athletes. The culmination of a final body shape and composition results from what Norton et al. (1996) termed *morphological optimization*. The same authors used four broad groups of athletic events to describe their model, combining morphological optimization and the evolution of humans, both athletes and non-athletes. These four groups are open upper-end, relative, absolute and open lower-end optimization. We will provide an example of the first group.

The first category (open upper-end optimization) contains sports where athletes with a larger absolute or relative size will have an advantage such as super-heavyweight lifting, Sumo wrestling and American football for body mass; basketball and heavyweight rowing for height. The effect of this optimization is the appearance of athletes in excess of 160 kg and world records for the super heavyweight lifters that have increased at a rate about twice that found with the other classes of lifters. Figure 1 illustrates the relationship between the weight lifted during world record lifts and the year of achievement for three weight classes. It is clear that the super-heavyweight records have increased at a greater rate than those in the two other weight classes.

Olds (2001) analyzed extensive data of elite rugby players. He reported major shifts in the physique of players who, as a whole, became taller, heavier and more mesomorphic. Over the last 25 years, particularly the body mass index (BMI), body mass and mesomorphy have been increasing at a rate twice the average increase over the century as a whole, and at rates that may be 5 times as great as drifts in the source population.

Data collected on the 'Australian rules' football players (Norton et al., 1996) also highlight the exaggerated rate of height of the tallest players relative to both the reference population and the smallest players over about 100 years.

The last example relates to NBA basketball players (Norton et al., 1996). Data collected since 1945 indicate that the rate of change in mean height of all players (2.25 cm/decade) is significantly greater than that of the general population. However, the rate of height increase for the taller NBA players is almost twice that of the mean height increase and about 4 times that of the general population.

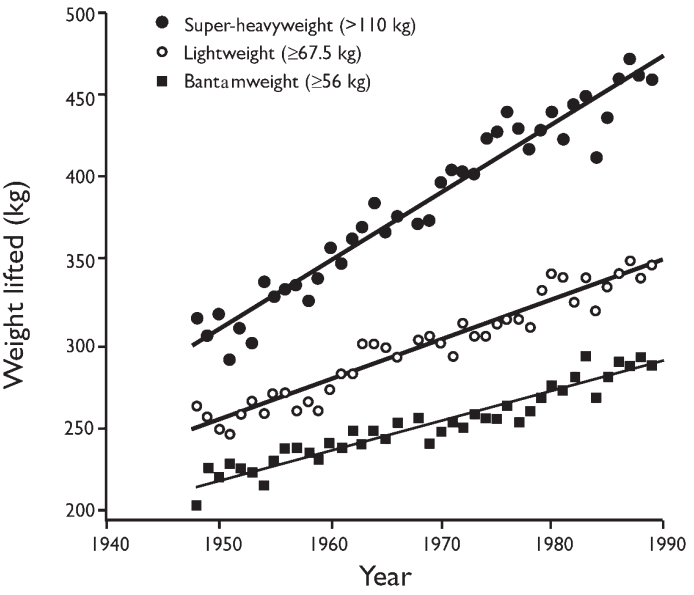

Figure 1. The relationship between the weight lifted during world record lifts and the year of achievement for three weight classes (graph graciously provided by Tim Olds).

A comparison of the change in body size from 1975 until now across 22 different sports tells us that the rate of change of body size is proportional to how much the characteristic body size deviates from the population average and thus the small

remain small or get smaller, while the big get bigger (Norton & Olds, 2001).

The trend toward open upper-end optimization is likely related to greater selectivity in recruitment, the generation of a genetic pool of large athletes, globalization of sport, the greater financial incentives in professional sports, but perhaps, and sadly enough, also drug (ab)use. This evolution is likely to continue in the future as the secular changes may persist and the sports may become more specialized, globalized and offering more financial incentives.

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SEKULARNE PROMJENE U SPORTU

Sažetak

Uvod

Pojam sekularnih promjena (poznatiji kao sekularni trend) i s njime povezane pojave tradicionalan je znanstveni problem kojim se bave humana biologija, auksologija (znanost o rastu) i sportska znanost ili kineziologija. Sekularni trend općenito znači promjene veličine tijela i drugih tjelesnih obilježja, zatim promjene pokazatelja zrelosti i motoričke učinkovitosti koje se zbivaju tijekom jednoga ili više desetljeća. Te promjene mogu biti pozitivne, što podrazumijeva povećanja i ubrzanja, ili negativne, tj. što podrazumijeva smanjenja ili usporavanja. No pozitivne promjene ne moraju biti ni poželjne ni dobrodošle - primjerice, povećanje masnoga tkiva.

Literatura o sekularnim promjenama (od svih tjelesnih karakteristika najčešće su se ispitivale visina i masa tijela) tijekom rasta i u ranoj zreloj dobi vrlo je opsežna i dolazi iz svih dijelova svijeta, a ispituje i mušku i žensku populaciju i visokih i niskih društvenih slojeva. Literatura je nešto manje obilna kada su u pitanju ispitivanja specifičnijih populacija, kakva je i populacija vrhunskih sportaša.

Na temelju literaturnih podataka o sekularnim promjenama u veličini tijela može se zaključiti slijedeće: neznatne su sekularne razlike porođajne mase i duljine tijela; povećanja u tjelesnoj visini i masi postaju očita pri koncu prve godine života i progrediraju s dobi sve do 12.-13. godine u djevojčica, odnosno 14.-15. godine u dječaka. Najveće sekularne razlike u masi i visini tijela očituju se tijekom puberteta, dok se nakon puberteta sve do mlađe zrele dobi veličina sekularnih povećanja progresivno smanjuje. Sekularne promjene su izraženije u Europi, SAD-u i Japanu, dok se u (nerazvijenim) zemljama Azije, Afrike i Latinske Amerike, ako se uopće i pojavi, bilježi tek neznatan, ako ne i negativan sekularni trend.

Razlike u tjelesnoj veličini djece različite dobi odražavaju i razlike u sazrijevanju. Danas djeca sazrijevaju ranije nego što su sazrijevala prije stotinu godina.

Što uzrokuje sekularne promjene u veličini tijela?

Postavljeno je nekoliko hipoteza o tome, a sve se mogu svesti na uklanjanje za rast inhibirajućih faktora uz istodobno uvođenje za rast stimulirajućih faktora. Tako se nabrajaju slijedeći faktori odgovorni za sekularna povećanja u visini i masi tijela tijekom prošlog stoljeća: poboljšani uvjeti života, bolji stambeni i sanitarni uvjeti, cijepljenje, urbanizacija, industrijalizacija, dosezi medicinske tehnologije, bolja prehrana, bolji okolinski uvjeti života, obilje hrane, zdravstvena i higijenska prosvijećenost, povećana migracija stanovništva, smanjenje (ili ukinuće) dječjeg rada i smanjenje broja članova u obitelji – sve te promjene vezane su za životnu sredinu ili političku klimu.

Bolja se prehrana smatra najvažnijim čimbenikom za pojavu sekularnih promjena, ali i za produženje očekivane životne dobi. Ipak, mnogi su znanstvenici doveli u pitanje potonju tvrdnju suprotstavljajući joj dokaze o tome da prekomjerno uživanje hrane tijekom djetinjstva i odrasle dobi povećava rizik od karcinoma i drugih kroničnih bolesti u srednjoj životnoj dobi.

Autor posvećuje osobitu pozornost članku Samarasa i Stormsa (2002) u kojemu su predstavljeni zapanjujući podaci o potencijalnom utjecaju povećanja visine tijela populacije SAD-a za 20% na biološku raznolikost i fiskalnu potrošnju.

Sekularne promjene u sportu

I u specifičnim populacijama, kakva je i populacija vrhunskih sportaša, također je zabilježen sekularan porast veličine tijela. Borms i Hebbelinck (1984) usporedili su tjelesne mase i visine sportaša sudionika olimpijskih igara u razdoblju od 1928. do 1976. godine. Usprkos nedosljednom uzorkovanju i raznolikom etničkom sastavu grupa sportaša, uočeno je znatno povećanje tjelesnih mjera. Naravno, vrlo je teško razlučiti koliki je bio doprinos sekularnih promjena per se, a koliko su povećanju pridonijele selekcija sportaša te promjene pravila i stila igre koje su mogle favorizirati krupnije sportaše.

Proučavanje mijena somatskih karakteristika sportaša kroz vrijeme jedan je od načina da se otkrije jesu li veličina i oblik tijela determinante uspjeha u nekom sportu. Autor, naime, pretpostavlja da je tjelesna građa bitan, ali nikako ne i jedini faktor koji određuje sportski uspjeh.

Da bi kvantificirali razlike u tjelesnoj visini i masi između sportaša (sportovi u kojima te dvije antropometrijske karakteristike igraju važnu ulogu) i populacije ne-sportaša, Norton i suradnici (1996) te Norton i Oldson (2001)

oblikovali su koncept, matematičku metodu izračunavanja *zone preklapanja* (overlap zone – OZ). To je matematički model za izračunavanje zone preklapanja između dviju distribucija u postocima normalne raspodjele. Najbolje se prikazuje kao stupanj preklapanja distribucije frekvencija dviju populacija i može se kvantificirati u statistički imenovanom OZ (za jednu varijablu) ili BOZ (bivarijatna zona preklapanja). Jednostavniji je princip da se populacija sportaša usporedi s tzv. «izvornom populacijom» iz koje sportaš dolazi. Što su populacije udaljenije, teže će biti izdvojiti sportaše sa željenim tjelesnim karakteristikama.

I u sportaša postoji tendencija morfološke optimizacije (*morphological optimization*) tjelesnih obilježja i građe. Norton i suradnici (1996) koristili su četiri velike skupine sportskih disciplina za opis svoga modela: optimizacije otvorenih gornjih krajeva, apsolutne optimizacije, relativne optimizacije te optimizacije otvorenih donjih krajeva U nastavku je autor prikazao primjere za prvu skupinu.

Analiza promjena tjelesnih mjera u 22 sporta od 1975. godine na ovamo otkrila je kako je brzina mijenjanja tjelesne veličine proporcionalna tome koliko se karakteristična tjelesna veličina otklanjala od prosjeka populacije – sitni su ostajali sitni ili su se još i smanjivali, a krupniji i veći su postajali sve krupniji. Trend morfološkog optimiranja otvorenog gornjeg kraja u sportu vrlo je vjerojatno povezan s povećanjem selektivnosti, genskim bazenom “velikih” sportaša, globalizacijom sporta, većim financijskim poticajima u profesionalnom sportu, ali, nažalost, i sa zloporabom ergogenih sredstava. Ta će se evolucija vrlo vjerojatno nastaviti i u budućnosti.

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