Somatic traits in the selection of potential elite swimmers

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ABSTRACT

STAGER, J.M. and BABINGTON, J.P. Somatic Traits in the Selection of Potential Elite Swimmers. *Kinesiology*, Vol. 2, No. 1, pp. 39-50, 1997. The identification of talent is a complex problem in competitive swimming. An assumption is made that adequate knowledge of the sport is available such that individuals with potential can be identified at an early age. For instance, traits consistent with success in the sport may vary as a function of the age of the athletes who are competing. Thus, traits judged to be important when competitors are peripubertal may not be those seen as important at a later age. One approach is to review characteristics of athletes who currently comprise the elite population. This makes a further assumption, however, that the sport has matured such that the competitors display traits which are related to swimming success. Other factors inherent in the selection or training process do not arbitrarily eliminate the eventual elite performers prior to their athletic maturity. An important case in point may be issues specifically pertaining to women swimmers and or the true sprint swimmer. Despite these problems, a number of somatic traits have been reported consistently in the literature pertaining to competitive swimming. Elite swimmers tend to be taller than a non-competitive cohort and have a greater arm to height ratio. This is true for both males and females. Swimmers weigh more than their sedentary peers due to greater lean mass as opposed to fat mass. The somatotype for swimmers is within the ecto-mesomorph region and the suggestion is that in general they are relatively late maturers, an observation that conflicts with earlier reports. The lung volumes of swimmers tend to be different from other athletes as well as the sedentary population. It may well be that as training, nutrition and other factors improve and the sport continues to mature, a clearer, albeit somewhat different, picture of the optimum traits necessary for success in swimming will develop.

Key words: SOMATOTYPE, STATURE, BODY WEIGHT, MATURATIONAL RATE, SPIROMETRY, SELECTION OF SWIMMERS

No one will argue the advantage of above-average height in basketball. It is also obvious that a large body size is an advantage in sports such as football and the lack thereof is important in international gymnastics. In competitive swimming, however, somatotypic advantages do not appear to be quite so obvious. Competitive swim coaches can cite examples of successful swimmers of different body shapes and sizes for both men and women. Pablo Morales and Michael Gross, Amy Van Dyken and Angel Martino are examples of wide contrasts in somatotypes in world class athletes competing in similar events. Performance in swimming is multifactorial and complex, and it may be this complexity that allows for morphological variation among successful swimmers. Clearly no single factor is responsible for elite performance in swimming. The questions at hand, however, are:

Are there somatic traits that portend or improve the odds of competitive success in swimming? Based upon certain traits, can athletes be selected into swimming whose body dimensions or somatotype will favor or lead to success at the highest level?

For talent selection to work, several problems need to be addressed. Few swimmers are developed within a season, let alone in a few years. By the time children reach physical maturity, it is generally too late to initiate an effective swim-training program that will result in international class athletes. Thus, to be of any significant success, the somatic traits ot interest must be evident or at least predictable during preadolescence or the peripubertal period. In the United States, our successful competitive swimmers begin routine training at an early age. Estimates available suggest that most of our collegiate and national-class athletes begin training between eight and nine years of age (Stager et al., 1984; Hinton, 1995). Measurements obtained from swimmers after these early years are difficult to interpret as the effects of training, selection and genetics are already intertwined. Because of the large number of children involved in competitive swimming in the United States, the 'selection' that occurs is often referred to as "natural" at least by Eastern European Sport Specialists (Bompa, 1985). Clearly, this has nothing to do with Darwinian evolution! It can truthfully be said that talent selection in the United States, as is the case in most other countries, is done primarily with a stopwatch!

The next problem to be addressed is, for selection to be successful, there must be clearly identifiable traits coincident with success in swimming. The common, first approach in identifying important somatic traits for a sport is to analyze data obtained from successful athletes. The assumption here is that the elite performers as a population will illustrate most clearly those genotypic traits important tor success. It is suggested that the further up the competitive ladder, the more homogeneous the population becomes in terms of the characteristics required tor success (Carter, 1970). To this end, data have been collected from many international class swimmers over the years (Carter and Marfell-Jones, 1994). This approach is only valid if the assumption is made that the sport has "matured" to the extent that the athletes participating in it are those that will perform to the highest level possible. It must be accepted that other factors, such as nutrition, training, techniques, facilities, coaching, etc., are not the primary limiting factors in terms of elite performance. In other words, other factors are not masking the importance of certain somatic genotypic or phenotypic traits.

In addition, there must be traits that can be identified that are significantly different from those of the general population. A weakness of much of the literature in this area is that values derived from nonathletes or a representative subset of the general population is generally lacking. Data are available from longitudinal growth studies, i.e., FELS, but statistical comparisons between athletes and controls are not generally made. Although it is important to know what athletes look like, it is just as important to know how they differ from the general population and which traits are phenotypic expressions and which are genotypic. One dilemma is defining the population suitable to compare the athletes with when the athletic cohort is multinational and/or multiracial. There have been somatotypic traits of elite swimmers that fit these criteria, unfortunately some of these traits appear to have changed over the last few years and may still be changing presently. These "changing traits" must be dealt with first.

For instance, it is possible that the athletes competing within the sport can dictate the traits necessary for success in it and that these traits may shift over time. Therefore, it must be accepted that traits we chose are only those that appear to favor success within the sport at present. This can be interpreted to mean that traits necessary for success in swimming may change over time as the sport matures and athletes participating within the sport ultimately become more competitive, in other words, the athletes competing in swimming now may dictate the attributes necessary for current success and that a decade or two from now, other traits may become more evident or important. Like-wise, traits that might have been suggested as a competitive advantage in the past may no longer be operational. We must be careful not to lose future talent due to our present ignorance!

As an example, competitive swimming has been portrayed as an "early entrance-early exit" sport in that swimmers begin training at a young age and end competition in their early teens. To a large extent this is almost an accepted fact, particularly for women swimmers. In this scenario, it was suggested that the early maturer would have a competitive advantage because, in general, early maturers are taller and stronger than late maturers at ages which span the competitive range (Malina, 1983). Supportive data for this hypothesis is derived from the developmental rates of swimmers. Menarche, the initial onset of menstruation, has been used as a convenient marker of developmental pace in women. Women swimmers were, for many years, cited as the exception to the observation that women athletes were older at menarche than sedentary controls (Malina, et al 1973, Malina et al 1978, Meleski et al 1982). Swimmers were reported to be younger at their first menstrual cycle than nonathletes in studies published in the 1960s and 1970s (Astrand, 1963). Later data suggested that swimmers were similar in age at menarche when compared to the general population (Peltenburg, 1984, Malina et al 1979, Malina, 1983). The most recent estimates, however, now suggest that, similar to women involved in other sports, women swimmers are significantly older at menarche than sedentary controls (Frisch, 1981; Stager, 1990; Malina, 1994) (Figure 1).

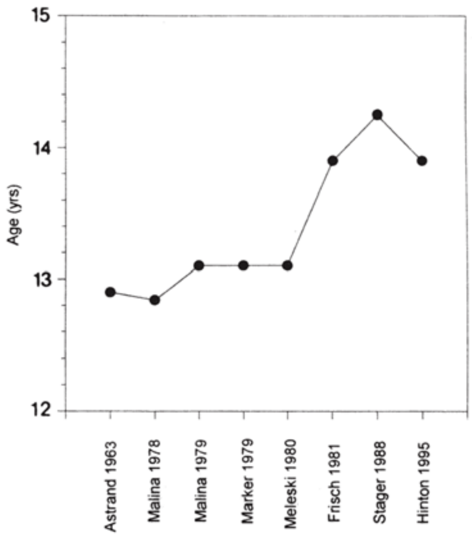

Figure 1. Mean age at menarche in swimmers over the last three decades.

Is this changing age of menarche due to the effect of training on maturation, i.e., has training changed? Or, is menarche linked to some somatic trait that signals a change in the population participating in swimming. And, of what relevance is this in terms of selecting potential elite performers?

The answer to these questions appears to be in the analysis of the age of the athletes competing at the national level (Daly et al, 1995). In the United States, women meeting a certain qualifying standard can compete at the National Championships regardless of age. Recent analysis of age records that were obtained from 1972 through 1994 indicates that the elite U.S. women swim population has increased in age by more than three years over these two decades (Figure 2).

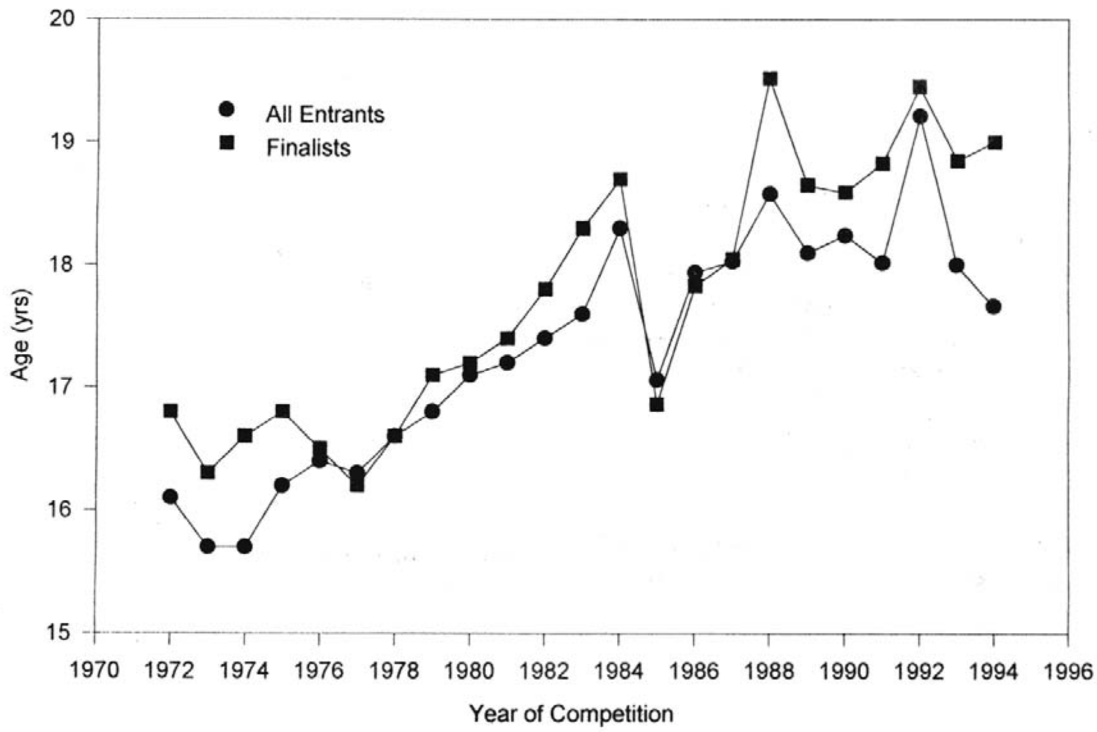

Figure 2. Mean age of all entrants and finalists competing at the U.S. Swimming National competition over the past 25 years (from Daly et al 1995).

If we include the Olympic data presented at the XI FINA World Sports Medicine Congress by Kavouras and Troup, we add several more years to this. It is anticipated that the 1996 U.S. Olympic swim team will be even older! Included within the analysis is a comparison of finalists with entrants. Results illustrate that the finalists were older than nonfinalists and sprinters older than distance swimmers. That this trend is generalizable to the international community is shown in Figure 3.

Astrand et al, (1963) identified three possible hypotheses that might account for changes in the characteristics of elite athletes within a sport over time: (1) The general population parameters as a whole from which the athletes are derived has changed. (2) The sport has changed such that the physical traits necessary tor success have changed, or (3) The training procedure and practices used within the sport have changed such that the physiological impact of this activity upon participants is different. There is current debate centered upon whether menarche in the general population is declining (Tanner, 1981). There is not much evidence that suggests training is beginning at earlier ages or practices are becoming more difficult. Thus, the hypothesis set forth here is that the increased age of competitors appears to have resulted in a change in the sport and thereby the somatotypic traits coincident with success in it. This reflects Astrand's second possibility.

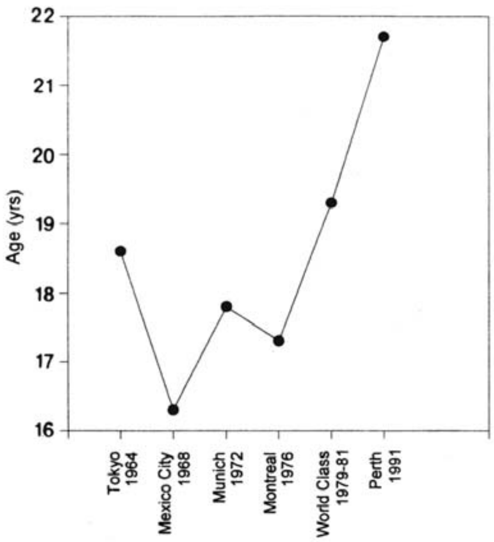

Figure 3. Mean age of swimmers at selected international events over the past three decades.

When all the athletes within a sport are young, those who mature at an early age, may in fact have a temporary competitive advantage when compared to later, slower maturers (Jones, 1949). Early maturing individuals tend to be taller, stronger and more agile than late maturers during the adolescent age (or until both groups reach the same biological state of development). (See Malina, 1983 for review.)

However, in general, the case can be made that later maturers are more athletically adept than early maturers when both reach biological maturity. In relation to physical size, late maturers are taller, have longer limbs, more linear physique, and more ectomorphic somatotype when compared to early maturers (Malina, 1994; Shuttleworth, 1937; Tanner, 1962). This appears to be related to a more prolonged adolescent growth spurt (Tanner, 1962). Later maturers have been shown to perform better on tasks requiring motor skills and in athletic events in which the body must overcome the force of gravity (Bar-Or, 1975; Beunen et al, 1983).

To coalesce this information, it appears that, due to the change in the duration of competitive participation, a change in the developmental attributes appropriate for success in swimming has occurred. As the duration of competitive participation and the participant age has increased, the temporary advantage of the early maturer has been superseded by the superior athletic attributes of the later maturer. Thus, it seems that changes within the sport have been caused in part by changes in society in terms of the opportunity acceptance and incentives resultant from competition. These changes have allowed us to identify traits seemingly important for success in swimming. As suggested below, most of these traits (stature, long-limb length, etc.) appear to be correlated at least in women with slow developmental pace. We must be careful therefore as coaches to encourage these late developers and not lose them early in their swimming careers.

A second approach to identifying important somatotypic traits, equally valid albeit somewhat more complex, is to employ theoretical dictates developed from ancillary fields to predict the optimal somatic traits of swimmers. Attempts have been made to apply hydrodynamic principles to human swimming with marginal success. Unfortunately, Clarys (1978) has concluded that "indisputable principles from fundamental hydrodynamics such as drag/surface area and drag/length ratios are not to be applied to the human body." Later, he broadened this conclusion by stating that "the shape of the human body has hardly any influence on the active drag." In addition, he further states that "shape, composition, and dimensions of the body exert little or no influence on the hydrodynamic resistance" (Clarys, 1979). These conclusions were reached because of the effects made by complex variables such as constant changes in body position and limb position. The author concludes that stroke mechanics and technique may play the primary role in this regard. This is not to say that body type or morphological characteristics are not relevant in swimming. The requirements to overcome the resistive elements to produce lift, etc., may indeed select for certain traits whose expression will enhance mechanics, techniques, improve efficiency or favor such factors as stroke length, or power production and force application. However, it seems appropriate to suggest that more research needs to be focused upon these aspects before this approach can be used in talent identification.

It therefore appears that the first approach to assess current elite athletes to identify important somatic traits is the only viable one at the present. Thus, the questions that must be answered from analysis of current elite athletes are: What is unique somatotypically about elite swimmers? Can these traits be observed at an early enough age to select individuals and then provide the necessary external stimuli to develop world-class athletes? In each variable discussed henceforth, an attempt to address both questions will be made.

Stature. Perhaps the trait that has been most consistently observed as different from that of sedentary populations is stature. That swimmers are taller than sedentary peers appears true for both males and females and this has been shown to be virtually independent of age (Males: Eriksson, 1978; Malina, 1994; Spurgeon and Giese, 1984; Troup, 1991; Females: Bernink, 1983; Andrew, 1972; Astrand, 1963; Peltenburg, 1984). Swimmers are taller than their sedentary cohorts from a young age, with differences becoming more pronounced beyond the age of 12 years (Figure 4). Information pooled from a variety of sources further suggests that swimmers have become taller (Figure 5) over the last three decades (Mazza et al 1994). That this trend will continue, remains to be determined. In terms of the nature of the height difference between swimmers and controls, it has been shown that differences in height can be accounted for by differences in leg length relative to trunk size (Richards, 1983). Both observations may again relate to developmental pace as later maturers have been shown to be taller and have increased long bone lengths (Shuttleworth, 1937, Peltenburg, 1984). (By the way, concern over intense training negatively impacting growth seems to be allayed by this data!).

The ability to predict adult stature has been studied for some time. Besides mid-parental height, menarcheal age and skeletal age are both associated with eventual adult height (Wellens et al, 1992). It has been suggested that height/weight ratios indicative of "linearity of build" are evident as early as the age of six years and persist throughout adolescence (McNeill and Livson, 1963). Finally, data exists that suggests for women swimmers, the father's height is a better correlation than the mother's or mid-parental height (Stager, unpublished). How these relationships are altered by routine intensive activity is not entirely known, but best estimates are that training has little impact upon inherited growth and development (Malina, 1994).

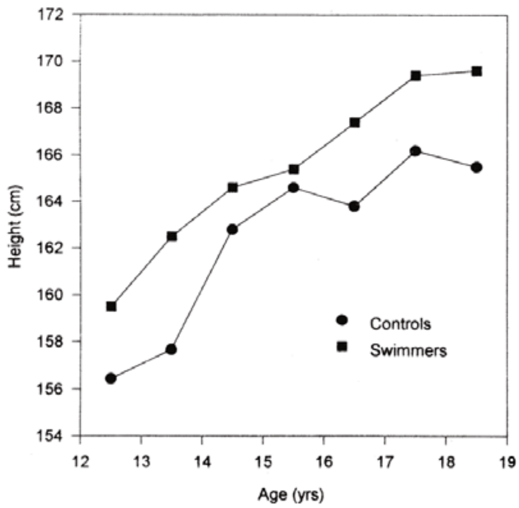

Figure 4. Mean height (cm) of swimmers and a control sample across different ages. Height is plotted at the midpoint of the age grouping.

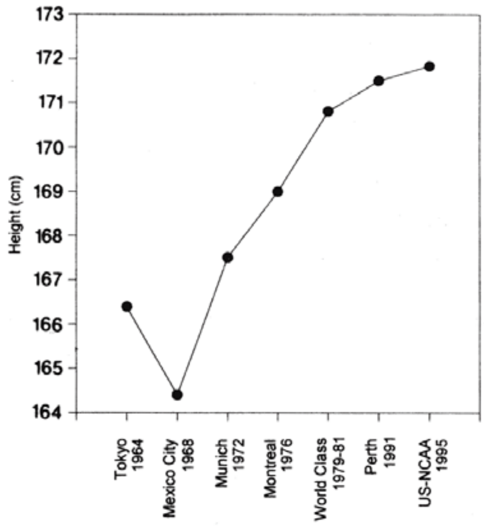

Figure 5. Mean height (cm) of swimmers at selected international competitions over the past three decades.

Body Weight. Swimmers tend to be of greater weight than sedentary peers (Peltenburg, 1984; Carter, 1994). This has been shown to be particularly true for women, more so than for men. In addition, the difference in weight when partitioned appears due to increases in lean mass rather than fat mass. Elite swimmers have been shown to have significantly lower body fat as a percentage of total body weight when compared to age-matched controls (Stager, Cordain and Becker, 1984). At the U.S. women's college-level, more competitive teams are known to have lower fatness on average than less competitive teams (Edwards, 1989). Further, within the post-pubertal female swimming population, the better performers have been shown to have greater lean mass than poorer performers, second in importance only to age (Stager and Cordain, 1984). Weight, however, is somewhat more difficult to interpret from data derived from athletic and nonathletic sources as weight cannot be interpreted to infer much about body composition. A wellknown effect of exercise is a modest increase in lean mass and a modest decrease in fat mass. Exercise may not necessarily cause a decrease in body weight, only a redistribution of weight toward lean body mass. However, when young-premenarcheal swimmers are compared to premenarcheal controls, the swimmers are shown to have a greater body density and weigh more (Figures 6a and 6b, Stager, unpublished). Given that muscle mass is not known to be enhanced by training (albeit strength is trainable) before adolescence, it may be that this is an inherent trait rather than one caused by environment (Ozmun et al 1994).

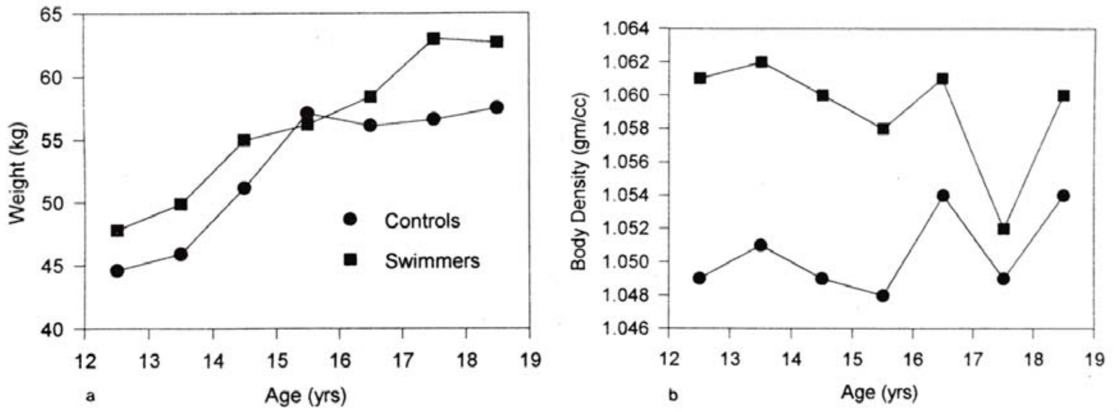

Figure 6. (a) Mean weight (kg) of swimmers and a control sample across different ages. (b) Mean body density (gm/cc) of swimmers and a control sample across different ages. For both figures, data is plotted at the midpoint of the age grouping.

Thus, although weight alone is not as important a variable as is lean mass, height/weight ratios may be indicative of greater lean mass in young swimmers. (Figure 7).

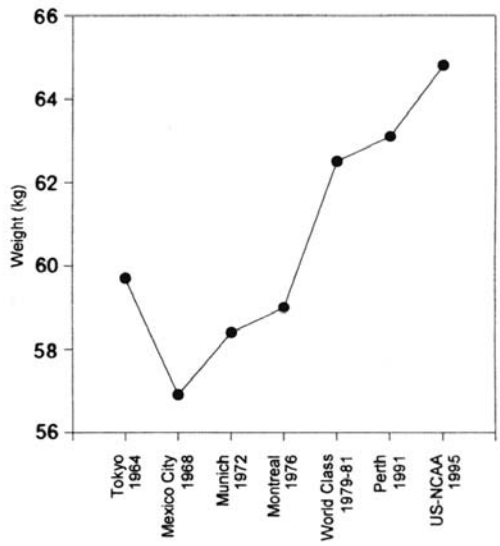

Figure 7. Mean weight (kg) of swimmers at selected international competitions over the past three decades.

It needs to be recognized that forcing young adolescent athletes to emulate successful mature athletes through artificial means can destroy performance and be life threatening in certain circumstances.

Somatotype. Somatotype, as defined by Carter and Heath (1990), is briefly described as a quantification of the shape and composition of the body using a three-number rating representing endomorphy, mesomorphy and ectomorphy. The numbers are given in the same sequence (i.e., 3-5-3) where the first, endomorphy is the relative fatness, mesomorphy is the relative muscularity, and ectomorphy is the relative linearity or slenderness (Carter and Heath, 1990). The most recent somatotype for elite male swimmers is reported to be 2-5-3 which is in the ectomesomorphy range.

The female swimmer is reported to be 3-4-3, an upper central somatotype. Differences within the sport suggest that distance swimmers of both sexes are more endomesomorphic than sprinters or middle-distance athletes (Carter and Marfell-Jones, 1994). Over time, it appears that all swimmers are becoming less endomorphic, more mesomorphic and more linear (Carter and Marfell-Jones, 1994).

Bouchard et al., (1980) estimates the genetic contribution to somatotype to vary slightly among the three principal components. However, inheritedness for all three appears to explain a moderate amount of the overall somatotypic variance; between 25 to 80%.

Limb length and body ratios. In a comparison of swimmers, it was shown that the better swimmers tended to be taller and had greater limb, hand and foot lengths (de Garay, 1974). Female swimmers have been shown to have greater limb/trunk ratios and shoulder hip ratios as compared to sedentary controls (Richards, 1983). Armspan to height ratios for swimmers is reported to be 1.05 for men and 1.03 for women as compared to a reference population in which this ratio is reported to be 1.0 (Montpetit and Smith, 1988). These findings tend to be consistent with later skeletal maturity and a later reproductive maturity. Thus, although limb length and body ratios are traits that may be identifiable at a young age, it is more likely they are correlates of a slower pace towards physical maturity.

Maturational Rate. In an attempt to determine the relationship between exercise and normal growth and development, the onset of reproductive function in several large competitive women swim populations was evaluated in the early 1960s, 1970s and 1980s (Stager et al., 1984). Girls were specifically targeted as the study population as most women can retrospectively determine this specific developmental event with minimal error. As mentioned above, previous reports suggested that swimmers were early maturers in contrast to athletes involved in other sports. This occurred although swimmers began training at a significantly younger age than other athletes. If training was to have an effect on developmental rate, then swimmers should be observed to be one of the oldest, if not the oldest at menarche of sportswomen. The conclusions derived from this most recent data were: (1) Women swimmers were older at menarche than nonathletic controls. (2) The older the population of swimmers, the later the age at menarche became. (3) Those with the latest age of menarche were observed to be the best performers. (4) The best performers were shown to have a significantly later age at menarche.

That this is an inherited trait has also been borne out by the literature (Johnson, 1974; Popenoe, 1928). Data derived from athletes and their sisters and mothers also confirms that developmental pace (as marked by menarche) is inherited and seemingly unaffected by training (Stager and Hatler, 1988; Baxter-Jones et al., 1994; Malina et al., 1994).

Relationship between mothers and daughters, swimmers and their sisters all confirm that swimmers and their relatives are older at menarche than controls, and that this later menarche is an inherited trait. The later maturer has been shown to have characteristically long legs for her stature, relatively narrow hips, and a generally linear physique (Tanner, 1962). Similar results remain to be described in males. Differences do exist while certain trends appear to be similar. Thus, the previously mentioned somatotypic traits, height, limb length, body ratios, etc., may all be correlates with later development.

Spirometry. Though not strictly somatotypic traits, another common finding in the literature pertaining to young swimmers, is large static lung volumes (Figure 8).

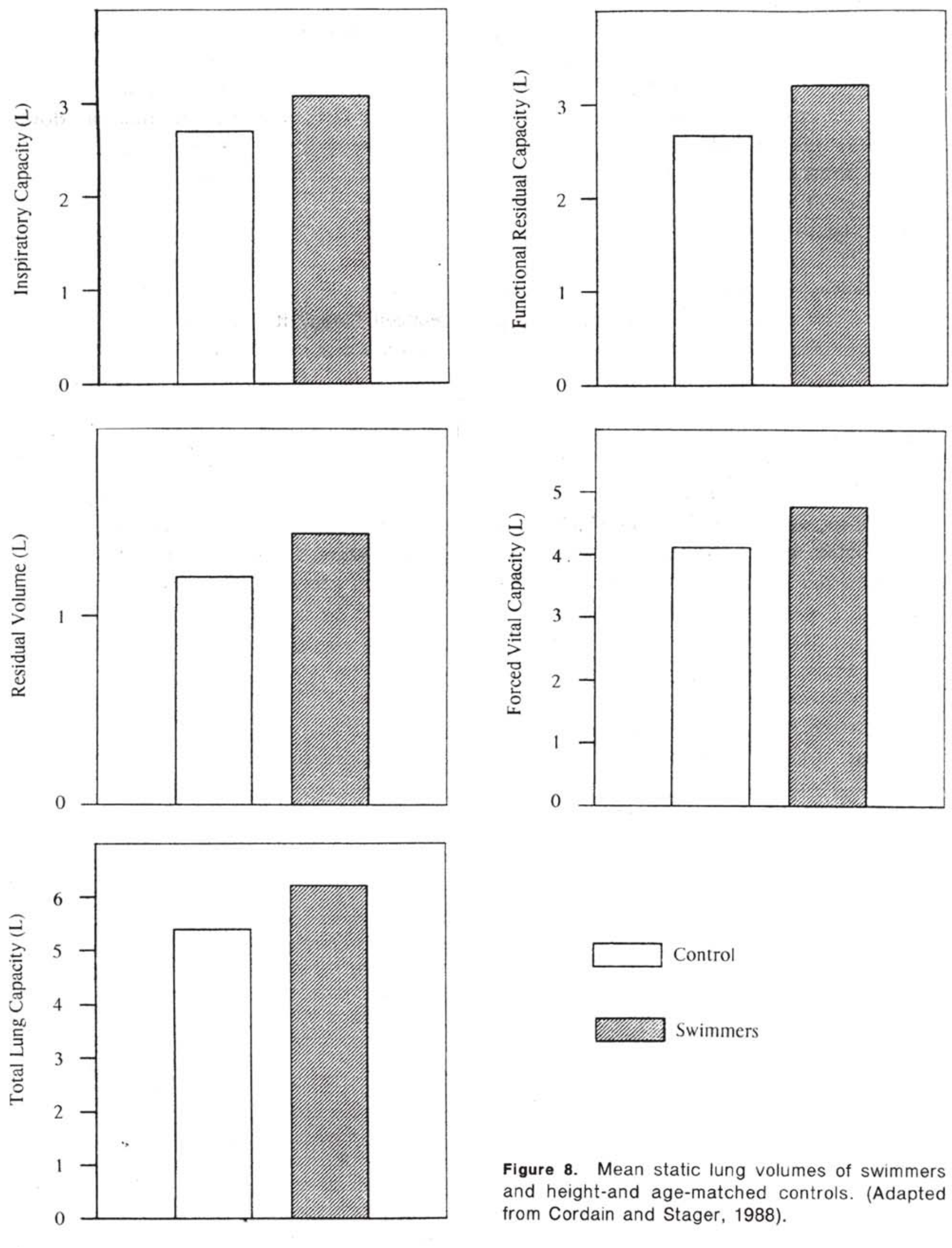

Figure 8. Mean static lung volumes of swimmers and height-and age-matched controls. (Adapted from Cordain and Stager, 1988).

Although it is generally accepted that physical training induces few morphological changes in the lung (Dempsey et al., 1977), repeated observations of swimmers show larger than predicted lung volumes (Bradley et al., 1985; Magel and Andersen, 1969; Zinman and Gaultier 1986). As lung volumes are reported to be highly inheritable, it has been suggested that large lung volumes may exist before the onset of training (Ericksson et al., 1978). Others have suggested that the lung volumes of swimmers show an advancement with age that cannot be ascribed to normal growth alone (Andrew et al., 1972; Zauner and Benson, 1981). Nevertheless, this later conclusion remains controversial (Vaccaro and dark, 1978). The advantage of this trait is also unclear, although it may be speculated that buoyancy resultant from a lower effective body density may be a positive performance factor. Alternatively, large lung volumes may allow for greater pulmonary diffusion or enhanced alveolar extraction which might also confer some competitive edge (see Cordain and Stager, 1988 for review). Additional properly designed long-term studies are required before eliminating this trait as a select, inherited parameter in elite competitive swimmers.

Summary. The available literature makes clear the concept of identifiable traits of elite competitive swimmers that are distinguishable from the general population. The argument has been made here and by many others that many of these traits appear inherited, few seem resultant from the specific stimuli of competitive swim training. More data are available for young women swimmers than for young men primarily because of interest in the effect of exercise on growth and reproductive development and because of the ability of women to recall important developmental events. A central theme appears to be one that supports the notion that a slower developmental pace appears positive in terms of eventual mature athletic performance. A second theme that is evident, yet subtle is that the continued participation by older athletes may have altered the traits necessary for success in swimming. Thus, it may be that reduced competitor turnover and enhanced persistence in swimming may well be keys in terms of the advancement of times within the sport. This discussion has centered upon somatic traits, primarily those related to body size. Additional comments could be added which would pertain to muscle fiber type, muscle mass, and peak power output. The aforementioned traits are also known to be related to athletic success and have also been shown to be largely influenced by genetics. It is argued that continued research in this area is warranted. It may well be that as training, nutrition and other factors improve and the sport continues to mature, a clearer, albeit somewhat different, picture of the optimum traits necessary for success will be developed.

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