



Multi-year training
(swimming, from childhood to adulthood)
: literature paper

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Abstract ;

The development of the young swimmer determines the scientific approach of the training process organization. Thus the design of training programs for young swimmers requires to know the biological age, whose determination remains an invasive method. However, there are easy methods for determining biological age, such as that of Wutscherk (1988), whose formula is based on a few anthropometric parameters. But before the Peak Height Velocity (PHV) the trainers refer rather to the chronological age and do not make a difference between the training programs of the two sexes (Bayli, 2004). High-level sport requires 10 years of preparation, i.e. an average of 3 hours training per day (Bloom, 1985; Bloom et al., 1990; Ericsson, et al., 1993; Ericsson and Charness, 1994, Salmela et al., 1998). Experience has shown that the age of best swimming performances is 22 years for women and 24 years for men, and that they occur in middle distance swimmers on average two years earlier than in sprinters (Allen et al., 2014 ; Buhl et al., 2013 ; Kollarz et al., 2013 ; Wolfrum et al., 2013 ; Knechtle et al., 2016 ; König et al., 2014), by preparing the technical, physical and psychological aspects for 8 to 10 years for women and 8 to 12 years for men, in order to reach the international level, without reducing the aforementioned deadlines. In this article, we wanted to emphasize the importance of growth and maturation in planning and periodizing a swimmer's long-term training process.

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1. Introduction

The human organism undergoes many changes during its lifetime, involving the evolution of physical dimensions (growth), functional (development) as well as tissues and systems (maturation) (Van Prahg, 2008).

Training exerts an influence on the various vegetative organic systems (maintenance of homeostasis), cardiovascular, muscular, tendon – ligament and joint. Each of them requiring a certain period of adaptation (Neumann, 1988), making the athlete different from the general population according to the *"Performance Sports Medicine Perspective"* (Speed et al., 2011).

High performance sport requires practice from an early age, for this, it is necessary to know the biological aspect of growth and more precisely its laws and factors.

1. Variations in growth from childhood to adult age

Growth depends on lifestyle and eating habits (Beunen and Malina, 1996) and is influenced by climatic (Macfarlane, 1963), environmental (hygiene, habitat, nutrition), psychosocial (Sussanne, 1986) and economical factors.

From the first year of the being's life, growth evolves with a certain speed, for example until the age of one year the height reached is 22 cm per year (early childhood). At 4 years old growth decelerates very quickly, and slows down and/or stabilizes around 11 years old and ends with a height peak velocity around 12 years old in girls and 14 years old in boys (Bayli, 2004). Finally around 14 - 15 years old, the speed of growth

slows down, more precisely around 16 - 17 years old for girls and 18 - 19 years old for boys.

In addition to the variation in speed, growth follows a rhythm that leads the individual to adult height (Hauspie, 2003).

The periods of stability and acceleration of growth obey the laws of alternations, proportions and asymmetries of puberty :

- a. Puberty laws : for example before puberty, there is a development of the lower limbs (bone growth in length), after puberty growth is more pronounced in the trunk, and muscle development takes over (Godin, 1935 *cité in* : Palau, 1993).
- b. Alternations laws, implies a dysmorphism and / or alternate growth of the different parts of the body, as well as the bones which are not developed at the same time, this is what is observed between the lower limbs and the trunk (Godin, 1935).
- c. Proportions laws : each part of the body corresponds to a precise stage of development, for example the brain reaches 80% of its adult size at 3 years old and 95% at 6 years old, while the growth of the body in overall is only 50% of adult standards (Eiben et al., 1986).
- d. The laws of asymmetries relate to the asymmetries of the double organs in children, which is quite natural (Palau, 1993).

2. The growth of muscle tissue

The muscular tissue of the child follows the same evolution as the height and the weight (figure 1), nevertheless the two sexes are not similar (Tanner, 1982). Muscle mass represents 25% of total weight at birth, and more than 40% in adulthood (Wilmore, 2002), but may increase with training and diet (Wilmore et Costill, 2006) and reaches adult height between the ages of 16 and 20 years old for the girls, and between 18 and 25 years old for the boys (Wilmore et Costill, 2006).

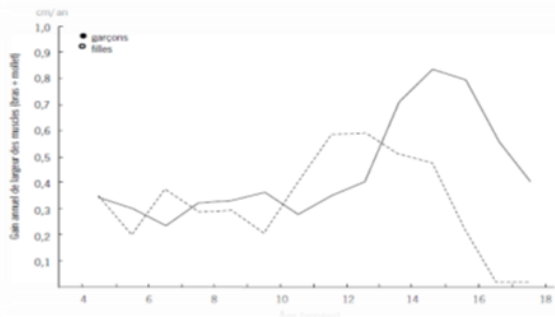


Figure 1. Evolution of muscle tissue according to age and sex (speed curve) (according to Tanner, 1962, 1978).

2.1. Puberty

The thumb sesamoid is a marker of bone maturation and/or puberty (Figure 2), but does not appear at the same time in both sexes (figure 3).



Figure 2. Sesamoid bones of the hand

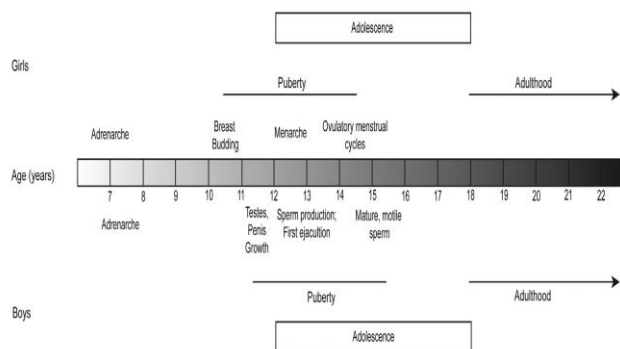


Figure 3. Average age of pubertal development in girls (top) and boys (bottom) (Marshall and Tanner, 1969, 1970; Sizonenko, 1989; Tanner, 1962) In: Mary Holder et al., (2014).

Puberty begins in girls around 10-11 years old and ends around 15-16 years old (Marshall and Tanner, 1969; Tanner, 1962) and is marked by the date of menarche which occurs after the *Peak height velocity* between 10 and 15.5 year old (Figure 4). In boys (figure 5) it begins at the age of 11-12 year old and ends around 16-17 year old (Marshall, Tanner, 1969; Tanner, 1962) and is marked at 13 years old by the sesamoid of the thumb (Marshall , Tanner, 1969; Marshall, Tanner, 1970; Tanner, 1962).

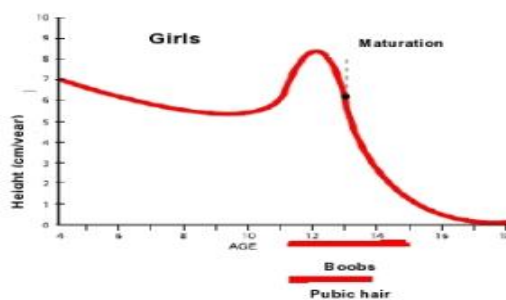


Figure 4. Manifestations of maturation in girls (modified from Ross and Marfell-Jones, 1991)

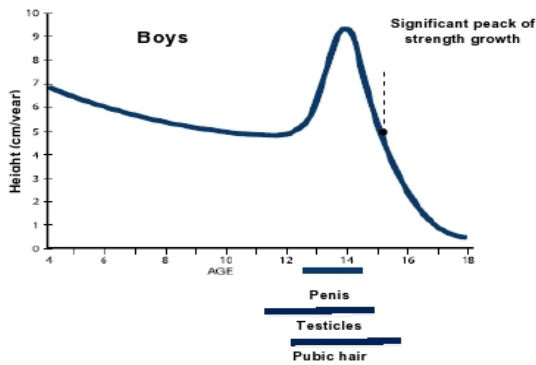


Figure 5. Manifestations of maturation in boys (modified from Ross and Marfell-Jones, 1991)

2.2. Physical activity, health and children

Physical activity is a structuring of bodily movements aimed at maintaining and improving physical condition" (Caspersen et al., 1985), lowering triglyceride levels and blood pressure in some cases, and improving the intellectual performance of the child. (Van Praagh, 2008: 31).

There are several types of physical activity that the child undertakes throughout his daily life and at school, but exercise remains the most planned and structured physical activity linked, to the physical condition, to the physical abilities, to performance (Van Praagh, 2008) and to child and adolescent health (Strong et al., 2005).

Physical activity in children seems to be influenced by several factors such as heredity (Scarr, 1966; Willerman, 1973), sex (Sallis et al., 2000), proximity to places that can facilitate physical activity (Bar-Or et al., 1998), parents' level of activity and inactivity (Moor et al., 1991), sedentary activities such as computer tools (Pate et al., 1994), school environment (Falgairette et al., 1996; Gavarry et al., 1998) etc.

Studies have repeatedly shown the benefits of an active life on health, maintaining an ideal weight, mental balance, intellectual performance, physical condition (Van Praagh, 2008) as well as on bone mineralization. (Janz et al., 2004).

The various international health organizations recommend 5 days per week of an average of 60 minutes of moderate to intense activity for young people (Van Praagh, 2008).

Finally, studies have clearly demonstrated that a lifestyle rich in regular physical activity of moderate intensity during childhood brings many health benefits in the short and long term (Taylor et al., 2000; Blair et al., 1996b).

2.3. Motor skills, training and children

Chronological age is the best indicator for developing speed, physical, physiological, mental, cognitive aspects, also sports skills and flexibility, while the peak heigh velocity period (puberty) is ideal for improving aerobic endurance and strength (figure 6). However, maximum strength can only be trained after this peak (Ross and Marfell Jones, 1991; Beunen and Thomis, 2000; Balyi and Ross, 2009a; Balyi and Ross, 2009b).

Figure 6 clearly illustrates the motor abilities trained as a function of chronological age (solid lines), and the sensitive periods (broken lines) related to developmental age, and to its deceleration (Balyi et al., 2005).

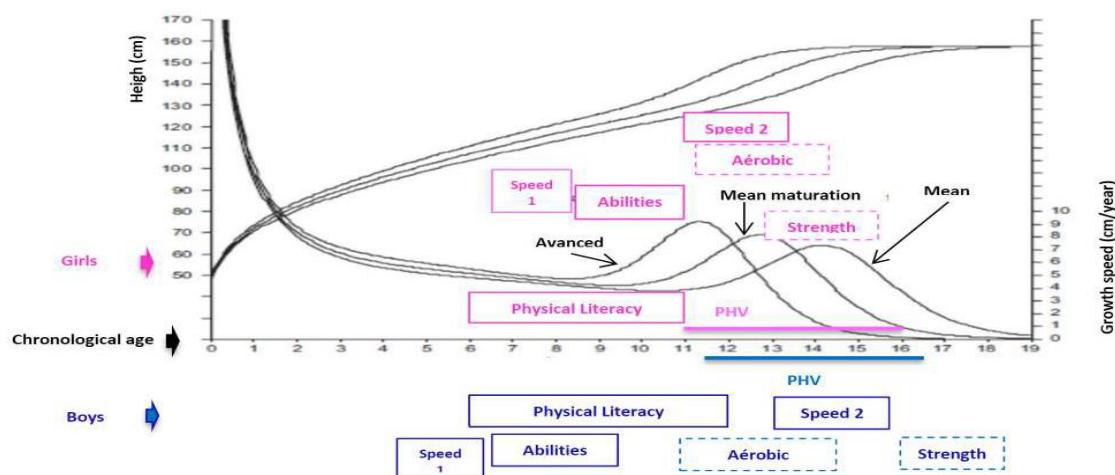


Figure 6. The appropriate times to obtain accelerated adaptation of certain biomotor components of boys and girls (Balyi and Way, 2005), with a theoretical example of 3 children at advanced, middle and late maturation according to Hauspie (2003). On the upper part of the graph we observe the height reached at each age and the lower part shows the annual increases in height. Legends : Solid lines mean training based on chronological age; Dashed lines indicate training based on developmental age; Speed 1: efforts of 5 seconds or less; Speed 2: efforts up to 20 seconds (power and alactic capacity); PHV peak height velocity (Balyi and Way, 2005).

Physical abilities are developed at practically similar rates throughout childhood and more so with the PHV, whether in girls or boys (Lloyd and Oliver, 2012).

2.4. Puberty and metabolism, aerobic and anaerobic

We can develop the maximum oxygen consumption (VO_{2max}) (Weber et al., 1976) and maximum anaerobic power (Fellmann and Coudert, 1994) at puberty. VO_{2max} can be influenced by training and changes in growth (Bar-Or, 1989) and at the same time it is a

favorable factor in endurance sport disciplines that engage large muscle groups (Astrand, 1980) such as swimming ; this is why height is considered as a good indicator of VO_{2max} (Kemper et al., 1983) and weight, a control parameter for the effects of maturation on VO_{2max} during childhood (Krahenbuhl et al., 1985).

Anaerobic capacity increases with puberty (Eriksson, 1971; Eriksson, 1980), and before this age the production of lactic acid is very limited due to the low enzyme activity (PFK and LDH) (Ratel and Martin, 2011) which is compensated by the aerobic energy system (Eriksson et al., 1971).

Studies have shown that it is possible to solicit the lactic anaerobic system in prepubertal children in continuous efforts between 10 s and 1.15 minutes and supramaximal intermittent efforts of 10 seconds of effort and 30 seconds of rest. (Ratel and Martin, 2011).

3. The sporting career of a swimmer

Multi-year sports training can be a powerful and useful modifier of natural growth and development (Vorontsov, 2002).

The multi-year training is subdivided into stages according to the particularities of biological growth and development and each stage has specific objectives. For instance Balyi (2003) establishes the different stages of an athlete's career with more or less differences for the two sexes as follows:

- Before 5 years old, an "active beginning";
- Between 5 and 8 years old, "have fun playing sports";
- Between 8 and 10 years old old, the evaluation of different physical abilities.
- Between 11 and 15 years old, appropriate time for adaptations due to the training stimuli of the different physical abilities;
- Between 16 and 19 years old old, training for competition;
- Between 19 and 22 years old old, train to perform;
- And up to 24 and over, training to win.

4. The career of the swimmer

There are no real restrictions regarding the age of initiation to swimming, but it is rational to start this learning at the age of 7 – 8 years old, and specialized training at 9-10 years old for girls and 10 – 12 years old for boys (Vorontsov, 2002).

It is essential to have acquired a wide range of motor skills before the age of eight (second childhood), before starting a sports career. So two essential stages will have to be acquired before starting a career in a given sport according to Balyi (2003) :

- 1) The stage of development of fundamental motor skills

This stage includes three steps:

- a. an initial stage (2 – 3 years old),
- b. an elementary stage (4 – 5 years old)
- c. and a mature stage (6 – 7 years old).

- 2) The Fundamental Stage 6 – 8 years old (girls) and 6 – 9 years old (boys)

The purpose of this stage is to learn fundamental motor skills with a playful méthode and through a multitude of sports practices (Balyi, 2003).

In swimming Shoukhardine (1989) identifies five stages through which a swimmer must pass throughout his career :

- 1) From 8 to 10 years old, this is the stage for learning the techniques of the chosen sport and multifaceted physical preparation;
- 2) From 10 to 12 years old, this is the stage of basic physical preparation, and the beginning of sport training;
- 3) From 13 to 14 years old, for girls and 14 to 15 years old for boys, this is the stage of special physical preparation and the beginning of sports development;
- 4) From the age of 15 for girls and 16 for boys, this is the stage of orientation towards high level performance;
- 5) From 17 to 18 years old, this is the stage of the maximum realization of the athlete's potential.

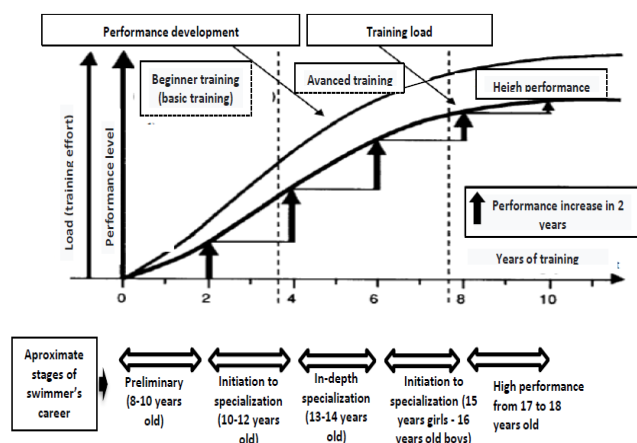


Figure 7. At the top, the graphic representation of the performance development progress according to Blum and Friedmann (1990) and at the bottom of the graph we can see the multiannual stages of a swimmer's career according to Shoukhardine (1989). The purpose of this stage is to learn fundamental motor skills with a playful méthode and through a multitude of sports practices (Balyi, 2003).

1) Preliminary preparation stage.

This stage begins in second childhood, from 8 to 10 years old (around 8 to 11 years old for girls and 9 to 12 years old for boys). According to Balyo (2003) at this age the child has the following potentialities:

- High capacity for blind initiation of integral motor actions but the child has bad gestural precision.
- Rapid psychic fatigue,
- Bad concentration of attention,
- Bad awareness of actions.,
- Elevated nervous excitement,
- Weakness of the peripheral vascular system,

- High degree of mobilization and bad economy of cardiac activity,
- Excellent joint mobility,
- Very high excitability,
- High ability of nervous and muscular processes.

Tasks from this stage

It follows that the major tasks of this stage aimed at the effective learning of techniques related to the chosen sport must be the following (Balyi, 2003):

- Development of the address and general coordination,
- Development of flexibility and joint mobility,
- Development of endurance,
- Familiarization with the history of the chosen sports discipline.
- Development of speed over times of less than 5 seconds.
- Assimilation of sports technique in general and that of the specialty in particular.
- Strengthen the muscular system with body weight and medicine balls.
- Improve lactic anaerobic power over times of 1 minute 5 secondes in continuous exercise and over 10 : 30 in intermittent (Ratel and Martin, 2011).

Organization of training

At this stage, young swimmers train 45 to 75 minutes per session, 3 to 4 sessions a week, including 20 to 30 minutes of additional work (games, gymnastics, athletics, etc.) and 30 to 45 minutes of initiation of techniques swimming.

2) Stage of initiation to specialization.

Between the ages of 10 and 12 years old, emphasis should be placed on strengthening children's health and acquiring physical fitness.

The sessions at this stage become training sessions although a considerable part of the time up to 30% is devoted to games. It is considered that the growth of the results is all the more stable as the preliminary preparation stage is longer (3 to 5 years).

At 10 to 12 years old we observe, increasing the speed of muscle contraction coordination as well as improving neuromuscular coordination and the stability of nervous processes. This age is the most favorable for the development of speed and coordination skills (Balyi, 2003).

The objective of initiation to specialization consists in perfecting the technique of movements and/or specialized motor skills as well as developing the speed of movements specific (Balyi, 2003).

The tasks to be solved are :

- Enrichment of the culture of the movements and of gestural coordination;
- Development of speed;
- Development of general endurance;
- Development of flexibility;

- Motivation to sport activity.

Organization of training

At this stage, young swimmers train 6 times a week (at some mesocycles up to 9 times), 90 to 120 minutes per session (40 min dryland training and 40 to 90 min mean session), with playful, repetitive, continuous, methods.

3) In-depth specialization stage

This stage is between 13 and 14 years old (girls) and 14 and 15 years old (boys) and the young swimmer should have at least 6 or 8 years of practice.

At this age, the following objectives should be achieved (Vorontsov, 2002):

- Emphasize the aerobic system and develop strength with the occurrence of peak height velocity ;
- And complete the technical development.

At this age we observe the highest degree of spatial orientation which contributes to the oriented development of the precision of the movements of the technique and the speed of the movements specific to the chosen sport.

Tasks according to Balyi (2003).

1. Technical improvement;
2. Aerobic training;
3. Flexibility training;
4. Perfecting specific physical abilities;
5. Developing and maintaining speed;

6. Development and maintenance of strength (for girls immediately after PHV and at the onset of menarche and for boys 12-18 months after the peak height velocity);

7. Hone competitive skills.

Organization of training.

Swimmers train 9 to 11 times per week with 2.5 to 3.5 hours per day and 45 to 60 min dryland training (5 to 8 times/week),

4) Athletic development stage

A minimum of practice of 6 to 8 years for girls and 7 to 9 years for boys is required for the transition to this stage. The age of 15 to 16 years old is the most favorable for the development of anaerobic endurance. At this age young swimmers have a high psychic reactivity, lowered suggestivity, lability of psychic processes, alteration of gestural coordination due to harmless psychological and morphological modifications. At this age, young athletes work to optimize physical and sports preparation, develop their technical and competitive skills (Balyi, 2003).

Tasks

1. Evolution of all the physical qualities required and the functional potential of the athlete
2. Perfecting the resistance of the body of the sportsman's psyche to considerable emotional and physical stresses
3. Individualization of technique
4. Refinement of the reliability and variability of the technique

Organization of sessions

At this stage, young swimmers train 9 to 12 per week main sessions (2 to 3.5h) and 5 to 8 dryland training (35 to 75 mins).

5) High Performance Stage

This stage is around 17 to 18 years old, the swimmer completes his training on all levels, and concentrates on the maximum realization of his potential in training and competitions in order to maximize his performance (Balyi, 2003). Training is organized according to an average frequency of 11 to 12 sessions per week at average volumes of 4500 km per year, which are subject to fluctuations, especially with the approach of major sporting events (Vergnoux, 2014).

The progressive increase in the volume of training throughout the career of the swimmer, proves to be beneficial on the adaptive level of the different systems and devices (Granata et al., 2016; Balyi and Hamilton, 2004). It is also accepted that young swimmers will have to accumulate a significant swimming volume during their training (Lloyd and Oliver, 2012).

For the majority of events, training at this stage should focus on the joint development of aerobic and anaerobic power (Hellard et al., 2017), with an adequate intensity prescription based on the body's physiological responses of the swimmer, according to the four intensity distribution models known in endurance sports (Stoggl and Sperlich, 2014) namely, the pyramidal, the polarized, the high volume and the threshold model (Seiler, 2010) for better monitoring of training.

Conclusion

In order to achieve the results of the international level, the times indicated for the training process in the different stages of the multiannual preparation of the swimmer must not be reduced. The progressive transition from one stage to another must therefore take into consideration the development and/or growth and maturation, which determine the means, the methods as well as the regularities of organization of the training process of the young swimmer.

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