Cross-Country Skiing **Monitoring Growth and Maturation**

Why Growth Measurements Are Needed?

Growth measurements enable an athlete's maturity level (i.e. development stage) to be identified and monitored so that training, competition and recovery programs will be designed based on developmental age and not chronological age.

When a coach develops a sport program for an athlete, the age of the athlete must be considered. This is not done by simply checking the date of birth (chronological age). There are a number of aspects that need to be considered, including:

1. Chronological age.
2. Developmental age (physical, mental and emotional).
3. Skeletal age.
4. General training age.
5. Sport-specific training age.
6. Relative age.

Chronological Age: Refers to the number of years and days elapsed since birth. Children of the same chronological age can differ by several years in their level of biological maturation. Athletes of the same chronological age between 10 and 16 can differ by as much as four or five years in their developmental age.

Developmental Age: Refers to the relationship between growth and maturation over time. Growth and maturation are two aspects of development that are often confused with each other:

- Growth refers to observable, step-by-step, measurable changes in body size such as height, weight and percentage of body fat.
- Maturation refers to more subtle qualitative system changes, both structural and functional in nature, in the organism's progress toward maturity; for example, the change of cartilage to bone in the skeleton.

Developmental age therefore refers to the degree of physical, mental, cognitive and emotional maturity. It is highly individualistic and is an amalgam of the child or adolescent's physical development. Physical developmental age can be determined by skeletal maturity or bone age.

Skeletal Age: Refers to the maturity of the skeleton determined by the degree of ossification of the bone structure. It is a measure of age that takes into consideration how far given bones have progressed towards maturity - not in size, but with respect to shape and position to one another.

General Training Age: Refers to the number of years in training while sampling different sports.

Sport-specific Training Age: Refers to the number of years since an athlete decided to specialize in one particular sport.

Relative Age: Refers to the differences in age among children born in the same calendar year. "Relative age effect" describes the observation that athletes born early in a selection year are over-represented in junior and senior elite teams compared to what might be expected based on national birth rates. It is well documented that relative age is a great advantage in athletic selections.

If relative age (which is only a 10-12 month difference) can have such a significant impact on selection, participation and performance, then it is obvious that developmental age (which may represent four to five years difference) can have a huge impact. It is therefore essential that coaches, programmers, parents and sport administrators have a good understanding of the maturation process and its consequences and take developmental age-related considerations into account when designing their programs.

Early and Late Maturing Children Drop Out of Sport at Different Times For Different Reasons

Adolescence is the period between childhood and becoming an adult. While both the start and end of this period are difficult to define, it is usually obvious when an individual is going through the many physical, psychological and social changes that accompany it. Not all children enter adolescence at the same age, and it takes different children different lengths of time to complete the process. In general, children who enter adolescence early pass through it faster than those who start later, and whether they start early or late partially depends on their body shape. Stockier, more muscular children usually enter adolescence earlier than their peers who are thinner and leaner.

The whole process starts at approximately age 10 - 11 for girls, and approximately two years later for boys. It usually takes three to four years to complete. This means that for girls aged 12, some will have almost completed the physical changes of puberty, while others have barely started. For boys the greatest range of development is found in 14 year olds.

Males. Male late developers are often at a great disadvantage. This is especially true in sports where age group competitions are held. As their peers go through puberty, late developing males find themselves much smaller, less muscular and physically weaker. Training and competing against bigger, stronger and faster opponents is not always fun, particularly in contact sports, and late developers therefore tend to drop out, despite the fact that in the long run they have greater potential for success. There are also disadvantages to being an early developer, though these take longer to materialize. Early in adolescence, early developers (who go through a relatively rapid but short adolescence) are bigger, stronger and faster than their peers and this often translates into sporting success. However, as late developing competitors go through their longer, more sustained, growth spurt, they eventually catch up with and surpass the early developers. With their late developing peers now bigger, faster, stronger and more skilled than them, the early developers tend to drop out of their sport. This usually occurs towards the end of adolescence.

Females. For females the situation is less clear, but appears to be reversed. For one thing, social pressures that occur in early adolescence frequently serve as a disincentive to continue sport involvement. For another, the body changes that come with maturation – changes that give early-developing males an advantage – have the opposite effect in early-developing females, in that it takes much longer for females to acquire the strength and fitness to take advantage of their increased body size and weight. In contrast, late developing females, who had success with their prepubescent bodies when their competitors developed before them, face the same difficulty when older.

Early and late maturing children drop out of sport at different times for different reasons, as explained in the text box to the right.

Characteristics of Early and Late Developers

Pre-adolescence
Early and late developers are approximately the same size and weight.

Early Adolescence
Males who develop early are bigger and stronger than late developers and often have success. Late developers tend to drop out at this age.

Females who develop early fall behind late developers in performance because their physical development impedes their performance. Early developers therefore tend to drop out.

Mid and Late Adolescence
Late developers eventually catch-up and pass early developers in physical development.

Early Adulthood
Males who develop late end up bigger and stronger than early developers and now have success (if they stayed in the sport). Early developers tend to drop out at this age.

The physical development of females who developed late begins to impede their performance. As a result, the capability of early developers (if they stayed in the sport) catches up. Late developers tend to drop out as success becomes more challenging.

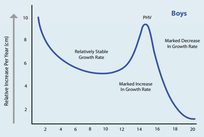
Peak Height Velocity (PHV)

Peak Height Velocity (PHV) is the maximum rate of growth in stature during the adolescent growth spurt. The age of maximum velocity of growth is called the age at PHV.

The rate of change in height varies through specific stages of growth and allows for "height cues" or rates of growth changes to be used as potential indicators of appropriate programming and evaluation content for developing athletes. In this the beginning of the growth spurt and the peak of the growth spurt are very significant considerations. For the most part, they are also relatively easy-to-obtain indications of the general developmental process that can be used to observe and monitor growth.

The following figures show the rate of change in height in boys and girls through the growth period.

Rate of Change in Height & Peak Velocity
(Adapted from Tanner, 1978 & Kahn, 1999)



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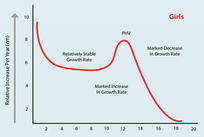


The Six Phases of Growth

In order to track PHV, data must be collected on a longitudinal basis, with the analysis of models and graphs. Somatic (muscle-skeletal) growth in the form of PHV follows six phases:

Phase 1: Chronological age zero to six. Very rapid growth during infancy, followed by rapid deceleration after age two. Measure standing height and weight on birthday.

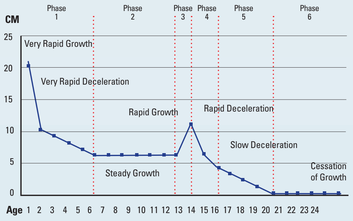
Phase 2: Age six to the onset of the growth spurt. Steady growth until the onset of the growth spurt. Measure standing height and weight every three months. If measurements take place outside the home (i.e. in a club setting), do the first measurement of the year at the starting point of the annual training and competition cycle.

Phase 3: From the onset of the growth spurt to peak of PHV. Rapid growth until peak is reached. Measure standing height, sitting height and arm span every three months.

Phase 4: From PHV to slow deceleration of growth. Measure standing height, sitting height and arm span every three months.

Phase 5: From slow deceleration of growth to cessation of growth. Measure standing height every three months.

Phase 6: Cessation of growth. Measure height and weight on birthday.



Determining a Velocity Curve

To determine the velocity curve, the increase in stature from one measurement time period to the next consecutive measurement time period is subtracted one from the other. For example, from 9 years to 10 years the increase in stature is 5.0 cm. By plotting the velocity curves it will be possible to clearly distinguish the rate of growth from one point in time to another. The velocity curve will immediately show distinctive growth points (for example, the onset of the acceleration in the curve, the peak in the curve and the deceleration in the curve).

Tables for Plotting Annual and Quarterly Growth

Chart 1: Standing Height Measurements Chart – Example

Age	9	10	11	12	13	14
Growth in cm	5	6	0.9 | 1.3 | 3 | 1	1.9 | 2.6 | 3.0 | 1.1	4.3 | 3.0 | 3.4 | 1.3	1.0 | 2.1 | 2.7 | 1.9
Total Growth in cm	5	6	6.2	8.6	12	7.7

15	16	17	18	19	20
2.1 | 1.6 | 1.3 | 2.0	1.4 | 0.7 | 0.9 | 1.0	1.1 | 0.5 | 0.6 | 1.0	0.7 | 0.3 | 0.5 | 0.6	0.4 | 0 | 0 | 0.4	0 | 0 | 0 | 0
7.00	4.00	3.2	2.1	0.8	0

Chart 2: Standing Height Measurement Chart – Blank

Age	9	10	11	12	13	14
Growth in cm						
Total Growth in cm						

15	16	17	18	19	20

Chart 5: Sitting Height Measurements Chart – Blank

Age	9	10	11	12	13	14
Growth in cm						
Total Growth in cm						

15	16	17	18	19	20

Chart 7: Arm Span Measurements Chart – Blank

Age	9	10	11	12	13	14
Growth in cm						
Total Growth in cm						

15	16	17	18	19	20

Chart 3: Plotting the Growth Velocity Curve for Standing Height – Example

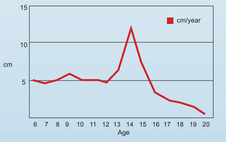


Chart 4: Plotting the Growth Velocity Curve for Standing Height – Blank

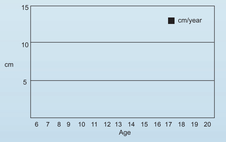


Chart 6: Plotting the Growth Velocity Curve for Sitting Height – Blank

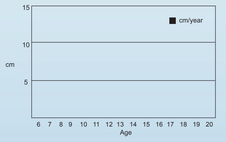
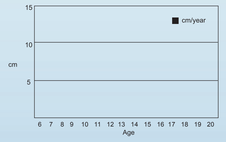


Chart 8: Plotting the Growth Velocity Curve for Arm Span– Blank



How to Measure PHV

Coaches and parents can use stature measurements (height) before, during and after maturation as a guide for tracking the development of children. Tracking allows coaches to address the sensitive periods of physical development (endurance, strength, speed, flexibility) and skill development.

Tools and Equipment for Measuring
When considering the equipment needed for measurement, one must look at how much emphasis is going to be put on the measurement of stature. If stature data is going to be heavily incorporated into training plans, data must be very accurate, and, if that is the case, higher quality equipment will be needed.

Ideal Equipment
- A free standing or wall mounted stadiometre.
- The stadiometre would have sliding headboards and a dial or digital read outs which would aid the ease of use.

Acceptable Equipment
- An anthropometre or retractable steel measuring tape.
- A headboard.
- A smooth floor with a straight flat wall at 90 degrees.

Unacceptable Equipment
- A cloth measuring tape.
- Flexible material.
- Carpeted floor.
- An uneven floor.
- No backboard.

Example #1: Two measurements within 0.4 cm of each other.

- Stature measurement #1 – 166.2 cm.
- Stature measurement #2 – 166.3 cm.

The above two measurements are within the acceptable range and the mean measurement recorded is 166.3 cm.

Example #2: Two measurements not within 0.4 cm of each other.

- Stature measurement #1 – 162.2 cm.
- Stature measurement #2 – 162.9 cm.
- Stature measurement #3 – 162.6 cm.

The first two measurements are not within 0.4 cm of each other. Therefore the median of the three scores needs to be used and the recorded score will be 162.6 cm.

What to Measure?
Determining the rate of growth is dependent on accurate measurements. Therefore measurements need to be made to the nearest 0.1 cm. Each athlete should be measured and recorded twice, but these measurements should not differ by more than 0.4 cm. If they do not differ by more than 0.4 cm, the mean of the two measurements should be taken. If they do differ by more than 0.4 cm, a third measurement should be taken, and the median of all three measurements should be calculated.

When to Measure
For several reasons it is important that coaches do not become obsessed with the number of times height is recorded:

- Athletes may become bored;
- Athletes may become preoccupied with measurements, particularly if they perceive they are not growing as fast as their peers; and
- Intervals between testing periods need to be long enough to allow for substantial growth over and above what would be expected to occur through measurement error (Williams, 2009a).

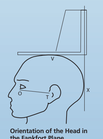
It is recommended that:

- Measurements are made once quarterly;
- Measurements are made as close as possible to the same day in the month;
- Part of a training session is set aside for measurements;
- Measurements are taken after a day of rest. This will ensure there are no confounding effects of training from the previous day; and
- Measurements are taken at the beginning of the training session, as athletes will not be prone to any effects from the training session (stretching, bouncing, drop jumps, etc. can all have an impact on stature (Williams, 2009a).

The earlier the measurements can occur prior to the growth spurt, the greater the opportunities are for the coach to adjust the training program according to the growth rate. As PHV occurs typically at 12 years for females and 14 years for males, it would be beneficial to have as many measurement points as possible prior to this age.

Protocols for Measuring Growth

How to Measure
When measuring a child's height, it is important to pay careful attention to the technique being used, so that the results will be meaningful. Ideally two measurers should be present, one to perform the positioning of the athlete and one to record the actual measurement. If a second measurer is not available, it is still possible to get valid results, but to do so extra attention needs to be given to the technique. For proper measurement of height refer to the figure at right.



Orientation of the Head in the Fankfort Plane

Measuring can only be accurate if the athlete's head is level. The orbitale (O) is located on the lower or most inferior margin of the eye socket. The tragion (T) is the notch above or superior to the tragus or flap of the ear, at the superior aspect of the zygomatic bone. This position corresponds almost exactly to the visual axis when the subject is looking directly ahead.

Standing Height Measurement

- The athlete should stand erect in bare feet with heels, buttocks and shoulders pressed against the stadiometre.
- The heels should be together; the arms should be hanging freely by the athlete's side; the palms of the hands should be facing the thighs.
- The athlete should look straight ahead, take a deep breath and stand as tall as possible.
- The tester then applies gentle upward traction to the athlete's skull, behind the ears, to ensure the trunk is fully stretched.
- The tester/assistant draws down the measuring bar to the athlete's head and records the standing height to the nearest 0.1 cm.

Sitting Height Measurement

- The athlete should sit on the base of the stadiometre, with knees slightly bent. The hands should rest on the knees.
- The buttocks and shoulders should rest lightly against the stadiometre, which should be positioned vertically behind the athlete. The tester needs to ensure that there isn't a gap between the buttocks of the athlete and the stadiometre.
- The tester then applies gentle upwards traction to the athlete's skull, behind the ears, to ensure the trunk is fully stretched.
- The tester/assistant draws down the measuring bar to the athlete's head and records sitting height to the nearest 0.1 cm.
- Once sitting height is calculated, it can be subtracted from the stature score in order to derive the leg length height.

Arm Span Measurement

- The first step is to mount the tape measure on the wall – at the approximate height of the shoulders of the athletes being tested. The tester/assistant must ensure that the starting point of the tape measure is fixed to a corner of the wall. This is where the athlete's fingers must be fixed.
- The athlete should stand erect with stomach and toes facing the wall, feet together and head turned to the right.
- The arms should be extended laterally at shoulder level (horizontal) with the palms of the hands facing forwards (towards the wall). The fingers should be stretched out.
- The tip of the athlete's middle finger should be aligned with the beginning of the tape measure (corner of wall) and the arms should be outstretched along the tape measure.
- The tester/assistant then uses a ruler held vertically to the tape measure to record total arm span to the nearest 0.1 cm.

Photo Credit: Getty Images

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