LET'S TALK ABOUT GROWTH AND MATURATION

NOT ALL KIDS OF THE SAME AGE ARE AT THE SAME STAGE

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kids back 2 sport

TERMINOLOGY

There is often confusion over the different terminology around growth and maturation. For the purpose of this guide, the following definitions are the intended meaning.

Growth is not the same as maturation and we need to understand the difference to effectively diagnose, treat and develop younger athletes.

Child development is regarded as the process that creates both biological and behavioural developmental change over time.

Growth is the process of physical change in size, shape, or composition of the whole body or any part of it. It is measured by assessing height, weight or length of the limbs or trunk.

Maturation is the process of progress towards a biologically mature or adult state. it can be regarded in terms of of timing, tempo and status (Malina et al 2015). Maturation timing and tempo varies between individuals, and between biological systems. Not all tissues and organs progress at the same time or rate, for example, a child may be skeletally more mature but sexually, less mature.

Developmental age refers to the child's physical, mental, emotional, or intellectual maturity age not their birth date. Development can be more advanced in one system, yet delayed in another.

Biological age (BA) refers to the biological status or maturity of the athlete

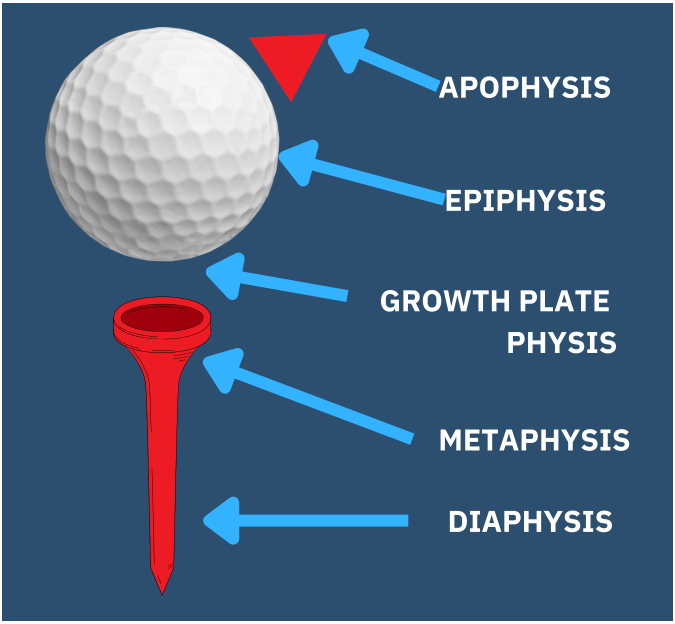
Chronological age (CA) refers to the actual age of the athlete in days, months and years. Most youth sports are organised into groups and teams according to chronological age. Different sports adopt different cut off points with some being based on academic years and others by calendar year.

GROWTH TISSUE

At birth, much of the skeleton is cartilaginous, but after birth, a process of secondary ossification centres develop in each end of long bones which promote both increase in length and shape to bones. Bone ossification, or osteogenesis, is the process of bone formation. This process starts during embryonic development in the primary ossification centres.

The primary and secondary ossification centres are separated by the epiphyseal growth plate. This growth plate (physis), is split in to several layers and enables the process of elongation of the long bones. Once maximal length is achieved the growth plate fuses, but until that time it is vulnerable to injury. The epiphysisis the pressure weight bearing surface and the diaphysis is the bone shaft. Think of it like a golf ball sitting on a tee peg, separated by the physis.

Other secondary ossification centres create shape to the bone, but not length, providing attachments for ligaments and tendons (apophyses). Injuries to the apophysis include conditions such as Sever's or avulsion injuries around the pelvis.



TIMING OF BONE OSSIFICATION

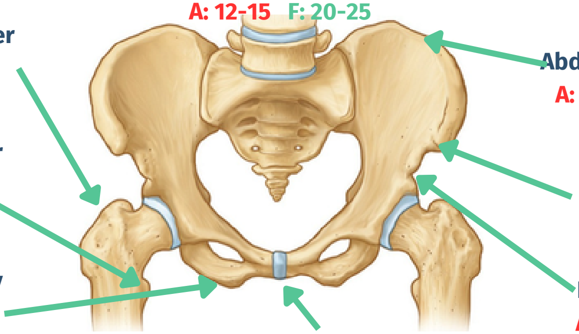
The timing of ossification is different from bone to bone, but occurs in a predictable sequence of development and progression until around the age of 25-30. On average, bone maturation is approximately 2 years earlier in girls than in boys. However, children mature at different times and rates, with some children maturing as much as 3 years earlier or later than their peers.

Several factors affect maturation including:

- Gender
- Hormones
- Ethnicity
- Pathology
- Stress
- Genetics

With so many factors affecting timing of maturation, care should be taken when applying research from one group of athletes to another setting.

Certain conditions that affect adolescents can only occur when the physis is open. For example, Sever's is the primary cause of heel pain in sporty children aged between 8-14 when the calcaneal physis is open. Once the physis fuses post puberty, Sever's no longer is a consideration and other differential diagnoses must be sought. Knowledge and understanding of paediatric anatomy, the timing and pattern of secondary ossification centre appearance, and an assessment of maturation is therefore important to be able to assess skeletal development, and to be able to make an accurate clinical diagnosis.



GROWTH SPURT

Growth is rarely linear, often occurring in periods of rapid acceleration. Different parts of the body grow at different times. Most commonly, this is in a distal to proximal direction (from the foot to the spine). This explains why children often look like they have disproportionately big feet relative to the rest of their body, followed by a time when they look like they have hugely long legs and in proportion to little trunks.

There is a period of accelerated growth in adolescence with the point of maximal adolescent growth termed **peak height velocity (PHV).** This is driven by hormones and coincides with the onset of puberty usually around aged 11-12 in girls and 13-14 in boys with growth spurts of between 5-12cm in males and 5-9 cm in girls. It may last 24-26 months and varies in intensity between individuals. Growth velocity (growth rate) is typically calculated as the absolute change per year.

The period of increased weight observed following PHV is known as the **peak weight velocity (PWV**) with ranges between 7-9 kg per year for girls and 8-10 kg per year in boys. The literature regarding the timing of the lag behind PHV varies but may occur within 2 months after PHV in boys and later in girls between 3-10 months.

Data can be plotted on growth charts to enable normal and abnormal patterns to be observed. Being able to predict when PHV might occur is helpful in terms of managing the athlete and injury risk reduction strategies. However, some athletes sail through puberty with ease, especially those with an extensive training history in that sport (load tolerant), whilst others, who are relatively new to the sport (load naive), or who have a lower capacity due to injury, nutrition, sleep or stress (load sensitive) may be more vulnerable to overuse injuries (Jayanthi et al. 2021).

To be able to assess the PHV accurately, it is important to start regular measurements e.g. every 4 months, of the child ahead of PHV. As the spine usually starts to grow after the legs, particularly in boys, measuring both standing and seated height might be useful.

There is a huge variation of skeletal maturity between children of the same chronological age. Two children with the same date of birth may be as much as 3 years ahead (early maturation) or behind (late maturation) or on time compared to their peers in terms of maturation. Physical differences of up to 29cm in height and 3-8.6kg of fat free mass have been observed in athletes of the same chronological age. This can create a mismatch in size, strength and power and may result in injury when two children of vastly different physical attributes are playing against each other.

Not all biological systems develop at the same rate, so an athlete may be skeletally mature for their age and yet be cognitively, socially, and emotionally less advanced. Neither height, nor age equate to maturity and can disadvantage some tall children who, because of their height have greater expectations placed upon them to behave in a more adult manner. Being the oldest child in a year group, does not necessarily mean they are the most mature.

How old is not how mature, so we need to be able to calculate maturation, not just record their date of birth.

Maturation should be considered in terms of status, timing, and tempo.

Status	Maturity at given time	Skeletal age – wrist x-ray, secondary sex characteristics% of adult height (PAH) at a given examination point
Timing	Age at which maturational events occurs	Age of PHV or menarche or pubertal stages
Tempo	How quickly they are changing	Rate of change via multiple regular measurements over time

Maturity timing - the age at which maturational events such as PHV, menarche or pubertal stages occur in terms of early, on time, or late maturers.

In female athletes, maturity timing can be assessed via age at which menarche occurs. However, there are certain medical conditions such as relative energy deficiency in sports (REDs) , hormonal imbalances and gynaecology conditions that can delay the onset of menses, so the athlete could be amenorrheic, and yet, skeletally mature. If the female athlete has not started menses by the age of 15 they should consult a doctor. Recollection of exact age of menarche has been found to be inaccurate.

Maturity tempo = how quickly the athlete is changing determined by serial measurements

Tracking regular longitudinal measurements of height and weight every 3-4 months before PHV allows assessment of rate of change and can be displayed on growth curve graphs to identify patterns of change to predict when PHV might occur. Measurements need to be accurate and methodology consistent.

Maturity status = maturity at a given time

To assess maturity status, it can be based on:

1. Absolute maturity status: how far is the athlete along in the maturation process
2. Relative maturity status: is the athlete earlier or later than average for their CA.

Skeletal age (SA) of the distal radius on x-ray is an accurate method but lacks practicality in the clinical setting.

Secondary sexual characteristics (breasts, genitalia, pubic hair) can be assessed but is often embarrassing for the athlete and poorly self-assessed.

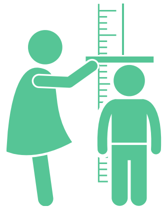
Maturity offset (MO) - a prediction of the time before of after PHV. Biometric measurements of height, age, weight, sitting height, and leg length are used in a calculation with greater accuracy the closer to PHV the child is.

Percentage of adult height (% of PAH)

The percentage of predicted adult height (% of PAH) at the time of observation is an indicator of maturity status that is increasingly used in youth athletes. Through a series of calculations, involving the child's height and weight and the parental height, it is possible to predict the child's potential full adult height. This is termed predicted adult height (PAH). This figure is then used to assess the % of PAH on a given day. Those athletes who are closer to their predicted height are regarded as more mature.

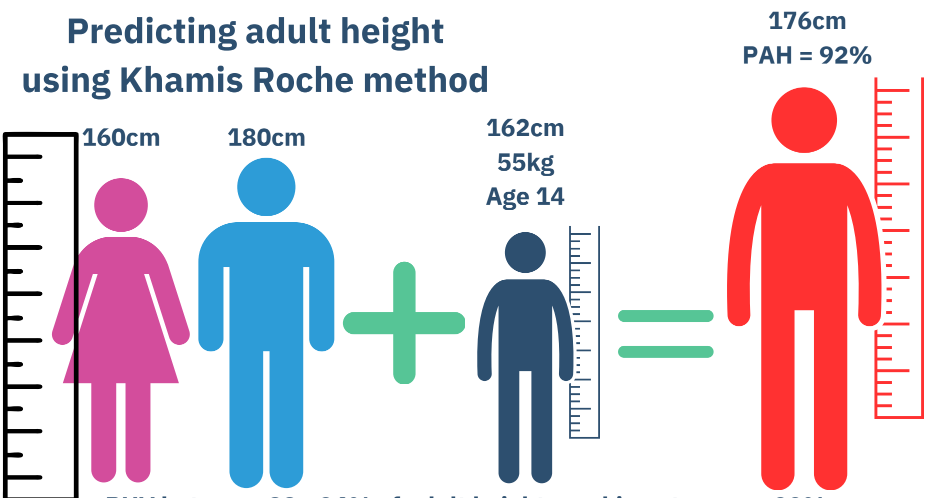
The calculation requires:

- Father height
- Mother height
- Child height
- Child weight
- DOB



An example of a biobanding tool used to estimate % of PAH is found on the University of Bath website
https://stories.bath.ac.uk/growing-our-future-sports-stars/index.html

Predicting adult height using Khamis Roche method



PHV between 88 - 96% of adult height, peaking at approx 92%

% OF PAH

In this example, the child's mother is 160cm and the father is 180cm. The child is currently aged exactly 14 and is 162cm in height and weighs 55kg.
Using a Khamis Roche calculation, the child's predicted adult height is 176cm. He is currently at 92% of his full predicted adult height.

Across multiple studies, data has highlighted that PHV occurs between 88-95% of PAH with some variation between studies. Much of the early work in this area was done using groups of predominantly white children and it is recognised that this may vary in different population groups.

Commonly the following bands are used:
Pre PHV: < 88%
Circa PHV: 88–95%
Post PHV: > 95%

Peak PHV has been observed in boys around 92% of PAH. In our example this child might be assumed to be around the peak of his PHV at 92% based on these bands.

Benefits of using PAH

Having a non invasive method for assessing adult height is helpful for:

- Guiding assessment of the stage of ossification of the skeleton to support differential diagnosis
- Talent identification - interpreting whether a child is faster or stronger due to early maturation giving a physical advantage.
- Will the child meet specific height requirements for a specific role or position in a sport e.g. soccer goalkeeper?
- Being able to organise children in to playing groups according to maturation not age

% OF PAH

Limitations of using PAH

Multiple methods have been used to calculate PAH with the most widely used being the Khamis Roche method (1994) with accuracy levels of around 2.2cm for the 50th percentile and 5.3 cm for the 90th percentile (Malina & Cumming 2019).

Limitations identified include:

- Not able to source parental heights
- Parents overestimate self-reported height
- Limited research across different ethnicity groups
- Accuracy

Combining several methods of assessing maturation using longitudinal data gathered over an extended period is ultimately likely to be more accurate than using single snapshot assessments. Using skeletal age in conjunction with % of PAH has increased the level of accuracy. Newer research is emerging (Monasterio et al.2023) highlighting how growth curve graphs may provide a more accurate non-invasive means of estimating PHV.

It is important to know the age group classification cut off points for each sport when working with young athletes. A child may be in the same school year as another competitor but have to play in a different age group for some sports based on their DOB.

Within education and sport, children are often categorised into quartiles determined by their birth month with the oldest children being born in Q1 and youngest children born in Q4. In some sports, such as rugby union, and in other areas such as employment and education, children in Q1, who were older in terms of chronological age have been widely reported to experience greater long term success. This effect has been termed the **relative age effect (RAE)** which refers to the biased distribution of birth dates within an age group cohort. However, this concept works on a premise that older children will be more mature and this is not necessarily the case.

Just because you were older, does not necessarily mean you are more mature.

In a more recent study, Johnson et al (2017) highlighted that early maturation, not age, was a greater factor in determining selection into youth soccer academies with up to 10 times more "early maturing" athletes being selected and retained. This could suggest that children who were later to develop were potentially missing out on opportunities for athlete development.

Early developer	Late developer
Faster, stronger, more agile	Disadvantaged across size, speed, strength, and power
Greater self-esteem (not girls)	Low self esteem
Rely on strength not technique/tactical development	Rely on skill /tactics not power
Poor work ethic	Greater work ethic
Not experienced failure	Used to setbacks
False confidence	
Not faced tough challenges/competition	More successful, IF they are given the chance to succeed within the system.

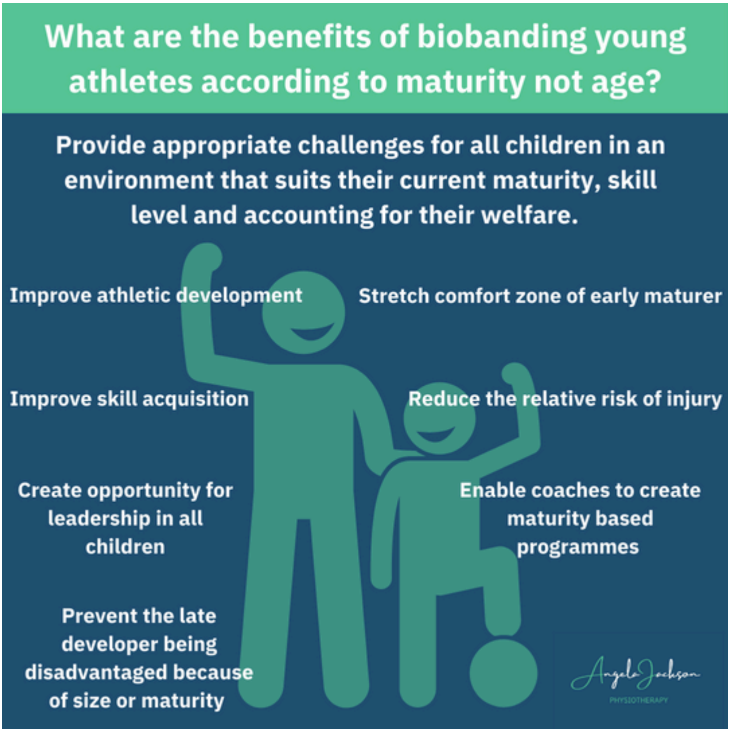
There are both advantages and disadvantages of being early or late to develop with differences between the sexes. Girls who are early developers tend to be taller, heavier and stronger but often have lower self-esteem favouring power based sports like tennis. Boys who are taller and stronger are often faster, can throw, kick and hit harder so experience early success. Those who are later to develop, may need more support and encouragement to persevere when faced with much bigger or more mature athletes, however they often develop more tactically and technically and show greater resilience when faced with setbacks.

Since the introduction of assessments for growth and maturation has become more widely utilised, the introduction of biobanding has been adopted in some sports which should aims to reduce the bias towards just selecting bigger and more mature children.

Biobanding" is grouping athletes according to maturity status rather than the traditional age groups based on date of birth for some aspects of training and competitions.

More mature children could play up an age group to stretch them socially, physically or technically, and less mature players could play down to give them greater opportunity to dominate and lead. This may improve athletic development and reduce the relative risk of injury providing advantages for both early and late developers especially between the ages of about 9–15 years in girls and 10–16 years in boys (Cumming et al., 2017).

Biobanding is not a replacement for age group training but can be incorporated into a programme to give all athletes the opportunity to experience challenges and skill acquisition in an environment that suits their current maturity and skill level.
It allows coaches to develop assessment tools to potentially prevent the late developer being disadvantaged because of size or maturity and allow athletes to train according to the level they are ready for.



With the right environment, the later developer can be nurtured and enabled to progress in the sport. By early adulthood, these maturity-associated differences are less obvious and in some sports, the trend towards higher numbers of early developers being selected has been shown to be reversed.

Having examples of players who were late developers may help the child have greater faith that patience and time spent developing a greater technical and tactical skill set has long term benefits.

Practitioners should be alert to research based on age groups not maturation. They should also be aware of whether research completed in specific sports is heavily biased towards early or late develops before comparisons are made.

PHV & INJURIES

An increase in injuries has been observed to occur both before, during and after the adolescent growth spurt (PHV). Potential causes for this increase in injury rate have been cited as being associated with an increase in bone length which may reduce bone mineral density and create longer levers and therefore greater forces. Longer levers may affect neuromuscular control and therefore in some athletes create a period of "athletic awkwardness" A soft tissue lag behind bone growth creates greater traction forces on the muscle attachments on to the immature apophysis causing chronic apophysitis or acute avulsion injuries.

Growth occurs in the feet before or in early PHV and children often experience pain more foot related conditions during that time. As the child continues to grow, the injuries follow a distal to proximal pattern moving up through the knee to the pelvis and spine. The pattern of injuries also changes, from being more apophyseal injuries before and during PHV to more muscle injuries after PHV. Following puberty, these surges in testosterone cause increased strength and power in larger muscle groups such as the quadriceps and hamstrings. This may mean they exceed the capacity of the relatively immature attachments to the bone and cause a greater risk of apophyseal avulsion injuries too.

There is some conflict in the research as to whether there is a greater risk of injury in early maturers who tend to have a stronger, faster PHV or in later maturers who tend to have a slower overall speed of change. Children who grow at a faster rate (>7.2 cm/year) seem to be at greatest risk (Monasterio et al. 2024).

Athlete development does not mean athlete restriction and emphasis should not be placed only on assessing maturation and relative proximity to PHV in determining whether an athlete should reduce their training load. The key factor is in assessing performance, wellness and how well they are coping with their current training level.

References available on request

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Angela Jackson was a young athlete who had an injury that ended her sporting dreams. That has fuelled a passion to deliver high-quality diagnosis and treatment for all young athletes in a career as a physiotherapist spanning 35 years. She has helped athletes of all ages and abilities achieve their potential including supporting her own 2 children to international success.

For almost two decades, she has worked as the Physiotherapist to the Cheshire Cricket Board and advises Premier League Football Academies across the globe.

As a passionate educator, Angela lectures internationally, is the author of multiple online courses, and advocates for a specialised approach to rehabilitating injured young athletes through the platform, "Kids Back 2 Sport.

COMPREHENSIVE SUPPORT FOR PARENTS, PRACTITIONERS, TEACHERS, AND COACHES

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