UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

Title: A review of the role of Resistance Training in current Long-Term Athletic Development Models.

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Declaration of Originality

I hereby declare that this project is my own work and that it has not been submitted for any academic reward, or part thereof, at this or any other educational establishment

Signed: 

Abstract

This paper explores the existence and implementation of resistance training in various long-term youth athletic performance models. The updated statement from the National Strength and Conditioning Association in 2009 indicated that smart, structured strength and conditioning programs, of which include resistance training, can greatly benefit athletic performance by improving physical qualities such as speed, strength, stamina and agility, all of which have a great carryover affect to sports performance. It has also shown that the effectiveness of this carryover affect depends somewhat on the program's sports specificity and periodization. By first defining general athletic performance, and how it can be improved, the implementation of resistance training in youth sports as a means to improve youth athletic performance and potential can be further investigated. Once this has been established, four long-term athletic development plans are reviewed. From these models, no major apparent guidelines on resistance training or strength and conditioning can be found. The four models are models provided by the International Olympic Committee (IOC), Gaelic Games Association (GAA), English Football Association (FA) and Athletics Canada (AC). After reviewing these four models, the only mention of strength and conditioning or resistance training can be found briefly in the IOC and AC models. Even within these two models, there are no definitive guidelines on strength and conditioning, leaving a gap in the research whereby sports specific strength and conditioning training could be implemented. As a result, resistance training and strength and conditioning are of a lesser importance to sporting bodies during the creation of long-term athletic development plans.

Keywords: strength training, power training, athletic development, athletic performance, youth athletic development, youth, teen, adolescent, strength and conditioning, team sports.

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Chapter 1: Introduction

Advancements in sport science research and applications over the past 2 decades has led to a notable increase in physical athletic performance which may be due to a greater understanding of a wide variety of training and recovery methods. Running parallel to these advancements is the increased emphasis on competition and performance within youth sports. This increased emphasis has led to various sporting bodies establishing plans to focus on the development of youth athletes in the long-term. These plans have culminated on Long Term Athlete Development models being compiled by various sporting organisations as a form of guidelines for athletes and coaches. The purpose of this literature review was to:

- Define the characteristics of athletic performance and how athletic performance is improved through appropriate planning, periodized and specific programming.
- Explore how these factors are can influence youth athletic performance.
- Review current long-term athletic development models to find any commonalities or differences, and analyse the strength & conditioning techniques, if any, used within.
- Establish the primary factors that will lead to the greatest chance of success for a long-term athletic development model.

Research Question: What is the best Long-Term Athletic Development model available for youth athletic development in sport?

This question is relevant as there seems to be a current lack of guidance from governing bodies of various sports as to the correct or most efficient means of developing youth and adolescent athletes in an athletic capacity. The understanding of this question may identify a clear and suitable approach to Long-Term Athletic Development for coaches, athletes and sporting organisations, which in turn may increase the overall quality of play and development of the sport.

The review first defines athletic performance, the factors effecting athletic performance and how it can be assessed. The second section of the review is focused on youth athletic performance and how the information from the first chapter is applicable to youth sports. This is done so by independently reviewing four Long-Term Athletic Development plans of national and international sporting bodies and then discussing the commonalities and differences between all four.

The research for this review took place between 5th October 2018 – 12th March 2019. The following databases used were through the University of Limerick student portal; Scopus, Web of Science, SPORTdiscus, Medline, Cinhal and PubMed, as well as GoogleScholar and Google. Key words used in the Boolean searches were as follows; Strength Training, Power Training, Athletic Development, Youth Athletic Development, Youth, Teen, Adolescent, Strength and Conditioning, Team Sport. All searches were limited to show papers published in 1996 or newer.

Chapter 2: Literature Review

Athletic Performance

a. Defining athletic performance and athletic potential.

According to the U.S National Library of Medicine (2019), athletic performance can be defined as a "complex trait that is influenced by both genetic and environmental factors". Performance is the result of stamina, strength, flexibility, game skill and knowledge, therefore all these traits must be trained to improve performance. (Harris 2013) By improving these traits, we are increasing athletic potential. The components that define a person's potential for athletic ability are determined by the nature and nurture of the athlete. There is an ongoing debate as to which of the two factors is most impactful on athletic development and performance and this debate generates questions over the role of environment (nurture) and genes (nature), and which of the two carries the greatest influence on performance. (Davids & Baker 2007) While nature describes the natural characteristics that contribute to a person's performance, nurture is a culmination of the qualities created and formed by the persons training and experience. As coaches we cannot alter the genetic makeup of an athlete therefore the enhancement and improvement of an athlete's environment in terms of training and experience is the most impactful factor available to change to improve performance.

b. Factors effecting performance.

The factors that define an athlete's environment include the quality and quantity of sleep, hydration, nutrition and exercise (Pilcher & Huffcutt 1996, Murray 2007, Rodriguez *et al.* 2009).

Although there is no evidence that lack of sleep reduces athletic performance, poor sleep quality and quantity increases naturally occurring pro-inflammatory cytokines which in turn, can lead to disfunction within the immune system. Immune system dysfunction can lead to infection, which in turn can reduce muscular recovery and increase central nervous system fatigue, both of which are counterproductive to performance. (Fullagar *et al* 2015) Recent studies on sleep have displayed a strong correlation between hours sleep and likelihood of sickness and those who sleep less than 5 hours are 4.5 times more likely to have a cold that those who sleep 7 hours. (Prather *et al.* 2015).

It has long been proven that dehydration has negative effects on exercise and sport performance as well as overall physical function. These effects are exaggerated more so by increased exercise duration, intensity and climate. The effects of sweat and sodium loss

through exercise and thermogenesis can be reduced proper post exercise hydration and coaches should provide informed methods of rehydration to athletes to do so. (Murray 2007)

Recovery from training and performance is greatly enhanced by correct nutrition. With the popularization of fad diets in both the general public and athletic population the most successful diets are ones that are sustainable, and all have common traits to their success. Adherence to the diet and awareness of calorie consumption in relation to your goal are they two primary factors of a successful diet and these are seen as the foundations for successful dieting and healthy eating. The next step to be taken for successful healthy eating is having the correct macro-nutrients in your diet. Like calories, macro-nutrient content (carbs, fats and protein) varies from person to person, with protein often being under consumed. This is counterproductive to training and performance as protein is the primary macro-nutrient in cell recovery and with poor recovery comes poor performance. Intra-exercise nutrition consists primarily of fast releasing carbohydrates as carbohydrates are the primary source of fuel for the body's anaerobic and aerobic energy systems. Athletes should be informed of the consequences and benefits of sleep, hydration and nutrition but it is a joint responsibility between coaches and athletes to ensure successful implementation of the information across the board.

While a team Strength & Conditioning coach can recommend means of improving the initial three, sleep, hydration and nutrition, with good cooperation with athletes they can help extensively improve levels of strength, endurance and overall fitness. One way this can be achieved is by the implementation of resistance training programs.

c. Resistance Training.

The term resistance training refers to training modalities where a resistive force is applied to muscles creating physiological adaptation. Conceptually when we create stimulus for our muscles, these muscles became fatigued. The extent to which we recover from this fatigue allows us to train and eventually improve. To create the greatest athletic potential, adherence to resistance program provided by the coach is necessary from the athlete. Successful resistance training programmes generate physiological adaptions such as increased neuromuscular recruitment, while fatiguing muscle body capacity. The recovery from the fatigue accumulated from the stimulus allows for improved movement patterns, enhanced muscular strength and power, as well as a reduce likelihood of sports-related injury

likelihood. This, in turn, increases athletic potential, improves sports performance as well as providing longevity in sports (Faigenbaum *et al.* 2009).

d. Periodization and Specificity.

When reviewing literature on resistance training programs in sport, periodization and specificity are the primary programming principles taken into consideration when creating a program for an athlete.

Periodization refers to a method of dividing training into small segments or periods throughout a year to allow an athlete to focus on what is necessary to improve athletic performance. Periodization is broken into two key factors, cycles and phases. The three types of cycles in periodization are macro-cycles, meso-cycles and micro-cycles. A macro-cycle is the longest cycle length and is generally a 12-month period of training. A meso-cycle is the medium length cycle and its length can vary anywhere from 4 to 12 weeks in length. Each meso-cycle is usually designed with the intention of developing one phase of training. A micro-cycle is the subdivision of a meso-cycle and it accounts for the frequency, intensity and volume of training throughout a week of training. Each sport that has an annual pre-season, season and off-season uses different phases at different times of the year. These 4 phases are recovery, general preparation, pre-competition and competition (Lidor *et al.* 2016).

In terms of strength and conditioning in team sports, general preparation is the focus of the meso-cycles leading up to the beginning of the season. The aim of a general preparation cycle is to improve physical performance by increasing lean muscle mass via hypertrophy. Once a base of hypertrophy training is attained and an athlete has an increased level of muscle mass, training focus turns towards basic strength and the application of the newly found muscle mass to more functional uses. Eventually, when a good level of basic strength is established training the attention turns to power training. In a power training phase, training focuses on more explosive movements. Plyometric exercises and other explosive forms of lifting such as Weightlifting is often incorporated at this stage. These phases consist of high volume and frequency micro-cycles to create strength and explosiveness which have a positive carry over affect to athletic performance (McKinlay *et al.* 2018). Once this meso-cycle finishes the pre-competition phase begins. The goal of this phase is to maintain fitness levels established in the previous phases and begin to incorporate skill development into each micro-cycle. For

this new set of micro-cycles' frequency is reduced while intensity increases as training specificity is increased.

Specificity in a resistance training program refers to the exercise selection in a meso cycle and is relation to the athletes' sport and phase of training. Specificity encapsulates the concept that training replicates the conditions faced in competition therefore bridging a transfer from training to performance. An example of specificity would be a swimmer transitioning to increased swimming training for conditioning as opposed to land training in the form of running, cycling, rowing etc. Another example of specificity would be a soccer team becoming more soccer specific with their training by sprinting with a ball for speed training instead of purely sprinting from point to point without a ball. After the pre-competition phase, training frequency and volume is reduced, and intensity remains high for the competition phase. Once the competition phase is over, volume, frequency and intensity are reduced for the recovery phase. This is generally the shortest meso-cycle as there is very little fatigue accumulated to recover from injuries from the season as well as to prevent mental and physical burnout. The recovery phase is also used to prepare athletes for the cycles to start again for another season with a general preparation phase. (Gamble 2006)

e. Assessing athletic potential and performance.

Although there is no established measurable scale or unit of athletic potential, athletic performance can be measured using various tests both specific and non-specific to a sport. As there are a substantial number of physical and psychological variants that could be included in a test of athletic ability, for this review 8 assessable aspects of performance have been selected:

1. Functional Movement Screen
2. Agility
3. Strength
4. Power
5. Speed
6. Muscular Endurance
7. Anaerobic Capacity
8. Cardiovascular Endurance.

The 8 components of performance can be defined further as follows:

1. *Functional Movement Screen (FMS)* is a predictive screening process carried out by coaches. The screening consists of 7 fundamental movement patterns that provide observable performance tasks that require adequate balance, stability and mobility to complete. The 7 movements are graded from a scale of 1-3 to determine a score of max 21 and the 7 exercises are an overhead deep squat, trunk stability push up, hurdle step, in-line lunge, shoulder mobility, active straight leg raise and rotatory stability. Successful FMS informs a coach on any movement restrictions an athlete might have that may need to be assessed and fixed prior to training or if they are physically ready to begin a resistance training program. (Hoogenboom *et al.* 2013)
2. *Agility* can be defined as the ability to change direction at speed. Many factors dictate an athletes' level of agility some of which include technique, straight sprint speed, anthropometry and various leg muscle qualities. Although there is no universal measure of agility, various testing protocols can allow coaches to quantify levels of agility by timed drills such as shuttle runs, cone drills etc. Results from these drills can be compared to scores from previous scores or standards set by individual organization or bodies. (Shepard & Young, 2006)
3. *Strength* in sport and training refers to the repetitive muscle action against high loads. Strength, like all aspects of resistance training can be both general and specific to a sport. General strength training is important as it increases an athletes' muscle size and strength. When specificity is increased, and strength is used with resistive sports movements, an effective transfer of enhanced muscle strength to sports performance occurs. An increase in muscular strength is accompanied by a change in neuromuscular coordination and an improvement in performance. (Komi 2008) Testing strength can be done in many ways, 1 repetition maximums on various lifts such as squat bench or deadlift can indicate an athletes' readiness for moving on to an explosive or power training phase.
4. *Power* is defined as the rate of doing work. When examining power in sports and exercise we are referring to muscular power/explosiveness. Muscular power is tested and used to quantify and understand the force velocity profile of an athlete. Tests of power can be carried out in the form of various ballistic assessments such as medicine ball throws, jump measurements and countermovement exercises. The results of these

tests provide coaches with reading of force and velocity production, which can be used to calculate athletic power. (NSCA & McGuigan 2017)

5. *Speed* is defined as the length of time to travel from one point to another. In the sporting world everyone wants to be faster. Being fasters allows for greater sporting performance. (Coultman 2018) There are various types of speeds; reactive speed and maximum speed. Reactive speed rather than maximal speed holds greater importance in sports performance. Reactive speed refers to the ability to react to a stimulus as fast as possible. In sports this stimulus can be anything from the blowing of a whistle to the bounce of a ball in from of a player. Maximal speed refers to maximum speed an athlete can reach. In sports like basketball, rugby and soccer reactive speed hold greater importance as it is often the initial first step acceleration that determines who wins a contest to a breaking ball or a rebound. Often in team sports maximal speed may never be reached, therefore in strength and conditioning, a higher emphasis is placed on reactive speed rather than maximal speed. (Cronin & Hansen 2005)
6. *Muscular Endurance* plays a significant role in sports performance and can be defined as a sustained amount of repetitive force generation against resistance to a point of muscular failure. It can also be defined as the ability of a muscle or group of muscles to perform continuously without fatigue. (Yadav & Bulsara 2018) Improved muscular endurance allows an athlete to perform at a higher level of intensity for a longer duration which benefits overall sports performance. Increased muscular endurance has also been shown to delay the onset of blood lactate accumulation, which creates the burning sensation within muscle bodies, allowing a higher level of performance to be sustained for a longer period. (Farrell *et al.* 2018) Muscular endurance can be tested using repetition maximums at various loads, either body weight or free weight. Muscular endurance can be tested in various ways such a maximum repetition squat test for specifically testing leg muscle endurance. A test like this can be modified for various levels of training experience. For example, if an athlete has never barbell back squatted before, an alternative would be to air squat or dumbbell squat. Likewise, if an athlete has a substantial amount of training experience a maximum repetition back squat could be used to test muscular endurance. Muscular endurance tests like those mentioned above can provide coaches with a quantifiable level of stamina a player has and therefore allow a coach to include means of improving muscular endurance when writing an athletes' training program.

7. *Anaerobic Capacity* is similar to muscular endurance in that anaerobic capacity tests the maximum capacity of an energy system over a period of time. Anaerobic exercise refers to exercise that combines the output of the adenosine triphosphate (ATP), phospho-creatine and lactic acid energy systems in the body. The typical length of time for anaerobic capacity is between 30 seconds to 2 minutes. (Wood 2008) By increasing anaerobic capacity, athletes can perform high intensity bouts of exercise more frequently in both training and game settings and therefore improve overall sports performance.
8. *Cardiovascular Endurance* refers to the level of endurance an athlete can sustain for a period using the aerobic energy system. When improved and developed cardiovascular endurance can lead to enhanced attributes of sports performance such as increased distance ran, level of work intensity and the frequency of intense work periods. (Helgerud 2001) The most accurate and accredited test for measuring cardiovascular endurance is measuring VO2 max – the rate of oxygen uptake over a sustained, exhaustive period. Distance/time runs and cycling tests like shuttles are the most common and accurate tests used. (Pate *et al.* 2012)

The result of these types of tests can be used in analysis of an athlete's potential to create an estimate of how well they will perform in a sport. A real-world application of this can be seen in the National Football League (NFL) combine. This is a 4-day event where top collegiate football players are invited to display their athleticism and skill over a variety of tests. The tests used to examine the prospects are:

1. 40-yard dash (Testing reactive and maximal speed & acceleration)
2. Bench press (max repetitions at 225lbs/100kg to test strength and muscular endurance)
3. Vertical jump from a standing position (testing lower body power and explosiveness)
4. Broad jump (testing explosiveness from a static position and balance)
5. 3 cone drill (testing agility and reactive speed)
6. Shuttle run (Testing lateral quickness, acceleration and agility)

The results of these tests provide a string indication to a team's scout of an athletes' potential to be successful, however, there is no guarantee that the athlete will indefinitely live up to the

potential. Many factors such as injury, lack of adherence to training and psychological barriers can influence the extent to which an athlete can succeed.

Youth Athletic Development.

a. Defining Youth Athletic Development

Adolescence is defined as the transitioning from childhood to adulthood following the onset of puberty (Curtis 2015). It has been shown above that athletic performance is a product of the development of athletic potential, both long term and short term. However, when examining the development of athletic potential within adolescents aged between 12-17, the 8 components of performance described above are not the only contributing factors to successful performance. Good quality sleep, hydration and nutrition also play a favourable role in development. Although these factors are often perceived as lesser importance in both coaches and athletes, it is important that they are examined when striving for optimal performance.

With this being said, there are substantial differences between the development of adolescents and the development of adults. Up until recently the resistance training and athletic development concepts that were used for adolescents were the same as those used for adults. Essentially adolescents were treated like "miniature adults" (Faigenbaum *et al* 2009). However, from more focused research it has been shown that physiological and psychological traits vary and develop substantially in the transition from adolescents to adulthood and therefore should be taken into account when coaching such age demographics (Shirtcliff *et al.* 2009).

b. Long Term Athletic Development (LTAD)

Tanner Staging, also known as the Sexual Maturity Rating is an objective means of measuring the physiological changes that occur during adolescence. Developed during the 1940's-1960's, the scale tracks the development of secondary sex characteristics and classifies the characteristics into a group from one to five (Emmanuel 2018). This scale has been adopted by medical professionals as an indicator as to the physical stage of a male or female adolescent and has proven successful and somewhat accurate in its use. In contrast,

there is yet to be a universal scale or model to determine the maturation stage of a youth or adolescents' general athletic development or abilities.

The complexities of designing such a scale have a substantial amount of intricacies that often create many variants for an accurate scale to be successfully developed. In an attempt to establish scales and guidelines national and international sporting federations have designed sports specific long-term athletic development (LTAD) models to provide a blueprint for coaches, athletes and parents to follow to allow for a better sporting career in the future.

c. Current LTAD Models

The foundation for continued success in any sport is based on long term athletic development structures from which guidelines are provided for coaches, athletes and parents to follow. As previously mentioned, various sporting governing bodies have established LTAD programs as guidelines for their specific sport. Below are some examples of LTAD programs form different national and international sporting bodies and the characteristics of each.

International Olympic Committee (IOC)

The IOC is a not-for-profit international organization consisting of volunteers whose purpose is to build a better world through sport. The IOC collaborates with international sporting federations, athletes, national olympic committees and other national and international bodies to promote Olympic values and create a fair competitive environment for athletes, teams, coaches and countries. The IOC is responsible for the creation of plans and project with various national Olympic committees on a wide variety of sports related topics (IOC website). The IOC partnered with the Team USA, the United States Olympic Committee to create a long-term athletic development plan that is universal to all Olympic sports and since its creation has been a reputable source of training structures for all ages. The aims of this developmental plan are as follows:

- To create universal access for all athletes to multiple sports which in turn can allow for the creation of an active and healthy lifestyle,
- Improve physical literacy by emphasizing motor and foundational skills which will develop fundamental skills that are transferable between sports.

- Create a generation that loves sport, physical fitness and a generally healthy lifestyle with the hope of passing that passion on to the next generation. (International Olympic Committee, American Development Model, 2014)

The IOC athletic development plan is comprised of 5 stages. Each stage represents a different age group with advised training philosophies for each group.

*Stage 1: Discover, Learn & Play***.** (Ages 0-12)

The aim of Stage 1 is to introduce children to multiple sports as early as possible so that they will play as much as possible. The increase in play time will allow for the development of motor skills, which are transferable across all physical aspects of life, while also teaching the children fundamental rules of the games they are playing. This stage requires loosely structured coaching that will allow fun and enjoyment through exploration and discovery.

Stage 2: Develop & Challenge. (Ages 10-16)

The purpose of the develop and challenge stage of athletic development is to allow an athlete who has engaged in sport to explore more organised forms of training. This stage also consists of initial competition and organizes sports clubs, both of which are aimed at further developing sports specific skills. It is at this point that the improvement of physical, psychological, technical and tactical skills are introduced to the young athletes.

Strength and Conditioning coaches may also be introduced into an athletes training regime at this stage in order to help improve all physical skill components as mentioned above. The primary focus of strength and conditioning coaches during this stage is to introduce athletes to various types of training modes they can use in their routines. There is not a substantial amount of focus placed on actually building physical strength or developing muscle mass at this stage, but rather a focus on learning correct exercise form and how strength and conditioning coaches can benefit an athletes' training and overall development

Stage 3: Train & Compete. (Ages 13-19)

At this stage of training athletes begin to train and compete in a sport that matches their long-term sporting goals as well as their developmental needs. It is during this stage that the role of strength and conditioning coaches and team coaches becomes more prevalent. This stage calls for the increase in structured training with teams and coaches. It is also suggested that

information on nutrition and sports psychology be introduced to athletes in order to further understand their sport and their body.

Sport specific skill is increased during this stage and athletes take part in local, regional and international competition throughout.

Stage 4: Excel for High Performance or Participate and Succeed (Ages 15+)

It is at this stage, generally in high school that an athlete decides as to whether they increase their commitment to sport and train for high performance or remain playing for fun, healthy and social aspect of the sport in a less competitive setting.

- *Excel for High Performance*

If an athlete decides to pursue a level of high performance, they are generally committing to a year-round, long-term training program to develop maximum athletic potential focused on a single sport under the supervision of master/elite level coaching. Competition at this stage is most often at a national or international level against elite competitors.

- *Participate and Succeed*

If an athlete prefers to take a more relaxed approach to their sport at this age, the focus of playing and training will be to enjoy the sport and the health benefits of participation. Often athletes and teams at this level compete at local and regional competition with teams of likeminded involvement.

*Stage 5: Thrive & Mentor***.** (Active for Life)

The final stage in the IOC & Team USA development plan illustrates the transition from playing to becoming a sports coach or advocate and contributing off the playing field. Retaining physical fitness and activity levels is also encouraged at this stage and competition takes place at a master's level. Support for the next generation of clubs and teams is highly encouraged here as the passing of knowledge to the next generation is very important in creating a healthy sporting environment.

While the Team USA & IOC's model has detailed multiple aspects of youth athletic development, including physical, psychological, technical and tactical, there are other models from many other sporting bodies that seem to have neglected these factors. The model used by the Gaelic Athletic Association (GAA) in Ireland has very little structure regarding psychological and tactical development.

Gaelic Athletic Association (GAA)

The GAA player development model is designed in stages, similar to the Team USA and IOC model above. The model categorizes players into 3 stages depending on age and each category focuses on a set of aims suitable to the age of the players.

Stage 1: Play to Learn (Ages 4-11)

The emphasis of this initial stage is to allow children to play as much as possible. Similar to the IOC model, there is little to no structure when it comes to refereeing games. The primary technical focus of this stage is to develop fundamental skills, movement skills and basic sport specific skills. The early stage of the GAA's model is intended to create an interest for GAA sports (Hurling, Camogie, Gaelic Football, Handball), however there is no encouragement to participate in sports outside the organisation, unlike the IOC which encourage multiple sports until a level of high performance is reached in one. This is understandable due to the fact that there is a 58% dropout rate from athletes ages 12-21 therefore developing a key interest in GAA at an early age is paramount for retaining numbers.

The GAA has created a program called Go Games, targeted at athletes in Stage 1 of the development process. These Go Games are ran in both GAA Clubs and in Schools to allow for greater exposure of the sport to the kids. Go Games aims to introduce competition to athletes at a young age however, these competitions do not keep track of scores and are not strictly refereed therefore allow for fun, flowing games. The Go Games principle are aligned to the end of Stage 1 and allow for a transition in to the more structured stage 2.

Stage 2: Learn to Compete (Ages 12-17)

The aim of stage 2 is to introduce players to more structured game play in training and as the stage progresses there is a greater emphasis placed on competition. Tactical development is mentioned briefly within the model at this stage but there is no information provided on how

or why it should be developed. There is also a focus on reducing the symptoms of over-training in this stage, which is a common occurrence when an athlete becomes passionate about a sport and commits a large amount of time to their training and not enough time on their recovery.

In the IOC model it is at this stage that strength & conditioning and resistance training is introduced, but it is not introduced here by the GAA model. The IOC has detailed how sport science and nutritional information should be used by athletes at this stage as they can benefit through the reduction of over training symptoms, but the GAA model has simply mentioned how reducing over training is an aim of the stage without providing information as to how do so.

The eligibility to play at an adult level aligns with the ending of this stage. Preventing young athletes from training with older adult athletes not only allows the players to train, play and develop physically and technically with athletes their own age and size, but it also reduces the likelihood of injury and fatigue that can occur when playing with multiple teams of different levels in the one sport at the same time.

Stage 3: Compete to Win (Ages 18+)

The final stage in the GAA model compete to win and it is at this stage that competition is the number one focus of teams. It is hoped that players will have developed all of the physical and technical skills required for the adult/senior level and tactical development is the primary focus of training with competition being held at all stages from a local, regional or national level.

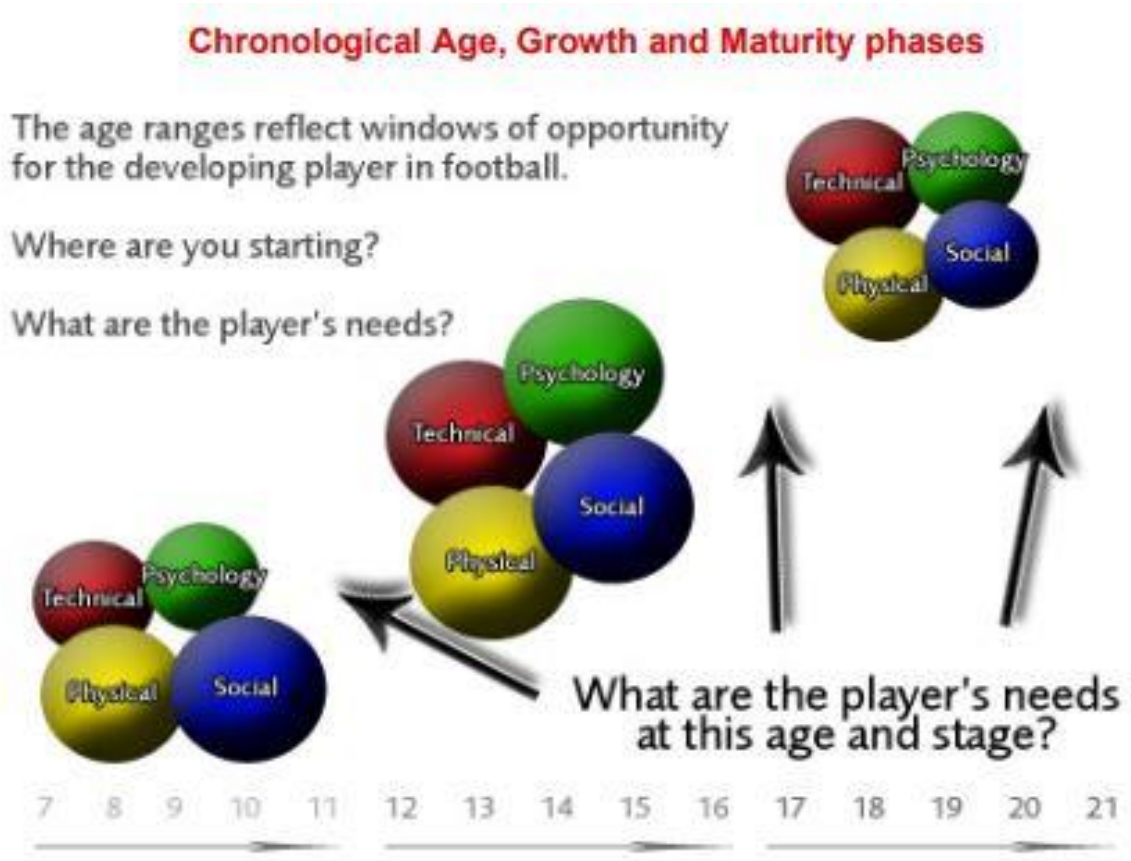
It is at this stage that strength and conditioning coaches are introduced to teams and athletes and the focus of these coaches is, like in any other sport, to physically prepare teams for season and help teams recover and prepare in an off-season and pre-season. This introduction is at a much later stage than in the IOC model. Another difference between the IOC model and GAA model is that the GAA model does not provide any aims that encourage long-term interaction outside of playing like coaching or managing or assisting with a team.

Unlike the GAA, the English Football Association (FA) have set a reviewed development plan in place for both player and coaches. The plan provides a logical player development and coaching education pathway for all involved by the integration of all forms of football.

English Football Association (FA)

The FA have adopted a long-term athletic development model through recommendation from Sporting England, a non-departmental body under the department of Digital, Culture, Media and Sport. The model is divided into 8 age categories from ages 5 up with each category aiming to develop various physical, technical, psychological and social traits both on and off the football field. The FA's model provides little to no guidance regarding the recommended type of activities for each stage, but instead divides each stage and allows for interpretation of what should be achieved at each stage. The FA have included a graph showing the age and corresponding importance of skill development at each stage. (Fig. 1)

Figure 1: FA development plan



Stage 1: FUNdamentals (Ages 5-8)

Stage 2: Enjoyable Practise (Ages 8-11)

Stage 3: Developing Practise (Ages 11-14)

Stage 4: Training for Competition (Ages 14-16)

Stage 5: Understanding Competition (Ages 16-18)

Stage 6: Developing Winning (Ages 18-20)

Stage 7: Training to Win (Ages 20+)

Stage 8: Retaining People in Football (Any mature adult age)

The order of importance in trait development shifts from social, physical, psychological then technical, to an equal importance placed on all 4 traits as a child progresses in age. Once again there are no guidelines as to when attention should be focused on strength & conditioning, nutrition and recovery but this is due to the fact that this model encompasses 8 different forms of football therefore the requirements for each form will differ slightly from team to team. The 8 variations of football that use the FA model are professional, mini-soccer, boys, community, disability, Futsal, girls and schools' soccer and all of these variations require slightly different levels of physical ability.

The FA, GAA and IOC models have all been designed for the development of children and adolescents within a team sport structure and therefore the developmental focus of the athletes' physical traits are skewed slightly in favour of team sports related physical components as opposed to individual sports related development. Athletics Canada has created a 9-stage model that focuses on general development in the early stages and continued individual development throughout a sporting career.

Athletics Canada (AC).

The Athletics Canada (AC) long-term athlete development (LTAD) plan is a concise 22-page document that consists of 9 stages of athletic development focused for single athlete participation in athletics. The importance of an early start in sports and athletics is emphasised by the statement "Children who don't develop fundamental motor skills by age 12 are unlikely to reach their genetic athletic potential". This philosophy is further emphasised throughout, with the overall aim of model being to develop skills early then

refine the competitive skills at a higher level/later stage. Similar to the IOC model, the AC development system progression is based on training, competition and recovery that correlates with an athletes developmental age instead of their chronological age and the entire model is based on an "athlete centred – coach driven" philosophy. The 9 Stages are as follows:

Stage 1: Active Start (Age: 0-6 male & female)

The aim of the active start is to make play and physical activity fun and exciting while also making it a component of daily routine throughout life. This stage takes place in settings such as Kindergartens and community programs. There are no coaches present at this stage but the children are surrounded with adults educated on nutrition and the importance of daily physical activity. The emphasis is placed on fun and movement but on top of this it is recommended that children should not be sedentary for any longer than 60 minutes at a time, apart form when sleeping. In terms of physical development, the primary focus of this stage is for kids to become exposed to and focus on the fundamentals of movement, running, jumping, kicking, throwing and catching. The model also mentions 'wheeling' as a fundamental movement that is developed at this stage for those in a wheelchair which is quite considerate as there is a lack of representation for people with disabilities in sport within the models reviewed thus far.

Stage 2: Fundamentals stage (Age: 6-9 males, 6-8 females)

The objective of this stage is to develop agility, balance, coordination and speed (ABC's) among the young athletes while also reinforcing the importance of daily play and physical activity. Speed development trainability in the areas of agility, quickness and segmental speed in a multi-directional manner with movements under 5 seconds long are optimal at this stage. It is here that coaching structure is introduced, at a minimal level, to help prevent injury. This is done so by educating athletes on simple rules involving safety and etiquette. There is also an introduction to flexibility exercises to develop and maintain optimal ranges of motion however, all activities are all-inclusive with no formal competition or periodization at this stage. Children are also encouraged to participate in multiple sports at this level in an aim to develop physical and psychological traits with play time of 10 hours of semi-structured play per week recommended for kids at this stage to help develop these skills.

Stage 3: Learning to Train (Age: 9-12 male, 8-11 female)

One of the objectives of this aim is to continue to enhance ABC's to develop overall sports skills. It is at this stage that physical, mental, cognitive and emotional components begin development by means of well-structured training programs. During this stage gender differences become more apparent due to growth driven by puberty therefore formal musculoskeletal screening begins during this period to accommodate for individual differences that may create the need for adjusting training activities. In order to provide more structure and feedback, testing and monitoring methods are introduced as a means of tracking progress. Ancillary capacities such as warm ups and cool downs are introduced at this stage to allow for successful performance and injury prevention. Talent identification tends to begin at this stage, but competition numbers are open and there continues to be no formal training periodization set in place for athletes.

Stage 4: Training to Train (Age: 12-16 males, 11-15 females)

Stage four is the most critical stage of development as Peak Height Velocity (PHV) is reached during this stage. PHV is the fastest rate at which a person grows during their lifetime and this occurs due to puberty. PHV is characterised by bone growth first. Once the bones grow the skeletal muscles adapt to the bone structure. If incorrectly monitored, imbalances and performance reduction may occur. Because of this, supervision and monitoring become critical through this stage to prevent any physiological adaptions counter-productive to performance. Once again, speed development has an increased emphasis in this phase and in addition to it is the introduction of formal weight training (FWT). FWT is introduced to girls at the onset of menarche and boys 12-18 months post PHV. With the addition of more structure in the form of FWT, planned training consisting of peaks, tapers, and other meso-cycles, and competition modelling are introduced. This occurs near the end of the stage as it leads into the 5th stage, Learning to Compete.

Stage 5: Learning to Compete (Age: 16-18+ males, 15-17+ females)

Stage 5 introduces the challenge of competition and with that challenge comes more specification and formal training. Specificity and periodization of training blocks and meso cycles are used to a greater extent as a means to develop sports specific physical preparedness and implement area specialization. This is done so by streaming athletes into one event area, such as sprinting, long distance, throwing, etc., in order to develop speed, strength, aerobic capacity and power relative to the area to the most optimal extent. Competition becomes

organised into seasons at this stage and because of this a practice to competition ratio of 90/10 is suggested to prevent injury or burnout and also to allow for minor improvements in technique. Athletic seasons are limited to 10 months long in order to provide athletes with a break from competition both mentally and physically.

Stage 6: Train to Compete (Age: 18-21+ males, 17-21+ females)

This stage in the development model sees athletes refining their event area specialization to optimize event preparation. Event specific testing and monitoring is introduced at this stage to spot any weakness in performance that may be present. At this stage athletes begin to regard themselves as "full-time athletes" and with that, begin to develop mental preparation techniques to prepare for the stress and pressure of high-level competition. These factors tend to transition athletes from the belief that their sport is a hobby to the idea that it is a lifestyle, which if successful, leads them to stage 7.

Stage 7: Learning to Win (Age: 20-23+ male & female)

Stage 7 is the stage where all of an athlete's energy and resources are focused on competing at the highest level possible. Testing and monitoring in this phase is used to maximise an athletes physical and psychological potential, while also helping the athlete to identify when to compete when it counts. At this stage the athlete is "Full-time", often part of a high-performance squad, training multiple times daily with high specificity in preparation for key events. Competition at this stage takes place at a regional and national level. The importance of psychological preparation is critical at this stage in order to prepare athletes for stage 8, winning for a living.

Stage 8: Winning for a Living (Age: 23+ male & female)

This is the final competitive stage of the model and it is at this level that all training, recovery, monitoring and testing is focused solely on reaching maximum performance potential. Competition at this level takes place at international and Olympic levels, where athletes are often representing their country and are considered professionals. It is at this stage that athletes are often regarded as being at their peak of performance. This does not last forever therefore towards the end of this stage athletes begin to think about reintegrating back into everyday life and transitioning from an athlete to a coach or other member of a club/organization. This leads to the final stage, stage 9.

Stage 9: Active for Life (Age: Any)

The active aging stage, like in other models, is open to athletes of every age who are not competing at a high-performance level in main stream competition. It is a critical stage for high performance athletes as it helps them integrate into the real world, free from the high-performance training and competing structure. Athletes are also provided with information on how to become coaches and trainers while also being encouraged to still maintain an active lifestyle and compete recreationally if they please. This stage does not go into too much detail about reintegration as every athlete is so different and integration for each individual can vary drastically given individual circumstances.

Overall, the AC LTAD model is a very concise model as it incorporates multiple aspects of long-term development in detail, from early age introduction to developing advanced sport specificity and competing at a high level, and reintegration into society after sport, something that is seldomly talked about by other sporting bodies.

Comparing LTAD Models

The four models reviewed above all share the same broad goal, create a structured pathway of long-term athletic development (LTAD) to improve overall sports performance while raising and maintaining the standards of their respective sports as a whole. Although the models share the same goal, the means by which they plan to achieve this goal varies from model to model.

Commonalities between the models.

The first stage of all four models focuses on learning the basic skills of the games and activities, having fun and generating an interest in the sport of choice. For a sports club/sporting body, the benefits of developing an interest in sport at a young age is key to retaining athletes for future teams. A larger pool of athletes looking to be selected for a team means that the standard of the team is raised which, in turn, leads to a higher standard of play. For an athlete, the larger the squad of potential athletes for a team, the more likely an athlete will be motivated to play harder and train harder to attain a playing role in the team. Evidence would suggest that participation in sport at a young age can reduce the likelihood of obesity which in turn reduces the likelihood of chronic diseases such as heart disease and stroke. Early participation also promotes the growth of healthy bones, muscles, ligaments and joints,

while also improving mobility, stability, flexibility, strength and many other physical fitness attributes beneficial in everyday life (Lloyd *et al.*2012).

These attributes and characteristics can all be developed with the co-operation of a team coach and a strength & conditioning, however in all models there is a lack of detail as to at what stage an athlete, or a team should seek out the services of a strength & conditioning coach. Due to this lack of awareness, there is no measurable scale (such as the Tanner Staging) of physical preparedness to which athletes can compare themselves to relative to age and developmental stage, as mentioned previously. Because of this, injury likelihood in youth athletes is increased due to the anecdotal evidence that many parents seek strength & conditioning services separate to their child's team training to give them a competitive edge. This competitive edge, initiated by pushy parents can also lead to the child's resentment of a sport and unfortunately is too common an occurrence (Irish Independent, 2017) Athletic potential can also be reduced by the delay of the introduction to strength & conditioning in youth team sports. This is evident through studies of the effects of strength & conditioning programmes on children and adolescents in team sports (Athletics Canada 2001, McKinlay *et al.* 2018, Harries *et al.* 2018,).

The overall lack of strength & conditioning guidance in the early athletic development stages is apparent in all of these models, although the IOC briefly mentions that an athlete should avail of sports science information in once they reach a high-performance stage. However, this is understandable as young kids aged 12 and younger are encouraged to play multiple sports in their formative years and the introduction of strength & conditioning training at this stage could possibly lead to burnout which in turn could lead to a reduction in participation.

Differences between the models.

When examining and comparing the GAA, IOC, FA and AC models it is clear that chronological age is the defining factor by which you are initially categorized. For example, the 3 stages of the GAA model are categorized from ages 4-11, 12-17 and 18+, each stage leading directly into the next once a certain age is reached. Similar in the FA Model each of the 8 stages are categorized by biological age from ages 5 to 20+, again with each stage directly leading to the next once the certain age is reached. Unlike the GAA, FA and AC models, the stages in the IOC model overlap with each other through all stages. The ages are from 0-12, 10-16, 13-19 & 15+. This overlap is well designed as it takes biological

development into consideration when assigning an athlete to a stage. Gender differences are taken into consideration in the AC model but are not in the other three models. This is important as it is well known that females generally mature physically earlier than males do and therefore should be allowed to progress accordingly. As mentioned above, parents often seek 1-on-1 strength & conditioning coaching and personal training for their kids to give them a competitive advantage and to allow them to develop at a faster pace than other kids their age. This advantage can create a significant gap among young athletes in the same age group and therefore the overlap of developmental stages allows for those athletes with less athletic potential to develop and play with kids their own level as they develop while also allowing those athletes who are highly developed for their age to train and play with kids at their level.

The IOC model also identifies that not all athletes want to play at a high-performance level and the majority of athletes play for the social aspect and the enjoyment of the sport and also the benefits of taking part in physical activity and competition. The IOC model does so by outlining the various pathways available for non-elite athletes such as local leagues, recreational leagues and intra-mural leagues where competition and winning isn't the only objective, but overall enjoyment and participation in the game is. Although all models have developed pathways to high performance, the AC model is the only model to include a final stage focused primarily on reintegration into society after competition. This is important as athletes often find it difficult to transition from highly structured days planned around training and competition to everyday life where they are not confined to restrictive training schedules. (Olympic Athlete 365, 2018).

The IOC and FA models do not mention long-term participation in playing sport, instead the final stage in these models are focused on retaining athletes for coaching, managing, refereeing and general sporting assistance. These roles are not as attractive to athletes who are not up to elite standards as those on the top teams and often this is why participation rates drop off as athletes grow up. In contrast, the GAA model does not mention participation once an athletes' playing career is finished. There are many speculative reasons for this. For instance, due to the fact that all GAA sports are amateur and under GAA rule managers officially do not get paid a salary, there is little to no incentive to take a coaching or managing position as the time requirements are often quite immense and require lots of travel and time commitment (Irish News 2018). In contrast, some of the highest paid coaches in the

FA and IOC often make in the hundreds of thousands, if not millions of dollars yearly for their duties.

Chapter 3: Conclusions & Recommendations.

Conclusions.

The four plans that have been examined in this review, IOC, GAA, FA & AC, all categorize athletes by chronological age at the early stages of their career. In the IOC and AC models as the players continue to develop, athletes are categorized by level of performance which usually occurs at age 16+. It is at this stage that players who have the ability to compete at national, international or Olympic levels are separated from those who play at a local or regional level and it is here that there is a notable difference in the level of training. As mentioned previously, this form of division, by performance level instead of chronological age, is generally where strength & conditioning coaches are introduced into the training process. At this stage, athletes search for advantages from every aspect of both training and recovery, including, nutrition, hydration, sleep as well as highly structured and sports specific resistance training programs.

Unlike the IOC and AC models, the previously mentioned form of categorization is not used in the GAA and FA models as athletes are categorized by age from beginning to end of playing career. This lack of formal categorization means that there are no separate guidelines for athletes who would like to just play recreationally vs athletes who would like to play at a high-performance level. This could possibly lead to a feeling of neglect from athletes who do not have any lower performance level teams or leagues they could participate in, and this in turn may lead to a decline in participation.

A lack of participation once an athlete finishes playing may be due to the fact that many coaches, assistants and managers are underpaid or unpaid for coaching at local and regional levels. These roles require a high level of commitment and often fulfilling these positions purely for the love of the game is not incentivising enough to retain athletes post playing. In contrast to the lack of pay at lower levels, higher level coaches are often paid very high salaries for the same level of commitment which may seem unfair to those coaching at lower levels.

The previous chapter has examined the literature available from four long-term athletic development plans and from which, there is no single long-term athletic development model that can be applied definitively to all youth athletes and all sports. Chronological age, gender

differences, stage on the tanner developmental staging, and level of physical performance should all be accounted for when planning for long-term development.

Recommendations

It is recommended that a higher importance be placed on strength and conditioning as well as the development of overall general physical qualities in every sporting model. The rationale behind this recommendation is that children, as mentioned in the review, who fail to develop their fundamental motor skills by age 12 are unlikely to reach their genetic athletic potential. This could be achieved by the governing bodies of sports establishing their own sport-specific long-term athletic development plan that accounts for variants of youth athletes of all ages and levels of athletic performance within the sport. Another aspect that could be included in a sport specific model would be formal testing of skill and physical development over an extended period. This testing, examples of which can be found at the beginning of the review, would not be a means of competition among young athletes, but rather a quantitative measure of development over time that would double as motivation for the player and feedback for the coaches.

If a sporting body was to create a detailed long-term athletic development plan, within the strength and conditioning section, athletes should be educated more on resistance training techniques, periodization, specificity, factors influencing recovery, such as sleep, nutrition and hydration. It is recommended that these plans require a qualified strength and conditioning coach to educate and supervise the athletes which in turn would allow for all players to be given the same opportunity to develop athletically. This possibility could potentially reduce, if not eradicate, the problem that has arisen with parents hiring private strength and containing coaches and personal trainers to give their children an unfair advantage against their fellow athletes at a young age.

Another problem that is faced with many organizations is the lack of participation post playing career. This would seem to be because the majority of coaches are not paid in amateur sports and for a coach to get paid for coaching they would often have to coach at an international or professional level. It is recommended that in order to counteract this, monetary incentives should be provided to coaches and ex-players to stay with clubs,

although it is understandable that smaller clubs often couldn't afford this due to lack of funding and sponsorship. These funds could be acquired from higher up in the organisations with a possible reduction in salary for elite players and coaches. Alternatively, international sporting bodies could introduce a small tax on professional players' annual salaries, the money from which would be given to grassroot local and regional clubs and teams in an effort to incentivise better pay for coaches which in turn would result in better quality coaches.

To sum up, current long-term athletic development plans are a step in the right direction to improving the overall quality of and participation in sports from a young age. A greater importance should be placed on all coaching staff, both strength & conditioning coaches and team coaches, to allow for the continual development which in turn may raise the standard of sport and the quality of the athletes produced.

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