KNOWLEDGE AND APPLICATION OF LONG-TERM ATHLETIC DEVELOPMENT
CONCEPTS IN YOUTH ATHLETES: A PILOT STUDY

by

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ABSTRACT

The purpose of this study is to examine the psychometric properties of an instrument used to identify knowledge and application practices of individuals currently able to apply long-term athletic development principles in youth sport environments (i.e. sport and strength and conditioning coaches, athletic and club directors). Participants completed an online survey regarding their knowledge of the Long-Term Athletic Development Model (LTAD), Developmental Model of Sports Participation (DMSP), and Youth Physical Development model (YPD) and if their training reflects the principles specific to one model over another. Participants included 217 males and 71 females with a mean age of 32.8 ± 11.2 years that identified themselves as either a sport coach (n = 134) strength and conditioning coach (n = 108), sport administrator (n = 25), or other (n = 17). A principal component analysis was used on the Likert items that qualified for inclusion based on their KMO and Bartlett’s Test of Sphericity values. Eight components were extracted based on the correlation of individual items and relationships between components were identified and discussed. The items were also forced into three components in order to be compared with the sections of the survey. These components were more reliable, although they explained less variance than the original model. Additional research is needed to obtain more reliable data that can be used to evaluate and modify coaching education systems of sport organizations to align with the principles of long-term athletic development outlined in the LTAD, DMSP, and YPD models.
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CHAPTER I

INTRODUCTION

As president Franklin D. Roosevelt expressed in an address at the University of Pennsylvania in 1940, “We cannot always build the future for our youth, but we can build our youth for the future”.¹ This statement can be directly applied to the concept of long-term athletic development (LTAD). Although it is impossible to predict a young athlete’s involvement or success in sport, children should be educated on the basic concepts of strength and conditioning and sport to prepare them for a lifetime of participation in sport and physical activity.¹ This education should be provided systematically with assistance from qualified professionals to ensure safety and well-being are a priority through the development of movement patterns, muscle qualities, psychosocial skills, and sport-specific skills.²

Three primary models have been developed to provide direction for practitioners programming for and educating athletes on these concepts. These models include the Long-Term Athletic Development model (LTAD), Developmental Model of Sports Participation (DMSP), and the Youth Physical Development model (YPD).³-⁵

The LTAD model is applicable to athletes of any age and is divided into seven stages athletes progress through based on developmental age and is quantified with corresponding chronological age ranges. This model outlines optimal times for athletes to begin training strength and conditioning activities, what percentage of their time should be dedicated to training versus competing, and appropriate times for athletes to engage in multiple sports to develop movement skills or choose a primary sport to train in to
maximize their athletic potential.\textsuperscript{4-6} The purpose of this model is to discourage early specialization (in late specialization sports) in order to encourage athletes to adopt an active lifestyle after their competitive sporting careers cease.\textsuperscript{1,7}

The DMSP recognizes three pathways athletes 7-18 years of age can choose in their early sporting careers: early specialization, early sampling, and recreational participation.\textsuperscript{7} Similar to the LTAD model, the DMSP favors the early sampling pathway with progression through three developmental phases with a progressively narrowing sport focus identified as the sampling, specializing, and investing years.\textsuperscript{6-8} The model is supported by seven postulates backing sport programs utilizing the early sampling pathway. Various studies indicate that engagement in this pathway is critical for maximizing sport participation while minimizing early dropout by allowing children to engage in multiple sporting environments.\textsuperscript{3}

The YPD model is a newer alternative introduced in 2012 that offers a comprehensive approach to training athletes 2-21+ years of age within a philosophy that promotes individualization, athlete-centered training, and places emphasis on child development over performance outcomes.\textsuperscript{2} This model provides guidelines for the appropriate timing and development of fitness components including speed, agility, power, and strength in relation to biological age, accounting for individual rates of maturation and development. This approach is intended to empower strength and conditioning coaches to develop diverse training programs in a further attempt to keep athletes interested in the benefits of training while promoting the health and well-being of youth athletes.\textsuperscript{2}
While these models suggest optimal training methods and progressions for late specialization sports in a general sense, there is a lack of information found on the athletic development processes used specifically in individual sports’ cultures. With large scale junior club tournaments becoming the primary network for college recruiting, early specialization is becoming more prominent for athletes desiring to play at the collegiate level. Pressure from club sport coaches, high school sport coaches in the same season, and parents may be discouraging young athletes from engaging in a variety of sports because of conflicting practice and competition schedules, cost of competing in multiple sports (monetary, time, athlete fatigue, etc.), and/or lack of knowledge of optimal specialization and sampling times outlined by these models. All three models of long-term athletic development suggest avoiding early specialization because of the increased likelihood of athletic careers being stunted due to the increased risk of overuse injuries, athlete burnout from future involvement in sports and physical activity, and the risk of athletes not reach their full potential available through normal growth, maturation, and training.

Researchers identified little research indicating the levels of knowledge and application of these models among personnel involved with the development of youth athletes, especially in the United States. Research by McKeown and Ball in 2013 indicated that of the 65 respondents from Australia, Canada, Great Britain, Ireland, and New Zealand, most were familiar with the LTAD model and had very little understanding of the DMSP and YPD models. Authors identified a “need for greater understanding of long-term development for everyone involved in junior sport, in particular
the coaches, parents, and administrators.”10 This may be related to the reports of coaches’ desires for more individualization and practical application of the theories discussed in the three models.10 This indicates a need for modification to the current coaching education programs that needs to offer youth coaches more structure and suggestion on how to apply the concepts of these three models in their practice.

The purpose of this study is to examine the psychometric properties of an instrument that can be used to identify the level of knowledge of individuals involved in the development of junior athletes regarding three models of youth athlete development; the Long-Term Athletic Development Model, the Developmental Model of Sports Participation, and the Youth Physical Development Model.
LIST OF DEFINITIONS

Adaptation: refers to changes in the body as a result of a stimulus that induces functional and/or morphological changes in the organism. The degree of adaptation is dependent on the genetic endowment of an individual.\(^4\)

Athleticism: is the ability to repeatedly perform a range of movements with precision and confidence in a variety of environments, which require competent levels of motor skills, strength, power, speed, agility, balance, coordination, and endurance.\(^1\)

Chronological age: the number of years and days elapsed since birth.\(^4\)

Coefficient of efficiency: the equivalent of an input-output ratio expressed as a percentage of the actual number of children that participate in a specific sport program at a given time (e.g., at age 10) over the number of the same children that participate in the same sport at a later time (e.g., at age 13). A coefficient of efficiency of less than 100% from childhood sport participation to adolescence sport participation would indicate that certain children have dropped out of a specific sport and are no longer available to train for elite performance in this sport.\(^3\)

Critical period of development: the point in the development of a specific capacity when training has an optimal effect.\(^4\)

Deliberate Play: the intentional and voluntary nature of informal sport games in contrast with three other types of activities: 1) the free play activities of infancy and early childhood, 2) the “structured practice” activities typical of organized sport, and 3) deliberate practice activities.\(^3\)
**Deliberate practice:** any training activity that is performed with the specific purpose of increasing performance, that requires cognitive and/or physical effort, and is relevant to promoting positive skill development.³

**Development:** the relationship between growth and maturation. Includes social, emotional, intellectual, and motor realms of the child.⁴

**Developmental age:** the degree of physical, mental, cognitive, and emotional maturity. Physical developmental age can be determined by skeletal maturity or bone age after which mental, cognitive, and emotional maturity is incorporated.⁴

**Early Sampling:** an approach that encourages youth to engage in a variety of sports or activities and a number of positions within a given sport.¹

**Early specialization:** the concept of a child participating in year-round intensive training within a single sport or physical activity at the exclusion of others.¹

**Fundamental Movement Skills (FMS):** serve as a building blocks for sport-specific movement patterns and should typically be the focus within physical development programs for children starting in early childhood so they can develop their gross motor skills.²

**Growth:** the most significant biological activity during the first 2 decades of life and is defined as an increase in the size attained by specific parts of the body, or the body as a whole.¹

**Health:** a condition of well-being free of disease or infirmity and a basic and universal human right.¹
Long-Term Athletic Development: the habitual development of “athleticism” over time to improve health and fitness, enhance physical performance, reduce the relative risk of injury, and develop the confidence and competence of all youth.¹

Maturation: progress toward a mature state and varies in timing, tempo, and magnitude between different bodily systems.¹

Peak Height Velocity (PHV): maximum rate of growth in stature during growth spurt. The age of maximum velocity of growth is called the age at PHV.⁴

Peak Weight Velocity (PWV): is the maximum rate of increase in weight during growth spurt. The age of maximum increase in weight is called the age at PWV⁴.

Physical Literacy: refers to the mastering of fundamental motor skills and fundamental sport skills.⁴

Puberty: the point at which an individual is sexually mature and able to reproduce.¹

Qualified professional: an individual that possesses (a) an appropriate understanding of pediatric exercise science, exercise prescription, technique evaluation, and testing methods, (b) relevant coaching experience and a strong pedagogical background, and (c) a recognized strength and conditioning qualification, for example, the Certified Strength and Conditioning Specialist (CSCS) certification.¹

Trainability: a period of faster adaptation to stimuli and the genetic endowment of athletes as they respond individually to specific stimuli and adapt to it accordingly. Trainability has been defined as the responsiveness of developing individuals to the training stimulus at different stages of growth and maturation.⁴
**Training age**: the age where athletes begin planned, regular, serious involvement in training.¹

**Well-being**: is defined as a positive and sustainable state that enabled an individual, group, or nation to thrive and flourish.²

**Window of Opportunity**: existence of naturally occurring periods of accelerated adaptation for a range of biomotor qualities.²

**Youth and young athletes**: both children (up to the approximate age of 11 years in girls and 13 years in boys) and adolescents (typically including girls aged 12–18 years and boys aged 14–18 years).¹
CHAPTER II

REVIEW OF THE LITERATURE

This study will examine how/if youth sport coaches are educated about the LTAD, DMSP, and YPD models and how/if they implement them in their training. Below is a brief review of the literature describing these models and how they have been applied in various sport settings.

**Long-Term Athletic Development Model**

The Long-Term Athletic Development Model (LTAD) is a seven-stage model that is built on physiological principles of growth, development, and optimal periods of skill acquisition. This model outlines optimal levels of training and competition for youth athletes throughout their development while fostering enjoyment in sport and physical activity while helping them optimize their performance.

LTAD was created with hopes of counteracting shortcomings and their consequences that hinder the Canadian sport system. These shortcomings fall under two broad categories relating to athletes being trained improperly/nonspecifically and issues with coach and parent knowledge and enforcement of proper training. Developmental athletes in the Canadian sport system are often forced to over-compete and undertrain at all ages, developing athletes are being prompted to engage in adult training and competition programs, and female athletes being forced to engage in training/competition programs designed for male athletes. Often these competition systems interfere with athlete development by having an excess of competitions.
Coaches prior to the introduction of the LTAD model would use chronological age as opposed to developmental age when planning training and competitions which neglects the critical periods of accelerated adaptation of training. Furthermore, preparation at any age/level is geared toward the short-term outcome of winning instead of the process. This can cause coaches to not include proper teaching of the fundamental movement skills. This can be a function of a system that has the most knowledgeable coaches working at the elite level instead of at the developmental level where it is imperative to have quality, trained coaches. If sport organizations were building from these fundamental movement skills taught in physical education programs in schools and recreational community programs, it would suffice but this is not the case. A lack of parental knowledge of LTAD also contributes to athletes specializing early because it is not reinforced to athletes that they need diverse sport experiences to be a more complete athlete.

The model is divided into seven stages including Active Start, FUNdamentals, Learn to Train, Train to Train, Train to Compete, Train to Win, and Active for Life. The first three stages encourage physical literacy and sport for all athletes, the next three stages focus on excellence in sport, and the final stage is designed to encourage a physically active lifestyle. The first four stages are generally appropriate for all late-specialization sports. In the Training to Compete and Training to Win stages, the age ranges have more variance across different sports.

The next section explains the general objectives of each stage, training types, and amount of competition athletes should be exposed to, and what parents can do to foster a positive sport experience for their children.
**Stages of LTAD Model:**

**Active Start (ages 0-6 years old)**

The general objectives of the initial stage center around introducing children to an enjoyably active lifestyle, promoting healthy body weight, assisting with physical and emotional development, and learning how to move properly. Children in this stage should be participating in a variety of physical activities, both organized activities and exploratory free play, in order to enhance the development of brain function, coordination, social skills, gross motor skills, emotions, leadership, and imagination.

It is important for children to be able to explore their physical environments to learn how to develop basic movements such as running, jumping, wheeling, twisting, kicking, throwing, and catching. Introductory gymnastics and swimming programs are an excellent way to provide different environments for them to learn how to move and acquire new sets of movement skills. These new movements skills become the foundation for more complex movements used in their athletic careers.

This stage should include daily activities that provide opportunities for children to build confidence and boost self-esteem using a variety of fun and challenging sports activities while also including non-competitive games that focus on participation. Children should be exposed to activities that are both fun and active and should avoid being sedentary for more than 60 minutes at a time.

**FUNdamentals (males age 6-9, females age 6-8)**

The second stage is termed FUNdamentals because of its focus on learning fundamental movement skills and building overall motor skills by engaging in a variety of sports. By participating in multiple sporting activities, children get to develop the “ABC’s of Athletics” including running, jumping, wheeling, and throwing and the
“ABCs of Athleticism” which include agility, balance, coordination, and speed. These skills must be practiced and mastered before sport-specific movement skills are introduced.

Speed is a critical element to develop during this stage because the first window of opportunity for its development occurs from ages 6-8 in girls and 7-9 for boys. If developing speed is overlooked during this stage, it can be detrimental to a child’s future engagement in physical activity and sport. Athletes should train their linear, lateral, and multi-directional speed in short bursts lasting less than 5 seconds. Games can, and should, be used in efforts to develop speed, power, and endurance in order to maintain a fun atmosphere while training those qualities.

Athletes at this stage can begin basic strength training using medicine balls, swiss balls, and body weight. All programs should be well-structured and monitored by a qualified coach but there is no periodization present.

During this stage, parents should arrange for their children to be physically active every day in a variety of sporting activities that incorporate short bursts of activity rather than one long training session. Participation should be limited to once or twice a week in the child’s preferred sport and accented with other sport participation 3-4 times per week. These sporting activities should revolve around the school year and be supplemented with a variety of sport camps during the summer and winter holidays.

The sports they are involved in should focus on running, jumping, throwing, catching, and kicking. Youth athlete coaches in an organized setting should introduce young athletes to the simple rules of the sport and begin screening for talent at these ages. The importance of having fun and enjoying participation should be emphasized.
over focusing on results during this stage and unstructured play should still be encouraged.⁶

Long-term enjoyment of physical activity and sport is fostered during this stage which is important for athletes transitioning from a competitive to recreational sport atmosphere.⁴ Children who develop fundamental movement skills are more likely to enjoy physical activity later in life and have more success in their athletic careers.⁶

Learn to Train (males 9-12, females 8-11)

Once the fundamentals of sports are introduced to young athletes, they move to the Learning to Train stage (females age 8-11, males 9-12) where they are developmentally ready to acquire and refine general sports skills that were introduced in the previous stage.⁴

This stage is essential for future athletic success because it is when athletes narrow their focus on three sports that they enjoy and are more likely to succeed in.⁴ Although talent identification can begin during this stage, performance at this age is not necessarily indicative of an athlete’s potential level of performance level in a particular sport.⁶ Athletes competing in team sports should all be given the chance to compete, this stage is not the time for less-developed players to be confined to supporting the more gifted players at this young age.⁶

As parents and coaches start to identify talented children, the idea of specializing their child in a single sport presents itself. However, if children specialize early in sports where late specialization is beneficial, this can be detrimental to the later stages of skill development and the refinement of fundamental sport skills.⁴ To help children to fully develop and refine their athletic skills, parents should encourage their children to play at least 3 different sports.⁴ However, sport specific training should be limited to 3 times per
week with participation in additional sports 3 times per week at these ages. The National Coaching Certification Program (NCCP) suggests the goal in this stage should be 70% of activity time spent training and the remaining 30% engaging in actual competition and competition-specific training. This balance can be achieved by having 2-3 practices for every game they play but will vary based on sport and individual needs and sport involvement. Balyi et al confirm that athletes who utilize this suggested ratio of competition to training time are better prepared for both short and long-term competition than those who are solely motivated by winning.

Training hours may now be dedicated to a strength and conditioning program including body weight exercises, medicine ball and stability ball training, and exercises that include hopping and bouncing. Children should be encouraged to develop their endurance through relay-type activities or other games where they are forced to move continuously for a set period of time. Balyi et al suggest that speed training should continue to be trained in this stage through rapid, darting movements or change of direction movements incorporated during the warm-up. At this time, single or double periodization can be incorporated into their workout regimen, depending on the sports they choose to focus on. In addition to strength and conditioning training, Balyi et al identify this stage as an ideal time to introduce athletes to mental preparation, such as mental, cognitive, and emotional development.

**Train to Train (males 9-12, females 8-11)**

This stage begins when the athlete experiences their major growth spurt around age 11 in boys and age 9 in girls, although large variation in timing between individuals exists. Athletes are identified as early, average, or late maturers based on their aerobic and strength trainability at certain ages. Strength training gains around these ages
depends on when athletes reach sensitive periods of accelerated adaptation. The NCCP identifies two sensitive periods for girls which fall after reaching peak height velocity (PHV) and during the onset of menstruation, while males only have one period about 12-18 months following PHV.

During this stage, athletes can start to apply what they have learned during training in an increased level of competition in the sport and position they choose to specialize in. Balyi et al limit sports specific training to 6-9 times per week with athletes being trained using daily competitive situations such as practice matches or competitive games and drills. As the amount of time spent competing rises to 40%, athletes need to learn and develop the skills to cope with physical and mental challenges of competition by incorporating basic mental preparation skills into their training. Although the importance of competition rises, having too much competition in practices wastes valuable training time whereas having too little slows the learning of technical, tactical, and decision-making skills that can only be learned in a competitive and game-like atmosphere.

The NCCP suggests this stage as an optimal time for athletes to start engaging in aerobic training to develop their stamina (endurance) since the body can adapt to this type of training easier than in previous stages. Sports-specific skill training, speed, strength, and flexibility training should be included in this stage and broken down into cycles with different training foci, known as periodization. The importance of incorporating flexibility training increases during this stage because of the rapid growth for bones, tendons, ligaments, and muscles.
Equipment quality and ability to meet the needs for each child’s size, strength level, and ability reduces the chance of injury and allows them to have fun and succeed while developing certain attributes.4,6 Balyi et al suggest this is the optimal stage for athletes with disabilities to invest in sport-specific equipment, such as wheelchairs and athletic prostheses, so they are able to compete at their highest ability.

Balyi et al label the Learning to Train and Training to Train stages as the most important stages of athletic preparation because they can benefit or hurt young athletes if not executed with the proper balance of training, competing, and timing of specialization for their age and development.

**Train to Compete (males 16-23+, females 15-21+)**

By this stage, athletes have specialized in one sport and are typically focus year-round training on one event.6 Balyi et al state that athlete training in this stage can now consist of sport or position specific physical conditioning along with integrated mental, cognitive, and emotional development to optimize their performance and learn how to compete. Athletes must fully develop their Train to Train skills and physical preparation before committing to start Training to Compete.4,6

All physical and mental preparation should be individualized for each athlete so they can build their own strengths, eliminate weaknesses, and optimize recovery from training for their specific event or position.6

Balyi et al recommend that competition and competition-specific training can increase to 60% and overtake fitness training in this stage. The sports-specific technical, tactical, and fitness training should take place 9-12 times per week.4 Athletes prepare for high-level competition by using the skills they have developed in competition conditions.
created in practice through modelling and training specific aspects of what they expect to see during competition.

**Train to Win**

The final stage in athlete development in a competitive training environment is called Train to Win. Only the most dedicated and elite athletes reach this stage because it is centered around preparing to win at the highest levels of sport. Athletes must have an established competence of technical, tactical, and psychological skills to enter this stage while working to maximize their strength, endurance, flexibility, skill, speed, nutritional preparation, decision-making, and psychological preparation to succeed at this level. Athletes that succeed in this stage have engaged in and progressed through physical conditioning at developmentally appropriate times.

The NCCP emphasizes the importance of periodization in this stage so athletes can peak at major competitions while accounting for the demands of the sport and the strengths of the individual athletes. Training years should be divided into one, two, three, or more cycles depending on the strengths of the athlete and the demands of the sport. Frequent programmed rest times must be included to prevent physical and mental burnouts while maintaining fitness levels.

Balyi et al suggest that athletes should be engaging in sport specific technical, tactical, and fitness training 9-15 times per week during this stage with 25% of time dedicated to training and 75% dedicated to competition and competition-specific training.

**Active for Life**

The final stage included in the LTAD is known as Active for Life and can be entered at any age or stage, most frequently following the Learning to Train phase. It is characterized as a transition from a competitive athletic career to engaging in physical
activity and participating in sports to stay active.\textsuperscript{4,6} This transition can be caused by a negative experience in a competitive sport (being cut from a team, not making performance standard, etc.) which can deter the athlete from competing in any type of sport again.\textsuperscript{6} If individuals choose to stop competing in their sport, the NCCP\textsuperscript{6} suggests encouraging them to try sports where they are inclined to train and perform well or where health, activity, and social needs can be met. This aids in having early success when trying new sports if the athletes have previously mastered fundamental movement skills during the FUNdamentals and Learn to Train stages.\textsuperscript{6} Athletes ceasing competition in high-performance outlets should be encouraged to engage in less intense competition, master’s events, or other sports at the recreational level.\textsuperscript{4,6} Balyi et al\textsuperscript{4} recommend individuals should strive for 60 minutes of moderate daily activity or 30 minutes of intense activity for adults.

Balyi et al\textsuperscript{4} suggests that the Active for Life stage has a better chance of implementation if the athlete’s physical literacy is achieved before the training to train stage and if they have positive experiences in sports before they leave the competitive environment. Retired athletes with the desire to stay involved in sport can also explore careers involved with athletics such as sport management, coaching, officiating, or administration.\textsuperscript{6}

Granacher et al\textsuperscript{11} encourage muscular fitness training throughout all stages throughout the LTAD to promote the development of motor skills and performance, to improve markers of health and well-being, and to reduce the risk of sustaining injuries specific to their sports.
By implementing muscular fitness, young athletes may benefit through the stimulation of their athletic development process, preparing them to tolerate the demands of long-term training and/or competition, and by inducing long-term health promoting effects that continue into adulthood.¹

10 Pillars of successful long-term athletic development:

In response to the growing interest in the LTAD model, the National Strength and Conditioning Association (NSCA) developed a position statement taking existing literature and current practices in the field and created 10 pillars of successful long-term athletic development. By having these pillars in place, the NSCA hopes to a) help prevent or minimize sports-related injuries in youth athletes, b) help nurture a more holistic approach to long-term athletic development, and c) endorse the benefits of a lifetime of healthy physical activity.¹ These 10 pillars include the following:

1. **Long-term athletic development pathways should accommodate for the highly individualized and nonlinear nature of the growth and development of youth.**

   Lloyd et al¹ refute previous assumptions that children are miniature adults and should be treated as such using a variety of research showing clear age- or maturity-related differences between children and adults in terms of their anatomy, physiology, muscular size, structure, activation patterns, and function, and metabolic profile. These differences in the muscular systems of children typically reduce force-producing or force-attenuating abilities which affects absolute measures of physical performance and their risk of injury.¹ Additionally, the metabolic profile in children allows for more efficient oxidative metabolism and shorter recovery rates from high-intensity exercise when
compared to adults.\textsuperscript{1} Lloyd et al\textsuperscript{1} suggest that aerobic and anaerobic exercise thresholds will likely vary as young athletes progress through different stages of development.

Lloyd et al’s NSCA Position Stand\textsuperscript{1} references other age- and/or maturity-related differences that develop in a nonlinear fashion at different rates during childhood and adolescence including changes in the skeletal, cardiovascular, respiratory, and endocrine systems. Studies referenced by Lloyd et al\textsuperscript{1} explain that individual variation in biological maturity in these areas is very apparent when comparing groups of children of the same chronological age. This biological maturity refers to the progression toward a mature state with variation in the magnitude (extent of change), timing (onset of change), and tempo (rate of change) occurring in the different systems within the body.\textsuperscript{1} This breadth of natural progression youth athletes experience in their skeletal, cardiovascular, respiratory, and endocrine systems makes it difficult for practitioners to determine whether the changes in performance and recovery ability are due to specific training methods or merely the process of growth and maturation.\textsuperscript{1} Lloyd et al\textsuperscript{1} suggest that practitioners working with youth athletes should understand the science of pediatrics so they are able to a) differentiate the causes of performance adaptations, b) prescribe training programs to fit the needs and ability levels of the individuals, and c) understand how growth, maturation, and training interact to enhance the training response and development of athleticism.

Lloyd et al\textsuperscript{1} utilize a variety of sources to outline eight levels of sport and physical activity and how they affect growth and development. The eight levels are as follows:

a) Physically active children will typically outperform sedentary children in most indices of physical performance.\textsuperscript{1}
b) Inactivity is associated with a high chance of becoming overweight or obese during the developmental years.\(^1\)

c) Physical activity, exercise, and sport are preventative treatments for unfavorable weight status and an important precursor for healthy growth and development.\(^1\)

d) There is a positive relationship between motor skill competence and physical activity across childhood.\(^1\)

e) It is essential for all youth to be encouraged to enhance athleticism from an early age by engaging in multifaceted training inclusive of a range of difference modes of training.\(^2\)

f) Previous misconceptions regarding physical training on the course of growth and development are not supported by the literature, especially when comparing correlational and cross-sectional data.\(^1\)

g) Well-supervised physical training does not limit the development of secondary sex characteristics, postpone age at menarche, or restrict eventual height development.\(^1\)

h) When training is prescribed systematically with included rest periods, moderate-to-high intensity exercise is essential for the development of bone mineral density during childhood and adolescence which is beneficial for long-term skeletal health (especially for females).\(^1\)

2. **Youth of all ages, abilities, and aspirations should engage in long-term athletic development programs that promote both physical fitness and psychosocial well-being.**

   While children’s engagement in physical activity inherently impacts the development of physical fitness, Lloyd et al\(^1\) urge practitioners to not underestimate the potential impact from dietary behaviors, educational stress, sleep patterns, psychosocial health, and external pressures from friends, family, and coaches. These additional factors
affect youth athletes’ engagement in and enjoyment of sport, adherence rates to training programs, and the extent and rate of physical fitness development.\textsuperscript{1} Despite these factors influencing the training process of youth, there are often inconsistent levels of understanding and limited coordinated planning from personnel responsible for the long-term welfare and well-being of children and adolescents. Lloyd et al\textsuperscript{1} suggest this lack of planning is contributing to two primary outcomes that are present in pediatric literature. The first outcome references the increasing number of youth that is sedentary, overweight, or obese that demonstrate inadequate physical fitness standards, muscular strength levels, and motor skill competency.\textsuperscript{1} As this number increases, the relative risk of injury of these inactive children increases when they begin engaging in physical activity and sports.\textsuperscript{1}

“Exercise deficit disorder” (EDD) is a term proposed to describe a condition including reduced levels of moderate-to-vigorous physical activity that adversely impact the health and well-being of youth.\textsuperscript{1} According to Lloyd et al\textsuperscript{1}, children engaging in behavioral patterns consistent with EDD should be given exercise interventions that aim to develop general athleticism though the acquisition of fundamental movement skills and foundational strength.

The second primary outcome in the literature discusses the increasing number of youth athletes presenting with sport-related injuries caused by overexposure to high volumes of sport-specific training and competition without sufficient rest and recovery time.\textsuperscript{1} These injuries can be an initial step in the progression though nonfunctional overreaching, overtraining, burnout, and eventual dropout from sport.\textsuperscript{1,4,6} To prevent this progression, youth athletes should be encouraged to engage in multiple different activities
and sports, avoid year-round training in a single sport, and have training quality and volume closely monitored and modified by coaches and parents to provide adequate rest and recovery.\textsuperscript{1,4,6}

The LTAD model is designed to provide a structured program that will help control training variables, such as the amount of physical activity, to reduce the risk of overtraining and enhance the development of athleticism through physiological adaptations that occur in each stage of development.\textsuperscript{12} It is generally understood that the provision of a structured training program will produce superior results for athletes of any age when compared to those with unstructured training or a complete absence of training.\textsuperscript{12}

It is imperative that all youth (including inactive, overweight, or obese individuals) are given equal opportunities to participate in dynamic, integrated, and evidence-based training programs that foster the development of healthy bones and skill-related components of fitness.\textsuperscript{1} Whether athletes train in their sport to improve their performance or are participating at a recreational level, Lloyd et al\textsuperscript{1} explain that their training programs should be specific to their individual needs by preparing them for the demands of their sport(s) and providing them with the recommended amounts of physical activity while accounting for limitations imposed by the training environment.

In addition to physical training, young athletes must be offered ample support to encourage the development of a positive sense of self-worth, self-confidence, motivation, and enjoyment of these activities to foster lifelong participation in sport and physical activity.\textsuperscript{1}
3. **All youth should be encouraged to enhance physical fitness from early childhood, with a primary focus on motor skill and muscular strength development.**

Lloyd et al\(^1\) indicates that the primary goal of long-term athletic development programs should be to develop resilient, strong, and technically proficient youth that can maintain motor skill competence within the demands of any sporting or recreational activity. Early engagement in developmentally appropriate training during childhood is an acceptable method of optimizing future athleticism, lifelong health and well-being, and reducing the relative risk of injury.\(^1\)

Engagement in physical activity, with or without a competitive nature, is vital for the acquisition of fundamental motor skills (including locomotive, manipulative, and stabilizing movements) and foundational strength.\(^13\) During childhood, neural plasticity is heightened and involves pruning and overall strengthening of the synaptic pathways in the brain allowing children to take advantage of their motor skill potential.\(^13\) When the corticospinal tissue is highly adaptable, neural activation and control should be exercised to build neuromuscular coordination and force production capabilities which underpin the development of motor skills and muscular strength.\(^1\)

Coordination and muscular strength should not be viewed as separate entities, but rather components that should be developed together as prerequisites for motor skill function and performance.\(^1\) Lloyd et al\(^1\) state that muscular strength is strongly associated with several physical qualities in youth, namely speed and power. Therefore, by enhancing muscular strength through resistance training, physical performance and markers of health in obese and overweight youth are improved and there is a decrease in the risk of sports-related injury.\(^14,15\)
In order to properly execute the fundamental motor skills, the sequence of multi-muscle, multi-joint, and multiplanar movements must be coordinated and complimentary force production and attenuation is required. Lloyd et al suggests a multidimensional strength and conditioning program that uses a variety of training modes can help develop these movements while developing bone health and skill-components of fitness.

Early childhood is a critical time for developing a proficient physical “vocabulary” of fundamental motor skills that serve as the foundation to build more advanced and complex specific motor skills on. A meta-analytical review of 34 training studies referenced in Lloyd et al’s NSCA Position Stand highlights the increased trainability of motor skills in children by revealing that children had approximately 50% more resistance training-induced gains in motor skills than were found in adolescents.

There is no single chronological age that is considered acceptable to begin formal training, but recent guidelines recommend that children should be emotionally mature enough to accept and follow directions in addition to possessing satisfactory levels of balance and postural control before starting resistance training. This emotional maturity and body control typically occurs near ages 6-7.

In order to reach these levels of competence, Lloyd et al suggest that children should engage in exploratory and deliberate play including activities designed to develop fundamental motor skills and foundational levels of strength (such as gymnastics or other bodyweight management techniques) from birth until age 5-6. When children are mature enough to participate in organized sports, they are developmentally ready to participate in strength and conditioning activities that are specific to their developmental stage. This
fits into the long-term approach to developing athleticism outlined in Lloyd et al’s NSCA Position Stand.¹

4. **Long-term athletic development pathways should encourage an early sport sampling approach for youth that promotes and enhances a broad range of motor skills.**

As previously mentioned, there are two approaches of early athletic development: sampling and early specialization. The literature encourages youth to choose a sampling approach over the early specialization pathway which increases risk of injury, the reduction of an athlete’s motor skill development and standard of performance later in life, and an increased chance of overtraining and dropout from sport or physical activity.¹,⁷

Experts caution practitioners against overexposing youth to a narrow range of specific movement patterns with inadequate time to rest and recover because it can result in a reduced motor skill portfolio.¹⁸ Research indicates the reduction of an athlete’s motor skill portfolio as a result of early specialization predisposes them to a higher risk of injury and lower physical performance in their sport.¹,¹⁸ In opposition, exposing youth to diverse sports and physical activities makes them less likely to chronically overstress specific regions of the musculoskeletal system because of the variety of movement skills they perform and subsequently develop.¹ Lloyd et al¹ state that getting youth to adopt a movement variability philosophy will ensure that the forces applied to their body will constantly be changing which will promote more whole-body adaptation which will facilitate changes in coordination and reduce injury risk. As an added benefit, as athletes develop a greater spectrum of fundamental motor skills they are more able to produce
more intricate and reactive global movements that are used in sports, physical activity, and free play.\textsuperscript{13}

The risk of overuse injury in athletes who specialize early seem to be a function of the repetitive submaximal loading on the musculoskeletal system without enough recovery time to elicit adaptation.\textsuperscript{1,7} Recent research suggests that when a youth athlete participates in more hours of sport practice per week than their number of years in age or the ratio of organized sports to free play time exceeded 2:1, athletes were at an increased risk of injury.\textsuperscript{1} Tenforde et al\textsuperscript{17} suggest a threshold of 16 hours per week and a limit of 8 months of training per year has been identified to monitor training volumes of youth athletes to lower risk of injury.

One study using data on 1,190 individuals indicated that with age and time spent playing their sport accounted for, sports specialized training was a significant independent risk factor for acute and serious overuse injury.\textsuperscript{1} Another study on female youth athletes by Myer et al\textsuperscript{16} indicated that those who specialized at an earlier age increased their chances of obtaining a knee injury by 50\%. Authors conveying these findings also reported knee pathologies including patellar tendinopathy and Osgood-Schlatter disease had a relative risk 4 times higher in athletes who were specialized in one sport as opposed to those in multiple sports.\textsuperscript{16} Data in Lloyd’s article indicated better performances in gross motor coordination and standing broad jump tests in 10-12-year-old boys that used a sampling approach when compared to those that used an early specialization approach.\textsuperscript{7} In addition, analysis of retrospective data in a variety of sports indicated that individuals who were involved in 3 or more sports between ages 11 and 15
were more likely to play national compared with club standard sport between ages 16-18.¹

Tenforde et al¹⁷ also state that high training volumes associated with early specialization contribute to this augmented risk of injury.¹⁸ In a study by Eime et al¹⁸ examining 2,721 high school athletes across a variety of sports, high volumes of training and competitive workloads showed to be the most influential risk factor for injury. Adolescent baseball pitchers¹⁷ and runners¹⁸ were highlighted as being susceptible to overuse injury because of high training volumes.

Data revealed that in sports that are measured in centimeters, grams, or seconds (track and field, swimming, weightlifting), athletes who specialized later and were exposure to a lower volume of specific practice earlier in life were more likely to achieve elite performance in adulthood.⁷ In addition, athletes who specialized in their sports earlier were found to experience less success late in their careers despite early accomplishments.⁷

5. Health and well-being of the child should always be the central tenet of long-term athletic development programs.

Regardless of the extent of a child’s involvement in competitive or recreational physical activity, Lloyd et al¹ emphasize that health and well-being should be a key priority or any long-term athletic training program. Participation in sports has been identified as a viable means of promoting well-being in youth.¹

As referenced in Lloyd et al’s NSCA Position Statement¹, the International Olympic Committee stated that youth should engage in sports if the process is both pleasurable and fulfilling to sustain participation and success at all levels. These
philosophies apply to all forms of physical activity for youth, including a well-rounded
strength and conditioning program. The primary reason for initial engagement in sport
and physical activity for children is for enjoyment and to experience a variety of
activities. Likewise, a lack of fun and enjoyment is frequently the main cause of dropout
from sport.

To encourage well-being in youth, Lloyd et al urges practitioners to seek to
develop the following qualities in their athletes: a growth mindset, self-determined
motivation, perceived competence, confidence, and resilience. By developing a growth
mindset, athletes will begin to believe that effort, purposeful practice, and guidance from
a qualified coach will lead them to develop and succeed as an athlete. Self-determination
urges a child to participate in sports or physical activity because they are interested in it,
they enjoy doing it, it brings them intrinsic satisfaction, and it challenges them. It is
important to grow perceived competence in young athletes, especially adolescents,
because peer support becomes influential because social comparison is prevalent.Sheppard and Young state that developing confidence in young athletes is strongly
related to reduced anxiety and positive emotions which foster successful athletic
performance. Lastly, resilience refers to the ability of an individual to retain stability or
recover quickly under significant adverse conditions which is essential for athletic
success.

To foster the development of these qualities, Lloyd et al advise coaches to
incorporate a combination of mental skill training exercises and process-oriented goals
while keeping an element of fun in all training sessions. The training environment should
include developmentally appropriate training programs with clear and positive feedback to help athletes see that task failure is a positive step in the learning process.\(^1\)

Young athletes need to have ample encouragement and be reminded that the ultimate goal of their training is to develop chronic and sustainable adaptations instead of short term gains in performance.\(^1\) In addition, training must respect the basic welfare and well-being of the child by considering the athlete’s technical competency, training experience, and their current stage of growth and development while providing sufficient rest time to enable recovery and normal growth processes to occur.\(^1\) Lloyd et al\(^1\) strongly cautions coaches against creating or implementing any kind of training program that includes any kind of physical exertion that could be considered abusive. Forced physical exertion intended as punishment can have severe mental and physical consequences for young athletes and can deter them from engaging in sport and/or physical activity.\(^1\)

6. **Youth should participate in physical conditioning that helps reduce the risk of injury to ensure their ongoing participation in long-term athletic development programs.**

Although it is impossible to eliminate injuries in uncertain athletic environments, research by McLeod et al\(^{15}\) indicates that athletes can reduce their relative risk of injury by as much as 50% by engaging in a well-rounded, developmentally appropriate strength and conditioning program. Such a program should include resistance training, speed and agility training, motor skill and balance training, and appropriate rest.\(^{14,15}\) This decreased chance of injury is likely due to improved movement biomechanics, increased muscular strength, and enhanced functional abilities.\(^1\) In order to promote long-term athletic development principles, it is crucial that coaches convey the importance of youth athletes participating in a strength and conditioning program to prepare them for the demands of
their sport and physical activity.\textsuperscript{1} Sports participation alone a) does not provide sufficient stimulus to develop high levels of athleticism in youth, b) allow individual needs to be address such as muscle imbalances or reduced ranges of motion, or in some cases c) fulfill the daily physical activity guidelines set for youth.\textsuperscript{1}

Although the previous section was specific to training athletes to prepare them for performance in their sport, existing data supports the inclusion of preparatory conditioning for injury prevention in youth not involved in sports is critical as well. Children who are not physically active, overweight, and obese are twice as susceptible to activity-related injuries while engaging in competitive and recreational sports and general activity than their normal weight peers.\textsuperscript{1} This concept referenced by Lloyd et al\textsuperscript{1} as “underuse” is suggested to be the most dangerous risk factor for an increasing number of youth which emphasizes the critical importance of long-term athletic development models.

Injury rates have shown to be higher during times of rapid development, such as the adolescent growth spurt, because there are disproportionate growth rates between structural tissues as bone grows earlier and faster than muscle and tendons do.\textsuperscript{19,21} Although Lloyd et al\textsuperscript{1} states that linear bone growth precedes muscle and tendon growth, research has shown that bone mineralization typically lags causing increased bone porosity and probability of fracture. These inconsistent growth trends between these structures can lead to decreased flexibility and discomfort around joints.\textsuperscript{19} Additionally, increases in growth rate cause body mass and height of center of mass to increase without the equivalent adaptations in strength and power which can lead to excessive loading of the musculoskeletal system during dynamic and reactive actions.\textsuperscript{20,21} Young female
athletes, for example, are more susceptible to knee injuries during their growth spurt because their stature and body mass undergo rapid increases before hip and knee strength are sufficiently developed, especially hamstring-to-quadricep ratios.\textsuperscript{20}

In summary, regardless of a child’s involvement in athletic activities, all youth should be involved in a long-term training program to equip them with a basic level of athleticism suitable to withstand the physical demands of their chosen activities and to counterbalance risk factors associated with growth and maturity.\textsuperscript{1}

7. **Long-term athletic development programs should provide all youth with a range of training modes to enhance both health and skill related components of fitness.**

Data obtained by Benson et al\textsuperscript{14} using cross-sectional interventions indicates that both children and adolescents undergo significant changes in motor skills, muscular strength and power, running speed, agility\textsuperscript{22}, and endurance performance. Extended strength training interventions have induced significant improvement in relative lower body strength, faster change of direction speed, and 30-meter sprint speed.\textsuperscript{1,22} These studies do not, however, consider the influence of sex or maturation on the rate and magnitude of change.\textsuperscript{1} This overlooks the influence of growth, maturation, and training which makes it difficult to determine the causes of these improvements.

Although there is strong evidence suggesting that strength and motor skill development leads to meaningful gains in physical performance, Lloyd et al’s NSCA Position Stand\textsuperscript{1} identifies a lack of evidence showing which mode of exercise should be utilized during specific stages of development. In the past, the LTAD model has promoted a theory based on windows of opportunity that provides youth with specific periods in which to train specific aspects of fitness.\textsuperscript{1} If those aspects are not trained in the
correct windows, performance capacity will be limited later in life.¹ This theory has been criticized because of the lack of longitudinal evidence to support it.¹

Existing pediatric training literature suggests that both children and adolescents can make worthwhile gains in all components of fitness, regardless of the developmental stage.¹ Therefore, it is suggested that long-term training programs should seek to develop athleticism throughout both childhood and adolescence.²⁻²³

Recent findings show that when both children and adolescents benefit when they are exposed to a variety of training methods.¹ Findings in Lloyd et al.’s article found that both boys who had reached PHV and those who had not both made significant improvements in jumping and sprinting following varied 6-week resistance training programs.¹ Similar findings in a meta-analysis on different training methods and their effect on sprint speed development revealed that young males who had not reached PHV improved their sprint speed more following plyometric training in contrast to those who had reached PHV had better results after a program combining strength and plyometric training.¹ Lloyd et al.¹ explains that plyometric training promotes similar neural adaptations that naturally occur with growth and maturation before puberty, whereas using a combination of strength and plyometric training likely stimulates both neural and structural adaptations occurring after the pubertal growth spurt happens.

In order to validate these claims of synergistic adaptation and determine an optimal training prescription of youth in various stages of development, additional longitudinal research will have to be performed.¹

8. Practitioners should use relevant monitoring and assessment tools as part of a long-term athletic development strategy.
With the athletes’ well-being and welfare in mind, Lloyd et al\textsuperscript{1} advocate for practitioners to use appropriate monitoring and assessment tools in addition to age-appropriate programming. Without careful monitoring by qualified professionals, youth are at a higher risk for being exposed to excessive training loads, contraindicating training methods, and inadequate rest and recovery leading to overreaching or overtraining.\textsuperscript{1} Monitoring strategies should include teaching children and their parents about basic self-reporting monitoring strategies encompassing sleep patterns, nutritional habits, and physical activity outside of scheduled training sessions.\textsuperscript{1}

Practitioners can use these assessments to determine effective training strategies and mechanisms of adaptation, aid in program design, and to instill motivation in the athletes to gain understanding of the demands placed on their bodies in their sport or activity.\textsuperscript{1} Measuring physical growth throughout childhood and adolescence can also help coaches identify the athletes’ relative risk of injury and aid in early talent identification.\textsuperscript{1} These measurements should include quarterly assessments of stature, limb length, and body mass to show and analyze growth curves and identify PHV and PWV.\textsuperscript{2} The data collected on growth trends can help explain fluctuations in performance and identify youth who may be at risk of experiencing a growth-related injury.\textsuperscript{1}

Assessments can also aim to identify talented athletes; however, this favors early maturers and excludes youth that mature later.\textsuperscript{23,24} Furthermore, comprehensive talent identification is often time-consuming and expensive and produces success rates that are uncertain.\textsuperscript{24}

Monitoring strategies used in long-term athletic development programs should depend on the efficacy and relevance of the tests, their measurement error, practitioner’s
expertise, and the availability of time, equipment, and facilities. Additionally, these tests should be accurate, reliable, valid, and provide data that is meaningful to the athlete and practitioner. Physical capacities such as muscular strength and power, aerobic capacity, running speed, and motor competency can be evaluated using minimal equipment but can also be tested using more complex equipment depending on what is available to the practitioner. Lloyd et al. indicate the importance of considering both the process of performance (technical skill while performing the test) and the product of performance (their physical score on the assessment when evaluating young athletes.

Although physical assessments may seem more applicable to sport performance and injury risk, it is imperative that practitioners monitor their athletes’ well-being to get a holistic representation of the individual. Lloyd et al. offer a variety of methods of monitoring well-being using a modified version of the Profile of Mood States questionnaire, recovery-stress questionnaire, acute recovery and stress scale, and simple well-being questionnaires assessing fatigue, sleep quality, general muscle soreness, stress levels, and mood. These assessments have been shown to be valid assessments of mood, nonfunctional overreaching, and perceived well-being in a group, respectively. Analysis of the testing results can help practitioners identify potentially at risk for low well-being and motivation levels for continued participation in sports and/or physical activity. It is essential for practitioners to understand the warning signs of low well-being and overtraining including appetite loss, increased injury frequency, frequent tiredness or respiratory infections, inability to cope with training loads, heavy and stiff muscles, and abnormal sleep patterns.
Because children are being evaluated, Lloyd et al\textsuperscript{1} emphasizes that adherence to ethics of pediatric testing is critical as well as obtaining parental consent prior to testing.

9. Practitioners working with youth should systematically progress and individualize training programs for successful long-term athletic development.

When adopting a long-term athletic development pathway, it is essential that qualified professionals practice an individualized, progressive, and integrated approach when programming strength and conditioning activities.\textsuperscript{1} The individuals participating in the training program should drive qualified professionals’ program design, implementation, and refinement based on their individual skill level, level of fitness, experience, technical competency, and the relevant qualities applicable to their sport/activity.\textsuperscript{1} Program design will also be affected by available facilities available for training and the amount of time athletes have which is limited by pressures of academic work and the need for socializing with family and friends.\textsuperscript{1}

Additional challenges arise in youth training programs because periodization is driven by allowing adequate rest and recovery to enable natural growth processes to occur.\textsuperscript{1} This becomes difficult to balance with training stimuli when individuals are participating in multiple sports or activities within the same season or successive seasons.\textsuperscript{1} Lloyd et al\textsuperscript{1} emphasize the importance of mandatory rest and recovery periods in youth athlete training plans, regardless of pressures from parents or other sport coaches. By programming rest and considering training and competition schedules, athletes will be able to optimize their physical development and minimize accumulated fatigue.\textsuperscript{1} Researchers suggest that the majority of time be focused on general preparatory training with a focus on developing fundamental movement skills and foundational
As athletes age and mature, more time can be spent on developing sport-specific skills. Practitioners should be aware of the increased risk of injury present in intensive competitions lasting 6 or more hours with insufficient rest and should advocate for predetermined rest intervals between repeated bouts of activity when multiple competitions take place on the same day. Prior to a competition, Lloyd et al recommends that youth should be allowed 48 hours of rest and be encouraged to sleep for 7 or more hours per night because of the negative effects of insufficient sleep on health, learning, and physical performance.

Because growth and development in youth is not a linear process, practitioners need to be flexible and responsive to variations of the individuals’ timing, rate, and magnitude of psychosocial maturation in addition to different learning rates and styles. Lloyd and Oliver’s reference to “adolescent awkwardness” which is characterized by a temporary disruption in motor control and total-body coordination caused by the elongation of limbs may be cause for a practitioner to adjust the training program to reduce the load associated with programmed motor patterns. This requires professionals to have an in depth understanding of the training process paired with the ability to observe, teach, and correct techniques that align with key pediatric exercise science principles.

Qualified professionals and sound pedagogical approaches are fundamental to the success of long-term athletic development programs.

Practitioners enforcing a long-term athletic development program should have a wide range of teaching strategies to ensure that all youth are exposed to mentally
stimulating and physically challenging training programs that motivate and inspire holistic youth athlete development. Coaches must be able to communicate these teaching strategies effectively and have a variety of coaching skills to promote a motivational learning climate. This kind of climate should allow youth to participate in a multitude of developmentally appropriate activities aimed at enhancing competence and eventually experiencing success in those activities while allowing engagement in personal reflection. Together, these factors maximize the development of athleticism and promote intrinsic motivation in youth which inspires youth athletes to participate in sports, improve and develop their skills, and reduce the likelihood of being motivated solely by external rewards such as trophies or monetary compensation. By creating an intrinsically motivating environment, Lloyd et al states that the negative effects of stress are minimized and helps athletes to understand that success is a function of effort, hard work, and desire.

To maximize the learning process in the early stages of athleticism development, instruction, guidance, and feedback should be provided on basic motor patterns using a combination of visual demonstrations and external cues. Recent evidence from a study involving young gymnasts referenced in Lloyd et al’s NSCA Position Statement supports the use of external cues over internal cues based on the improved attentional focus found when using externally oriented cueing during rotational jumping techniques.

Any individual managing children in a competitive sport or recreational physically active environment should be effective at planning and instructing structured sessions, managing a range of behaviors, empowering athletes, varying their volume and
tone of voice, and teaching in a way that inspires youth to remain physically active throughout their lifetime.¹

**LTAD and Resistance Training**

**Fundamental Movement Skills**

Lloyd and Oliver² define fundamental movement skills as the building blocks for sport-specific movement patterns and state that they should typically be the focus within physical development programs for children starting in early childhood to help develop their gross motor skills. The development of these skills is crucial for children to master in a fun and safe environment to produce effective performance of more complex sports movement in later stages of development.² Functional movement skills and sport-specific skills (SSS) should always be present and emphasized in strength and conditioning programs throughout childhood and adolescence. The level of application of both skill types depends on which developmental stage they are currently in.² Fundamental movement skills should be emphasized before the start of puberty, whereas when adolescence begins more focus should be given to SSS.²

**Strength training**

Although there is a lack of formal literature covering optimal methods of initiating resistance training during the LTAD model and how it coincides with biological age, it is now accepted that children can safely and effectively participate in strength and conditioning training if they are supervised by qualified personnel who prescribes them programs². Through a series of randomized controlled trials, systematic reviews, meta-analyses, and position stands the positive effects of resistance training on muscular fitness, health, sport-related, and everyday activities have been studied and described in
healthy, non-athletic children.\textsuperscript{11} Because these findings were found in non-athletic children, researchers were careful to not directly apply these results to athletic children because of the differences in trainability caused by physiology and increased motor performance.\textsuperscript{11}

The long-term athletic development model has suggested the window of opportunity for strength training in youth is between 12-18 months after PHV occurs which typically is around the same time as peak weight velocity (PWV).\textsuperscript{2} During this time, adolescents go through periods of rapid gains in muscle mass caused by the increase of androgens circulating throughout their bodies\textsuperscript{2}.

Research has revealed that training using free weights produced the largest gains in muscular strength in youth athletes, followed by the combination of machine-based and free weight training, functional training, plyometric training, and solely machine-based training.\textsuperscript{11,26,28} Granacher et al\textsuperscript{11} explain that free weight training is superior to other training methods because it forces an increase in muscular stabilization of the trunk and limb joints in order to control the weights in multiplanar movements. The literature suggests that resistance training is an effective way to improve muscular strength in youth athletes of any age and it should be introduced in the late childhood stages of the LTAD.\textsuperscript{11} In terms of relative strength gains, it appears that child athletes have a higher level of trainability than adolescents do and that free weight training is particularly effective.\textsuperscript{11}

Strength development results from a combination of muscular, neural, and mechanical factors.\textsuperscript{2} In the prepubertal years, the neuromuscular system has accelerated development which provides a basis for strength development to be targeted during this
Lloyd and Oliver suggest that strength training should be targeted during childhood and after the adolescent spurt because both groups can achieve improvements in muscular strength through training.²

**Barriers to the adoption of LTAD**

Having a model that outlines what practitioners should be programming for their athletes during various developmental stages is only effective if it is adopted and implemented by relevant personnel.⁵ Beaudoin et al⁵ identifies the primary barrier to the adoption of LTAD is a lack of knowledge and education/literature provided to new and existing coaches. If coaches are not aware of the types of training they should be programming for their athletes at different stages in their development, they cannot implement the suggestions.⁵ There is a need for a better understanding of the principles of LTAD, the science behind those stages and coaching.⁵ A barrier to this understanding is the perceived complexity of the model held by parents and coaches.⁵ This can be countered by providing additional education and tools for coaches to utilize when planning their training sessions.⁵

The culture and organizational structure of some sports also make it difficult to enforce these principles.⁵ Women’s gymnastics and figure skating have been identified as early specialization sports³,⁵ which opposes the LTAD model and its campaign for late specialization to foster lifelong involvement in sport. The structure and culture of triathlon was also identified to be difficult to implement LTAD principles.⁵

The “win at all costs” mentality in coaches and parents is also a barrier to the implementation of LTAD.⁵ This mindset prioritizes results and competition and is often rooted in the personal beliefs that practicing other sports is not advantageous in the
development of their athlete. If these beliefs are held, it can make early specialization a more appealing option. On the surface, scientific research concluding that it takes 10-years and 10,000 hours of training for an athlete to reach elite levels supports these beliefs. However, applying this to late specialization sports can be detrimental to an athlete’s future in sport.

**Impact of LTAD**

The LTAD model can help both physically active and inactive parents alike produce a more active population. It provides a framework for parents to be physically literate by providing them knowledge on how to maintain a healthy lifestyle by being physically active, staying hydrated, eating the right foods, and recovering properly to compete in sports past youth. Parents are very influential in directing their children into physical activity later in life by encouraging their children to have a positive attitude about being active by promoting confidence in their kid’s movement skills at an early age. Balyi et al encourages parents to facilitate their kids’ understanding of physical, mental, cognitive, and emotional development.

In order for the LTAD model to be successful, coaches must be highly skilled, trained, and certified so they understand the stages of athletic development and what needs to take place during these stages. The model will have an impact on how coaches are educated and developed, on sport specific coaching education by National Sports Organizations (NSOs), and identify a need for part-time and full-time coaches that work with developmental athletes. For coaches and parents to learn this information to pass on to their athletes, there need to be programs available through club or community organizations. Schools, clubs, and community sports programs should then be run in a
way that is supported by the model to rationalize the competition system from local to national levels.\textsuperscript{4}

Through the implementation of LTAD, the goals of the Canadian Sport Policy can be achieved. These goals include: 1) having a higher proportion of their population involved with quality sport programs at all levels and forms of participation, 2) expanding the pool of talented athletes in order to achieve world-class results at the highest levels of competition, 3) having an ethically based athlete centered development system in place that is modified and strengthened as needed, and 4) having collaboration and communication with stakeholders that is connected to the sport system.\textsuperscript{4} Balyi et al\textsuperscript{4} hop that integrating this model will influence changes to the structure and delivery of educational programs, force adjustment of competition calendars, offer simple pathways for progression, help athletes reach higher and more consistent levels of success, make athletes the focus of planning and decision-making, provide a basis for monitoring and evaluating program effectiveness, and start a framework for interventions at each stage.

LTAD provides an opportunity for sport scientists to help educate coaches and athletes on the science behind the development of sporting techniques and create new methods of training and monitoring athletes to help produce high level competitors on an international level.\textsuperscript{4} Further research in areas of physical development, mental/cognitive development, emotional development and trainability, and athlete readiness factors is inspired as a result of the introduction of this model.\textsuperscript{4} In addition, this model sets a precedent for appropriate levels of competition and lengths of competitive phases during each stage while providing normative data for children during their development.\textsuperscript{4}
With the increased obesity levels in the United States, Balyi et al\textsuperscript{4} stresses a growing need for American children to be educated about living a healthy lifestyle with ample levels of physical activity. Implementing the LTAD model in the United States will a) highlight the need for frequent and high quality physical education programs, b) highlight improved teacher training in elementary schools regarding fundamental movement and sport skills, c) offer and encourage college courses teaching physical literacy to educators and coaches to apply when they are teaching and coaching, and d) establish sport academies designed to enrich the training environment specifically in the Train to Train stage.\textsuperscript{4}

In order for LTAD to be successfully implemented in the United States, the government must endorse concepts in the model.\textsuperscript{4} Sport governing bodies, schools, recreation centers, and club sport programs must offer support and introduce the framework as well. While certain sports have begun to adopt the model, it would benefit each sport to have their own LTAD model they can implement that is more applicable to their specific training methods.\textsuperscript{4} Coaching education quality should be analyzed and modified as needed so they are aware of developmental milestones they need to adjust their coaching strategies to be sensitive of.\textsuperscript{4} Sport organizations, teachers, and coaches need to cooperate when structuring and scheduling competitions in each sport to work in accordance with LTAD principles and goals for each stage of development.\textsuperscript{4} All sport coaches should emphasize a full range of motor and sport skills during the FUNdamentals and Learning to Train stages.\textsuperscript{4,6} Information on the Active Start and FUNdamentals stages should be developed and distributed so parents and coaches in all sports understand its importance and implement related activities in sport-specific
sessions for younger children. And finally, there needs to be multiple sport-specific organizations that support and declare their dedication to implementing LTAD principles in their specific sports for the youth sport culture to fully adopt and follow the LTAD model.

**Developmental Model of Sports Participation**

The Developmental Model of Sports Participation (DMSP) shares similar principles as the LTAD model regarding the dangers of early specialization but focuses more on the psychosocial maturation of the athletes ages 7 to 18 years old. The DMSP features characteristics that promote continued participation and personal development for all athletes involved in sport, not strictly performance. The DMSP is divided into 3 developmental pathways that categorize an athlete’s career as either 1) elite performance through early specialization in a single sport, 2) elite performance through the sampling of multiple sports, or 3) recreational participation through sampling.

**Pathways in DMSP**

**Early Sampling Pathway**

This pathway involves individuals passing through three developmental phases with progressively narrowing sport focus. The stages include 1) the sampling years (6-12 years of age), 2) the specializing years (13-15 years of age), and 3) the investing years (16+ years of age).

The sampling years are characterized by individuals engaging in a wide range of activities and sports, the majority being deliberate play activities. This period is an essential building block for self-regulated investment in elite sport starting during adolescence and continuing into adulthood. Sport programs that focus on early sampling
emphasize meeting the needs of child development by fostering the enjoyment of various sport activities and free play.³

As athletes progress into the specializing years, they switch to a more even balance of deliberate play and deliberate practice and decrease the number of sports they participate in.⁷ When they reach the investing years, there is an excess of deliberate practice in one primary sport which may be accompanied by small amounts of deliberate play in another sport, if any other sport participation is present at all.⁷

The early sampling pathway is divided into two main elements: involvement in various sports and deliberate play.

**Involvement in Various Sports**

It is imperative for youth sport programs to prioritize the development of diverse sport skills while maximizing participation and minimizing dropout. Côté et al³ state that by allowing children to experience different physical, affective, and psycho-social environments, they are able to acquire the foundational physical, personal, and mental skills required to specialize in one sport in adolescence. The different environments allow for eclectic social interactions with their peers and related adults (parents and coaches) and allows them to learn how to adapt their emotional and self-regulating skills that can be applied in one primary sport in the future.³ Experiencing a variety of sporting experiences is often linked to a longer sport career and better transfer of technical, conceptual and physiological performance while allowing athletes to start to identify which sport they should specialize in based on their skillset.²
Deliberate Play

Deliberate play is defined as “the intentional and voluntary nature of informal sport games in contrast with three other types of activities: 1) the free play activities of infancy and early childhood, 2) the “structured practice” activities typical of organized sport, and 3) deliberate practice activities. According to Côté et al, deliberate play encompasses free play activities including running, climbing, jumping, and roughhousing, but includes organization and unique patterns of behavior. These unique behavior patterns can be manifested by modifying rules of an existing sport to make athletes at a specific age or skill level able to play using the available equipment, space, and number of people in their environment. Because rules are manipulated based on the situation, a deliberate play environment is easy to create and does not require structured parameters such as an organized practice or adult supervision.

Early Specialization

The early specialization pathway describes the path to elite performance where athletes between ages 6 and 12 choose to limit the diversity of their sport experience by participating in extensive training in one primary sport. Specialized athletes engage in extensive hours of deliberate practice in a primary sport with little to no engagement in any other sports. The need for extensive amounts of deliberate practice beginning at a young age is drawn from research indicating that it takes an average accumulation of 10,000 hours or 10 years of deliberate practice to achieve expertise or be considered elite in a chosen domain. To put this into perspective, this is equivalent to dedicating specific practice to one sport for 3 hours every day for 10 years. This threshold drives the
introduction of high amounts of intense, structured practice in a specific domain in young athletes.⁴⁰

Athletes who specialize are often provided more resources including space, equipment, and playing opportunities during their childhood which can manifest into forced participation in a training regimen.³ Sport specific cultures/bodies, coaches, and parents forcing participation in excessive amounts of deliberate practice and training can be used to identify talented children from a large pool of their peers.⁶ However, this method is not always supported by a child’s motivation to participate in athletics which Côté et al³ says can lead to early dropout. In addition, sport programs that force athletes to specialize early through early selection, skill acquisition, and intense training during childhood may negatively influence the athlete’s coefficient of efficiency and cause them to not reach their full potential available through normal growth, maturation, and training.³

Although there is research to support the 10,000-hour rule, Côté et al³ reference cases where expert performance in a sport has been achieved with 3,000-4,000 hours of sport specific training in sports where peak performance is reached after maturation. However, in sports where peak performance is achieved prior to puberty such as women’s gymnastics, figure skating⁵, and soccer, early specialization is viewed as necessary to reach the elite level.⁷

While early specialization has been found in several studies to be a suitable path to elite performance, it assumes that specializing in one sport and engaging in deliberate practice is superior to deliberate play and involvement in various sporting activities during childhood to promote elite performance in adulthood.³
Denzin\textsuperscript{30} suggests that specialization should be reflected on a continuum. This continuum would include athletes that participates in a single sport throughout the year while engaging in other sports concurrently and those that participate in intense training cycles in different sports on a year-round basis as early specializers.

**Recreational Pathway**

The recreational pathway is characterized by high amounts of deliberate play paired with low amounts of deliberate practice throughout the development of the athlete.\textsuperscript{3} The decision to continue participating in sports at a recreational level typically occurs around age 12 when other athletes typically start to specialize in one primary sport.\textsuperscript{3}

**Postulates of DMSP**

The postulates of the DMSP integrate performance, participation, and personal development and are consistent with sport-specific and general theories of child and adolescent development.\textsuperscript{5} They focus on key processes including deliberate play, deliberate practice, early specialization, and early diversification and the environment in which these processes occur.\textsuperscript{5} Côté et al\textsuperscript{3} presents evidence stating that programs requiring higher levels of investment and that discourage children from participating in a variety of activities may not be providing an optimal environment for lifelong participation in sport or future success in elite competition.

1. **Early diversification (sampling) does not hinder elite sport participation in sports where peak performance is reached after maturation.**

   Exposing youth athletes to diverse sporting activities during the sampling years should not be seen as a discriminating factor that limits sport expertise, but rather as a
foundation for optimal development in the pathway to elite performance in sports where peak performance is achieved in adulthood. Studies presented by Côté et al using elite ice hockey, field hockey, basketball, netball, baseball, tennis, triathlon, and rowing athletes have found that elite performance in these sports is typically developed after a period of sport sampling. These studies indicate that early specialization was not necessary to achieve expertise in their sport. This is not surprising given the age of peak performance in these sports usually occurs after the athlete has reached full maturity in their late 20s or early 30s. Most athletes in these sports specialize in their main sport around age 13-15 and be fully committed to training in that sport around age 16.

Although there have been studies indicating the long-term success achieved in adulthood utilizing the early specialization approach, Côté and Vierimaa suggest that the associated personal development and long-term participation costs can deter a large number of youth from continuing to participate in sport. This can be attributed to the increased likelihood of burnout, dropout, injuries, and less enjoyment in sport. Nurturing talent through a variety of sport activities and not focusing solely on performance in one sport during childhood facilitates the long-term development of elite performance while giving children a more positive sport experience.

The caveat to this postulate is relevant to sports where peak performance occurs before full maturation, such as women’s gymnastics and figure skating. Early specialization in these sports tends to be a strong predictor of elite performance because peak performance generally occurs in the mid-late teen years.

2. Early diversification (sampling) is linked to a longer sport career and has positive implications for long-term sport involvement.
Studies on sport participation into adulthood indicate that early diversification in multiple sports during childhood is linked to continued engagement in sport later in life. This is likely because these athletes are able to develop the foundational skills for a wide range of recreational sporting activities they can engage in when they grow older. Early diversification in youth may also help prevent repeated injuries to a specific region of the body by varying the movement patterns they engage in and developing qualities that may not be utilized when engaging in only one sport.

Studies have shown that athletes who compete in sports where peak performance is reached after maturation generally have longer careers than athletes who compete in sports where early specialization is the norm (women’s gymnastics and figure skating). In opposition, early specialization has been shown to shorten peak performance, increase rates of dropout and burnout, increase the risk of injuries in young athletes. Several studies in swimming, ice hockey, and tennis analyzed the link between early specialization and increased sport attrition demonstrate that athletes who began engaging in sport specific training activities at a young age (ages 9-10) were more likely to end their sport careers earlier than those who specialized later (ages 12-13).

3. **Early diversification (sampling) allows participation in a range of contexts that most favorably affects positive youth development.**

   There is strong empirical evidence in developmental psychology research that shows that a crucial part of successful development of youth is a wide variety of experiences during early development. Early diversification through sampling multiple sports can facilitate intrapersonal skills, prosocial behavior, a healthy identity, diverse peer groups, leadership skills, and social capital. These diversified experiences can
provide participants the opportunity to self-regulate their involvement, and promote different interpersonal skills to adapt to unique and everchanging social settings and enable them to create and maintain positive peer relationships.\textsuperscript{5,6,31} Each sport offers a distinct social context and opportunities for socialization, so by allowing athletes to engage in multiple sports, they increase their chances of promoting a broader spectrum of developmental experiences and outcomes\textsuperscript{3}. For example, if an athlete competes in an individual sport such as tennis they are likely to spend a greater portion of their time engaging in one-on-one quality time with their coach in comparison to a more team-oriented sport such as basketball.\textsuperscript{3} Even in sports with similar structures (soccer and field hockey, for example) can give athletes very different experiences based on the unique combination of coaches and teammates they are surrounded with.\textsuperscript{3}

Fredricks and Eccles also found that adolescents that were involved in a higher number of extracurricular activities were more likely to have better psychological adjustment and belonging in a school.\textsuperscript{31}

4. High amounts of deliberate play during the sampling years build a solid foundation of intrinsic motivation through involvement in activities that are enjoyable and promote intrinsic regulation.

Theories of motivation such as the Self-Determination Theory and Achievement Goal Theory suggest that motivation in young athletes can be developed through early involvement in intrinsically motivating activities such as deliberate play.\textsuperscript{5} The self-determination theory predicts that when athletes engage in deliberate play and other intrinsically motivating activities, their overall motivation level will be positively
influenced and will impact the individual’s willingness to participate in deliberate practice in an externally controlled environment.³

When analyzing motivation, Côté et al³ suggest that children become involved in deliberate play because of their own interest in the activity, not because of external rewards such as winning prizes or simply improving their performance. By initiating their own involvement in sport, this may help children become more self-directed and engaged in their participation in sport.⁵

Children’s motivation in sport can also be fostered during their sampling years by creating a “mastery” or “task” climate that is facilitated by promoting a deliberate play environment.³ Several studies have suggested that active athletes that were exposed to a deliberate play environment during their childhood may increase the level of participation and commitment to sport.⁵ This type of intrinsically motivating climate during athletes’ sampling years helps children become more self-determined and foster commitment in their future participation in sport.³

5. A high amount of deliberate play during the sampling years establishes a range of motor and cognitive experiences that children can ultimately bring to their principal sport of interest.

Deliberate play allows children to explore their physical abilities in a variety of contexts without requiring many resources (specific equipment, coaches, referees, the correct number of players for an actual game, etc.).³ While feedback and instruction from a coach in an organized practice setting are advantageous for athletic development, it is unclear whether engagement in an organized practice environment is greater than engagement in deliberate play activities.³ Several retrospective studies have examined the
deliberate play activities of elite athletes and have found that in sports such as tennis, rowing, baseball, and hockey, athletes reported participating in high amounts of deliberate play during their youth.\(^3\)

Several authors have argued that the time spent engaging in unstructured play environments provides many benefits including increased creativity in sport, adaptability in motor skill performance, flexibility, and variability which are key elements in developing successful athletic performance.\(^2\) Additional performance advantages have been found during stressful or high-pressure situations because the motor skills were learned implicitly in a playful environment.\(^5\)

6. **Around the end of primary school (about age 13), children should have the opportunity to either choose to specialize in their favorite sport or to continue in sport at a recreational level (Transition 1: childhood to adolescence).**

   In sports where peak performance is achieved in adulthood, Beaudoin et al\(^5\) state that specialization is not necessary before age 13. By allowing young athletes to have diverse sport experiences, they have higher quality learning experiences and develop physical competencies and/or perceptions of competence which nurtures motivation to continue in their sport, performance, and personal development.\(^5,6\) Psychological processes such as perceived competence and identity are developed in part by comparing themselves with their peers.\(^5\)

   Early adolescent children in this stage begin to recognize that their performance is influenced differently by effort, practice, and ability individually.\(^5\) Although the understand that these factors affect their performance, they do not understand competition or sport performances to the extent adults do.\(^5\) Coaches need to be cognizant of this, so
they do not overemphasize performance through deliberate practice or excessive amounts of structured practices during childhood.\textsuperscript{5}

The transition from sampling to specializing or recreational phases in early adolescence is marked by a a) reduction in the number of sporting activities, b) an increase in hours spent practicing and/or a higher intensity of practice, c) a greater emphasis on competition and success, and d) traditionally more support needs to be provided by the family, school, or club.\textsuperscript{3}

7. Late adolescents (around age 16) have developed the physical, cognitive, social, emotional, and motor skills needed to invest their effort into highly specialized training in one sport (Transition 2: early to late adolescence).

By age 13, youth are cognitively and physically ready to commit to one sport, however, investing in only one sport requires a few more years of maturity to enter the investment stage at the developmentally appropriate time.\textsuperscript{5} It is suggested that late adolescents (~16 years old) can meet the demands of competitive sport in terms of their psychological, social, emotional, and physical maturity.\textsuperscript{5,6} Individuals in this stage are also able to comprehend the benefits and costs of intense focus on one sport and are able to make an independent decision about investing in a specific sport.\textsuperscript{3} In order for athletes to become competitive and successful at an international level, they need to participate in intensive, sport-specific training programs that are implemented at the developmentally-appropriate times.\textsuperscript{5}

In most sports, full time commitment to one sport before age 16 is not necessary to achieve high performance levels in the majority of sports.\textsuperscript{5} However, in sports where
specialization occurs before age 16, research has indicated negative outcomes including an increase in injuries and a decrease in sport enjoyment.\textsuperscript{5}

A study referenced by Côté et al\textsuperscript{3} examined the differences in the amounts of sport specific practice time professional ice hockey players accumulated during the sampling years and investment years.\textsuperscript{3} The authors found that the average number of hours accumulated during the sampling years was roughly 10\% of the total hours invested (459 of 3,072 total hours) while an average of 56\% occurred during the investment years (2,215 of 3,072 hours).\textsuperscript{3} These figures support the identification of the investment years as the period in which elite athletes are devoted to specialized training.\textsuperscript{3}

**Youth Physical Development Model**

The Youth Physical Development Model (YPD) is an alternative model to the LTAD and DMSP models that encompasses athletic development from early childhood all the way to adulthood (ages 2-21+).\textsuperscript{2} This new model provides sport coaches, strength and conditioning coaches, physical educators, and parents with an overview of physical development while explaining the timing and reasons behind the training and emphasis on each component of fitness.\textsuperscript{2} It offers a comprehensive approach to the development of young athletes that permits individualization, is centered on athletes, and values the development of the child higher than performance outcomes.\textsuperscript{2} Although this approach may sacrifice short-term performance success, it should provide long-term benefits by promoting a sense of well-being through the development of intrinsic motivation for training and perceived competence in technical, physical, and developmental tasks.\textsuperscript{2} If
these attributes are established early on, these athletes will be more likely to stay interested and engaged in their sports and persist through adverse situations.\(^2\)

The YPD advocates the development of FMS from an early age which are associated with physical and psychological health benefits in children.\(^2\) The progression suggested in this model is designed to enable children to continually master new tasks throughout their developmental years which leads to increased enjoyment, perceived competence, satisfaction, and beliefs that effort causes success.\(^2\) The development of different fitness components are consistent and overlap throughout the model which allows strength and conditioning coaches the ability to develop diverse training programs that keep young athletes engaged while promoting their well-being.\(^2\)

**Resistance Training and YPD**

**Strength Training**

The YPD model suggests that the development of muscular strength should be a priority throughout all stages of development for athletes of both genders because it is speculated that muscular strength transcends all other components of fitness with respect to performance enhancement and injury prevention.\(^2\) LTAD recommends strength be trained after PHV or at the age of menarche in girls and 12-18 months following PHV in boys.\(^4\)

Early research indicates that muscular strength (including stature) could influence up to 70% of the variability in a variety of motor skills in 7-12-year old boys including throwing, jumping, and sprinting.\(^2\) Additional research suggests close associations between muscular strength and FMS development, running speed, muscular power, change of direction speed, plyometric ability, and endurance.\(^2\)
In addition to underpinning other components of fitness, muscular strength is essential for performance enhancement and lowering the risk of sport-related injuries in youth strength and conditioning programs. In 2011, NATA suggested that approximately 50% of overuse injuries in youth sports could be prevented to some extent by engaging in appropriate preparatory conditioning methods including proper strength training. This is particularly important for athletes engaging in high amounts of aerobic fitness training because they are at an increased risk of fractures.

Strength development sessions should not be considered an extra addition to a young athlete’s developmental program but should an essential part of their training that can replace another form of training (endurance training, skill session, etc.).

**Hypertrophy Training**

The YPD model suggests that hypertrophy training should be interspersed with strength training after the adolescent spurt and PHV occur (age 14 for males, 12 for females) to help athletes make further gains in muscular strength and overall performance.

Introducing hypertrophy training following adolescence allows more significant training-induced increases in muscle mass because of the larger serum concentrations of testosterone, estradiol, growth hormone, and progesterone. Higher concentrations of these hormones are directly linked with the stimulation of protein synthesizing pathways that cause pubertal growth and adaptations in skeletal muscle.

**Muscular Power Development**

Muscular power refers to the rate at which muscles perform work (Power = work/time = force * velocity). In order to achieve the greatest increases in power,
exercises should involve both components of the power equation, such as plyometrics. Plyometric exercises are initiated by a rapid stretch in a muscle during the eccentric breaking phase which produces high forces at ground contact. During the subsequent concentric phase, the same muscle group is forced to shorten quickly to accelerate the body vertically.

Although plyometrics alone are able to stimulate both strength and speed, a sub-analysis regarding training type revealed that they are unable to provide the greatest magnitude of changes in muscular power and are exceeded by sessions including a combination of weight and plyometric training, machine-based training, and free weight training. This finding could be attributed to the increased balance that is required to perform plyometric exercises. Because the bases and implements typically used in plyometric exercises produce a less stable environment than other training methods, the force output is lower than the more stable methods. Since youth balance capabilities are not fully developed, findings referenced in Voigt and Hohmann emphasize the need for plyometric training to be paired with resistance training to achieve optimal power gains in youth.

Apart from its omission in the current LTAD model, power development is typically emphasized after the onset of puberty. However, the YPD model suggests some focus should be given to training power before puberty occurs. This is based on research showing meaningful improvements in muscular power in both children and adolescents, although the magnitude and rate of development may not match those occurring after the onset of puberty. It is suggested that the key period of power development starts at the
onset of adolescence and continues throughout adulthood because maturational influences cause rapid improvements in muscular power.  

**Speed Development**

The LTAD model suggests that the windows of opportunity for speed development fall around ages 6-8 and 11-13 for girls and from age 7-9 and 13-16 for boys. During these windows, children are likely undergoing a preadolescent spurt occurring near PHV. Neural adaptations that help develop speed are present, such as increased intramuscular and intermuscular coordination and improved motor control programs. Additional adaptations that contribute to speed development include increased androgen concentrations, fiber-type differentiation, resting levels of adenosine triphosphate (ATP) and creatine phosphate levels, along with further structural development of musculotendon units.

Alternative research indicates that speed development is influenced by maturation which implies that speed is trainable throughout childhood and adolescence.

A study referenced in Lloyd and Oliver revealed that prepubescents benefitted most from engaging in training that incorporated higher levels of neural activation (plyometrics and sprint training), while adolescents responded better to training involving both neural and structural development (strength and plyometrics). These findings suggest that prepubescent children should develop their existing physical qualities using plyometrics, technical competency, and sprint work in their speed development whereas adolescents should maximize overall speed gains through strength training, plyometrics, and sprint training. These methods might support the concept of windows of opportunity
and training certain attributes during specified points of natural development, but it does not discount the idea that trainability remains the same throughout childhood.  

**Agility Training**

Agility encompasses change of direction speed (including technique, straight line sprint speed, lower limb strength, and anthropometry) and cognitive function (perceptual and decision-making processes).  

Although it is acknowledged as a requirement for optimal performance in the majority of sports, agility is one of the most under-researched fitness components in pediatric literature. The LTAD model presents no window of opportunity for its development because it is challenging to determine a set time frame, age and/or level of maturation that determines agility performance. The YPD model suggests that agility should be targeted during both pre-pubescence and adolescence.  

Since the prepubertal years are an opportune time to enhance strength and speed, it is logical to develop agility (which encompasses leg strength and sprint speed) and reinforce the accuracy of movement patterns and coordination. During this time, strength and speed are heightened by neural changes resulting in an improved rate of force development.  

When children reach adolescence, they typically develop more strength from additional neural maturation and have large increases in lean muscle mass attributed to increased serum androgen concentrations. As the muscle structure changes, peak force and peak rate of force development are likely to increase which provides an ideal time to develop agility.
Children undergo rapid developments in the neuromuscular system with the rates of brain maturation peaking between 6, 8, 10, and 12 years of age. This neural plasticity presents an ideal opportunity to develop motor control programs including basic change of direction techniques and progressing to more sport-specific agility movements as the athlete approaches adolescence.

Cognitive function as it relates to agility encompasses visual scanning, knowledge of the situation, pattern recognition, and anticipatory qualities. There is minimal research that examines the influence of growth and maturation on these components and how they affect agility performance. During late childhood and adolescence, research suggests that cognitive capacities outside sporting situations increase and that repeated exposure to a given stimulus produces faster response times because of its capacity to strengthen existing synaptic pathways. There is lacking evidence that these theories translate to actual sporting situations where athletes must react rapidly to everchanging stimuli (opponent movements, body position, ball trajectory, etc.). However, it is suggested that agility training should become more challenging using open, unplanned training methods with progressively more sports-specific movements to continually overload the training stimulus as the individual transitions from childhood to adulthood. The locomotive vocabulary that pre-pubertal children develop early on should continue to develop throughout adolescence and into adulthood through the rise in learning opportunities provided by experience in sport-specific environments.

As with speed development, coaches should understand that athletes in this stage are learning how to control their bodies with newly elongated limbs which can cause decrements in motor control performance, commonly called “adolescent awkwardness.”
Because of this newfound awkwardness, it is necessary that athletes relearn and perfect previously acquired movement patterns. Strength and conditioning coaches need to be cognizant of these developmental processes and modify their workouts to accommodate these changes.

**Mobility Training**

The LTAD model suggests the window of opportunity for mobility training (also referred to as suppleness) from ages 6-10 for both genders, with the emphasis during PHV. Similarly, the YPD model proposes that middle childhood (age 5-11) serves as the critical period for individuals to incorporate flexibility and mobility training. Research suggests that boys ages 9-12 commonly have reduced forward trunk flexibility and girls beginning at age 11 demonstrate heightened flexibility. These trends support prepubescence as a favorable time to develop mobility and adolescence and adulthood being the time to maintain acquired levels.

Lloyd et al. recommend that the development and maintenance of mobility is an essential part of any sort of athletic program to ensure athletes can attain sufficient ranges of motion to successfully compete in their sports.

**Endurance and Metabolic Conditioning**

In Balyi’s article, it is suggested that a proper window to develop endurance (referred to as “stamina”) occurs at the same time as the onset of PHV. However, Lloyd and Oliver’s conflicting research due to confounding results and a lack of longitudinal empirical evidence deny a window of opportunity to be defined by the LTAD model. Despite a lack of evidence, endurance and metabolic conditioning are affected by growth-related changes occurring during childhood involving cardiovascular systems (both
central and peripheral), neuromuscular function, and metabolic capacities. As these changes occur pre-, during, and post-puberty, it is logical that endurance performance in the form of VO\(_2\)max makes meaningful improvements and remains trainable into adulthood.

Although the focus on endurance and metabolic conditioning should increase as a young athlete ages, the YPD model suggests that it should never be the primary focus of an individual’s training. This assumes that athletes will develop sufficient sport-specific endurance to meet their needs through participation in sport practices and competitions. Within the realm of physical education common in primary schools, cardiovascular endurance defaults as the most widely evaluated aspect of fitness because it is safer than administering resistance training testing with a population with low levels of training experience.

**Conclusion**

Through various research studies on both early and late specialization sports, the LTAD, DMSP, and YPD models provide direction for qualified professionals to drive their training with youth athletes. Each model is unique in how stages or postulates are defined, but they all share similarities in their goal of developing youth athletes with a variety of training methods implemented at specific times during young athletes’ growth and maturation. The similarities and differences of these three models are outlined in Table 1 in appendix E.
CHAPTER III

METHODS

The purpose of this study is to identify the level of knowledge of individuals involved in the development of junior athletes regarding three models of youth athlete development, the Long-Term Athletic Development Model, the Developmental Model of Sports Participation, and the Youth Physical Development Model.

Participants

Individuals including sport and strength and conditioning coaches, club and athletic directors that have been actively involved with sports for a minimum of two years were eligible for inclusion in this study. These individuals were chosen because they have an enormous impact on the youth sport environment and experience and can encourage or deter many children from continuing participation in sports or physical activity.

A total of 289 individuals participated in this study with 217 males, 71 females, and one who neglected to indicate sex. The mean age of the participants was 32.8 ± 11.2 years. The majority of participants identified themselves as sport coaches (n = 134), followed by strength and conditioning coaches (108), sport administrators (n = 25), and other (n = 17). Most participants indicated 7+ years of coaching experience (n = 123) followed by < 3 years (n = 61), 3 < 5 years (n = 61) and 5 < 7 years (n = 41).

Recruitment

Participants were recruited from middle school, high school, and club sport organization websites and posts containing the direct link to the survey on social media platforms including Facebook, Twitter, LinkedIn, and Instagram. The participants were
recruited via email received a brief introduction to the purpose of the survey, the link to the survey, and an informed consent statement ensuring that respondents knew that they were consenting to inclusion in the study by completing the survey. Two weeks following the initial email, respondents received a second email serving as a reminder to complete the survey and be included in the study. Copies of both emails are included in appendixes A and B. For participants that utilized social media to participate, researchers allowed the snowball or chain sampling method of recruitment to increase sample size. This enabled participants to recruit other participants by forwarding the initial recruitment email and sharing posts containing the link to the survey on social media. A copy of the social media post is included in appendix C. Ethical approval for this study was granted by the Institutional Review Board for the Protection of Human Subjects.

A minimum of 200 participants was needed to effectively examine the psychometric properties of this instrument. Researchers obtained 289 responses, but only 278 were complete and usable for analysis. The respondents identified themselves as a sport coach (high school/middle school/club), strength and conditioning coach, athletic director, or club director. To be included in the study, participants had to be actively involved with developing junior athletes and have at least two years of experience. Ethical approval for this study was granted by the Institutional Human Research Ethics Committee.

**Procedures**

**Survey Development**

The measurement instrument that was used in this investigation was adapted from McKeown and Ball. The new survey was divided into four main sections by content:
Long Term Athlete Development models, Growth and Maturity Related Assessments, Strength and Conditioning Training, Professional background. The first section included seven questions that examined the participant’s level of background knowledge and understanding of long term athlete development models and their perception of their effectiveness. The questions in the second section focused on the physical assessment of junior athletes. These 12 questions aimed to elicit information regarding coaches’ implementation of testing for growth markers and performance in different aspects of athleticism. A range of question types were used to illicit the desired level of information. Most of the question formats were altered to measure answers using a Likert Scale approach to obtain more accurate information by increasing content validity through keeping participants engaged and alert by using positively and negatively stated questions rather than repeating the same question type multiple times. Additionally, questions not relevant to the research question were eliminated.

The new instrument was presented to a panel of experts on youth athlete development to create additional content validation. A copy of the survey is included in appendix D.

Data Entry and Statistical Analysis

Survey data obtained via Survey Monkey will automatically be transferred a Microsoft Excel document for analysis. Data was analyzed using SPSS 25 where data was checked for outliers and descriptive statistics were obtained. A principal component analysis with a direct oblimin rotation was used. Subsequent analysis was based upon frequency analysis and not on qualitative answers.
INTRODUCTION

As president Franklin D. Roosevelt expressed in an address at the University of Pennsylvania in 1940, “We cannot always build the future for our youth, but we can build our youth for the future”\(^1\). This statement can be directly applied to the concept of long-term athletic development (LTAD). Although it is impossible to predict young athletes’ involvement or success in sport, children should be educated on the basic concepts of physical development and sport to prepare them for a lifetime of participation in competitive and recreational physical activity\(^1\). This education should be provided systematically with assistance from qualified professionals to ensure that safety and well-being are a priority through fundamental principles such as: the development of movement patterns, muscle qualities, psychosocial skills, and sport-specific skills\(^{1-3}\).

Three primary models have been developed to provide direction for practitioners programming for and educating athletes utilizing the foundational principles: Long-Term Athletic Development model (LTAD), Developmental Model of Sports Participation (DMSP), and the Youth Physical Development model (YPD).

The LTAD model is applicable to athletes of any age and is divided into seven stages; Active Start, FUNdamentals, Learn to Train, Train to Train, Train to Compete, Train to Win, and Active for Life. Athletes progress through stages based on developmental and chronological age ranges\(^4\). This model outlines optimal times for initiating strength and conditioning activities and delineates the percentage of time spent
training and competing. Additionally, LTAD model frames appropriate developmental age ranges for athletes to engage in multiple sports to develop general athleticism and when to choose a primary sport to focus their training efforts, in order to maximize their athletic potential. This model discourages early specialization (in late specialization sports) to decrease risk of overuse injury and athlete burnout while encouraging athletes to adopt an active lifestyle after their competitive sporting careers cease.

The DMSP recognizes three pathways that athletes (7-18 years old) can choose in their early sporting careers: early specialization, early sampling, and recreational participation. Like the LTAD model, the DMSP favors the early sampling pathway with progression through three developmental phases labeled the sampling, specializing, and investing years. The DMSP supports the early sampling pathway through seven postulates that integrate performance, participation, and personal development and include general and sport-specific theories of child/adolescent development. The importance of deliberate play, development of intrinsic motivation, and exposure to different sporting environments to promote long-term participation in sport are highlighted in the DMSP. Various studies of athletes competing in tennis, hockey, and swimming referenced in Côté et al.’s article indicate that the early sampling pathway is critical for maximizing sport participation while minimizing early dropout by allowing children to engage in multiple sporting environments.

The YPD model is an alternative model that offers a comprehensive approach to training athletes 2-21+ years of age through individualization, athlete-centered training, and emphasizes child development over performance outcomes. The YPD model provides guidelines for appropriate timing and development of fitness components (i.e.,
speed, agility, power, strength, etc.) in relation to biological age and athletes’ individual rates of maturation and development.\textsuperscript{2} This intends to empower strength and conditioning coaches to develop diverse, developmentally appropriate training programs to keep athletes interested in the benefits of training while promoting the health and well-being of youth athletes.\textsuperscript{2}

While these models suggest general optimal training methods and progressions for late specialization sports, information on the athletic development processes used specifically in a variety of sporting cultures is lacking. With large scale junior club tournaments and showcases becoming the primary network for college recruiting\textsuperscript{9}, early specialization is becoming more prominent for athletes desiring to play at the collegiate level. Pressure from club/high school sport coaches and parents may be discouraging young athletes from engaging in a variety of sports because of conflicting practice and competition schedules, cost of competing in multiple sports (monetary, time, athlete fatigue, etc.), and/or lack of knowledge of optimal specialization and sampling times outlined by these models.

Beaudoin et al\textsuperscript{5} conducted semi-structured interviews of 24 coaches in the Canadian sport system to identify coaches’ adoption and implementation of the LTAD model. Canadian coaches perceived a mismatch between the model’s long-term and short-term vision and results and identified a lack of compatibility of LTAD with the demands of their sport.\textsuperscript{5} Additionally, coaches perceived difficulty/complexity in the process of determining/identifying windows of opportunity which deterred full implementation of the LTAD model in their coaching.\textsuperscript{5} In a study by McKeown and Ball\textsuperscript{10} the researchers administered a survey to sixty-five strength and conditioning
coaches, sport scientists, and other professionals from several different countries (New Zealand, Great Britain, Australia, Canada, and Ireland) to examine awareness, understanding, and use of the three common athlete development models (LTAD, DMSP, and YPD). Results indicated that coaches are most familiar with the LTAD model and that strength, power, and movement assessments were widely used by coaches to aid in programming and coaching decisions. A need for future research was indicated. Using the McKeown and Ball study as an initial framework, a survey was adapted to potentially generate a greater response rate by offering mostly multiple-choice and Likert-type questions, and by allowing a more diverse population to take the survey. The purpose of this study is to examine the psychometric properties of this instrument to identify knowledge and application practices of individuals currently involved in the long-term athletic development process (i.e. sport and strength and conditioning coaches, athletic and club directors).

METHODS

Participants

A total of 289 individuals participated in this study, including 217 males, and 71 females; one participant left this question unanswered. The mean age of the participants was 32.8 ± 11.2 years. Individuals involved with the youth sport environment (e.g., sport and strength and conditioning coaches, club and athletic directors) that have been actively involved with sports for a minimum of two years were eligible for inclusion in this study. Most respondents identified themselves as a sport coach (n = 134) followed by strength and conditioning coach (n = 108), sport administrator (n = 25), and other (n = 17). The
majority of participants indicated 7+ years of coaching experience (n = 123) followed by < 3 years and 3 < 5 years (n = 61) and 5 < 7 years (n = 41). Table 1 indicates the sport(s) participants were primarily involved with.

<table>
<thead>
<tr>
<th>Sport Involvement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Sports</td>
<td>97</td>
</tr>
<tr>
<td>Volleyball</td>
<td>52</td>
</tr>
<tr>
<td>Football</td>
<td>28</td>
</tr>
<tr>
<td>Cross Country/Track &amp; Field</td>
<td>17</td>
</tr>
<tr>
<td>Soccer</td>
<td>16</td>
</tr>
<tr>
<td>Basketball</td>
<td>14</td>
</tr>
<tr>
<td>Rugby</td>
<td>14</td>
</tr>
<tr>
<td>Ice Hockey</td>
<td>8</td>
</tr>
<tr>
<td>Tennis</td>
<td>7</td>
</tr>
<tr>
<td>Baseball/Softball</td>
<td>6</td>
</tr>
<tr>
<td>Swimming</td>
<td>5</td>
</tr>
<tr>
<td>Rowing</td>
<td>3</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>3</td>
</tr>
<tr>
<td>Other (weightlifting, golf, netball, wrestling, Gaelic games, etc.)</td>
<td>12</td>
</tr>
</tbody>
</table>

**Recruitment**

Participants were recruited from middle school, high school, and club sport organization websites and posts containing the link to the survey on social media platforms including Facebook, Twitter, LinkedIn, and Instagram. A snowball or chain sampling method of recruitment was used, which enabled participants to recruit other participants by forwarding the initial recruitment email and sharing posts containing the link to the survey on social media. The participants received the link via email were sent a reminder email two-weeks following the initial recruitment email to encourage more participation. Ethical approval for this study was granted by the Institutional Review Board for the Protection of Human Subjects.
Survey

The electronic survey used in this investigation was adapted from McKeown and Ball. The survey is divided into four main sections: Long Term Athlete Development models, Growth and Maturity Related Assessments, Strength and Conditioning Training, and Professional Background. The first section included seven questions that examined the participant’s level of background knowledge and understanding of long term athlete development models and their perception of model effectiveness. The questions in the second section focused on the physical assessment of junior athletes. These 12 questions aimed to elicit information regarding coaches’ implementation of testing for growth markers and performance in different aspects of athleticism. These 11 questions in the third section described types of training athletes perform outside of sport practice. And the fourth section of the survey contained nine questions asking demographic information including sport involvement, title, and experience. We wanted to analyze the psychometric properties of the questionnaire, so we left demographics out.

Formatting was altered to create Likert type questions. Additionally, participants were kept engaged and alert by using positively and negatively stated questions rather than repeating the same question type and answer order multiple times in a row. The instrument was modified by a panel of youth athlete development content experts in order to improve content validity.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 25.0. Principal component analysis (PCA) with a direct oblimin rotation was used to explain the variance in 27 Likert items in the first three sections of the survey.
component analysis is a statistical method that is used to take a number of variables (the Likert items of this study) and reduces them to one or more components that explain the variance of the items.\textsuperscript{34} Two PCA’s were used. The first was done without forcing the factors, while the second was forced into three actors, as the questions fell into three categories on the original survey. Pearson correlations were used to test relationships between components. Data was screened for outliers, and a total sample of 278 participants was used.

**RESULTS**

**Principal Components Analyses**

For both the forced and non-forced solutions, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was .79, with the Bartlett’s Test of Sphericity rejecting the null hypothesis of the correlation matrix being an identity matrix (Approximate $\chi^2$ (351) = 2427.6, $p < .001$). For the non-forced solution, all individual KMO’s were at or above .7, except for the items 14: Performance Assessment Utility and 26: Mental Training, which had KMO’s of .67 and .69, respectively. These items were not candidates for exclusion because of communality values that exceeded .5. Hence, all items were candidates for inclusion for principal component analysis. The pattern matrix was interpreted and the table for the items’ KMO and communalities are shown in Table 2.

Although communalities were smaller for the forced solution, they were still candidates for inclusion due to the high individual KMO’s.
Table 2: Individual Items, communalities, and sampling adequacy

<table>
<thead>
<tr>
<th>Item</th>
<th>Communality (non-forced)</th>
<th>Communality (forced)</th>
<th>KMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.62</td>
<td>.49</td>
<td>.85</td>
</tr>
<tr>
<td>2</td>
<td>.58</td>
<td>.47</td>
<td>.78</td>
</tr>
<tr>
<td>3</td>
<td>.65</td>
<td>.51</td>
<td>.85</td>
</tr>
<tr>
<td>4</td>
<td>.39</td>
<td>.34</td>
<td>.73</td>
</tr>
<tr>
<td>5</td>
<td>.64</td>
<td>.40</td>
<td>.68</td>
</tr>
<tr>
<td>6</td>
<td>.64</td>
<td>.44</td>
<td>.79</td>
</tr>
<tr>
<td>7</td>
<td>.61</td>
<td>.46</td>
<td>.84</td>
</tr>
<tr>
<td>8</td>
<td>.62</td>
<td>.29</td>
<td>.83</td>
</tr>
<tr>
<td>9</td>
<td>.78</td>
<td>.77</td>
<td>.79</td>
</tr>
<tr>
<td>10</td>
<td>.68</td>
<td>.45</td>
<td>.71</td>
</tr>
<tr>
<td>12</td>
<td>.41</td>
<td>.31</td>
<td>.71</td>
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<tr>
<td>13</td>
<td>.68</td>
<td>.28</td>
<td>.70</td>
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<tr>
<td>14</td>
<td>.76</td>
<td>.13</td>
<td>.67</td>
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<tr>
<td>15</td>
<td>.61</td>
<td>.47</td>
<td>.88</td>
</tr>
<tr>
<td>16</td>
<td>.46</td>
<td>.37</td>
<td>.83</td>
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<tr>
<td>17</td>
<td>.79</td>
<td>.76</td>
<td>.84</td>
</tr>
<tr>
<td>18</td>
<td>.61</td>
<td>.14</td>
<td>.76</td>
</tr>
<tr>
<td>19</td>
<td>.70</td>
<td>.12</td>
<td>.70</td>
</tr>
<tr>
<td>20</td>
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<td>.50</td>
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<td>21</td>
<td>.68</td>
<td>.38</td>
<td>.83</td>
</tr>
<tr>
<td>22</td>
<td>.75</td>
<td>.74</td>
<td>.81</td>
</tr>
<tr>
<td>23</td>
<td>.65</td>
<td>.39</td>
<td>.81</td>
</tr>
<tr>
<td>24</td>
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<td>25</td>
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<td>.12</td>
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</tr>
<tr>
<td>27</td>
<td>.66</td>
<td>.41</td>
<td>.77</td>
</tr>
<tr>
<td>29</td>
<td>.56</td>
<td>.26</td>
<td>.75</td>
</tr>
</tbody>
</table>

*Note n = 278

For the non-forced solution, eight components were extracted based on the Keiser’s “eigenvalues greater than 1” rule. This rule postulates that every item contains an eigenvalue of 1, and hence any combination of items that has an eigenvalue of < 1 should not be interpreted. This model explained about 62% of the instrument’s variance.
Non-Forced Solution Components

Component 1 contained six items that addressed understanding and use of the models of long-term athletic development and was therefore named Model Use & Understanding (MUU). Component 2 contained six items that broadly addressed their athletes’ participation in various training modes. Hence this component was named Athlete Bodyweight/Lightweight Resistance Training (ABRT).

Component 3 contained three items pertaining to athlete participation, and coaches’ assessment of endurance, and was named Athletic Endurance Assessment (AEA). Component 4 contained three items pertaining to anthropometry assessment. This component was strongly negatively correlated with its items and was labeled Anthropometry Non-Assessment (ANA) to reflect this relationship. Two other items (9 & 22), were moderately correlated to this component.

Component 5 contained two items pertaining to the frequency of practitioners’ assessment of an athlete’s movements. Because of the negative relationship with the component with its items, the component was named Movement Non-Assessment. Component 6 contained two items pertaining to the frequency of coach assessment of athletes’ performance of sport specific skills and how often their athletes engage in mental training. The component was called Sport-Specific Skill Assessment/Mental Training (SSMT). One other item (8) was moderately correlated to this component. Low reliability was observed for components 5 & 6.

Component 7 only contained one item that asked practitioners their perception of the effectiveness of performance assessments with their athletes. This component was labeled Performance Assessment Utility (PAU). Two other items were moderately
correlated with this component (18, 15) and one item was moderately negatively correlated with this component (21).

Component 8 contained four items pertaining to the frequency of practitioner assessment of athletes’ maximal strength, strength endurance, power, and flexibility/mobility. A strong negative correlation was identified with the items; therefore, this factor was named Maximal Performance Non-Assessment (MPNA). The results are in Table 3 below.

Table 3: Pattern Matrix (n = 278)

<table>
<thead>
<tr>
<th>Item</th>
<th>MUU</th>
<th>ABRT</th>
<th>AES</th>
<th>ANA</th>
<th>MNA</th>
<th>SSMT</th>
<th>PAU</th>
<th>MPNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>3: DMSP Understanding</td>
<td>.80</td>
<td>-.06</td>
<td>.01</td>
<td>-.09</td>
<td>.03</td>
<td>.09</td>
<td>.05</td>
<td>.05</td>
</tr>
<tr>
<td>6: LTAD Frequency of Use</td>
<td>.76</td>
<td>.04</td>
<td>.14</td>
<td>.15</td>
<td>.03</td>
<td>-.16</td>
<td>-.05</td>
<td>-.02</td>
</tr>
<tr>
<td>17: LTAD Understanding</td>
<td>.75</td>
<td>-.01</td>
<td>-.01</td>
<td>-.22</td>
<td>-.07</td>
<td>-.18</td>
<td>-.04</td>
<td>.07</td>
</tr>
<tr>
<td>8: DMSP Frequency of Use</td>
<td>.73</td>
<td>.06</td>
<td>-.04</td>
<td>.15</td>
<td>-.03</td>
<td>.33</td>
<td>.05</td>
<td>-.12</td>
</tr>
<tr>
<td>9: Understanding of YPD</td>
<td>.59</td>
<td>-.01</td>
<td>-.08</td>
<td>-.46</td>
<td>-.03</td>
<td>-.20</td>
<td>-.08</td>
<td>.04</td>
</tr>
<tr>
<td>22: YPD Frequency of Use</td>
<td>.59</td>
<td>.01</td>
<td>-.11</td>
<td>-.44</td>
<td>-.03</td>
<td>-.19</td>
<td>-.04</td>
<td>.04</td>
</tr>
<tr>
<td>20: Medicine Ball Training</td>
<td>.13</td>
<td>.69</td>
<td>-.06</td>
<td>-.03</td>
<td>-.01</td>
<td>.06</td>
<td>.08</td>
<td>-.03</td>
</tr>
<tr>
<td>16: Flexibility Training</td>
<td>-.05</td>
<td>.64</td>
<td>-.05</td>
<td>-.05</td>
<td>-.14</td>
<td>.01</td>
<td>-.15</td>
<td>-.05</td>
</tr>
<tr>
<td>24: Stability Ball Training</td>
<td>-.10</td>
<td>.62</td>
<td>-.06</td>
<td>-.09</td>
<td>.11</td>
<td>.16</td>
<td>-.02</td>
<td>-.09</td>
</tr>
<tr>
<td>12: Speed/Agility Training</td>
<td>.04</td>
<td>.55</td>
<td>.13</td>
<td>.17</td>
<td>.17</td>
<td>-.04</td>
<td>.12</td>
<td>-.05</td>
</tr>
<tr>
<td>4: BW/Light Weight Exercise</td>
<td>.13</td>
<td>.49</td>
<td>.07</td>
<td>.30</td>
<td>-.14</td>
<td>-.10</td>
<td>-.04</td>
<td>-.03</td>
</tr>
<tr>
<td>5: Anaerobic Capacity Assessment</td>
<td>.03</td>
<td>-.05</td>
<td>.73</td>
<td>.10</td>
<td>-.14</td>
<td>.09</td>
<td>.11</td>
<td>-.10</td>
</tr>
<tr>
<td>29: Endurance Training</td>
<td>-.01</td>
<td>.12</td>
<td>.72</td>
<td>-.13</td>
<td>.09</td>
<td>.06</td>
<td>-.02</td>
<td>.21</td>
</tr>
<tr>
<td>10: Aerobic Endurance Assessment</td>
<td>.01</td>
<td>-.09</td>
<td>.69</td>
<td>-.13</td>
<td>.02</td>
<td>-.15</td>
<td>-.06</td>
<td>-.32</td>
</tr>
</tbody>
</table>
### Table 3 cont.

<table>
<thead>
<tr>
<th>Component</th>
<th>MUU</th>
<th>ANA</th>
<th>MNA</th>
<th>SSMT</th>
<th>ABRT</th>
<th>AES</th>
<th>MPNA</th>
<th>Cronbach's α (with moderately correlated items)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27: Assess Height</td>
<td>-.03</td>
<td>.04</td>
<td>.13</td>
<td><strong>-78</strong></td>
<td>-.03</td>
<td>.10</td>
<td>.12</td>
<td>.04</td>
</tr>
<tr>
<td>1: Seated Height/Limb Length</td>
<td>.18</td>
<td>-.14</td>
<td>.01</td>
<td><strong>-67</strong></td>
<td>-.12</td>
<td>.04</td>
<td>-.14</td>
<td>-.05</td>
</tr>
<tr>
<td>7: Body Weight</td>
<td>.11</td>
<td>.06</td>
<td>.15</td>
<td><strong>-63</strong></td>
<td>.10</td>
<td>-.18</td>
<td>.15</td>
<td>-.15</td>
</tr>
<tr>
<td>19: Movement Competency Assessment</td>
<td>.03</td>
<td>.02</td>
<td>-.15</td>
<td>.02</td>
<td><strong>-76</strong></td>
<td>-.18</td>
<td>.27</td>
<td>-.04</td>
</tr>
<tr>
<td>25: Gen. Athletic Moves Assessment</td>
<td>.01</td>
<td>.09</td>
<td>.17</td>
<td>-.02</td>
<td><strong>-73</strong></td>
<td>.11</td>
<td>-.03</td>
<td>-.01</td>
</tr>
<tr>
<td>13: Sport Skill Assessment</td>
<td>-.02</td>
<td>-.20</td>
<td>.11</td>
<td>.08</td>
<td>-.07</td>
<td><strong>76</strong></td>
<td>.11</td>
<td>-.15</td>
</tr>
<tr>
<td>26: Mental Training</td>
<td>.01</td>
<td>.21</td>
<td>-.03</td>
<td>-.10</td>
<td>.11</td>
<td><strong>71</strong></td>
<td>-.04</td>
<td>.10</td>
</tr>
<tr>
<td>14: Performance Assessment Utility</td>
<td>-.01</td>
<td>.03</td>
<td>.05</td>
<td>-.11</td>
<td>-.20</td>
<td>.10</td>
<td><strong>84</strong></td>
<td>.06</td>
</tr>
<tr>
<td>23: Strength Endurance Assessment</td>
<td>-.03</td>
<td>.02</td>
<td>.19</td>
<td>.03</td>
<td>-.13</td>
<td>.11</td>
<td>-.14</td>
<td><strong>-71</strong></td>
</tr>
<tr>
<td>18: Max Strength Assessment</td>
<td>.05</td>
<td>.09</td>
<td>-.09</td>
<td>.03</td>
<td>.24</td>
<td>-.12</td>
<td><strong>34</strong></td>
<td>-.62</td>
</tr>
<tr>
<td>21: Flexibility/Mobility Assessment</td>
<td>.05</td>
<td>.19</td>
<td>.00</td>
<td>-.23</td>
<td>-.24</td>
<td>.13</td>
<td><strong>34</strong></td>
<td>-.55</td>
</tr>
<tr>
<td>15: Power Assessment</td>
<td>.00</td>
<td>.21</td>
<td>.04</td>
<td>-.36</td>
<td>-.10</td>
<td>-.02</td>
<td><strong>30</strong></td>
<td>-.42</td>
</tr>
<tr>
<td>% variance explained</td>
<td>19.1</td>
<td>12.4</td>
<td>7.6</td>
<td>5.4</td>
<td>4.7</td>
<td>4.7</td>
<td>4.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Cronbach's α</td>
<td>.87</td>
<td>.69</td>
<td>.64</td>
<td>.73</td>
<td>.49</td>
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<td>Cronbach's α (with moderately correlated items)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.49</td>
<td>-</td>
<td>.31</td>
<td>.10</td>
<td>.67</td>
</tr>
</tbody>
</table>

*Note: Item key is included in appendix F*

### Component Correlations: Non-Forced Model

Negative relationships existed between MUU and three other components: ANA, MNA, and SSMT. A positive relationship between ABRT and AES was identified, while ABRT shared a negative relationship with MNA and MPNA. A negative relationship between AES and MPNA was identified, while a positive relationship between MNA and
MPNA existed. Finally, PAU and MPNA were negatively related. The nature of these relationships are displayed in Table 4 below.

**Table 4: Component Correlations**

<table>
<thead>
<tr>
<th></th>
<th>MUU</th>
<th>ABRT</th>
<th>AES</th>
<th>ANA</th>
<th>MNA</th>
<th>SSMT</th>
<th>PAU</th>
<th>MPNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABRT</td>
<td>-</td>
<td>-</td>
<td>.120*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AES</td>
<td>-</td>
<td>.235**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ANA</td>
<td>-.123*</td>
<td>-</td>
<td>-</td>
<td>-.235**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MNA</td>
<td>-.118*</td>
<td>-.123*</td>
<td>-</td>
<td>-.118*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SSMT</td>
<td>-.151*</td>
<td>-</td>
<td>-</td>
<td>-.118*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PAU</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MPNA</td>
<td>-</td>
<td>-.223**</td>
<td>-.179*</td>
<td>-</td>
<td>-.179*</td>
<td>-.130*</td>
<td>-</td>
<td>-.121*</td>
</tr>
</tbody>
</table>

*significant at the $p = .05$ level; **significant at the $p < .001$ level

After examining the eight components with eigenvalues greater than 1, an analysis forcing three components was used. Three components seemed viable because it enabled a comparison of these components to the usable categories of questions identified on the initial survey. Although the initial survey was divided into four main sections, the last section asked demographic information using question formats that were not used in either PCA.

**Forced Solution Components**

For the forced solution, three components were forced, which explained about 39% of the instrument’s variance. Component 1 contained ten items that addressed understanding and use of the models of long-term athletic development and was therefore named Model Use and Understanding (MU). Component 2 contained eight items that focused mostly on types of training athletes engaged in (medicine ball, plyometrics, etc.) with few questions on athlete assessment. Hence this component was named Athlete Training (AT). The third component contained nine items that emphasized the assessment
of various physical capacities more than different training methods, therefore the component was named Athlete Assessment (AA). The results are in Table 5 below.

**Table 5: Forced Pattern Matrix (n = 278)**

<table>
<thead>
<tr>
<th>Item</th>
<th>MU</th>
<th>AT</th>
<th>AA</th>
</tr>
</thead>
<tbody>
<tr>
<td>17: LTAD Understanding</td>
<td>.87</td>
<td>.02</td>
<td>-.02</td>
</tr>
<tr>
<td>9: Understanding of YPD</td>
<td>.87</td>
<td>-.08</td>
<td>.06</td>
</tr>
<tr>
<td>22: YPD Frequency of Use</td>
<td>.86</td>
<td>-.04</td>
<td>.03</td>
</tr>
<tr>
<td>3: DMSP Understanding</td>
<td>.71</td>
<td>.05</td>
<td>.01</td>
</tr>
<tr>
<td>6: LTAD Frequency of Use</td>
<td>.64</td>
<td>.20</td>
<td>-.09</td>
</tr>
<tr>
<td>1: Seated Height/Limb Length</td>
<td>.51</td>
<td>-.30</td>
<td>.41</td>
</tr>
<tr>
<td>7: Body Weight</td>
<td>.46</td>
<td>-.10</td>
<td>.46</td>
</tr>
<tr>
<td>8: DMSP Frequency of Use</td>
<td>.43</td>
<td>.30</td>
<td>.02</td>
</tr>
<tr>
<td>13: Sport Skill Assessment</td>
<td>-.41</td>
<td>-.10</td>
<td>.41</td>
</tr>
<tr>
<td>26: Mental Training</td>
<td>-.26</td>
<td>.16</td>
<td>.16</td>
</tr>
<tr>
<td>20: Medicine Ball Training</td>
<td>.12</td>
<td>.69</td>
<td>-.01</td>
</tr>
<tr>
<td>2: Plyometrics Training</td>
<td>.06</td>
<td>.65</td>
<td>.09</td>
</tr>
<tr>
<td>16: Flexibility Training</td>
<td>.01</td>
<td>.61</td>
<td>.01</td>
</tr>
<tr>
<td>4: BW/Light Weight Exercise</td>
<td>.02</td>
<td>.60</td>
<td>-.12</td>
</tr>
<tr>
<td>12: Speed/Agility Training</td>
<td>-.08</td>
<td>.56</td>
<td>-.03</td>
</tr>
<tr>
<td>24: Stability Ball Training</td>
<td>-.11</td>
<td>.56</td>
<td>.03</td>
</tr>
<tr>
<td>18: Max Strength Assessment</td>
<td>.05</td>
<td>.28</td>
<td>.19</td>
</tr>
<tr>
<td>19: Movement Competency Assessment</td>
<td>.21</td>
<td>.22</td>
<td>.10</td>
</tr>
<tr>
<td>10: Aerobic Endurance Assessment</td>
<td>.04</td>
<td>-.09</td>
<td>.68</td>
</tr>
<tr>
<td>5: Anaerobic Capacity Assessment</td>
<td>-.15</td>
<td>.03</td>
<td>.62</td>
</tr>
<tr>
<td>27: Assess Height</td>
<td>.33</td>
<td>-.21</td>
<td>.56</td>
</tr>
<tr>
<td>23: Strength Endurance Assessment</td>
<td>-.11</td>
<td>.22</td>
<td>.54</td>
</tr>
<tr>
<td>15: Power Assessment</td>
<td>.20</td>
<td>.26</td>
<td>.51</td>
</tr>
<tr>
<td>29: Endurance Training</td>
<td>-.07</td>
<td>-.04</td>
<td>.47</td>
</tr>
</tbody>
</table>
Table 5 cont.

<table>
<thead>
<tr>
<th></th>
<th>MU</th>
<th>AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>21: Flexibility/Mobility Assessment</td>
<td>.14</td>
<td>.28</td>
</tr>
<tr>
<td>25: Gen. Athletic Movement Assessment</td>
<td>.04</td>
<td>.21</td>
</tr>
<tr>
<td>14: Performance Assessment Utility</td>
<td>.02</td>
<td>.13</td>
</tr>
<tr>
<td>Cronbach’s α</td>
<td>.74</td>
<td>.64</td>
</tr>
<tr>
<td>% variance explained</td>
<td>19.1</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Component Correlations: Forced Model

Positive relationships were identified with AA, MU, and AT. The nature of these relationships are displayed in Table 6 below.

Table 6: Forced Model Component Correlations

<table>
<thead>
<tr>
<th></th>
<th>MU</th>
<th>AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AA</td>
<td>.12*</td>
<td>.23**</td>
</tr>
</tbody>
</table>

*significant at the $p = .05$ level;
**significant at the $p < .001$ level

DISCUSSION

Both the forced and non-forced model showed similar groupings of questions based on content. Assessment of seated height and weight was found to be closely related to knowledge and application of long-term athletic development models, whereas assessment of maximal physical abilities (power, strength, etc.) was not. Those coaches who were knowledgeable about the models were also more likely to focus on movement analysis over sport-specific skills or mental training with their athletes. Practitioners who feel performance assessments are useful tend to evaluate their athletes’ performance using a variety of measures (speed/agility, power, etc.), excluding aerobic and anaerobic capacity testing (i.e., Beep Test or sprint tests).
Component Relationships: Non-Forced Model

Model Use and Understanding Relationships

A negative relationship was identified between MUU and ANA, MNA, and SSMT. The relationship between MUU and ANA implies that the more practitioners know about the three models of long-term athletic development, the less likely they are to practice non-assessment of anthropometry of their athletes. This makes sense because the LTAD and YPD models use windows of opportunity based on peak height velocity and peak weight velocity as the basis for determining when to implement different types of training.\(^2,4\) Therefore, the more that coaches know about and implement these models, the more they value performing anthropometric measurements such as standing height, weight, and seated height. The negative relationship between MUU and MNA (i.e., knowledge and non-assessment) implies that the more practitioners know about these models and implement their principles, the more likely they are to practice assessment of movements. All three models of long-term athletic development suggest a period of sport sampling when athletes are young, so they can develop a more diverse set of movement skills instead of only performing movements specific to one sport.\(^1,2,6,8\) This supports that coaches that are more knowledgeable about this suggestion would seek to develop young athletes and assess their athletes performance of a wider variety of general athletic movements. The negative relationship between MUU and SSMT implies that the more practitioners know about and apply the principles of the three models the less they are focusing on the assessment of sport-specific skills and using mental training techniques. This is supported by the early sampling phases emphasized in all three models and the focus on performing all general athletic movements often, instead of specializing in one
sport where single sport sport-specific movements become the focus early on and lead to
overuse injuries.\textsuperscript{1,2,6,8}

**Athlete Bodyweight/Lightweight Resistance Training Relationships**

The relationship between ABRT and AES suggests that the more athletes are
reported to participate in bodyweight and lightweight resistance exercise (including
stability ball, medicine ball, sprint/agility, and plyometric training) the more they are
participating in endurance exercise and being assessed on their aerobic endurance and
anaerobic capacity. This indicates that coaches are implementing diverse training plans
with their athletes; this is essential for youth athletes to engage in developmentally
appropriate activities to advance aspects of their physical fitness to elevate sport
performance.\textsuperscript{1,2,6,9} The negative relationship between ABRT and MNA (i.e., resistance
training and movement \textit{non-assessment}) implies that the more athletes are reported to
participate in bodyweight and lightweight resistance exercise, the more likely they are to
be assessed on their movement quality. This supports the idea that if coaches are training
their athletes using a variety of athletic movements using bodyweight or light weights
throughout their development, they are constantly assessing and correcting how well their
athletes are performing those movements.\textsuperscript{1} The negative relationship between
components ABRT and MPNA (i.e., athlete bodyweight/lightweight resistance training
and maximal performance \textit{non-assessment}) implies that the more athletes are reported to
participate in bodyweight and lightweight resistance exercise, the more likely they are to
be assessed on maximal performance (i.e., strength, power, etc.). Similar to the previous
relationship, this supports the idea that if athletes are engaging in bodyweight and
lightweight resistance exercise, the more their coaches will be assessing improvement and performance in the qualities they are developing through various training methods.\textsuperscript{1}

**Athletic Endurance Assessment Relationships**

The negative relationship between AES and MPNA (i.e., endurance assessment and maximal performance non-assessment) suggests that the more athletes are assessed on their aerobic endurance and anaerobic capacity, the more likely they are to be assessed on maximal performance. This suggests that coaches who assess aerobic endurance and anaerobic capacity in their athletes are more likely to also be performing other performance assessments such as maximal strength, power, and flexibility.

**Anthropometry Non-Assessment**

No additional component relationships were identified with ANA other than those previously listed; however, two other items (9 & 22), were moderately correlated to this component. The additional items described coaches understanding and the frequency of use of the YPD model. The correlation to the YPD model implies that coaches that use this model to guide their training are more likely measure the anthropometrics of their athletes to identify windows of opportunity for optimal introduction of training methods.\textsuperscript{2}

**Movement Non-Assessment Relationships**

The relationship identified between MNA and MPNA (i.e., movement and maximal performance non-assessment) suggests that coaches that value assessing their athletes’ general athletic movements and movement competency, are more likely to value assessing maximal performance on strength, strength endurance, power, and flexibility tests as well. The opposite is also implied; meaning that coaches that do not assess their athletes’ movements are probably not assessing maximal performance either.
Performance Assessment Utility Relationships

The negative relationship between PAU and MPNA (i.e., assessment utility and non-assessment) suggests that if practitioners believe performance assessments are useful with their athletes, they are more likely to practice maximal performance assessment. This implies that if practitioners believe that performance assessments are useful with their athletes based on their utility in determining proper training for their athletes as described in the LTAD and YPD models, they are more likely to be assessing maximal performance of their athletes. Moderate correlations were identified with items 18 and 15 which describe coaches’ use of maximal strength and power assessments with their athletes. The correlation to the coaches’ perception of utility of performance assessments is logical. The negative correlation identified with item 21 could indicate that sport and strength and conditioning coaches do not value the assessment of flexibility/mobility to the same extent as other performance assessments. However, this may be an area of concern based on research by Palmer et al. in 2014. Their research on division I soccer players indicated that passive stiffness of the posterior hip and thigh muscles in addition to traditional power characteristics (i.e., countermovement vertical jump, peak power, etc.) may be an effective measure of identifying athletes with high overall athletic performance.

Sport-Specific Skill Assessment/Mental Training

No additional component relationships were identified with SSMT other than those previously listed; however, item 8 loaded onto this component with a moderate correlation. Item 8 describes the reported frequency of use of the DMSP. The link to this...
component is justified because DMSP values a wholistic approach to sport skill and psychosocial development of athletes through a variety of sport and cognitive experiences, rather than strictly focusing on the skills needed for one sport from a young age.\textsuperscript{3,8}

Maximal Performance Non-Assessment

No additional component relationships were identified with MPNA other than those previously listed; however, one item showed a moderate negative correlation with this component (10). Item 10 describes coaches’ assessment of their athletes’ level of aerobic endurance. This is a logical fit with the other items in component 8 as it completes a well-rounded testing battery for aspects of general fitness including the performance assessments grouped in component 8 (i.e., strength endurance, flexibility, max strength, power).

Component Relationships: Forced Model

Model Use and Understanding Relationships

A positive relationship was identified between MU and AA. This indicates that the more coaches know about the three models of long-term athletic development, the more likely they are to assess their athletes using a variety of performance tests. This is logical because the LTAD and YPD models use anthropometrics to determine windows of opportunity to train different attributes.\textsuperscript{2,4} As coaches begin integrating more forms of training, they will likely want to assess their athletes’ performance to track improvement. A moderate correlation with item 27 was also identified. This item references how frequently practitioners measure height; a logical fit with this component and the identification of PHV for windows of opportunity as previously mentioned.\textsuperscript{2,4}
Athlete Training Relationships

A positive relationship was identified between AT and AA. This indicates that the more athletes are engaging in a variety of training modalities, the more likely their coaches are assessing them on their performance utilizing different types of exercise. This relationship makes sense because if coaches are having their athletes perform activities designed to make them improve specific qualities/skills, they will want to quantify efficacy of their training program through a series of performance assessments. An additional correlation was identified with item 8 that describes practitioners’ use of the DMSP. This positive relationship suggests that the more coaches are using the DMSP in their training, the more likely their athletes are exposed to different training types. The DMSP supports engagement in a variety of different sport environments and cultures, therefore it makes sense why it would load onto this component.

Athlete Assessment Relationships

Relationships between AA were previously identified with MU and AT. Additionally, there were three items (1, 7, 13) that loaded onto this component with a similar magnitude to their primary component, MU. Items 1 and 7 reference seated height/limb length and bodyweight measurement frequency. It makes sense these two items would have strong correlations to both MU and AA because coaches are likely to assess these qualities if they are identifying and implementing windows of opportunity to dictate training or if they are already assessing athletes in other areas. Item 13 correlated with AA with the same magnitude as with MU; however, the relationship with MU was negative. This means that the more coaches are assessing physical capacities in their athletes, the more likely they will be assessing sport-specific skills as well.
Comparison of forced vs non-forced models

Both forced and non-forced models were interpreted for transparency and to explore the validity of the components within both models. The non-forced model revealed better communality values, however three components were unreliable. In contrast, though the forced model explained less of the variance between items, those components were more reliable, and is the recommended interpretation. Both models suggest similar findings with the relationships between components and overall grouping of items.

These findings indicate the importance of assessment of seated height and limb length; however, it is concerning that 65% of participants in this study indicated they have never assessed this in their athletes. The LTAD and YPD models suggest assessing athletes’ seated height to calculated PHV in their athletes as an indication of windows of opportunity to train certain physical qualities such as agility, speed, strength, power, mobility, and endurance. A coach in the study by Beaudoin et al indicated this lack of assessment at least on a monthly basis by the majority of coaches may be due to a lack of time and/or motivation. A lack of knowledge of measuring seated height and the implications it has for the introduction of different training methods for youth athletes is also a possible cause.

Comparison of forced model components vs original survey sections

As previously mentioned, the initial survey was divided into four main sections based on the content of the items: Long-Term Athletic Development Models, Growth and Maturity Related Assessments, and Professional Background. For descriptive purposes, a
comparison was performed between the three of the original sections on the survey to the components identified in the forced model: MU, AT, and AA.

Model Use and Understanding loaded all items in the first section of the original survey with the addition of items 1, 7, 13, and 26. Items 1 and 7 are the assessment of seated height/limb length and body weight which are essential for evaluating PHV and PWV in youth athletes. The positive relationship with MU is logical; however, standing height did not load onto this component. It is possible that the measurement of height is not related to knowledge of long-term athletic development models because it is common for coaches to assess for roster heights and for the purposes of college recruitment, not necessarily to determine appropriate training methods.

Items 13 and 26 also loaded onto this component with strong negative correlations. This indicates that the more coaches know about the models of long-term athletic development, the less coaches value assessing sport-specific skills and integrating mental training in their athletes. These negative relationships are appropriate because sport-skill assessment and mental training may be more useful with athletes specialized in a single sport. Thus, the more coaches know about and are implementing the guidelines in the models of long-term athletic development, the more their athletes are focused on other movement skills and assessments, rather than sport-specific training.

Athlete Training included six items from the Strength and Conditioning Training section of the original survey with the addition of items 18 and 19. Items 18 and 19 asked coaches how often they assess maximum strength and movement competency in their athletes. This grouping is reasonable; it suggests that if athletes are engaging in various
types of training (including resistance training), it is more likely that coaches will be assessing the quality of their movements and want to quantify their strength gains. Athlete Assessment included eight items from the Growth and Maturity Related Assessments section on the original survey with the addition of item 29. Item 29 asks coaches how often their athletes engage in endurance training outside of their sport practice. In all analyses run in this study, item 29 has not loaded onto the same component as the other lightweight/bodyweight forms of training (i.e., plyometrics, speed/agility, medicine ball, etc.). This may have been related to the majority of participants in this study reporting they work with sports with a primarily anaerobic nature (i.e., volleyball, football, hockey, etc.). Therefore, endurance training may not as much of a priority in their athletes’ training as other types.

Items 1, 7, and 13 showed strong correlations of the similar magnitude as with their primary component MU. These items encompass the assessment of seated height, bodyweight, and sport-specific skills. Items 1 and 7 had positive correlations with both MU and AA, meaning that coaches are more likely to assess seated height/limb length and bodyweight in their athletes if they are knowledgeable about the models of long-term athletic development or are performing other performance assessments on their athletes. However, Item 13 showed a strong negative correlation with MU but it revealed a positive relationship of the same magnitude with AA. This implies that coaches are likely to assess sport-specific skills if they are assessing other athletic qualities (i.e., anaerobic capacity, power, etc.), but they are likely to avoid this type of assessment if they are knowledgeable about the three models of long-term athletic development.
Study limitations

The two main limitations of this study were the unreliability of MNA, SSMT, and PAU in the non-forced model and the sampling method used to obtain data. Movement Non-Assessment and SSMT were not reliable as they did not reach or exceed the minimum .5 threshold. Note that PAU did not produce a Cronbach’s α value because it contained only one item.

The snowball sampling method used in this study has limitations. Cohen and Arieli\textsuperscript{37} state that the advantages of this method include locating, accessing, and involving populations that may be difficult to reach. This method enables researchers to locate the target population without an excess of time, money, and effort\textsuperscript{37} which was beneficial in this study. The snowball method enlists the cooperation of initial participants and the trust and cooperation of future participants based on their relationships with the initial participants.\textsuperscript{37} Cohen and Arieli\textsuperscript{37} state that this trust can enhance and facilitate cooperation in a population who may fear exposure, uncertainty or risk. Limitations of the snowball recruitment include the introduction of risk of enlisting respondents of a relatively homogeneous affiliation that may not be a representative sample.\textsuperscript{37} In this study, there were multiple experts in long-term athletic development using their connections to increase the sample size of this study. It is possible the experts recruited colleagues/friends with similar levels of knowledge and application of the models to participate in the study. If this occurred, the levels of knowledge of the majority of practitioners could have been inflated, thus giving an inaccurate representation of the entire population. Since there was little control over the distribution of this survey, it could have been sent to/taken by participants that did not qualify for this study as well.
This could reduce the validity and reliability of the conclusions presented here.\textsuperscript{37} Another limitation of this sampling method is its lack of randomness. The opportunity for bias toward more cooperative/knowledgeable participants who were more willing to participate could have been present in the study.\textsuperscript{37} If this occurred, crucial data would have been eliminated from the study that would further skew the representation of the knowledge level of the general population of coaches. Cohen and Arieli\textsuperscript{37} describe this concept as selection bias, which limits external and internal validity. It is suggested that the problem of selection bias may be partially addressed by a large sample size because the results can be replicated and consequently strengthen generalizations; however, bias can still be present in a large population.\textsuperscript{37}

It is also possible that coaches who were unfamiliar with the concepts described in the survey were uncomfortable exposing their lack of knowledge and failed to complete the survey. Items 1-3 and 5-9 were the only questions that had a 100% response rate. Specifically, eleven items (4, 9, 15, 17, 18, 19, 20, 21, 23, 29, 32) were skipped by one person each, nine items (10, 11, 13, 16, 22, 27, 28, 30, 31) were skipped by two, and four items (14, 25, 26, 37) were skipped by three people each. The most commonly skipped items were numbers 12, 24, 33, 34, 35, 36, and 38 which had four or more people that failed to answer. These items indicated specifics on sport involvement, title of the participant, and the frequency of athlete participation in various training types outside of practice. This issue could have been avoided by setting the survey to disable participants from moving to the next question without completing the current question.
Future directions

Repetition of this study is necessary to get an accurate representation of the knowledge and application practices of coaches of youth athletes internationally. Firstly, more objective sampling methods should be utilized to increase internal and external validity. In addition, the survey should be modified to produce data that is easier to manage and draw conclusions from. Minor edits for collecting/altering collection of demographic data in this study is needed, i.e., geographic location, sources of education, coach title, amount of experience, utilizing more closed ended questions. The researcher left certain questions open ended because it seemed beneficial at the time to include as many sports in study as possible. This allowed the inclusion and representation of more internationally popular sports (i.e. cricket, Gaelic games, etc.) and terms that may not be synonymous with the terms used to describe the participants’ role with the athletes (i.e. trainer vs sport coach vs strength and conditioning coach). However, this introduced ambiguity. Adding an item regarding the participants’ geographic location would enable researchers to make generalizations of the knowledge of coaches in specific sport cultures in the United States in comparison to other countries.

There is a need for a future study that performs validation using a confirmatory factor analysis on data obtained using this survey. This is a structural equation modeling method used to confirm the component loadings found in this study.

Implications/applications

Future studies should utilize a more reliable recruitment method. Researchers could obtain a list of all certified coaches in various sport organizations and randomly select coaches to survey. For increased content specificity, researchers should exclude
sport administrators and collegiate level coaches as viable participants. Although athletic/club directors may enforce a specific method of coaching in their organization, they are not directly responsible for the enforcement of those methods in practice.

Collegiate coaching practice may not be applicable for this type of research because their athletes have already progressed through the developmental stages discussed in all three models and are typically specialized in one sport. The training methods their athletes participate in and the frequency of their assessment of growth and maturity related assessments are not as critical as youth coaches. These two participant exclusions would allow the data to better represent the training methods and long-term athletic development concepts used in youth sports.

There is also need for a follow up study that explores the knowledge and application of these models by individual coaches and the sport-specific organizations they are a part of. The format of questions should also be altered to reflect the practices of the individual in comparison to the organization and how they are educated about coaching practices. This type of study could give experts in long-term athletic development insight on whether their models are being effectively taught to coaches and/or applied in a sport-specific context with youth athletes around the world. If results indicate that the majority of youth coaches are not educated about or applying the constructs outlined in these three models in their practice, the effectiveness of the coaching education and certification systems need to be examined and modified. Perhaps adapting the models for individual sport organizations is needed to enable coaches to better understand how to apply the models in their practice. Coaches need to be educated about and apply these principles in their training to decrease overuse injury risk and help
youth athletes reach their potential in sport while maintaining the motivation to stay involved in sport/physical activity in sport.
REFERENCES


APPENDICES

APPENDIX A – Recruitment Email

Greetings _____________!

My name is Kim Catlett and I am a Masters student at the University of Colorado Colorado Springs. For my thesis, I am surveying individuals involved in developing youth athletes to find if athletes are receiving the proper training for their age group and maturity level.

The survey should take about 10 minutes to complete and your participation will be anonymous and greatly appreciated. Your answers will help raise awareness of proper training methods for young athletes to prepare them for high level competition.

Thank you for your time and participation!

Kim Catlett, CSCS
B.S. Health Sciences
M.Sc. Sports Medicine: Strength and Conditioning
Hello again ______________,

Two weeks ago, you were contacted about completing a survey on long-term athletic development programs in youth athletics. Your response is critical to gaining knowledge about coaching practices in youth athletics and how they can be modified in order to prepare athletes for success later in their careers. I ask only for honest responses and 10 minutes of your time.

Thank you again for your time and participation!

Kim Catlett, CSCS

B.S. Health Sciences
M.Sc. Sports Medicine: Strength and Conditioning
APPENDIX C – Social Media Post

Hello all!

I am a current Graduate Student at UCCS and for my thesis I am in need of participants to take a quick 10-minute survey about the current knowledge and application of 3 models of long-term athletic development: Long-Term Athletic Development Model, Developmental Model of Sports Participation, and Youth Physical Development model.

If you are a current sport or strength and conditioning coach, athletic director, or club director please click the link below to take the survey. To help with recruitment, please forward email addresses of any potential participants you know and/or share this post on your profile.

Thank you in advance for your participation and involvement in this research!
Kim Catlett, CSCS
APPENDIX D – Survey (as seen on Survey Monkey)

Long-Term Athletic Development Questionnaire

Thank you for agreeing to take part in this survey. The purpose of this study is to assess knowledge of principles associated with long term athletic development among personnel involved with youth sports (sport coaches, strength and conditioning coaches, athletic directors, club directors, etc.). This survey was adapted from McKeown and Ball (2013). This survey should take approximately 10 minutes for you to complete. Your answers will be held in confidentiality and will only be reported with anonymity.

1. I assess **Limb Length** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

2. Outside of practice, how often do your athletes participate in Plyometric training (jumping, etc.)?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

3. How well do you understand Côté et al.’s Developmental Model of Sports Participation?
   a. Complete understanding
   b. In depth understanding
   c. General understanding
   d. Vague understanding
   e. No knowledge/experience

4. Outside of practice, how often do your athletes participate in Bodyweight Exercises (pushups, etc.)?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

5. I assess **Anaerobic Power** in junior athletes
6. How often do you use the Long Term Athletic Development model with working with developmental athletes?
   a. Never
   b. Some of the time
   c. Often
   d. Most of the time
   e. All of the time

7. How effective do you find the principle that you most favor in developing young athletes?
   a. Absolutely necessary
   b. Highly effective
   c. Generally effective
   d. Somewhat effective
   e. Not effective

8. I assess **Weight** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

9. How well do you understand Lloyd’s Youth Physical Development Model?
   a. No knowledge/experience
   b. Vague understanding
   c. General understanding
   d. In depth understanding
   e. Complete understanding

10. I assess **Aerobic Endurance** in junior athletes
    a. All of the time
    b. Often
    c. Sometimes
    d. Rarely
    e. Never
11. Describe the approach that best describes the planning of strength and conditioning activities/programs athletes engage in.
   a. **Randomized**—workout of the day style, spontaneous exercise selection, focused on improving fitness-assessment performance (push-ups, sit-ups, chin-ups, high intensity training, etc.)
   b. **Individualized**—specific to the needs of each individual athlete (regarding experience, training needs, stressors, etc.)
   c. **Periodized**—includes phases to increase endurance, hypertrophy, strength, or power for general health and physical conditioning
   d. **Other**

12. Outside of practice, how often do your athletes participate in Speed/Agility training (sprints, ladders, etc.)?
   a. All of the time
   b. Often
   c. Sometimes
   d. Rarely
   e. Never

13. I assess **Sport Specific Skills** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

14. How useful do you feel performance assessments are when dealing with junior athletes.
   a. Useless
   b. Somewhat useful
   c. Generally useful
   d. Highly useful
   e. Absolutely necessary

15. I assess **Explosive Strength/Power** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

16. Outside of practice, how often do your athletes participate in Flexibility training (stretching, mobility, etc.)?
   a. All of the time
b. Often
  c. Sometimes
  d. Rarely
  e. Never

17. How well do you understand Balyi’s Long-Term Athletic Development Model?
   a. No knowledge/experience
   b. Vague understanding
   c. General understanding
   d. In depth understanding
   e. Complete understanding

18. I assess **Maximum Strength** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

19. How useful do you feel movement assessments are when dealing with athletes?
   a. Not useful at all
   b. Somewhat useful
   c. Useful
   d. Very useful
   e. Essential

20. Outside of practice, how often do your athletes participate in Medicine Ball Training (slams, tosses, etc.)?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

21. I assess **Flexibility/Mobility** in junior athletes
   a. All of the time
   b. Often
   c. Sometimes
   d. Rarely
   e. Never

22. How often do you use the Youth Physical Development model with working with developmental athletes?
   a. Never
b. Some of the time
c. Often
d. Most of the time
e. All of the time

23. Outside of practice, how often do your athletes participate in Stability Ball Training (balance, core, etc.)?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

24. I assess **General Athletic Movements** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

25. Outside of practice, how often do your athletes participate in Mental training (visualization, etc.)?
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

26. I assess **Height** in junior athletes
   a. Never
   b. Rarely
   c. Sometimes
   d. Often
   e. All of the time

27. Are you responsible for the creation of strength and conditioning programs for your athletes?
   a. Yes
   b. No

28. Outside of practice, how often do your athletes participate in Endurance Training (long distance/duration)?
   a. All of the time
   b. Often
c. Sometimes
d. Rarely
e. Never

29. How often do you use the Developmental Model of Sports Participation with working with developmental athletes?
   a. All of the time
   b. Most of the time
   c. Often
   d. Some of the time
   e. Never

30. Select sex.
   a. Male
   b. Female

31. Age: ___

32. What sports do you currently have professional involvement with?
   ________________________________________________________________________

33. What is your title within the organization you are currently working for?
   ________________________________________________________________________

34. Indicate the primary sport(s) that you work with.
   ________________________________________________________________________

35. Indicate your length of involvement coaching youth athletes.
   a. 3 or less years
   b. 3-5 years
   c. 5-7 years
   d. 7+ years

36. What level of athlete do you currently coach?
   a. Varsity Collegiate
   b. Club (Collegiate)
   c. Club (High School)
   d. High School
   e. Middle School
   f. U12 or younger
<table>
<thead>
<tr>
<th>Model</th>
<th>Long-Term Athletic Development Model (LTAD)</th>
<th>Developmental Model of Sports Participation (DMSP)</th>
<th>Youth Physical Development Model (YPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Differences</strong></td>
<td>• Applicable to athletes of any age • Divided into 7 stages based on principles of growth, development, and optimal periods of skill acquisition • Stages specific to males and females based on trends of varied rates of development • Training focus determined by windows of opportunity determined by PHV, PWV, adolescent growth spurt, and onset of menarche in females • Provides specific guidelines for frequency and amount of time spent engaging in practice vs competition in each stage • Provides timelines for integration of specific training methods (resistance training, speed, endurance, psychological skills, sport-specific skills, etc.) • Created to overcome shortcomings in Canadian sport system</td>
<td>• Focuses on psychosocial maturation of athletes 7-18 years old • Categorizes athlete career into 1 of 3 developmental pathways: early sampling, early specialization, recreational • Early sampling pathway split into 3 stages: sampling years, specializing years, investing years • Delineates types of engagement in sport participation (deliberate play, deliberate practice, etc.) and the balance of each during each stage • Contains 7 postulates integrating performance, participation, and personal development using sport-specific and general theories of child/adolescent development</td>
<td>• Describes athletic development from early childhood into adulthood (ages 2-21+) • Provides coaches/educators with information on physical development and explains timing and purpose of training methods • Has specific timeframes and guidelines listed for the introduction of strength, hypertrophy, muscular power, agility, mobility, speed, and endurance training • Prioritizes muscular strength training throughout all stages of development</td>
</tr>
<tr>
<td><strong>Similarities</strong></td>
<td>• Promote early sampling approach in late specialization sports • Suggest narrowing sport focus after a period of engagement in multiple sports • Prioritize athletes’ lifetime involvement in sport and physical activity over short-term performance gains • Quantify stages of training/specialization based on principles of growth and development rather than strictly chronological age • Consider psychosocial development in addition to athletic skill development • Promote learning of fundamental movement skills prior to specialization in a single sport • Emphasize importance of having a qualified professional overseeing youth training programs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX F – Item Key

1. I assess Seated height or Limb Length in youth athletes…
2. How often do your athletes participate in Plyometric training (e.g. box jumps, hurdle jumps, etc.)?
3. How well do you understand Cote et al.’s Developmental Model of Sports Participation?
4. Outside of practice, how often do your athletes participate in exercises where only bodyweight is used for resistance (e.g. pushups, lunges, etc.)?
5. I assess Anaerobic Capacity in youth athletes (approximately 30-90 seconds of intense, maximal or near maximal effort such as a sprint tests) …
6. How often do you use Balyi’s Long Term Athletic Development model when working with developmental athletes?
7. I assess Body Weight in youth athletes…
8. How often do you use the Developmental Model of Sports Participation with working with developmental athletes?
9. How well do you understand Lloyd and Oliver’s Youth Physical Development Model?
10. I assess Aerobic Endurance in youth athletes (e.g. maximal/submaximal test lasting >2 minutes such as the Beep Test) …
12. Outside of practice, how often do your athletes participate in Speed/Agility training (e.g. sprints, agility ladders, etc.)?
13. I assess Sport Specific Skills in youth athletes (e.g. tennis/volleyball serve, basketball shot, etc.) …
14. How useful do you feel physical performance assessments are when dealing with youth athletes? (e.g. speed, agility, balance, power, etc.)
15. I assess Explosive Strength/Power in junior athletes (e.g. broad jump, vertical jump, medicine ball throw, etc.) …
16. Outside of practice, how often do your athletes participate in Flexibility training (e.g. stretching, mobility, etc.)?
17. How well do you understand Balyi’s Long-Term Athletic Development Model?
18. I assess Maximum Strength in junior athletes (using maximal weight assessments such as 1Rep Max) …
19. How useful do you feel assessing movement competency is when dealing with youth athletes (ie., ability to do bodyweight exercises such as squats, lunges, pushups, etc.)?
20. How often do your athletes participate in Medicine Ball Training (slams, tosses, etc.)?
21. I assess Flexibility/Mobility in junior athletes (e.g. sit and reach test, active straight leg raise, trunk rotation, goniometry, etc.) …
22. How often do you use Lloyd and Oliver’s Youth Physical Development model when working with developmental athletes?
23. I assess strength endurance in junior athletes (maximum number of pushups, plank hold, maximum number of repetitions > 8) …
24. Outside of practice, how often do your athletes participate in Stability Ball Training (e.g. balance, core, etc.)?
25. I assess General Athletic Movements (i.e., movement competency) in youth athletes (ability to jump, run, shuffle, etc.) …
26. How often do your athletes participate in Mental training (visualization, etc.)?
27. I assess Height in youth athletes…
29. How often do your athletes participate in Endurance Training (long distance/duration, small-sided games, high-intensity interval training, etc.)?