Consequences of Single Sport Specialization in the Pediatric and Adolescent Athlete

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KEYWORDS

• Pediatric • Adolescent • Sports injuries • Specialization • Burnout • Youth • Overuse

KEY POINTS

- An increasing number of youth are specializing in single sports at younger ages and engaging in repetitive, intensive activity.
- Early, single sport specialization has not been shown to improve future athletic performance, but has been shown to be detrimental both physically and emotionally.
- The adolescent growth spurt is a particularly vulnerable period of time for the youth athlete with repetitive microtrauma, placing the body at risk structurally.
- Identifying burnout is critical for the clinician taking care of youth athletes who specialize in a single sport.
- Long-term consequences extending into adulthood exist for the athlete who specializes at a young age.

EPIDEMIOLOGY OF YOUTH SPORTS PARTICIPATION

Organized sports participation among young athletes has increased tremendously over the past several years. According to the National Council on Youth Sports, nearly 60 million youth between the ages of 6 to 18 participated in organized athletics in 2008 compared with 52 million in 2000.[1] This rise has occurred with a concurrent drop in school-based physical education, with only 29% of all high school students participating in daily classes.[2] This has created an environment in which sports activity is highly structured and centered on the development of specific skills (eg, pitching, tumbling, dribbling) rather than a strong foundation centered around core physical principles, such as flexibility, endurance, and balance. This trend from unstructured free play to deliberate, adult activity has been well-documented in the media,[3,4] and has occurred simultaneously with youth sports becoming a profitable business entity.[5,6]

As a result, a culture has been created in which the definition of success in youth sports is defined not by laying the foundation for a healthy lifestyle, but rather the attainment of "elite" status. This

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push has been largely created by coaches and parents, many of whom measure their child's athletic participation by the attainment of collegiate scholarships and professional contracts. In 1993, Ericsson and colleagues[7] proposed that, to achieve expertise as a musician, one must practice 10,000 hours within that specialized field. This principle has been adopted by many parents as a justification for intensive, adult-style training for sports at increasingly younger ages. As a result, rather than playing a wide variety of sports at a moderate level of intensity during the early stages of physical development, there is increasing evidence that children are beginning to specialize at younger ages in 1 sport.[8–11] This trend is occurring even with multiple groups advocating delayed specialization.[12–15]

Single sport specialization can be defined as intensive, year-round training in a single sport at the exclusion of other sports.[16,17] This phenomenon is especially present in the media, whose attention is focused on athletic prodigies such as Tiger Woods, who are applauded for their dedication to a single sport as toddlers, rather than athletes, such as Steve Nash and Roger Federer, who have achieved similar levels of success while playing multiple sports in their youth.[4] Unfortunately, the desire to specialize is fallacious on multiple fronts.

First, the probability of achieving elite status is small for the vast majority of athletes. According to data published by the National Collegiate Athletic Association in 2013, the estimated probability of competing in collegiate athletics for high school athletes ranged from 3.3% to 6.8% for men's basketball, women's basketball, football, baseball, and men's soccer.[18] For that same group of sports, the estimated probability of competing at the professional level for high school athletes ranged from 0.03% to 0.5%.[18] When these data are coupled with the fact that the average athletic scholarship is approximately $10,000,[19] there is clearly a disconnect between the realistic chances of playing at the next level and, if one does make it, the rather modest amount of money that will be obtained. However, the argument could be made by some that, although the proposed rewards of single sport specialization are difficult to obtain, there exists either no other means to achieve that goal and/or the negative effects of attempting to achieve that path are minimal. The literature suggests otherwise.

From a theoretic perspective, Abernathy et al[20] have suggested that diversified sport training in early and middle adolescence may better foster elite athletic potential than specialization owing to a more positive transfer of skills. Looking at the youngest of cohorts, Fransen and colleagues[21] analyzed 735 boys aged 10 to 12 years of age and found that those who participated in various sports performed better on a standing broad jump and gross motor coordination than those who specialized in a single sport. Gullich and Emrich[22,23] examined athletic performance in Germany and found that the younger the age of recruitment of the athlete into specialized training programs, the earlier they left sports. Those athletes who progressed to higher levels of participation began playing sports at later ages.

At the collegiate level, DiFiori[24] examined a cohort of Division I athletes at their institution and found that 88% had participated in 2 to 3 sports as children, with the vast majority (70%) not specializing until the age of 12. In addition, the average age of specialization between collegiate athletes (15.4 years) and noncollegiate athletes (14.2 years) varied significantly.[24] Malina[17] also found that, among female collegiate athletes in the United States (particularly diving, tennis, golf, track and field, basketball, and volleyball), the majority had their first organized sporting experience in another sport. In addition, Vaeyens and colleagues[25] found that an early age of onset of high-volume, sport-specific training did not necessarily associate with success at the international level in adult sporting activity. Thus, the proposed benefits of single sport specialization are minimal.

In addition, there are multiple studies that document the overall negative effects of sports specialization in the context of limited future gain. Jayanthi and colleagues[26] examined more than 1200 athletes between the ages of 8 and 18, and found that athletes who spend more hours per week playing their sport than their age are 70% more likely to experience a severe injury. In addition, Holt and colleagues[27] found that youth athletes of higher socioeconomic status (and with private health insurance) suffered more serious overuse injuries, particularly because they were the group that demonstrated a trend toward more sports specialization and less free play. Combined with the risks of social isolation, overdependence, burnout, and manipulation,[16,17,28] the benefits of single sport specialization must be carefully considered within the context of the published risk, many of which are discussed in detail herein.

ANATOMY AND PHYSIOLOGY OF THE PEDIATRIC ATHLETE

To more fully understand the potential consequences of single sport specialization on the

pediatric and adolescent athlete, it is first critical to understand the physiologic and structural differences between the immature and mature athlete. Although there is no consensus on when sport specialization can safely occur, the age of 12 is generally used as a rough cutoff. This point is largely the age at which puberty and skeletal maturation begins.[28]

From a physiologic standpoint, aerobic (V_{O_2} max) and anaerobic capacity increase with age, youth athletes have a higher metabolic cost of running compared with adults, and they have more difficulty dealing with thermoregulation.[29,30] These are critical to understand when treating athletes who may be subjecting themselves to the intense demands of single specialization beyond the more commonly known overuse syndromes discussed herein.

From an orthopedic standpoint, the adolescent growth spurt is a critical time for athletic specialization. During this period, there exists a high risk of injury,[31] particularly involving the apophysis and physis,[32–34] when repetitive activity is performed. Multiple studies have demonstrated that the cartilage present about the physis, apophysis, and articular surfaces are more prone to injury (owing to a decreased resistance to force) during rapid growth phases.[35–37] This is particularly demonstrated by the predisposition of athletes of this age group to suffer injuries to the apophyseal, physeal, and cartilaginous regions (ie, gymnast wrist, Osgood-Schlatter disease, osteochondral lesions).

Hawkins and Metheny[38] outline the following concepts regarding these injuries. It is during rapid periods of growth that muscles and tendons lengthen, yet muscle hypertrophy does not occur at the same rate. As a result, muscles need to produce a greater percentage of their maximal force to produce the same movements that occurred before the growth spurt. This increased force is seen by the tendons. As an example, Hawkins and Metheny[38] calculated that 30% more muscular force is potentially required to develop the same lower leg angular acceleration for an activity such as kicking a ball after a growth spurt as compared with before the growth spurt. If an athlete can generate this force, it is then also transferred to tendons and subsequently the apophyses, potentially leading to overuse injuries if the activity is performed repetitively. If these principles are understood, activities such as strength training can be performed as long as a preparticipation medical evaluation takes place, overall body conditioning is emphasized, and maximal lifts and power lifting are avoided until skeletal maturity is achieved.[39]

The unique anatomy and physiology of the growing athlete places them at a baseline injury risk, which is multiplied by engaging in repetitive, intense activity that can occur with sport specialization.

CONSEQUENCES OF SINGLE SPORT SPECIALIZATION

Physical

Single sport specialization alone is not a problem; rather, the intensive, year-round training in a single sport at the exclusion of other sports causes these issues.[28] Continuous single sport participation subjects the body to the same, repetitive microtrauma and overuse. General guidelines to avoid problems include limiting overall weekly and yearly participation time, limiting repetitive movement (eg, pitching counts), and allowing for scheduled rest periods and/or cross-training during "rest" periods.[28] These recommendations must be individualized based on the athlete, their stage of skeletal maturity (especially during the adolescent growth spurt), and overall conditioning. When uncontrolled or unregulated training occurs, there are serious physical, emotional, and social consequences for both immediate and long-term sports participation.

There is a clear correlation in the literature between training volume and intensity and injury risk, particularly overuse injuries. In fact, the vast majority of injuries seen in a typical sports medicine clinic treating patients from ages 6 to 18 are related to overuse, up to 54.4% in some studies.[40] Furthermore, according to Rose and colleagues[41] in a study of 2721 high school athletes, there was a direct correlation of injury risk with increased weekly hours of sports participation. It therefore follows that, with single sport specialization, there not only exists a greater intensity and volume of training, but also an intensity and volume of training that is repetitive and leads to microtrauma.

For example, Jayanthi and colleagues[11] found that in junior elite tennis players the risk of a reported injury was 1.5 times more likely if they specialized only in tennis. Pitching represents perhaps an even more extraordinary case. Fleisig and colleagues[42] examined 481 youth pitchers (ages 9–14) over a 10-year period and found that pitching more than 100 innings per year increased injury risk 3.5 times. This effect of overuse is further exemplified in a case control study that compared injured and noninjured adolescent pitchers. The study found that the injured group pitched significantly more months per year, games per year, innings per game, pitches per game, pitches per year, and warmup pitches before a

game. These pitchers were also more frequently starting pitchers, pitched in more showcases, pitched with higher velocity, and pitched more often with arm pain and fatigue.[43] Clearly, specialization and injury risk are linked.

With regard to the specific injuries seen, the areas of the body that are most prone to overuse injury from repetitive trauma from single sport specialization in the growing athletes, as mentioned previously, are the apophysis and physis.[32–34] This concentration leads to a spectrum of common conditions, including Osgood-Schlatter disease (tibia tubercle apophysitis),[44] Sever disease (calcaneal apophysitis),[45] and Little League elbow (medial epicondyle apophysitis).[46] Physeal injuries such as Little League shoulder (proximal humeral physis)[47] and gymnast wrist (distal radius physis)[48] are also part of this spectrum of injury. Injuries to the cartilage of developing joint surfaces (osteochondral lesion) can also occur. As patients mature, they become more susceptible to adult injury patterns, including stress reactions and stress fractures of the spine (spondylolysis), femoral neck, patella, anterior tibia, medial malleolus, and foot (**Box 1**).[28,49–54]

Two specific areas of concern that have arisen with the increase in single sport specialization and warrant special consideration are the increasing rate of ulnar collateral ligament injuries in pitchers and traumatic knee injuries (ie, anterior cruciate ligament [ACL] tears). An increasing number of ulnar collateral ligament injuries are being seen in patients in younger and younger ages with specialization and overuse cited as the main culprits.[55–59]

Box 1
Common overuse injuries in the single sport athlete

Physical

- Osgood-Schlatter disease
- Sever disease
- Medial epicondyle apophysitis
- Distal radial physeal stress syndrome
- Proximal humeral physiolysis
- Stress fracture (ie, spondylolysis)

Emotional

- Burnout
- Social isolation
- Overdependence

From a knee standpoint, Hall and colleagues[60] examined 546 female basketball, soccer, and volleyball players, and found that those athletes involved in a single sport had 1.5-fold relative risk increased risk of patellofemoral pain, Osgood-Schlatter disease, and Sinding Larsen-Johansson syndrome compared with multisport athletes. This distinction is critical, because it has been noted that, among middle and high school female patients with patellofemoral pain, a potential association exists between the development of patellofemoral pain and a subsequent risk of developing ACL injuries later in adolescence.[61] This observation is made in the context of a youth sporting environment that has seen a rapid increase in the incidence of pediatric and adolescent ACL injuries.[62] The increased rate of ACL injury in the young age group has been attributed to early, single sport specialization coupled with a demand for peak performance during a time of change, particularly physiologically, when neuromuscular control and physical fitness may be lacking.[63]

Emotional

Although there is a tendency to concentrate on the physical manifestations of specialization, the psychosocial factors play as important, if not more important, role. Malina[17] described social isolation, overdependence, and burnout as potential consequences (**Box 2**).

Box 2
Red flags on in-office assessment of the single sport athlete

History

- Decreased performance despite weeks to months of recovery
- Mood disturbances
- Lack of enjoyment in sport
- Presence of triggers such as high training volumes, high time demands, monotony of training, excessive number of competitions.

Physical Examination

- Muscle tightness (positive Ober test, positive Thomas test, popliteal angle >25, ankle dorsiflexion <5, glenohumeral internal rotation deficit)
- Ligamentous laxity
- Q angle greater than 20
- Valgus knee collapse on single leg squat test

From an isolation perspective, the sheer number of hours that youth dedicate to their singular sporting endeavor limits their experiences with other children of their age group who may play other sports and/or no sports at all. In addition, particularly in sports such as gymnastics, home schooling is becoming increasing common, which potentially limits nonathletic interactions with other peers.

From an overdependence perspective, Malina[17] describes the extreme regulation of a young athlete's life in which "overdependence on others" and "loss of control of what is happening in life" can occur. Although not formally studied in a large group of young elite athletes, the constant scheduling of activities by adult influences (ie, parents, coaches, tournament directors) and an overexaggeration of self-worth (ie, "you are special because you excel in a sport") can also potentially negatively affect the young athlete who begins to specialize (and succeed) at a young age.

Burnout is perhaps the most studied consequence of specialization. Burnout has been defined by Smith[64] as a response to chronic stress when a previously enjoyable activity is no longer so. Multiple studies have suggested that early sport specialization can lead to premature cessation of participation either through injury or burnout.[65–67] A recent study by Simon and Docherty[68] looking at former division I collegiate athletes compared with noncollegiate athletes found overall scores lower for athletes on the Patient-Reported Outcomes Measurement Information System for physical function, depression, fatigue, sleep disturbances, and pain interference. This has also been seen by a study performed by Weigand and colleagues,[69] which found higher rates of depression in current college athletes (16.77%) versus former, graduated college athletes (8.03%). In addition, Yang and colleagues[70] found a 21% rate of depression in Division I athletes, particularly among freshman and females.

The sports specialization environment that defines elite performance as success includes high training and time demands, frequent competition, demanding performance expectations, inconsistent coaching practices, little personal control in decision making, negative performance evaluations, the need for perfectionism, the need to please, nonassertiveness, low self-esteem, high anxiety, and an unhealthy focus solely on individual athletic involvement.[17,28,71] A culture has been created in which sports have been transformed from enjoyable to an anxiety-provoking and stressful activity, leading to early departure from sport for many young athletes.

IN-OFFICE ASSESSMENT OF THE SINGLE SPORT PEDIATRIC ATHLETE

Overuse Injuries and Burnout

The in-office assessment of the single sport pediatric athlete should focus on signs of overuse and burnout. Overuse injuries occur owing to repeated submaximal loading of the musculoskeletal system with inadequate rest that prevents structural adaptation and healing. This process damages the muscle–tendon unit, bone, bursa, or neurovascular structures. Approximately 50% of all injuries seen in pediatric sports medicine are related to overuse.[28] Children may be at risk for overuse injuries owing to improper technique, poorly fitting protective equipment, training errors, and muscle weakness and imbalance.[72] There are 4 stages of overuse, in increasing severity: (1) pain in the affected area after physical activity, (2) pain during the activity, without restricting performance, (3) pain during the activity that restricts performance, and (4) chronic, unremitting pain even at rest.[73]

Burnout, also known as overtraining syndrome, failure adaptation, under recovery, or training stress syndrome, is well-described in the adult literature. It is a maladaptive response to excessive exercise that is not matched to appropriate rest, and it represents a systemic inflammatory process with diffuse effects on the neurohormonal axis affecting host immunology and mood. Potential triggers include increased training load without adequate recovery, monotony of training, and excessive number of competitions. The clinical diagnoses is accomplished through history demonstrating (1) decreased performance persisting despite weeks to months of recovery, (2) disturbances in mood, and (3) lack of sign/symptoms or diagnosis of other possible causes of underperformance.[74] Common manifestations in the pediatric athlete include chronic muscle or joint pain, personality changes, elevated resting heart rate, fatigue, lack of enthusiasm about practice or competition, or difficulty with successfully completing usual routines.[73]

When counseling in the clinic, the physician must recognize that there are no scientifically determined guidelines to define how much exercise is healthy and beneficial to the young athlete compared with what might put them at risk for overuse injuries and burnout. The American Academy of Pediatrics Council on Sports Medicine and Fitness recommends limiting one sporting activity to a maximum of 5 days per week with at least 1 day off from any organized activity. Athletes should also have at least 2 to 3 months off per year from their particular sport so that they can let injuries heal, refresh the mind, and work on

strength, conditioning, and proprioception in hopes of reducing injury risk.[73] Additionally, youth athletes should have at least 7 hours of sleep each day.[40]

Clinical Examination

In 1992, 5 medical societies—American Academy of Family Physicians, American Academy of Pediatrics, American Medical Society of Sports Medicine, American Orthopedic Society for Sports Medicine, and American Osteopathic Academy of Sports Medicine—collaborated to develop the Preparticipation Physical Examination. Now in its fourth edition, it is widely used to detect potentially life-threatening medical conditions and screen athletes for risk factors that may predispose them to injury or illness.[75] The medical history includes 50 questions and is the most sensitive and specific component of the Preparticipation Physical Examination; it can identify more than 75% of important orthopedic conditions affecting youth athletes.[75]

Beyond the Preparticipation Physical Examination, there are key history questions and physical examination maneuvers to screen for overuse injury and burnout in the single sport youth athlete (see **Box 2**). This includes assessment of athlete happiness and fatigue, parental pressure, and coach involvement, as well as the athlete's training workload, schedule, and equipment. Children or their parents may complain of unexplained underperformance.[74] Questions should include hours per week of activity as well as specifics such as miles per week of running or number of pitches per week. It is important to ask about the number of days off from structured activity, how many different teams the athlete is playing on, any use of supplements, and time spent on strength training, drills, and free play.

The physical examination starts when then patient enters the office with assessment of gait, because an antalgic gait is an immediate marker of injury. Otherwise, depending on the sport, specific areas to focus on for overuse injury are the lateral shoulder, medial elbow, lower back, anterior knee, lower leg, and heel. Point tenderness can be helpful for discerning certain apophyseal and physeal injuries such as Sever disease, Osgood-Schlatter disease, and Little League shoulder.[72,76]

In asymptomatic single sports athletes, there are specific maneuvers to determine those who may be at risk for injury. Boys and girls with a combination of muscle weakness, ligamentous laxity, and muscle tightness are at increased risk for overuse injuries. These overuse effects can be intensified by large body weight and length, high explosive strength, and lower limb malalignment.[77]

The single leg squat test identifies core strength and generally relates to landing, running, and cutting tasks. This maneuver has been shown to correlate well with 2-dimensional, frontal plane video of middle and high school athletes, and is a reasonable tool to assess dynamic knee valgus.[78] Dynamic knee valgus is associated with an increased risk of ACL injury.[79] Hip abduction, extension, and external rotation strength should also be evaluated because there is evidence that hip muscle weakness correlates with conditions such as patellofemoral pain syndrome and iliotibial band syndrome.[80] Additionally, the quadriceps angle can correlate with knee injury. In a prospective cohort study of 400 high school cross-country runners, a quadriceps angle of greater than 20° was associated with a 1.7 times greater risk of injury compared with runners with a quadriceps angle of 10° to 15° ($P<.05$).[81]

In several studies, generalized joint hypermobility has been shown to relate to insidious onset arthralgias, coordination problems, and exercise-related pain.[82,83] Screening for hypermobility has been standardized via the Beighton and Horan Joint Mobility Index, which combines thumb abduction, fifth metacarpal extension, elbow extension, hip flexion, and knee extension for a numerical score.[84]

Muscle tightness has also been shown to relate to injury. A study of 201 collegiate athletes showed that risk of injury increased 23% for each additional point on a 10-point muscle tightness scale (10 = all muscles tight).[85] Lower extremity muscle tightness can be measured in several ways: (1) the Ober test for the iliotibial band, (2) the Thomas test for the iliopsoas, (3) popliteal angle for the hamstring, and (4) ankle dorsiflexion for the gastrocsoleus. In overhead athletes, elbow range of motion and shoulder glenohumeral internal rotation deficit should be checked. Glenohumeral internal rotation deficit is a side-to-side asymmetry of more than 25° produced by acquired posterior capsular contracture or muscle stiffness, and is associated with various shoulder injuries in overhead athletes.[86]

Although history and physical examination are essential in the assessment of the single sport athlete, imaging can play an important role in diagnosis of injury. Imaging for stress reactions, stress fractures, and physeal or apophyseal injuries begins with radiographs, although early radiographs may detect as few as 15% of these injuries in the acute setting.[87] MRI thus offers an advantage over plain radiographs for early detection of these pathologies. MRI can also assist diagnosis of

osteochondritis dissecans, ligamentous injury, and tendinopathies. CT has a limited role in diagnosis for overuse injuries, and even in cases of spondylolysis, where CT was previously the gold standard, MRI has been shown to be more sensitive.[88]

ADULT CONSEQUENCES OF SINGLE SPORT SPECIALIZATION

Single sport specialization in the pediatric athlete can have lifelong consequences. For a few examples, we review common pediatric injuries that may occur in the single sport athlete, namely, ulnar collateral ligament tears of the elbow, ACL tears, and spondylolysis.

Ulnar collateral ligament insufficiency is a potentially career-threatening, or even career-ending, injury, particularly for the overhead throwing athlete. In the 1960s, before recognition of the ulnar collateral ligament, professional pitchers were often found to have adaptive changes secondary to prolonged and repetitive throwing, such as flexion contracture, hypertrophy of the dominant extremity, and valgus deformity of the elbow, and nearly 67% of pitchers had radiographic evidence of degenerative elbow disease.[89] If ulnar collateral ligament injuries are managed nonoperatively, only 40% to 50% of high demand throwers can return to play after an average of 6 months away from sport.[90,91] Even with surgery, studies have shown that as many as 26% of high school athletes cannot return to preinjury level of play.[56]

ACL injuries in the pediatric athlete also can have devastating consequences. The association of ACL tears with meniscal injury, and the relation between meniscal loss and degenerative knee arthritis, is well-described in the adult literature.[92] There are fewer pediatric studies, but early data suggest similar associations. In a study by Samora and colleagues[93] of 124 patients, lateral meniscal tears were found in 57% of patients and medial meniscal tears in 29%. There is an increased incidence of medial meniscal injury at the time of ACL surgery when patients are treated for longer than 6 weeks after injury.[92,94] Dumont and colleagues[92] also found that chondral injuries after ACL tear were highly correlated with coexisting meniscal tears, with the medial femoral condyle having the highest rate of injury—over 40% in youth 15 years or older with an ACL tear. These pediatric studies demonstrate the need for early surgery in youth with ACL tears, and show that ACL tears are accompanied by pathology that has potentially long-lasting impact on the life of the knee.

Children generally do well in the short term after conservative management for spondylolysis. A recent meta-analysis demonstrated that 84% of patients managed nonoperatively are able to return to pain-free or near pain-free unrestricted activities. This is despite a lack in radiographic healing, where 71% of unilateral and only 18% of bilateral lesions were found to heal on imaging.[95] Long-term studies show favorable outcomes for patients up to 11 years after diagnosis. However, it is unknown if these patients do well beyond their mid 20s. Patients with spondyloysis on plain radiographs over the age of 25 have more severe disk degeneration below the level of the defect than the general population, which suggests that children with persistent defects on radiographs may eventually have deterioration of function from disk disease.[96]

From just these examples, we see the potential consequences of injury in the pediatric athlete. With the rise of single sport specialization, these injuries are becoming even more common, and thus their effects are even more important. Proper education of athletes, parents, and coaches will allow for the prevention of these injuries.[97] Perhaps the most important concept that all involved should embrace is that a child complaining of pain should seek medical attention. The concept of “pushing through the pain” should not be mandated in youth athletics. With the proper education and utilization of a multidisciplinary team (including parents, coaches, psychologists, and nutritionists) a safe, enjoyable environment for our young athletes can be created.

SUMMARY

Early single sport specialization is an increasing problem among youth athletes and has not been shown to improve long-term athletic performance. There are multiple physical and emotional consequences for engagement in this form of repetitive microtrauma. It is essential for the clinician to understand the differences in adult and youth structure and physiology, particularly during the adolescent growth spurt when injury risk is high. A careful in-office assessment of these athletes with an understanding of the potential long-term consequences of early specialization is critical.

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