ADVANCING UNDERSTANDING OF EARLY SPECIALIZATION IN YOUTH SPORT

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Abstract

Objective: The overarching purpose of this dissertation was to better understand early specialization, through two main objectives. The first objective was to determine research gaps in existing literature, and the second was to develop a valid tool for measuring specialization based on the identified gaps.

Methods: In Chapter Two, a systematic review of the literature was conducted. Both non-data driven and data-driven studies were included to ensure a comprehensive understanding of the literature. Chapter Three describes a two-part study. In part one, 362 athletes were coded as specializers or non specializers depending on three different indicators used in previous research. In part two, 237 athletes were then coded to determine whether they were elite, pre-elite or non-elite in adulthood. Lastly, in Chapter Five, a Delphi-approach included 16 experts in the field to test elements of validity of the Sport Exposure Scale.

Results: Findings from Chapter Two indicated inconsistent definitions and measures used in the literature and a clear discrepancy between key components of early specialization and approaches used to classify early specializers. Chapter Three results showed the proportion of athletes classified as specialisers varied depending on the method used and that there was no clear advantage or disadvantage to being a specializer based on skill-level achieved. Finally, in Chapter Five, the content and face validity of the Sport exposure Scale was established when the Delphi panellists reached consensus for each item.

Conclusion: This dissertation highlighted gaps in the literature around early specialization and showed the implications of measurement imprecision. This dissertation attempted to provide a solution to these issues by creating the Sport Exposure Scale, which was designed to help advance not only our understanding of early specialization, but sport participation pathways in general. This dissertation provides areas for future research and has significant implications for research, stakeholders and society more broadly.

Dedication

To my Mom and Dad, if it wasn't for all the hours spent driving me to different sports and sitting in the stands over the years, I would not have developed a deep love of sport that pushed me into the field of sport psychology and athlete development. If not for the constant help with homework and emphasis on education I would never have had the confidence to pursue a doctoral degree. In other words, none of this was possible without.

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Chapter One: General Introduction

Introduction

Beyond physical fitness, sport is suggested to have psychological and social benefits due to its unique context (Eime et al., 2013). It has also been suggested that youth sport can lead to positive youth development outcomes such as confidence and competence, (Fraser-Thomas et al., 2005). Unfortunately, there are also risks associated with sport participation, as it has been linked to negative outcomes, such as increased alcohol consumption (Kwan et al., 2014) and overuse and acute injury (Merkel, 2013). With the large number of youth participating in sport (CFLRI, 2016), it is essential that sport be delivered to optimize positive outcomes while preventing negative ones. As such, researchers have attempted to outline common sport pathways and their outcomes.

There are two models of sport pathways commonly used in Canada; The Developmental Model of Sport Participation (DSMP; Côté, 1999; Côté & Fraser-Thomas, 2016; Côté & Hay, 2002) and the Long-Term Development in Sport and Physical Activity Model (LTD; Sport for life, 2019). The DMSP (Côté & Fraser-Thomas, 2016) suggests athletes follow three common pathways in their sport journeys a) recreational participation through sampling, b) elite participation through sampling and c) elite performance through early specialization, while the LTD (Sport for life, 2019) includes eight key stages. The stages most relevant to youth sport participation in the LTD (Sport for life, 2019) are focused on building physical literacy and a solid foundation of sport participation they include a) Active Start, b) FUNdamentals and c) Learn to train. Both the DMSP (Côté & Fraser-Thomas, 2016) and the LTD (Sport for life, 2019), emphasize multisport engagement during early development. This emphasis comes from research denoting the costs and risks associated with early specialization.

Few empirical studies have shown evidence that early specialization in sport is required to obtain an elite level, and there is research indicating that early specialization is not a prerequisite of becoming an elite athlete (e.g., Black et al., 2018; Bloom et al., 2021). In addition to the potential for elite attainment that may or may not follow early specialization, there appears to be potential for negative physical and psychosocial consequences associated with early specialization, such as injury (Jayanthi et al., 2020) dropout (Fraser-Thomas et al., 2008) and burnout (Strachan et al., 2009). Organizations/federations feel so strongly about early specialization in youth sport that many have released statements advising against it (e.g., American Orthopaedic Society for Sports Medicine, American Academy of Pediatrics; Brenner et al., 2016; LaPrade et al., 2016). These statements imply significant and serious negative outcomes associated with early specialization.

As an alternative to specialization, practitioners, and sporting organizations have instead advocated for multi-sport participation (i.e., diversification). There is little direct evidence that multiple sport participation is better from a physiological or psychological perspective, however there is some research that indicates it may be beneficial in the long term for athletic performance (Baker et al., 2005; Steinl et al., 2021). There may be an advantage to multi-sport participation in terms of becoming an elite athlete or, at the very least, that multi-sport participation does not hinder the process of elite athlete development (Bloom et al., 2021; Güllich et al., 2022). The little research there is on the topic of diversification does indicate there may be some advantages to multi-sport beyond becoming an elite athlete (DiStefano et al., 2017; Miller et al., 2018).

Evidently, there is a lack of consensus surrounding benefits and risks associated with sport participation patterns, across the field of youth sport as a whole. While many sport and

medical organizations would suggest the debate about specialization is settled, conflicting results are emerging in regards to the negative outcomes associated with specialization (Frome et al., 2019; Meisel et al., 2021; Ross et al., 2021; Watson et al., 2021). This raises questions around the strong condemnation of specialization and support of diversification if results are conflicting.

The following section outlines the findings around sport participation, specific sport participation pathways and potential outcomes. Additionally, it highlights existing gaps in the literature that are addressed in this dissertation.

Literature Review

Sport Participation

The benefits of physical activity have been well established. For example, regular physical activity has been shown to lead to increased cardiovascular fitness, weight management, increased muscular strength, flexibility and reduction in diseases such as type 2 diabetes (Reiner et al., 2013; Warburton et al., 2006). One form of physical activity that is shown to produce benefits beyond physical fitness is sport participation. Due to its unique context, sport is suggested to have psychological and social benefit (Eime et al., 2013). In a large study of adolescents, sport participants had higher social functioning, mental health and more happiness, compared with their non-sport peers (Snyder et al., 2010). Additionally, sport participation has been associated with emotional control, confidence, social well-being, enhanced self-esteem and lower odds of suicidal ideation (Holt et al., 2011; Linver et al., 2009; Taliaferro et al., 2011; Wiersma, 2008). Furthermore, team sport participation has been associated with reduced social anxiety, better emotional self-efficacy, and greater life satisfaction (Dimech et al., 2011; Valois et al., 2004; Valois et al., 2008). It has also been suggested that youth sport can lead to positive

youth development outcomes such as confidence, competence, and connections (Fraser-Thomas et al., 2005). Together, the above studies indicate participating in sport can have many benefits.

Unfortunately, there are also risks associated with sport participation. While the benefits of sport participation are more heavily studied, sport has been linked to some negative outcomes, such as increased alcohol consumption (Kwan et al., 2014). The most recognizable and prevalent risk associated with sport participation is injury. Each year there are approximately 2.6 million emergency room visits in the United States due to sport related injuries (Merkel, 2013). A large study of over 10,000 youth athletes in the United States found that 12.1% had sustained a concussion during their sport season (Tsushima et al., 2019). Moreover, among elite athletes in Canadian high schools, injury was one of the most reported reason for drop out from sport (Butcher et al., 2002). In 2011, it was estimated that each year in the Unites States approximately four million children sustain a sport or recreation related injury (Franklin & Weiss 2012). That number is likely higher today with the increased number of sport participants. Overuse and acute injuries in youth sport have been linked to numerous factors including, athletic identity, puberty, and sport specialization (Caine et al., 2014; McKay et al., 2019). Due to periods of increased growth velocity and slowly elongating muscles, researchers have suggested that puberty leaves young athletes vulnerable to a variety of sports related injuries (Merkle, 2013). Compounded with the increased training load often encouraged during adolescence, sports become a higher risk activity for adolescent athletes. A study on sport participation and injury risk in young athletes found intensity was significantly higher the week prior to an injury compared to the four previous weeks (Malisoux et al., 2013). Additionally, athletic identity has also been found to be a risk factor for injury in athletes. For example, one study found adolescents who have low athletic identity are more likely to be injured than those with high athletic identity (McKay et al., 2013).

Evidently, youth athletes may be in a unique position to experience many benefits of sport participation while also facing increased risk of injury.

Clearly, there are extensive benefits and risks associated with sport participation. With the Canadian Lifestyle and Fitness Research Institute reporting that 77% of youth aged 5-19 participate in some form of organized physical activity or sport (CLFRI, 2016), it is essential that sport be delivered in a manner that best optimizes children and youths' developmental outcomes. As such, researchers have attempted to delineate common sport pathways to map athletes' (optimal) journeys.

Sport Participation Pathways

This section provides an overview of the two most prominent models of sport participation pathways used in the Canadian context, one originating from scientific research and the other from policy makers and administrators working within the sport system.

The Developmental Model of Sport Participation

The Developmental Model of Sport Participation (DSMP; Côté, 1999; Côté & Fraser-Thomas, 2016; Côté & Hay, 2002) suggests athletes follow three common pathways in their sport journeys. The first pathway (i.e., recreational participation through sampling) and the second pathway (i.e., elite participation through sampling), begin with the sampling stage, marked by athletes sampling a number of different sports for the sole purpose of fun and enjoyment. This stage is comprised of mainly deliberate play activities (i.e., that are intrinsically motivating, designed to maximize fun/enjoyment and provide immediate gratification; Côté, 1999; Côté & Hay, 2002); the goal of the sampling stage is to gain basic motor skills and learn the fundamentals of sport. In the first pathway, athletes only ever participate at a recreational level and keep the focus on enjoyment throughout their lifespan. In the second pathway, as the

child ages, they progress into the specializing stage (i.e., roughly at age 13), which is marked by an increase of training in a main sport, accompanied by an increase in deliberate practice (i.e., activities that are not inherently enjoyable, designed for the purpose of improving performance and do not provide instant gratification), decrease in deliberate play, and a decrease in participation of other sports. Around age 16, the athlete enters the investment years which are marked by intense commitment and resources dedicated to one sport, with the probable outcome of attaining an elite level of performance.

The third pathway (i.e., elite performance through early specialization) begins differently. In this pathway, rather than sampling at an early age, athletes begin at the specialization stage from a young age, with training and participation in one sport and engaging in primarily deliberate practice. As one ages, training continues to increase, and more resources are invested with the probable outcome of attaining an elite level of performance. The DMSP (Côté & Fraser-Thomas, 2016) explicitly advocates for multisport participation during early stages of development (Côté et al., 2009).

Long Term Development in Physical Activity and Sport

In Canada, national and provincial sporting organizations align athlete development trajectories with the Long-Term Development in Sport and Physical Activity Model (LTD; Sport for life, 2019). The LTD (Sport for life, 2019) includes eight key stages. The stages most relevant to youth sport participation are focused on building physical literacy and a solid foundation of sport participation. Beginning with an “Active Start”, athletes master basic human movements, object manipulation and balance. By around 6 years of age, children progress to the “FUNdamentals” stage where they develop skills such as agility, coordination and speed, in addition to being introduced to basic rules of sport. From around 8 years old for girls and 9 years

for boys until adolescence, athletes are in the “learn to train” stage, where sport specific skill are taught and participation in competitions begins. Across all three of these stages, multisport engagement is emphasized, along with a focus on enjoyment, on the assumption that this builds the foundations for lifelong sport participation in some capacity. Whether this is in a competitive environment or a fitness-based atmosphere is determined after the first three stages.

Early Specialization

One consistency between both the DMSP (Côté & Fraser-Thomas, 2016) and the LTD (Sport for life, 2019) models, is the emphasis on multisport engagement during early development. This emphasis comes from research denoting the costs and risks associated with early specialization.

Early Specialization and Elite Attainment

There is much debate concerning whether early specialization is advantageous to becoming an elite athlete. Much of the rationale for early specialization in sport has been based on (rightly or wrongly) the deliberate practice framework (Ericsson et al., 1993). Ericsson and colleagues (1993) used data from several empirical studies of musicians to establish the theory of deliberate practice, noting expert musicians spent more time in practice aimed at improving performance than their non-expert counterparts. The authors suggested this specific type of training (i.e., activities that are not inherently enjoyable, designed for the purpose of improving performance and do not provide instant gratification), which they labeled ‘deliberate practice’, was the key difference between experts versus non-experts. Importantly, this framework promotes that in order to become an expert, one must engage in a large quantity of deliberate practice, and the more time spent in deliberate practice, the higher the attained level of performance. Further, the authors suggested that if someone starts deliberate practice at a later

age, they would be at a disadvantage to attaining elite status compared to their peers who began earlier. The extent to which this research is applicable to sports and whether the authors' conclusions directly endorse an approach to early specialization as a requirement to becoming an expert in sport is debateable. However, it is clear some have oversimplified and generalized this idea. Malcom Gladwell (2008), for example, in his mega-bestseller *Outliers*, popularized the theory of deliberate practice, touting the message that 10,000 hours is required to achieve expertise in any domain. Despite the lack of the merit behind this claim, media and sports organizations adopted the idea and promoted the message that the sooner one begins deliberate practice in their sport, the more likely they are to reach an elite level of expertise.

While few empirical studies have shown evidence that early specialization is required to obtain an elite level, anecdotally there are high profile examples of elite/professional athletes who followed this pathway, most notably Tiger Woods who began playing golf at age two. Further, some studies have highlighted associations between early specialization and elite performance, such as a recent study of Division I college athletes (Ahlquist et al., 2020), where researchers found those who were early specializers were more likely to be recruited and more likely to receive a scholarship than later specializing peers. However, there is also much research indicating that early specialization is not a prerequisite of becoming an elite athlete. For instance, in a study of 91 ice hockey players, the mean age of specialization was approximately 14 years of age for professional, NCAA Division I and NCAA Division II players (Black et al., 2018), indicating that athletes at these expert and pre-expert levels followed a later specializing pathway. In a similar study of women national hockey players, Bloom and colleagues (2021) found that the average age of specialization was 16 years old.

The trend of later specialization among high performers is seen not only in ice hockey players, as a study involving baseball and hockey players found that of the 1731 professional athletes surveyed, approximately 58% did not specialize early (Buckley et al., 2017). Similarly, in a study of Olympic and World champion track and field athletes, later specialization was found to be a key factor in their development (Huxley et al., 2017), while in a study of professional baseball players, 52% did not specialize early (Wilhelm et al., 2017). Combined, these studies indicate that while many (e.g., coaches, parents) believe early specialization is a key step in attaining elite status in sport, more current research is indicating those who do not specialize at a young age may be equally likely to attain an elite status. However, it is important to note that these studies are retrospective in nature (i.e., involve current athletes looking back up to 20 years). Because early specialization is a recently growing trend (Feeley et al., 2015), some researchers have suggested that the reason for the lack of early specialization leading to elite attainment is because the majority of athletes previously studied simply were not following this pathway yet, and that there will be an increase in the number of athletes who specialize early at the elite level in future studies (Ferguson & Stern, 2014). This notion has been supported by a recent study that found college graduates from the last decade were more likely to be classified as early specializers than those of previous decades (Rugg et al., 2021), indicating trends may already be changing.

Early Specialization and Negative Outcomes

Notwithstanding the potential for elite attainment that may or may not follow early specialization, there appears to be potential for negative physical and psychosocial consequences associated with early specialization. In a three-year case-control study, Jayanthi and colleagues (2020) found specialized athletes were more likely to be injured or have an overuse injury than

non- or low-specializers. Additionally, a retrospective study of college athletes found those who reported patterns of early specialization were more likely to report a history of injury, multiple college injuries and a greater number of total injuries (Alhquist et al., 2020), indicating potential negative physiological consequences of early specialization. Finally, a meta-analysis noted that athletes with high specialization were at an increased risk of sustaining an overuse injury compared to athletes with low and moderate specialization, and that athletes with moderate specialization were at a higher risk of injury compared to those with low specialization (Bell et al., 2018), suggesting that as one's degree of specialization increases so too does their risk of injury.

Beyond the physical consequences, there have also been connections shown between early specialization and negative psychosocial outcomes. In a study of competitive swimmers, Fraser-Thomas and colleagues (2008) found that patterns of early specialization were related to dropout in young athletes; those who started dry-land training and training camps earlier than their peers were more likely to drop out of swimming. It has also been suggested that early specialization is more likely to lead to burnout. Strachan and colleagues (2009) studied a sample of 74 youth athletes and found that athletes who specialized early were more likely to experience exhaustion (a key component of burnout) than athletes who followed a path of sampling in the early years. Additionally, in a study of ice hockey players, researchers found those who specialized early reported the highest levels of psychological needs dissatisfaction (McFadden, et al., 2016). More recently, highly specialized athletes reported being more exhausted, anxious, and depressed than their moderately specialized peers (Stockbower et al., 2020) raising concerns about the potential negative psychosocial consequences of early specialization. Organizations/federations feel so strongly about early specialization in youth sport that many

have released statements advising against it (e.g., American Orthopaedic Society for Sports Medicine, American Academy of Pediatrics). These positions statements include quotes such as, "Early sports specialization has been identified as damaging for the future physical and mental health of the athlete" (LaPrade et al., 2016, p.6), and "Young athletes who specialize too soon are at risk of physical, emotional, and social problems" (Brenner et al., 2016, p.5). These statements imply significant and serious negative outcomes associated with early specialization.

Early Diversification/Sampling

Early Diversification/Sampling and Elite Attainment

As an alternative to specialization, practitioners, and sporting organizations have instead advocated for multi-sport participation. Within the DMSP (Côté & Fraser-Thomas, 2016), this form of participation is referred to as sampling, however a more commonly used term in the literature is diversification. The exact components of diversification are not consistent, but the main premise is participating in multiple sports with a heavier focus on play and enjoyment rather than practice and performance (Ramsay et al., 2022). There is little direct evidence that multiple sport participation is better from a physiological or psychological perspective, however there is some research that indicates it may be beneficial in the long term for athletic performance. Childhood multi-sport is found to be more common among elite athletes from a variety of sports (Baker et al., 2005, Côté et al., 1999). For example, a study of National Football League players found the majority of first-round draft picks had been multi-sport athletes in youth (Steinl et al., 2021), and a study of national women's hockey players found 3.5 to be the average number of sports they participated in as children (Bloom et al., 2021). Moreover, a recent meta-analysis examining retrospective participation of elite athletes found that the difference between world class athletes compared to national level athletes was the amount of

multi-sport practice they had completed in childhood (Güllich et al., 2022). These studies indicate there may be an advantage to multi-sport participation in terms of becoming an elite athlete or, at the very least, that multi-sport participation does not hinder the process of elite athlete development.

Early Diversification/Sampling and Other Outcomes

As mentioned, there is a lack of research examining diversification specifically and/or directly. Often times, researchers study or review the potential consequences of specialization rather than showing or examining the benefits of diversification (e.g., Goodway & Robinson, 2015). Supporters of diversification suggest multi-sport participation is linked to a longer sporting career, intrinsic motivation, and developing a range of motor and cognitive experiences (Côté et al., 2009); however, the empirical evidence for these claims is not fully substantiated in the research. For example, research from Thomas & Güllich (2019) found intrinsic motivation was not correlated with childhood sport activities in a study of 178 elite youth athletes, and sport play during childhood was not related to self-determined motivation in adolescent soccer players (Hendry et al., 2014).

The little research there is on the topic of diversification does indicate there may be some advantages to multi-sport. Athletes who participated in multiple sports in their youth were found to have higher bone mineral density (Miller et al., 2018) and improved neuromuscular control (DiStefano et al., 2017) than their single-sport peers. Importantly, some have cautioned that multi-sport athletes may be at a greater risk of over-training and subsequent negative outcomes due to overlapping seasons of sports, no time off, and poor training load management (Kutz & Secrest, 2009; Scantlebury et al., 2018). Additional and purposefully designed research to

explicitly study diversification is required to better understand the potential benefits and/or costs of diversification.

The Problem

There is a lack of consensus surrounding benefits and risks associated with diverse sport participation patterns, across the field of youth sport as a whole. Many sport and medical organizations would suggest the debate about specialization is settled, as evidenced by the many statements advising against specialization mentioned previously. However, conflicting results are emerging in regards to the negative outcomes associated with specialization. For example, in contrast to many previous studies, recent research has found specialization to not be associated with overall number of injuries, or greater odds of previous injury (Frome et al., 2019; Ross et al., 2021). Additionally, specialization was shown to not be associated with increased risk of illness, or feeling physically or emotionally exhausted (Meisel et al., 2021; Watson et al., 2021). This raises questions around the strong condemnation of specialization and support of diversification if results are conflicting.

To better answer questions around specialization, researchers need to focus on ‘mechanisms of action’ rather than simply the end results. Moreover, such a change in focus would allow stronger evidence-informed policy. However, key reasons underpinning inability to determine driving mechanisms include (a) inconsistencies in conceptual issues related to early specialization, and (b) a general lack of precision in defining and measuring specialization.

Conceptual Issues

Due to ethics and logistics, study designs are unable to be experimental in nature; one cannot simply assign children to a specialization pathway and control all other factors to see the costs versus benefits of this type of engagement. As a result, the majority of research in this area

is correlational, yet much of the discussion on specialization comes from a cause-and-effect perspective (e.g., specialization leads to injuries, specialization does not lead to elite attainment). These designs make it difficult to conclude specialization is the "bad guy" in this debate; conceivably, diversified athletes become elite because they are more talented at sports in general which explains their participation in multiple sports. Additionally, some other variable (e.g., socioeconomic status affecting access to healthcare resources) may explain the higher rates of injury in specialized athletes. Instead of suggesting broadly that specialization should be avoided, researchers need to focus on understanding why this might be the case. Examining relationships between different facets of specialization and outcomes will help to address these conceptual issues.

Lack of Precision

Definitional precision. Across the literature, there is no clear and/or consistent definition of early specialization making it difficult to definitively conclude *what* early specialization is and *what elements* of it are detrimental. As Ferguson and Stern (2014) stated "there is no standardized definition for early sport specialization, with authors providing their own interpretation…. The lack of a concrete definition has led to confusion over what qualifies as early sport specialization" (p. 377-378). Additionally, Buckley and colleagues (2017) added "in 2017, the topic of single-sport specialization remains poorly defined, with many unanswered questions" (p.1). Conceptual definitions of early specialization vary. Some researchers stress the importance of year-round training (Wiersma, 2000), suggesting that sheer volume of training is the key factor defining early specialization. Other researchers suggest that exclusion of other sports and focus on one sport is the defining factor of early specialization (Buckley et al., 2017). Alternatively, some have suggested that biology is a key factor defining early specialization and

therefore is, when training does not match the physical maturation and development of an athlete (Balyi, 2005). A more comprehensive definition offered by Baker and colleagues (2009) has four components; early start age, early involvement in intense training, early competition, and early involvement in one sport. This definition indicates that there may be several defining characteristics of early specialization. Although it was posited in the DMSP (Côté & Fraser-Thomas, 2016) that type of training was a distinguishing factor between pathways (i.e., sampling consists of more deliberate play while specializing consists of more deliberate practice), current conceptualizations tend to ignore this key facet. It should be noted that a consensus definition of specialization was suggested by a Delphi panel of experts recently which states specialization is "intentional and focused participation in a single sport for a majority of the year that restricts opportunities for engagement in other sports and activities" (Bell et al., 2021, p. 1241), however this definition and the value it adds to the discussion has already been questioned (Güllich et al., 2022) as the operational definitions are lacking and there is not enough empirical data to determine cut-offs for dichotomized criteria.

The term diversification is even less defined, often being suggested as the opposite to specialization, with little detail or few key elements provided (Murata et al., 2021). When a definition is provided for diversification, similar to specialization, there is a lack of consistency. Some researchers suggest multiple sports as a focus (Travassos et al., 2017; Voigt & Hohmann, 2016), making the distinguishing factor the number of sports. Others indicate the type of activity is the key facet, adding *play* in multiple sports (Côté & Fraser-Thomas, 2016). Further, some suggest the leader of the activity should be a distinguishing factor of diversification, with Andrew et al. (2021) defining diversification as "multiple sports through extensive peer-led play in childhood, with little coach-led practice and specialization in a sport occurring later" (p. 1). In

order for research to move forward, there must first be clear and consistent definitions for both specialization and diversification.

Measurement precision. Along with the lack of consistent definitions of terms, the way in which research measures or operationalizes both specialization and diversification vary considerably. For example, Strachan and colleagues (2009) operationalized early specializers as participating for more than 15 hours per week in their main sport from a young age, while Black et al. (2018) labelled early specializers as those who participated in their sport at the exclusion of other sports by age 12. These inconsistent criteria mean that even within the same sport, athletes could be classified into different groups depending on the study they participated in. A study of parents' influence on early specialization measured specialization based on three options: (a) my child focuses on one sport only, (b) my child plays multiple sports but has a favourite, and (c) my child likes the sports he plays equally (Padaki et al., 2017). The relevance of preference (i.e., favorite or likes equally) in terms of measuring components of specialization is unclear and further highlights the lack of precision in measuring concepts.

In the field of sports medicine, Jayanthi and colleagues (2015) have developed and popularized a three-point specialization scale. This self-reported scale ranks athletes as low, moderate or high in terms of specialization, based on three criteria: (a) single sport training, (b) exclusion of other sports, and (c) year-round training (>8 months). An athlete is ranked based on how many of each criterion they meet, (i.e., one is low, two is moderate, and three is high). While this tool has been used relatively consistently to measure specialization, there are concerns about the validity of the scale as it ignores intensity or volume of training. For example, a recreational athlete who participates in a sport once a week for one hour, could be regarded the same as or more specialized than a competitive athlete who participates for 10 hours a week

depending on previous sport history. If one of the key negative properties of early specialization is increased intensive practice, one could argue that this three-point scale does not accurately capture specialization. Additionally, this scale and many other measures do not take age into consideration, a key factor in the definition of 'early specialization'. Without accounting for age, it is difficult to distinguish between early specialization (controversial, potentially harmful) and specialization (required at some point to become an elite athlete).

When looking at measurement of diversification within literature, once again there is even less precision than the measurement of specialization. The number of sports is often how diversification is operationalized (e.g., Bridge & Toms, 2013; DiStefano et al., 2018), with more than one sport being the marker for diversification. Some researchers collect a full developmental history to determine diversification, but in this case, the parameters used to classify athletes as diversifiers is unclear, often defaulting back to number of sports (e.g., Hayman et al., 2011). Researchers often include play as a conceptual marker of diversification, but few studies have measured play, and the ones that have, do not indicate how much play should be the marker of diversification (e.g., Rothwell et al., 2017). Unlike in specialization research, there is no tool designed specifically to measure level of diversification; it is only seen as a dichotomy.

Collectively, these gaps indicate that while practitioners and organizations advise against early specialization, and in favor of diversification, these recommendations are grounded in limited and unreliable evidence, with questionable validity. Moreover, individuals and organizations advocate against early specialization and in favour of diversification without understanding the mechanisms behind what makes early specialization harmful and/or diversification beneficial. For example, if hours spent in training is the most damaging aspect of

early specialization ,could a child participating recreationally in one sport year-round be at *less* risk of harm than a child who participates competitivity in multiple sports for many hours a week? Due to the inconsistencies in conceptual issues related to specialization, and a lack of precision in defining and measuring specialization and diversification, we are unable to answer this and similar questions, or to comprehensively understand driving mechanisms.

Guiding Framework

This dissertation will be guided by the Knowledge to Action (KTA) framework (Graham et al., 2006), specifically the knowledge creation funnel (Figure 1). The original KTA framework is comprised of two key processes: (a) knowledge creation, and (b) action. The action cycle includes activities needed for knowledge application and contains eight phases. While the action cycle will be an important next step following the completion of the dissertation, the objectives of this dissertation align most closely with the phases of the knowledge creation funnel, which will thus serve as the connecting thread between chapters.

Specifically, the knowledge creation funnel encompasses three levels: (a) knowledge inquiry, (b) knowledge synthesis, and (c) knowledge tools/products. The funnel begins at the *knowledge inquiry* level, which consists of first-generation knowledge or, all research studies and information available on the topic. As knowledge progresses down the funnel the knowledge becomes more refined. In the second level, *knowledge synthesis*, one attempts to make sense of the relevant knowledge from level one. This involves the aggregation and amalgamation of knowledge. The final level, *knowledge tools/products*, is the finished creation, generally a tangible solution to the identified problem that presents the knowledge in a clear and concise format. The first level *knowledge inquiry*, will be covered in Chapter Two of the dissertation through our systematic review. The second level, *knowledge synthesis*, will be covered in

Chapter Three and part of Chapter Four, through my attempts to understand the impact of measurement and combine the information to form the rationale for our developed scale. The final level (c) *knowledge tools/products*, is covered in part of Chapter Four and all of Chapter Five, where our developed scale (tool/product) is created and the validity tested.

Purpose, Objectives, and Research Questions

The overarching purpose of this dissertation is to better understand early specialization through two main objectives. The first objective focuses on determining research gaps in the existing literature and is addressed in Chapters Two and Three. The second objective involves developing a higher quality tool for measuring specialization based on the identified gaps, and is covered in Chapters Four and Five. These two broad objectives are achieved by examining four research questions. In Chapter Two, I explore how early specialization has been defined in previous research and discuss the limitations of this work. Chapter Three explores the ways this imprecision in measurement may impact research results. In Chapter Four, I provide the conceptual basis for the creation of a scale that more accurately measures important elements of specialization. Finally, in Chapter Five I begin to explore the validity of this new scale as a way of measuring specialization. The dissertation concludes with a general discussion of this research program, including broad conclusions and suggestions for future work.

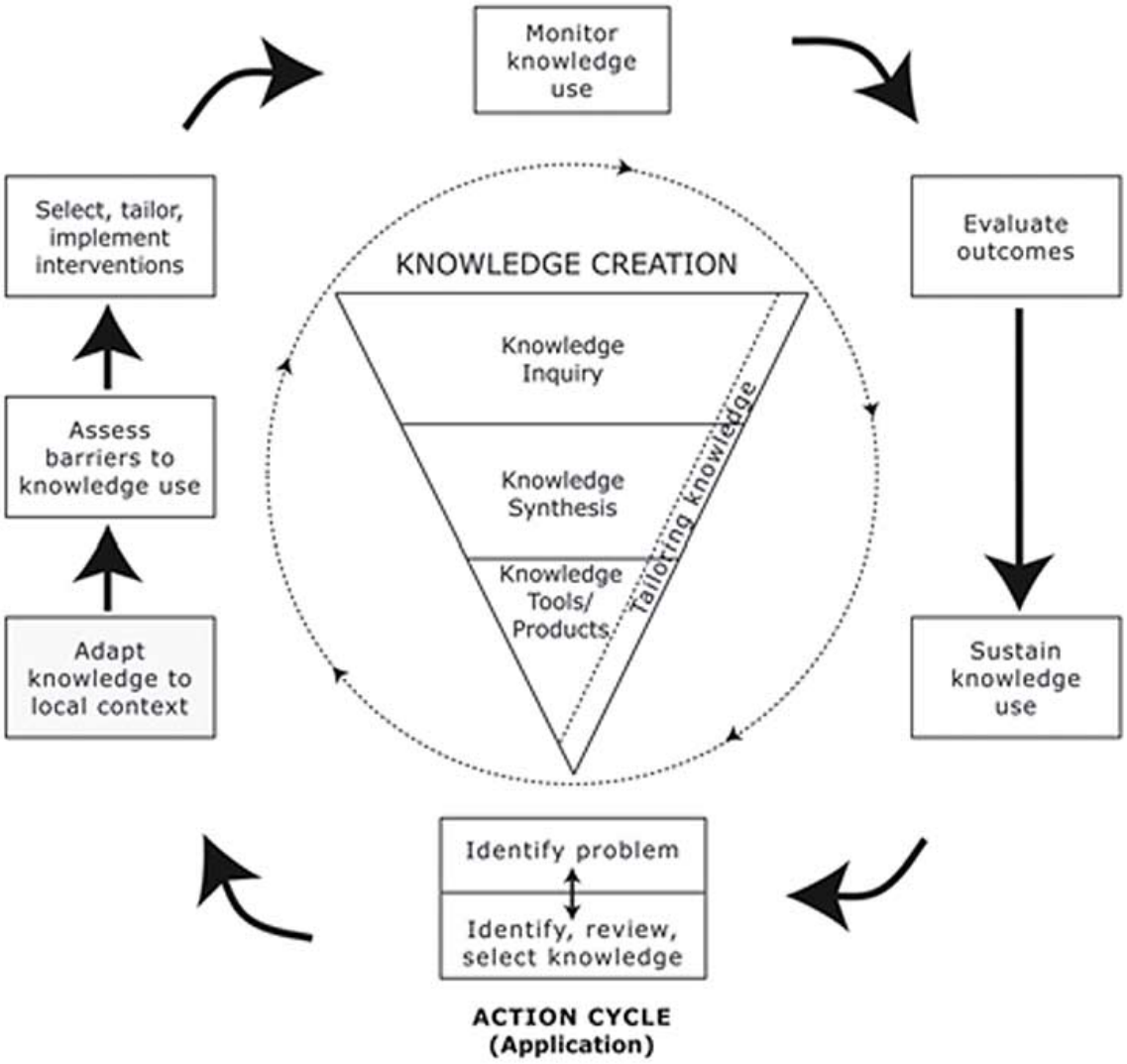

Figure 1. Knowledge to Action Framework (Graham et al., 2006)

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Chapter Two: What defines early specialization: A systematic review of literature

Mosher, A., Fraser-Thomas, J., & Baker, J. (2020). What Defines Early Specialization: A Systematic Review of Literature. *Frontiers in Sports and Active Living*. 2:596229. doi: 10.3389/fspor.2020.596229

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Abstract

Introduction While practitioners and organizations advise against early specialization, the lack of a consistent and clear definition of early specialization reduces the impact of recommendations and policies in youth sport. An important first step in understanding the consequences of early specialization is establishing what early specialization is. *Objectives* This PRISMA-guided systematic review aimed to determine the types, characteristics, and general content of early specialization papers within the literature, and examine how early specialization has been defined and measured in order to advance knowledge towards a clear and consistent definition of early specialization. *Data sources* Four different electronic databases were searched (SPORTDiscus, Web of Science, Sports Medicine and Education Index, and Scopus). Both non data-driven and data-driven studies were included to ensure a comprehensive understanding of the literature. *Eligibility Criteria* In order to be included in the review, the paper must: (a) Focus on specialization and explicitly use the term 'specialization'(b) Focus on sport and athletes (c) Be papers from a peer-reviewed (d) Be in English. And finally, (e) be available in full text. *Results* 1371 articles were screened resulting in 129 articles included in the review after applying inclusion/exclusion criteria. Results indicated a clear discrepancy between key components of early specialization and the approaches used to classify early specializers. *Conclusion* Future research should work towards developing a valid and reliable approach to classifying early specializers and establishing a consistent definition across studies.

Keywords: early specialization, definition, sampler, review, specializer

Introduction

In 2016, the Canadian Lifestyle and Fitness Research Institute reported 77% of youth aged 5-19 participated in organized physical activity or sport. According to the Aspen Institute's Project Play [1] , 38% of children aged 6-12 participated in sport on a regular basis in 2018, based on United States government population statistics [2], equating to approximately 9 million American children participating in sport regularly. Similarly, Australia reported 72.3 % of children under the age of 15 participated in some type of sport related activity in 2019 [3], while in England 86.4% of children ages 5-15 were reported to participate in sport in 2018 [4]. Due to the large number of youths participating in sport globally, researchers have attempted to better understand common sport pathways, and the benefits or consequences of sport participation.

One element of youth sport that has received more attention in recent years is early specialization, originally posited as athletes focusing on one sport that is practiced, trained and competed in year-round [5]. Models of athlete development (e.g., Developmental Model of Sport Participation) [6] suggest early specialization excludes an important period of development where youth should be participating in a range of sports with the purpose of fun and enjoyment, in favour of dedication and skill acquisition in one sport. However, expertise-centred models of skill development (e.g., Deliberate Practice Framework) [7] suggest that individuals who begin focused practice early have an advantage over those who start later. Despite the prominence of the notion of deliberate practice in discussions of coaching and athlete development, a growing body of literature suggests early specialization is not a prerequisite of becoming an elite athlete [8-11]. Further, particular indicators of early specialization have been linked to a host of negative consequences. Researchers have found those who specialize early are at greater risk of injury,

experience increased exhaustion, and are more likely to dropout than athletes who do not [12-14].

Over the past 20 years, at least seven major national and international sport and athletic associations, societies, federations, and organizations have released position statements advising against the practice of early specialization amongst youth athletes (e.g., American Orthopedic Society for Sports Medicine, American Academy of Pediatrics, International Society of Sport Psychology, National Association for Sports and Physical Education). Such strong consensus suggests there is clear and unambiguous evidence that early specialization is harmful and should be avoided in any context; however, further investigation indicates the evidence against early specialization may not be as robust as these position statements make it seem.

To begin, there are very few studies explicitly studying the consequences of early specialization; instead the literature is comprised heavily of review papers, commentaries, and editorials that reiterate previous findings. For example, a 2018 meta-analysis on specialization and overuse musculoskeletal injuries was comprised of only four studies [12], suggesting an overall lack of research. More importantly, there is no standard definition of early specialization. Several researchers have emphasized the lack of a clear and consistent definition and have suggested that this inconsistency makes it unclear what exactly constitutes early specialization [9,15]. Some have defined early specialization as "year round intensive training in a single sport at the exclusion of other sports" [16] while others proposed "the time when the athlete defined one sport as being more important than other sports" [17]. Further complicating conceptualizations, some have suggested it is the type of participation (i.e., deliberate practice) that is a key marker of early specialization [18] while others designate early start age and early involvement in competitive sport as key parameters of early specialization [19]. Without a

consistent definition of early specialization, it is difficult to conclude early specialization is as harmful to youth as many organizations are claiming. More importantly perhaps - the lack of a clear definition of this phenomenon makes improving developmental training environments difficult given it is not clear what element of specialization (e.g., intensity, early start age, over-emphasis on winning) may be driving any negative consequences that do exist.

A recent systematic review of early specialization [20] found that only 13 of 40 studies operationally defined 'specialization'. Among the few studies that provided an operational definition of specialization, the criteria used to distinguish early specializers varied considerably. Given these inconsistent criteria, athletes could be classified into different groups depending on the definitions used, raising concerning questions of reliability and validity of conclusions regarding early specialization. An important next step in determining the relationships between early specialization and developmental and performance outcomes, as well as identifying the mechanisms behind these effects, is to clearly define early specialization. [1]

Practice and research in sport psychology is strongly influenced by policy decisions, and therefore, unlike previous reviews which have examined only data-driven studies [12, 21, 22], this review will also include non-data driven articles. This will provide a more thorough understanding of the current state of literature (not just the state of the research) and overall understanding of the conceptions of 'early specialization' in sport psychology and related fields of study. We believe this variation to the formula of systematic reviews makes this a novel approach to understanding a concept in its entirety.

It is important to note this review did not focus on scientific or measurement-related issues concerning definitions of early specialization (e.g., the implications of a yes/no dichotomy

of specialization versus a continuous measure). The necessary evidence for an empirically substantiated definition of early specialization has yet to be established and while these issues are clearly important in the study of early specialization, they were outside the scope of this review.

The aim of this review was not to come to a conclusion about the potential consequences or benefits of early specialization, as has been done in the past; the goal of this review was to gain a thorough understanding of the entire breadth of literature on the subject. As such, the objectives of this systematic review were : (a) to determine the types, characteristics, and general content of early specialization papers within the literature, and (b) to examine how early specialization has been defined and measured in the sport literature across all fields of study (e.g., biomechanics, psychology, talent development) and populations, in order to advance knowledge towards a clear and consistent definition of early specialization.

Methods

Research Protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [23] was used as a guide for the exploration of literature. There is no protocol registered for this review.

Eligibility

In order to be included in the review, a priori criteria were established; specifically, the paper must: (a) Focus on specialization and explicitly use the term ‘specialization’; this meant that specialization had to be one of the key elements of the paper and not a footnote or added section. (b) Focus on sport and athletes; this ensured the focus was on sport specialization and not any other type of specialization (e.g., as it relates to medical expertise). (c) Be papers from a

peer-reviewed journal rather than exclusively empirical studies; any review, commentary, editorial etc. was eligible for inclusion, in order to capture any and all definitions of early specialization and a more comprehensive picture of the current state of the literature.[2] (d) Be in English. And finally, (e) be available in full text.

Information Sources and Search Strategy

Beginning in June 2019, in consultation with a professional research librarian a rigorous search strategy was created. To identify relevant literature, thoroughly thought out search strings and key words were used within four electronic databases (i.e. SPORTDiscus, Web of Science, Sports Medicine and Education Index, and Scopus). Key words included 'specialize' and 'sport' as well as synonyms such as 'year-round training' or 'single-sport'. For the keyword 'early' synonyms included 'youth', 'child' and 'adolescent'. Various combinations of these key words were used for each of the four databases. In order to ensure studies captured all components, the connector 'AND' was used, and to capture all variations, truncation was used. An example of a search string used in the Scopus database is (specialize* AND early AND sport*). In order to get a thorough understanding of the research into early specialization, papers could be published any time before June 2019, with a final search date of August 2019.

Study Selection

The initial search resulted in 1349 articles. An additional 22 were identified from reference lists of seminal papers, creating a total of 1371. After duplicates were removed, 876 articles were screened. Information from all articles including title, year of publication, authors and abstract was compiled in an excel document for organization purposes. At this stage, the

[2] Book chapters were not included in the review as they do not undergo a rigorous peer-review process and they are not indexed the way journals are, therefore they would not show up in our four databases.

titles and abstracts for all articles were screened based on the above criteria, in order to determine inclusion or exclusion. If the first author was unsure, another author was consulted, and discussion continued until a decision was reached. This screening resulted in the exclusion of 725 articles, with 151 articles for full text review. Of the 151 articles read in-full, two were found to not be in English, 13 were deemed to have not focused on sport specialization, two were conference proceedings, one was not peer-reviewed and four were un-retrievable for a total of 22 studies being excluded in this step, resulting in a final total of 129 studies included in the systematic review. For a complete flow chart, see Figure 1.

Data Collection

The remaining 129 articles were then put into a new spreadsheet for data extraction. The definition used for early specialization and purpose of each study were transferred to this new file to allow for further analysis. To cover the objectives of the review, for empirical studies, additional information regarding methods used, sample size, country of study, age and sex of sample as well as sport studied were extracted from each paper.

Risk of Bias and additional analysis

Given that the objectives of this review were to determine the types, characteristics, and general content of early specialization papers within the literature and to examine how early specialization has been defined and measured in the sport literature (i.e., not to summarize outcomes) a bias assessment was not performed. Additionally, because this was not a meta-analysis, no additional statistical analyses (e.g. meta-regression) were performed on the collected papers.

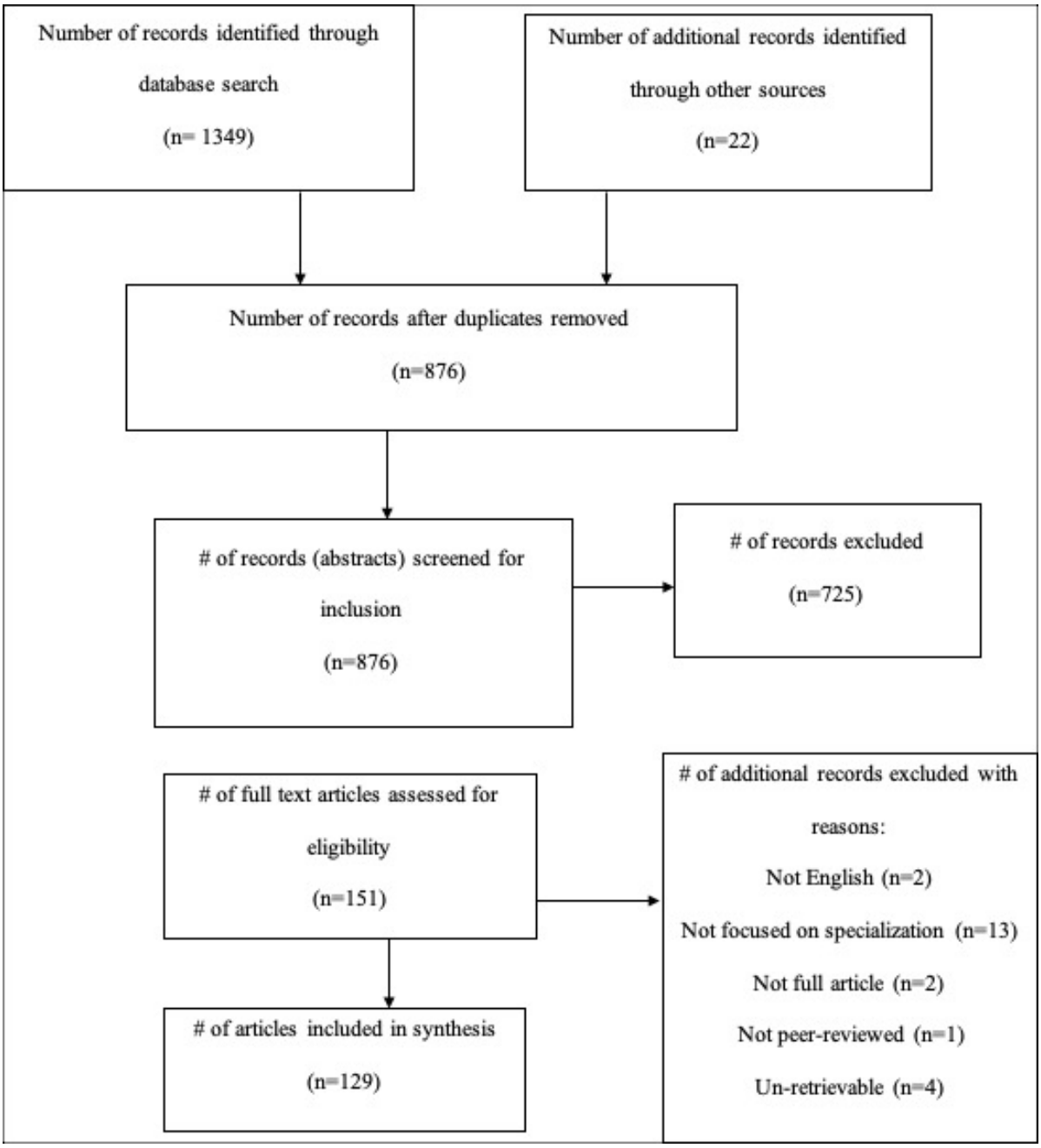

Figure 1. PRISMA flow chart outlining flow of information through the different phases of the systematic review.

Results

Paper Types, Characteristics, and Content

To achieve the first objective of the review, studies were first categorized based on article type (i.e., non-data-driven editorials/commentaries/reviews, systematic reviews/meta analyses,

and data driven studies), to gain a better understanding of the overall composition of the literature. Of the 129 papers included in the study, 43.4% (n=56) were non-data driven papers (i.e., editorials, reviews and commentaries) and 3.8% (n=5) were systematic reviews. The data-driven studies (n=68; 52.7%) were further divided into those that explicitly included specialization in the purpose (i.e., specialization specific; n= 48; 37.2%) and those that did not include specialization in the purpose but met all criteria to be included in the review (i.e., specialization general; n=20; 15.5%).

Table 1 provides an overview of the characteristics of non-data driven papers which included 36 reviews, eight commentaries, seven editorials, and five position/consensus statements. Among this category, the areas of focus were injury, talent development and policy (for full breakdown see Table 1). The five position statements were from five different organizations, which were all either against or relatively neutral towards early specialization, indicating a negatively skewed perception of early specialization.

Table 2 presents the data from the systematic reviews. The number of studies included in each review ranged from 3 - 40. Injury was the main focus of these reviews (n=3) while the remaining two were multidisciplinary in nature.

The characteristics of the data-driven studies are provided in Table 3. Within the 48 studies in the specialization specific category (i.e., explicitly included specialization in the purpose), there were a variety of outcomes studied. Injury studies (n=14) were the most prominent and were often epidemiological examinations of rates or risk of injury in early specializers. Specialization characteristics such as age of specialization or prevalence were also heavily studied (n=10). Talent development studies (n=9) focused on the training activities of elite athletes, often comparing them to their less successful peers. Psychological outcomes (e.g.,

burnout, mental toughness) and physical outcomes (e.g., landing error, anterior y balance performance), were less heavily studied (i.e., n=5 and n=4 respectively). The least studied areas in relation to early specialization were later physical activity (n=3), and skill transfer to other sports (n=1). There were also single studies that considered how specialization affected (a) ability to learn basketball skills in non – basketball players [117], and (b) health related quality of life [108]. The average sample size of studies in this category was 499.7 with a range from 1 to 3090. The studies were comprised of retrospective (n=16), cross-sectional (n=15), case control (n=8), descriptive epidemiological (n=4), longitudinal (n=1), prospective (n=1), case study (n=1), case report (n=1), and a single cohort studies. Studies came from a total of 11 different countries and there was a large variety of individual and team sports examined.

Finally, specialization general studies (i.e., did not explicitly include specialization in the purpose) were largely comprised of talent development studies (n= 16). These studies generally focused on the developmental activities of athletes who became elite or differences between elite and non-elite athletes, which meant that while early specialization was a focus in the article, the actual purpose of the paper was not necessarily to advance understanding of early specialization. The average sample size was 314 with a range from 12-1558. Studies were retrospective (n=17) or cross-sectional (n= 3) with one having a combined longitudinal/retrospective design. Participants were generally either males only or mixed samples of males and females, with only one study examining females only. Lastly, data was collected in nine different countries.

Definitions and Measures

As the second objective of the review was to examine how early specialization has been defined and measured, this section focuses on the conceptual and operational definition of early specialization as well as the approaches used to determine early specializers, across all types of

papers. In their 2019 scoping review, DiSanti and Erickson [20] established that year-round intense training in a single sport at the exclusion of other sports was the most commonly used definition in empirical studies. In line with this review of empirical studies, the four key components of this definition were used as a starting point for our analysis (i.e., year-round, intense training, single sport, and exclusion of other sports). Deliberate practice was also added as a definition component, as the previously mentioned Developmental Model of Sport Participation [6] suggests deliberate practice is also a key indicator of early specialization. Finally, as this review focuses on early specialization definitions were also coded depending on whether they included any information regarding an age threshold.

Definitions were extracted from all 129 articles and coded for each of the six individual components (i.e., year-round, intense training, single sport, exclusion of other sports, deliberate practice, and age threshold) of early specialization, which are presented in Table 4. Just over 20% (i.e., 20.9%, n=27) of the articles included the initial four-component definition of early specialization. The most frequent individual component of early specialization was single sport participation (i.e., 73.6%, n=95), while the least frequent individual component was high amounts/volume of deliberate practice at 9.3% (n= 12). Additionally, 44.2 % (n= 57) included year-round training, 41.9% (n=54) used exclusion of other sports and 31.8 % (n=41) considered intense training to be a key facet of early specialization. A particularly interesting finding was the lack of distinction between early specialization versus sport specialization; only 30.2 % (n=39) of the papers included some mention of early or young age as part of the definition for early specialization. Finally, 17.1% (n=22) of the 129 papers discussed and focused on early specialization yet had no explicit definition of early specialization.

While definitions lay the foundation for understanding components of early specialization, it follows that studies in turn must classify athletes according to these definitions. Further analysis was conducted on the measures used in the 48 data-driven specialization specific studies in order to better understand how researchers classified athletes as early specializers. A key step to measuring early specialization is determining what is meant by early, yet only 25 studies (52.1%) included a measure of age in their screening tool. Of those, 56% (n=14) used 'before the age of 12' as the cut-off for early specialization. To determine specialization status in the empirical studies, 18 different approaches or strategies were employed. It should be noted that while different indicators of early specialization were used, some of the constructs overlap. Fifteen (31.3 %) of the 48 studies used the 'Sport Specialization Scale' by Jayanthi and colleagues [16], 11 (22.9 %) used a single item question (e.g., 'Did you specialize before high school, yes or no?') while 10 (20.8%) collected a full developmental history of the athlete (e.g. hours in each sport, practice history, and number of sports at different ages). For a complete list of the different approaches used, see Table 5.

Discussion

Early specialization is currently a 'hot button' topic in athlete development research in particular and sport science more generally. Our review suggests much of the discussion in this area is driven by non-data driven, commentaries, editorials, and reviews, which undermines the extent to which recommendations about early specialization can be seen as evidence-based. Only 37% of the literature in this review included data-driven studies that were explicitly designed to advance our understanding of early specialization specifically, with 43% of the papers comprised of editorials, commentaries, or reviews. Common rhetoric around this issue assumes early specialization leads to injury, yet only 14 studies have actually examined this relationship with

certain indicators of early specialization and of those only five measured early specialization. Similarly, despite broad recommendations that early specialization increases risk of burnout from sport, only three studies explicitly examined this relationship. Given the findings contained in this review, we believe there is insufficient evidence to provide the foundation for the strong and 'conclusive' position statements around this topic. Importantly, there is also insufficient evidence to conclude there are no risks to early specialization. Despite messages to the contrary, the benefits and risks of early specialization remains an open topic for sport researchers.

The work summarized in this review raises important concerns about the state of the evidence against early specialization and how future research could be improved to resolve outstanding issues. The first issue relates to the conflating of 'early specialization' and 'sport specialization'. Most researchers would agree that the considerable training required to become an elite athlete necessitates eventual specialization at some point [140]. Researchers however advised against the practice of early specialization, suggesting this leads to negative outcomes such as increased injury rates [93] without associated benefits [27]. In the current review, only half of the studies identified measured an aspect of 'early'. This distinction between 'early specialization' and 'specialization' is important. 'Specialization' in a single sport may be associated with injury or other negative outcomes due to the link between specialization and overtraining [15] not the age at which it is occurring. Further, in order to properly study the effects of early specialization, it is important to clearly operationalize 'early'. Of the few studies in this review that measured early only about half used the same criteria (i.e., before age 12).

Another issue relates to the validity of the scales or tools used to determine specialization. The most commonly used scale is Jayanthi and colleagues' [16] Sport Specialization Scale, which uses three criteria (1. single sport training, 2. exclusion of other sports, and 3. year-round

training (>8 months)) to rank athletes as low (having only one of the criteria), moderate (two of three) or high on specialization (all three). Over 30% of the data- driven specialization specific studies in this review used this scale, despite concerns about the validity of this scale [69]. With this scale, for example, a recreational athlete who participates once a week for two hours in basketball, but quit soccer at age seven, would be regarded as more specialized than a competitive basketball player who participates for six hours a week but only ever participated in basketball, despite the fact that most practitioners would be more concerned about the latter. Furthermore, 20% of studies in this review used only a single item to measure specialization, raising further concerns about whether a single item is nuanced enough to adequately capture this multi-faceted concept. As noted in the results, 18 different approaches have been used to determine specialization status often inconsistently categorizing athletes. For instance, one study compared a self-classification method (i.e. are you a single sport or multi-sport athlete) to the 3-point 'Sport Specialization Scale', resulting in only 38% agreement on the athletes' categorization and differing results on the relationships between specialization status and injury history [81].

There were also inconsistencies between the definitions of early specialization and the markers researchers used to measure it. Over half of the studies mentioned 'intense' training in their definition of early specialization yet only three studies included any measure of intensity. These were unique case reports that collected a thorough background on one athlete. This misalignment between definition and method further highlights concerns with validity that mar this area of research.

These issues highlight the precarious foundation of the early specialization evidence base. Ferguson and Stern [15] noted 'All position statements are slightly different, but there is not one

single position statement that supports early specialization' (p. 380) - but it is unclear why researchers have been so quick to conclude against early specialization given the lack of a consistent definition or method of classifying athletes. Also concerning is that researchers are recommending multi-sport participation in lieu of early specialization [39] without understanding the harmful mechanism behind early specialization.

Around 73% of the papers in this review agreed that single-sport participation was a key component of early specialization, yet this component of specialization alone was not found to be associated with injury history [81]. The harmful mechanisms behind early specialization are undoubtedly more complex than just single-sport participation and advocating for multi-sport participation without fully understanding what aspect of early specialization is harmful may be short-sighted.

Future Directions

There are several important next steps for research in this area. First and most important, there needs to be a clear and consistent definition of early specialization that can be utilized across disciplines, organizations and researchers. The field will be unable to understand the potential consequences or benefits of early specialization without first establishing a clear understanding of the components and the requirements of this concept. Although it may be difficult to come to a consensus on a definition for early specialization, a Delphi-type approach (i.e. using experts' answers to questionnaires) could be a useful way to reach convergence. Experts could reflect on which previously used facets of early specialization are essential, which are less important, and which are missing. This could help the field establish a definition of early specialization that most agree with. Second, a valid and reliable scale that captures and categorizes early specializers is needed. Any future scales should include some measure of age in

order to distinguish ‘early specialization’ from ‘sport specialization’. Additionally, researchers may consider adding measures of intensity to the classification of early specializers to separate those who participate more recreationally from those at risk of overtraining. As noted by a previous systematic review [20], 92.5 % of studies used a dichotomy (i.e. specializer or not) to classify athletes. This likely over-simplifies a highly nuanced topic and future research should consider establishing a continuum of early specialization. Finally, there is a need for more research overall on this topic. Suggestions and statements need to be evidence-based and in order for that to happen there needs to be more evidence.

Limitations

While this review provides the first comprehensive look at all papers related to early specialization in sport, it is not without limitations. First the inclusion of non-data driven studies, while important for understanding the composition of the literature, made it impossible to synthesize all papers in the review uniformly. Additionally, the range of approaches used to classify athletes also made it impractical to perform a meta-analysis. Second, the inclusion criteria that studies ‘explicitly use the term “specialization”’ might have eliminated studies that focused on the same area but used other words to describe this pattern of participation. Finally, while the search strategy was created in consultation with a profession research librarian, the search string used could have limited the number of studies found through each of the four search engines (e.g., using the connector ‘AND’ could have excluded studies that did not include all the required search terms but were still relevant to the review).

Conclusion

This review has shown that there are troubling inconsistencies in the definitions of early specialization and the approaches used to classify athletes. Although this review does not directly establish a clear and consistent definition of early specialization, it is an essential first step.

While practitioners and organizations advise against early specialization, this review raises significant questions around the validity and reliability of the evidence underpinning these claims. Once a consistent definition of early specialization is established and researchers have created a valid and reliable measure to capture it, the work to determine negative consequences and benefits of early specialization can begin. Until then research and any recommendations around early specialization should be viewed with caution. To understand the mechanisms behind early specialization and *why* it is potentially harmful or beneficial, the field must first establish *what* early specialization is and *how* best to measure it.

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Table 1. Characteristics of non-data driven papers

Author	Type	Organization	Position	Area
American Academy of pediatrics [24] (2000)	Position Statement	American Academy of pediatrics	Neutral	Physical
Anderson & Mayo [25] (2015)	Review		Neutral	Skill Acquisition
Baker &Robertson-Wilson [26] (2003)	Review		Neutral	Talent and development
Baker et al. [19] (2009)	Review		Neutral	Multidisciplinary
Baker [27] (2003)	Review		Neutral	Talent and development
Bell [28] (2018)	Editorial		Neutral	Physical
Blagrove et al. [29] (2017)	Review		Against	Physical
Bodey et al. [30] (2013)	Review		Neutral	multidisciplinary
Branta [31] (2010)	Review		Neutral	Fundamental motor skills
Brenner [32] (2016)	Position Statement	American Academy of Pediatrics	Against	Physical
BryliNsky [33] (2010)	Review		Neutral	coaching
Callender [34] (2010)	Review		Neutral	Multidisciplinary
Capranica & Millard-Staffo [35] (2011)	Commentary		Neutral	Physiological and talent
Carson et al. [36] (2010)	Editorial		Neutral	Multidisciplinary
Coakley [37] (2010)	Review		Against	Parenting
Cote &Hancock [38] (2016)	Review		Neutral	Policy
Coté et al. [39] (2009)	Review		Against	Psychosocial
Côté et al. [40] (2009)	Position Statement	International Society of Sport Psychology	Against	Development
DiFiori et al. [41] (2017)	Editorial		Against	Talent and sport participation
DiFiori, et al. [42] (2014)	Position Statement	American Medical Society for Sports Medicine	Against	multidisciplinary
Feeley et al. [43] (2016)	Review	American Orthopaedic Society for Sports Medicine	Against	Physical
Geisler [44] (2019)	Editorial		Neutral	Decision to specialize
Gonçalves et al. [45] (2012)	Commentary		Neutral	Talent identification
Goodway & Robinson [46] (2015)	Commentary		Against	Physical growth, motor development
Gould [47] (2010)	Review		Neutral	Psychological
Griffin [48] (2008)	Review		Against	multidisciplinary
Hastie [49] (2015)	Review		Neutral	Pedagogy
Haugaasen & Jordet [50] (2012)	Review		neutral	Soccer talent
Horn [51] (2015)	Review		Neutral	multidisciplinary

Jayanthi & Dugas [52] (2017)	Review		Against	Physical
Kaleth, & Mikesky [53] (2010)	Review		Neutral	Physiological
Landers et al. [54] (2010)	Editorial		Neutral	Multidisciplinary
LaPrade et al. [55] (2016)	Consensus statement	American Orthopedic Society for Sports Medicine	Against	Multidisciplinary
Malina [56] (2010)	Review		Neutral	multidisciplinary
Mattson & Richards [57] (2010)	Review		Neutral	Biomechanical
Matzkin & Garvey [58] (2019)	Review		Against	Physical
Mostafavifar et al. [59] (2013)	Editorial		Against	multidisciplinary
Myer et al. [60] (2015)	Review		Against	Multidisciplinary
Myer et al [61], (2016)	Review		Against	Multidisciplinary
Naspe staff [62] (2006)	Commentary	National Association of Sport and Physical Education	Against	Multidisciplinary
Normand et al. [63] 2017)	Review		Neutral	Physical and psychological development
Pantuosco-Hensch [64] (2006)	Commentary		Neutral	multidisciplinary
Read et al. [65] (2016)	Review		Against	Physical
Reider [66] (2017)	Editorial		Neutral	Multidisciplinary
Sluder et al. [67] (2017)	Review		Neutral	Multidisciplinary
Smith [68] (2015)	Review		Neutral	Historical
Smith et al. [69] 2017)	Review		Neutral	Multidisciplinary
Smucny et al. [70] (2015)	Review		Against	multidisciplinary
Stewart & Shroyer [71] (2015)	Commentary		neutral	Multidisciplinary
Sugimoto et al. [72] (2017)	Review		Against	Physical and Talent
Torres [73] (2015)	Review		neutral	Philosophical
Waldron et al. [74] (2019)	Review		Neutral	Multidisciplinary
Weiss [75] (2015)	Commentary		Neutral	multidisciplinary
Wiersma [76] (2000)	Review		Neutral	multidisciplinary
Williams [77] (2018)	Commentary		Neutral	Physical
Wilson [78] (2006)	Review		Against	Multidisciplinary

Table 2. Characteristics of systematic reviews

Author	Number of studies included	Outcome studied
Bell et al. [12] (2018)	5	Injury
DiSanti & Erickson [20] (2019)	40	Multidisciplinary
Fabricant et al. [21] (2016)	3	Injury
Jayanthi et al. [79] (2013)	Did not specify	Multidisciplinary
Walters et al. [22] (2018)	Did not specify	Injury and development

Table 3. Summary of data-driven study characteristics

Authors	Sex of sample	Age of sample	Sample Size	Country	Sport	Study Design	Outcome(s) studied
Specialization Specific							
Beese et al. [80] (2015)	Female	Highschool	40	USA	soccer	Cross-sectional	landing error
Bell et al. [81] (2016)	Male/Female	13-18	302	USA	Soccer, basketball, tennis, volleyball	Cross-sectional	prevalence in high school
Bell et al. [82] (2018)	Male/Female	high school	354	USA	Volleyball, tennis, basketball, soccer	Cross-sectional	specialization characteristics
Bell et al. [83] (2018)	Male/Female	12 to 18	761	USA	soccer	Cross-sectional	injury
Black et al. [8] (2019)	Male	18-39	91	USA	Ice hockey	Retrospective	age of specialization
Bridge &Toms [84] (2013)	Male/Female	7 to 18	1006	Uk	Athletics, football, hockey, netball, rugby union, swimming, boxing, power lifting	Retrospective	Talent
Brooks et al. [85] (2018)	Male/Female	12 to 18	974	USA	Baseball, basketball, cheer/dance, cross-counrty, football, gymnastics, ice hockey, lacrosse, soccer, softball, swimming, tennis, track, volleyball, wrestling	Cross-sectional	knowledge attitudes and beliefs of specialization
Buckley et al. [9] (2017)	Male/Female	14 -26	3090	USA	Did not specify	Retrospective	rate and age of specialization, the number of months per year of single-sport training, and the athlete's perception of injury related to specialization.
Buhrow et al. [86] (2017)	Male/Female	18-23	102	USA	swimming/diving, golf, basketball, track and field/cross-country, softball, tennis, football, wrestling, soccer	Cross-sectional	mental toughness
DePhillipo et al. [87] (2018)	Male	12	11	USA	alpine skiing	Case Report	injury
DiCesare et al. [88] (2019)	Female	adolescent	79	USA	Basketball, Soccer, volley ball	Case control	lower extremity biomechnical deficits

DiStefano et al., [89] (2018)	Male/Female	8 to 15	355	USA	Soccer, basketball	Cross-sectional	landing technique
Ferguson & Stern [15] (2014)	Male	16	1	Canada	Baseball	Case Study	injury
Ford et al. [90] (2012)	Male/Female	under 16	328	Brazil, England, France, Ghana, Mexico, Portugal Sweden	soccer	Retrospective	Talent
Gallant et al. [91] (2017)	Male/Female	10-11 at start	756	Canada	Did not specify	longitudinal	physical activity and participation patterns
Ginsburg et al. [92] (2014)	Male	18-39	708	USA	Baseball	Retrospective	Talent
Hall et al. [93] (2015)	Female	middle and high school	357	USA	basketball, soccer, volleyball	Retrospective	injury
Hill [5] (1993)	Male	adults	152	USA	baseball	Retrospective	Talent
Jayanthi et al. [16] (2015)	Male/Female	7 to 18	1190	USA	Did not specify	Clinical case control	injury
Jayanthi et al. [94] (2018)	Male/Female	7 to18	1190	USA	Did not specify	Cohort study	injury, SES
Larson et al. [95] (2019)	Male/Female	12 to 13	137	canada	swimming	Retrospective	psych, burnout and dropout
Martin et al. [96] (2017)	Male/Female	college students	1041	USA	Football, track and field, soccer, cross country, swimming, diving, baseball , wrestling, basketball, golf, tennis, rowing, gymnastics, volleyball, field, hockey, softball, figure skating	Retrospective	prior sport experience, importance of specialization and Talent
McDonald et al. [97] (2019)	Did not specify	university/Olympic	143	USA	wrestling	Descriptive epidemiological study	injury
McFadden et al. [98] (2016)	Male	13-18	61	Canada	Ice hockey	Case control	psychological needs satisfaction, mental health
McGuine,et al. [99] (2017)	Male/Female	high school	1544	USA	Baseball/softball, basketball, football, soccer, tennis, track/cross-country, volleyball, wrestling,	Prospective	injury
McLeod et al. [100] (2019)	Male/Female	12 to 18	746	USA	soccer	Cross-sectional	soccer participation and

Mendes et al. [101] (2018)	Male	under 19 under 21	78	brazil	volleyball	Retrospective	specialization characteristics Talent
Miller et al. [102] (2017)	Male/Female	high school	295	USA	Basketball, soccer, volleyball, tennis	Cross sectional	anterior y balance performance, sex
Moseid et al. [17] (2019)	Male/Female	16	259	Norway	Did not specify	Cross-sectional	injury and illness
Noble &Chapman [103] (2018)	Male	adults	519		Marathon	Retrospective	Talent
Padaki et al. [104] (2017)	Male/Female	youth	201	USA	Soccer, basketball, baseball/softball, lacrosse, cross-country/track and field, football, swimming, tennis	Cross-sectional	parental influence
Padaki et al. [105] (2017)	Male/Female	7 to 18	235	USA	Soccer, basketball, baseball/softball, lacrosse, cross-country/track and field, football, hockey, volleyball, swimming, tennis, gymnastics	Descriptive epidemiological study	factors for specializing
Pantuosco-Hensch [106] (2010)	Male/Female	17-23	469	USA	Lacrosse, soccer, swimming, tennis	Retrospective	perceptions of ES
Pasulka et al. [107] (2017)	Male/Female	7 to 18	1190	USA	Soccer, basketball, volleyball, baseball/softball, football, cheer, hockey, lacrosse, badminton, tennis, gymnastics, dance, swimming, wrestling, track &field, cross-countr, martial arts, diving, figure skating, horseback riding, downhill skiing, fencing, golf	Clinical case control	injury
Patel et al. [108] (2018)	Male/Female	8 to 15	50 child 42 parents	USA	Tennis, gymnastics, soccer, basketball, swimming, football, golf, wrestling, track	Case control	health related quality of life
Post et al. [109] (2017)	Male/Female	12 to 18	2011	USA	Soccer, basketball, swimming/diving, ice hockey, volleyball, track/cross-country, lacrosse,	Case control study	injury

					baseball, football, softball, cheer/dance, gymnastics, tennis, wrestling		
Post et al. [110] (2017)	Male/Female	college students	343	USA	Basketball, golf, ice hockey, soccer, tennis, football, softball, wrestling, volleyball	Retrospective	Talent
Post, et al. [111] (2017)	Male/Female	grades 9-12	1544	USA	Gymnastics, ice hockey, lacrosse, soccer, swimming, tennis, track, volleyball, wrestling	Cross Sectional	injury and sex
Rugg et al. [112] (2018)	Male	adults	237	USA	basketball	Descriptive epidemiological study	injury and performance
Russell [113] (2014)	Male/Female	17-22	200	USA	Basketball, softball, soccer, football, baseball, volleyball, tennis, track cheer, gymnastics, dance, swimming, wrestling, badminton, bowling, boxing, hockey, mixed martial arts, tae kwan do	Retrospective	Physical activity and sport motivation
Russell et al. [114] (2013)	Male/Female	18-22	153	USA	Baseball, basketball, cheer, cross-country, football, gymnastics, ice hockey, soccer, softball, swimming, track, volleyball, wrestling, golf	Retrospective	Physical activity and sport motivation
Russell et al. [115] (2018)	Female	High school	77	USA	Soccer Volleyball Tennis	Cross-sectional	motivation and burnout
Santos et al. [116] (2015)	Male/Female	college students	34	Portugal	Basketball, football, rugby	Case control	transfer
Santos et al. [117] (2017)	Male/Female	college students	76	Portugal	Soccer, basketball, volleyball, indoor soccer, handball, rugby, roller hockey, swimming, table tennis, karate, athletics, trampoline, gymnastics, canoeing, kickboxing, tennis, dance,	Cross-sectional	basketball skills

					judo, pentathalon, badminton, equestrian, bodyboarding			
Storm et al. [118] (2012)	Male/Female	18-40	17	Denmark	Swimming, sailing, orienteering, golf, gymnastics, handball, soccer, badminton, kayak, rowing	Retrospective	Talent and culture	
Strachan et al. [14] (2009)	Male/Female	12 to 16	74	canada	Swimming Artistic gymnastics rhythmic gymnastics diving	Case control	sport experiences, personal development, and sport outcomes, namely enjoyment and burnout.	
Swindell et al. [119] (2019)		over 18	303	USA	All NCAA division 1 sport	Cross-sectional	motivation for specializing and age of specializing	
Wilhelm et al. [120] (2017)	Male	22-40	102	USA	baseball	Descriptive epidemiological study	injury and effectiveness	
Specialization General								
Arede et al. [121] (2019)		Both	under 13	68	Portugal	basketball	Retrospective	Talent
Baker et al. [122] (2005)		Male	24-40	28	Canada	triathlete	Retrospective	Talent
Coutinho et al. [123] (2015)		Both	23 or older	60	Portugal	volleyball	Retrospective	Talent
Cupples et al. [124] (2018)		Male	18 to 34	224	Australia	rugby	Retrospective	Talent
Fransen [125] (2012)		Male	6to12	735	Belgium	did not specify	Cross-sectional	Physical fitness, motor coordination
Güllich [126] (2014)		Male	adults	54	Germany	Field hockey	Retrospective	Talent
Güllich [127] (2017)		Both	25-30	166	Germany	All Olympic sports	Retrospective	Talent
Güllich & Emrich [128] (2014)		Both	Olympic athletes	1558	Germany	All Olympic sports	Retrospective /longitudinal	Talent
Güllich & Emrich [129] (2013)		Both	adults	695	Germany	All Olympic sports	Retrospective	Talent
Hendry & Hodges [18] (2018)		Male	15-20	102	UK	soccer	Retrospective	Talent
Leite & Sampaio [130] (2012)		Male	7-35	1170	Portugal	basketball	Retrospective	Talent
Leite et al. [131] (2009)		Male	adults	112	Portugal	roller-hocky, soccer, volleyball, basketball	Retrospective	Talent
Leite et al. [132] (2013)		Male	older than 24	120	Portugal	basketball	Retrospective	Talent
Livingston [133] (2016)		Both	7 to11	59	USA	soccer	Cross-Sectional	Parents perceptions and reasons for participating

Moesch et al. [134] (2013)	Both	adults	185	Denmark	Soccer, handball, ice hockey, volleyball	Retrospective	Talent
Moesch et al. [135] (2011)	Both	adults	243	Denmark	CGS sports	Retrospective	Talent
Sieghartsleitner et al. [136] (2018)	Did not specify	u13 to u18	294	Switzerland	soccer	Retrospective	Talent
Sugimoto et al. [137] (2019)	Female	12 to 18	236	USA	did not specify	Cross-Sectional	injury
Wall & Cote [138] (2007)	Male	13-15	12	Canada	ice hockey	Retrospective	Dropout and investment
Zibung et al. [139] (2013)	Male	adults	159	Switzerland	soccer	Retrospective	Talent

Table 4. Definitions provided for all studies

Authors	Definition provided	Year round	Intense training	Single sport	Exclusion of other sports	Young age	Deliberate practice
American Academy of pediatrics [24] (2000)	none						
Anderson & Mayo [25] (2015)	exclusive participation in a single sport on a year-round basis, with a primary focus on training and development in that sport.	YES		YES	YES	YES	
Arede et al.[121] (2019)	none						
Baker &Robertson-Wilson [26] (2003)	limiting sport participation to a single sport with the specific goal of guiding the child athlete to top achievement			YES		YES	
Baker et al. [122] (2005)	a shift from activities that are play like in nature to more structured and effortful training activities. In addition, the number of sport-specific training hours dramatically increases from initial involvement in the sampling years to committed involvement in the investment years						
Baker et al. [19] (2009)	Four specific parameters: early start age in sport; early involvement in one sport (as opposed to participating in several sports); early involvement in focused, high intensity training; and early involvement in competitive sport.		YES	YES		YES	
Baker [27] (2003)	to limit their childhood sport participation to a single sport, with a deliberate focus on training and development in that sport			YES		YES	
Beese et al. [80] (2015)	year-round participation in a single sport to the exclusion of other sports and activities	YES		YES	YES		
Bell et al. [81] (2016)	year-round intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES		

Bell et al. [12] (2018)	participation in a single sport at the exclusion of other sports			YES	YES	
Bell et al. [82] (2018)	year-round participation in sport at the exclusion of other sports	YES		YES	YES	
Bell et al. [83] (2018)	intense, year-round training in a single sport and may include the exclusion of other sports	YES	YES	YES	YES	
Bell [28] (2018)	none					
Black et al. [8] (2019)	participation in ice hockey at the exclusion of other sports at or before the age of 12 years			YES	YES	YES
Blagrove et al. [29] (2017)	training routines that focus on intensive training in a single sport (for .8 mo/y), or a total weekly training volume which exceeds the athletes' age in years, until late adolescence		YES	YES		
Bodey et al. [30] (2013)	emphasizes focused training in a single sport on a year-round basis.	YES		YES		
Branta [31] (2010)	none					
Brenner [32] (2016)	an athlete focuses on only 1 sport, usually at the exclusion of any other and often year-round	YES		YES	YES	
Bridge &Toms [84] (2013)	continual year-round training and development in a single sport between the ages of 6 and 12 years	YES		YES		YES
Brooks et al. [85] (2018)	specialize in a single sport at the exclusion of other sports			YES	YES	
Brylinsky [33](2010)	none					
Buckley et al. [9] (2017)	intense, year-round [8 months/year] training in a single sport with the exclusion of other sports	YES	YES	YES	YES	
Buhrow et al. [86] (2017)	engaging in year-round training in one regulated, competitive sport at the elimination of all other sports	YES		YES	YES	

Callender [34] (2010)	none						
Capranica & Millard-Stafford [35] (2011)	as the age or point in time in an athlete's development when sports training and competition is restricted to and focused upon a single sport in the pursuit of elite performance			YES			
Carson et al. [36] (2010)	none						
Coakley [37] (2010)	year-round specialization in a single sport	YES		YES			
Côté &Hancock [38] (2016)	none						
Côté et al. [39] (2009)	investing in one sport on a year round basis from a young age with the goal of developing expertise	YES		YES		YES	
Cote et al. [40] (2009)	a high volume of deliberate practice and a low amount of deliberate play in one sport and focuses on performance as early as age six or seven					YES	YES
Coutinho et al. [123] (2015)	an early start age in doing one specific sport and an early investment in deliberate practice (i.e. highly structured and intensive activities, with the explicit goal of improving performance)		YES	YES		YES	YES
Cupples et al. [124] (2018)	single-sport involvement, low deliberate play and progressive investment in deliberate practice with age			YES			YES
DePhillipo, et al. [87] (2018)	intense training year-round in a specific sport starting at a young age	YES	YES	YES		YES	
DiCesare et al. [88] (2019)	a year- or near year-round commitment to one sport at the exclusion of others	YES		YES	YES		
DiFiori et al. [41] (2017)	none						
DiFiori, et al. [42] (2014)	intensive, year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES		
DiSanti & Erickson [20] (2019)	intensive year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES		

DiStefano et al. [89] (2018)	only participate in 1 sport at an early age, with goals of achieving elite athletic success			YES		YES	
Fabricant et al. [21] (2016)	year-round intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES		
Feeley et al. [43] (2016)	intensive, year-round training in a single sport to the exclusion of other sports	YES	YES	YES	YES		
Ferguson & Stern [15] (2014)	intense year round training in a specific sport with the exclusion of other sports at a young age	YES	YES	YES	YES	YES	
Ford et al. [90] (2012)	begin during childhood in relatively high intensity practice and competition in their primary sport. They engage in relatively little play activity in the primary sport and in relatively few or no other sports during this period. It usually also involves identification and selection into a talent development programme in the primary sport during childhood		YES	YES		YES	
Fransen [125] (2012)	enter their primary sport at an early age and participate in a high amount of deliberate practice in their primary sport with almost no deliberate play in any other sports					YES	YES
Gallant et al. [91] (2017)	early sport specializers (ie, high OPA level, low UPA level, and participation in 1 sport only)			YES			
Geisler [44] (2019)	three primary criteria: (1) intensive training or competition in organized sports for more than 8 months per year, (2) participating in one sport to the exclusion of participation in others, and (3) involving prepubertal aged children (prior to 12 years		YES	YES	YES	YES	
Ginsburg et al. [92] (2014)	which necessitates a high volume of deliberate practice in a single sport as early as six or seven years of age and a purposeful focus on			YES		YES	YES

	training and skill development						
Gonçalves et al. [45] (2012)	none						
Goodway & Robinson [46] (2015)	focused involvement in one sport and a large number of hours of deliberate practice with the goal of improving sport skills and performance outcomes during childhood			YES		YES	YES
Gould [47] (2010)	none						
Griffin [48] (2008)	none						
Guellich & Emrich [126] (2014)	Reinforced intensity and expansion of domain-specific practice,		YES				
Guellich [127] (2014)	early concentration in one sport with reinforced sport specific DP/training that is subsequently expanded through all age periods.			YES		YES	YES
Güllich & Emrich [128] (2013)	none						
Güllich [129] (2017)	represent the poles of a continuum differing in exclusivity and intensity of early, sport-specific practice/training, involvement in different sports and non-organised sport activities.		YES	YES	YES		
Hall et al. [93](2015)	with intense year-round training in a single sport at the exclusion of other sports or activities,	YES	YES	YES	YES		
Hastie [49] (2015)	intense, year-round training in a single sport with the exclusion of other sports	YES	YES	YES	YES		
Haugaasen & Jordet [50] (2012)	high amount of deliberate practice, low deliberate play, one sport			YES			YES
Hendry &Hodges [10] (2018)	high volumes of domain specific deliberate practice in one sport from an early age			YES		YES	YES
Hill [5] (1993)	limited their participation to one sport which they practiced trained and competed in year round	YES		YES			
Horn [51] (2015)	none						

Jayanthi et al. [16] (2015)	year-round intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Jayanthi & Dugas [52] (2017)	year-round intense training in a single sport with the exclusion of other sports	YES	YES	YES	YES	
Jayanthi et al. [79] (2013)	intense, year-round training in a single sport with the exclusion of other sports	YES	YES	YES	YES	
Jayanthi et al. [94] (2018)	intensive, year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Kaleth, & Mikesky [53] (2010)	this practice typically involves children (ages 6 to 12) who commit almost exclusively to a single sport, train and compete year-round, and have high internal—and often external—expectations	YES		YES		YES
Landers et al. [54] (2010)	specialization in one sport or in one position in a sport, at increasingly younger ages, in order to compete at the highest levels.			YES		YES
LaPrade et al. [55] (2016)	1. Participation in intensive training and/or competition in organized sports greater than 8 months per year (essentially year round)34 2. Participation in 1 sport to the exclusion of participation in other sports (limited free play overall)33 3. Involving prepubertal (seventh grade or roughly age 12 years) children.	YES	YES	YES	YES	YES
Larson et al. [95] (2019)	(a) involving prepubertal children; who (b) participate in one sport to the exclusion of others, with limited free play overall; and (c) participate in intensive training and/or competition in organized sports for more than 8 months/year		YES	YES	YES	YES
Leite &Sampaio [130] (2012)	involved targeted involvement in a single sport			YES		

Leite et al. [131] (2009)	a shift from activities that are play-like in nature to more structured and effortful training activities. In addition, the number of sport-specific training hours dramatically increases from initial involvement in the sampling years to committed involvement in the investment years						
Leite et al. [132] (2013)	limit their childhood sport participation to a single sport, with a deliberate focus on training and development in that sport			YES			
Livingston [133] (2016)	deliberate practice or training with the purpose of improving skills						YES
Malina [56] (2010)	specialized, systematic training in a single sport at a relatively young age with the goal of attaining elite status			YES		YES	
Martin et al. [96] (2017)	participate in a single sport on a year-round basis, with a focus on training and development in that single sport	YES		YES			
Mattson & Richards [57] (2010)	characterized by participation in specific, intense training for a single sport at a competitive level at an early age		YES	YES		YES	
Matzkin & Garvey [58] (2019)	intensive year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES		
McDonald et al. [97] (2019)	intensive training/competition in organized sports greater than 8 months per year, participation in one sport with the exclusion of all other sports, and involvement of children who are prepubertal or approximately 12 years of age		YES	YES	YES	YES	
McFadden et al. [98] (2016)	specialize in one sport before the age of 12, youth engage in high amounts of deliberate practice in a single sport,			YES		YES	YES

McGuine,et al. [99] (2017)	none						
McLeod et al. [100] (2019)	extensive year-round training in a single sport at the exclusion of others	YES		YES	YES		
Mendes et al. [101] (2018)	Young children may have an early starting age in highly structured and intensive activities with the explicit goal of improving performance in a sport		YES				
Miller et al. [102] (2017)	year-round intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES		
Moesch et al [134], (2013)	early involvement in the main sport, often occurring in early to middle childhood, with very little or no involvement in other sports			YES	YES	YES	
Moesch et al. [135] (2011)	normally occurring in early to middle childhood, with little or no involvement in other sports. Additionally, the importance of a high amount of deliberate practice is stressed during all ages			YES	YES	YES	YES
Moseid, et al. [17] (2019)	the time when the athlete defined one sport as being more important than other sports						
Mostafavifar et al. [59] (2013)	year-round sport-specific training, participation on multiple teams of the same sport and focused participation in a single sport	YES		YES			
Myer et al. [60] (2015)	intensive year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES		
Myer et al. [61] (2016)	including year-round sport-specific training, participation on multiple teams of the same sport, and focused participation in a single sport	YES		YES			
Naspe staff [62] (2006)	none						
Noble &Chapman [103] (2018)	none						

Normand et al. [63] (2017)	intense, year-round training program in a single sport at the exclusion of other activities	YES	YES	YES	YES	
Padaki et al. [104] (2017)	focusing on a sport to the exclusion of other sports and playing and training in the sport more than 8 months per year prior to the age of 12			YES	YES	YES
Padaki et al. [105] (2017)	the combination of playing and training in a single sport for greater than 8 months per year,playing a single sport “to the exclusion of participation in other sports,” and starting this commitment prior to age 12 years			YES	YES	YES
Pantuosco-Hensch [64] (2006)	athletes limiting their participation to one sport which is practiced, trained for and/or competed in on a year round basis	YES		YES		
Pantuosco-Hensch[106] (2010)	athletes limit their athletic participation to one sport which is practiced, trained for, and competed in throughout the year	YES		YES		
Pasulka et al. [107] (2017)	year-long, intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Patel et al. [108] (2018)	intense, year-round training in a single sport with exclusion of other sports	YES	YES	YES	YES	
Post et al. [109] (2017)	year-round intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Post et al. [110] (2017)	year-round participation in a single sport at the exclusion of other sports	YES		YES	YES	
Post, et al. [111] (2017)	year-round, intensive training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Read et al. [65] (2016)	as early age involvement in one chosen sport during the period of early-to middle childhood (up to age 13 years) with no subsequent			YES	YES	YES

Reider [66] (2017)	participation in the other sports or activities available specializing in one sport to the exclusion of all others			YES	YES	
Rugg et al. [112] (2018)	intensive year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Russell [113] (2014)	limited their participation to one sport which they practiced trained and competed in year round	YES		YES		
Russell et al. [114] (2013)	limited their participation to one sport which they practiced trained and competed in year-round	YES		YES		
Russell et al. [115] (2018)	limited their participation to one sport, which was practices for and competed in throughout the year, to the exclusion of other activities	YES		YES	YES	
Santos et al. [116] (2015)	these categories follows the guidelines of the Long-Term Athlete Development model					
Santos et al. [117] (2017)	specialised participation in early childhood, promoting highly structured training as the answer to current competitive demands					YES
Sieghartsleitner et al. [136] (2018)	whether young talents should focus on a single sport specific domain early			YES		YES
Sluder et al. [67] (2017)	an athlete participating in a single main sport on a year-round basis (greater than 8 months per year) and/or quitting all other sports to focus on a single sport	YES		YES	YES	
Smith [68] (2015)	limiting participation to one sport which is practiced, trained for and/or competed in on a year-round basis	YES		YES		
Smith et al. [69] (2017)	None					
Smucny et al. [70] (2015)	intensive, year-round training in a single sport at the exclusion of other sports	YES	YES	YES	YES	
Stewart & Shroyer [71] (2015)	none					

Storm et al. [118] (2012)	none					
Strachan et al. [14] (2009)	investing at least 15 hours per week in their respective sports and involved from a young age.					YES
Sugimoto et al. [137] (2019)	year-around (more than 8 months per year) and quitting other sports in order to focus on one sport	YES		YES	YES	
Sugimoto et al. [72] (2017)	year-round, high-intensity training specialized to a single sport at an early age	YES	YES	YES		YES
Swindell et al. [119] (2019)	year-round training and participation in a single sport at the exclusion of other sports	YES		YES	YES	
Torres [73] (2015)	a practice in which young athletes commit to train and compete almost exclusively in a single sport.			YES		YES
Waldron et al. [74] (2019	high intensity, year-round training in a single sport, with the exclusion of other sports	YES	YES	YES	YES	
Wall & Cote [138] (2007)	intense training in one sport at a young age		YES	YES		YES
Walters et al. [22] (2018)	none					
Weiss [75] (2015)	none					
Wiersma [76] (2000)	year-round training in a single sport at the exclusion of other sport or nonsport activities	YES		YES	YES	
Wilhelm et al. [120] (2017)	intense, year-round training in a single sport with the exclusion of other sports	YES	YES	YES	YES	
Williams [77] (2018)	participation in a single sport and reporting more than 8 months per year training for that sport			YES		
Wilson [78] (2006)	year-round training in a single sport at the exclusion of other activities	YES		YES	YES	

Zibung et al. [139] (2013)	None	YES	YES

Table 5. Measures used to determine early specialization

Authors	Specialization determined by	Young age measured	Age used for young	Measure of intensity
Beese M et al. [80] (2015)	Single vs multi-sport	No	None	no
Bell et al. [81] (2016)	Sport Specialization Scale/ Single vs multi-sport	No	None	no
Bell et al. [82] (2018)	Sport Specialization Scale	No	None	no
Bell et al. [83] (2018)	Sport Specialization Scale	No	None	no
Black et al. [8] (2019)	Full history	Yes	Before 12	no
Bridge &Toms [84] (2013)	Single vs multi-sport	Yes	6-12	no
Brooks et al. [85] (2018)	Sport Specialization Scale	No	None	no
Buckley et al. [9] (2017)	Single Item "Did you quit other sports to focus on one sport?"	No	None	no
Buhrow et al. [86] (2017)	Single item " At what age did you specialize in year-round training in one sport?"	Yes	14	no
DePhillipo et al. [87] (2018)	Case report	Yes	11	yes
DiCesare et al. [88] (2019)	Single vs multi-sport	NO	None	no
DiStefano et al. [89] (2018)	Sport Specialization Scale	Yes	Did not Specify	no
Ferguson & Stern [15] (2014)	Case report	No	None	yes
Ford et al. [90] (2012)	Full history	Yes	6-12	no
Gallant et al. [91] (2017)	Full history	Yes	6-11	no
Ginsburg et al. [92] (2014)	Full History	Yes	Before 12	no
Hall et al. [93] (2015)	Full history	No	None	no
Hill [5] (1993)	Single Item "did you specialize during highschool?"	No	None	no
Jayanthi et al. [15] (2015)	Sport Specialization Scale	Yes	Did not specify	no
Jayanthi et al. [94] (2018)	Sport Specialization Scale	No	None	no
Larson et al. [95] (2019)	Full History	Yes	Before 12	yes
Martin et al. [96] (2017)	Single item "Did you specialize before college?"	Yes	Did not specify	no
McDonald et al. [97] (2019)	Single item "What age did you specialize?"	Yes	Before 12	no
McFadden et al. [98] (2016)	Sport Specialization Scale	Yes	Before 12	no
McGuine,et al. [99] (2017)	Sport specialization Scale	No	None	no
McLeod et al. [100] (2019)	Sport Specialization Scale	No	None	no
Mendes et al. [101] (2018)	Full history	Yes	Before 12	no
Miller et al. [102] (2017)	Sport Specialization Scale	No	None	no
Moseid, et al. [17] (2019)	Single item "At what age did you decide to focus on your sport?"	Yes	Before 12	no
Noble &Chapman [103] (2018)	Did not specify	Yes (sport specific)	19-23	no
Padaki et al. [104] (2017)	3 item importance scale	Yes	Did not specify	no
Padaki et al. [105] (2017)	Self-assignment	No	None	no
Pantuosco-Hensch [106] (2010)	Full history	Yes	Before 12	no
Pasulka et al. [107] (2017)	Sport Specialization Scale	No	None	no
Patel et al. [108] (2018)	Qualitative interview	No	None	no
Post et al. [109] (2017)	Sport Specialization Scale	No	None	no
Post et al. [110] (2017)	Sport Specialization Scale	No	None	no
Post, et al. [111] (2017)	Sport specialization Scale	No	None	no
Rugg et al. [112] (2018)	Single vs multi sport	No	None	no
Russell [113] (2014)	Single item "did you specialize as a youth?"	Yes	Before Adolescence	no
Russell et al. [114] (2013)	Single item "did you specialize as a youth?"	Yes	Before 15	no
Russell et al. [115] (2018)	Single item	No	None	No

	“Are you a specializer or not?”			
Santos et al. [116] (2015)	Full History	Yes	Did not specify	no
Santos et al. [117] (2017)	Full history	Yes	Before 12	no
Storm et al. [118] (2012)	Qualitative Interview	Yes	Before 12	no
Strachan et al. [14] (2009)	Hours per week	No	None	no
Swindell et al. [119] (2019)	Did not specify	Yes	Before 12	Did not specify
Wilhelm et al. [120] (2017)	Single item “Did you specialize before high school, yes or no?”	Yes	Before high school	no

Chapter Three: Proportions of Early Specializers Varies According to Methods and Skill Level

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Abstract

Sport researchers have warned about the lack of a clear and consistent definition of early specialization, while others have raised concerns around the validity of methods used to classify athletes as 'specializers'. The current investigation includes two studies examining the implications of varying classification methods for exploring both specialization and early specialization in sport. Study 1 examined whether different approaches to defining and measuring specialization affected the classification of athletes throughout development and provided a 'profile' of the sample in terms of developmental milestones related to specialization. Results indicated the proportion of athletes classified as specializers varied depending on the method used and athletes generally met specialization milestones after the age of 12. Study 2 examined the proportions of athletes who achieved 'elite', 'pre-elite', and 'non-elite' status in adulthood who were early specializers as determined by different methods. Results showed the method used changed the proportion of athletes classified as specializers at each level and there was no clear advantage or disadvantage to being a specializer. Combined, these studies provide intriguing data regarding the implications of different measures for assessing specialization in young athletes.

Keywords: early specialization; development; milestones; classification

Introduction

Early specialization has been defined many ways, with little consistency between studies[1]. Collectively, however, these studies generally indicate early specialization involves dedicating large amounts of time and effort to one sport from a young age in pursuit of becoming an elite athlete [e.g., 2-5]. Precise determination of 'young age' and 'early' have yet to be established across the field [6]; however, the Developmental Model of Sport Participation (DMSP) suggests 12 years of age or earlier as a critical cut-off point [2].

The number of athletes following the path of early specialization has appeared to have seen an increase in recent years, arguably due to the professionalization of youth sport [7]. While there is much debate about the potential negative outcomes associated with *early* specialization, the need to eventually specialize is strongly supported [8].

Much of the theoretical rationale for early specialization is found in the deliberate practice framework [9]. Ericsson and colleagues used data from musicians as the foundation for the framework, noting that expert musicians spend more time in highly focused, effortful practice aimed at improving performance compared to their lesser skilled peers. The authors suggested engagement in this specific type of training (i.e., activities that are not inherently enjoyable, designed for the purpose of improving performance and not instantly gratifying, which they labeled 'deliberate practice') was the key mechanism explaining differences between those who achieve expertise and those who do not. Essentially, this framework is grounded in the notion that in order to become an expert, one must engage in a large quantity of deliberate practice; the greater the time spent in deliberate practice, the higher the attained level of performance. Importantly for our context, Ericsson and colleagues [9] suggested those who started deliberate practice at a later age (i.e., specialized later) were at a disadvantage compared to their peers who began earlier.

Despite the suggestions that early specialization in sport is increasing, recent studies have found later specialization (described as specialization after the age of 12) to be more common among elite athletes. The average age of specialization was 14 years of age in a study of elite hockey players, with only 12% of athletes specializing before age 12 [10] Similarly, in a study of Olympic track and field athletes, 17 was the average age of specialization [11]. Despite these and other studies providing evidence against the necessity of specializing early, many parents and athletes still believe early specialization is the optimal way to become a top performing athlete. In a large study of 3090 athletes playing at high school, collegiate, and professional levels, 79.7%, 80.6%, and 61.7%, respectively, agreed that specializing in one sport helps an athlete play at a higher level [12]. Additionally, a study of over 900 youth athletes found 91% believed specialization in one sport increased their chances of getting better at their sport and 66% felt it would increase their chances of making a college team [13]. Unfortunately, early specialization is linked to an increased risk of injury and potential for burnout [4, 14], which is why many sport organizations have advised against the practice (e.g., American Academy of Pediatrics) [7]. However, findings regarding early specialization should be interpreted with caution, as multiple authors [e.g.,12, 15-17] have highlighted several methodological shortcomings.

For many years, sport researchers have warned about the lack of a clear and consistent definition of early specialization [12, 15], while others have raised concerns around the validity of current methods used to classify athletes as ‘specializers’ [16, 17]. A recent systematic review by Mosher et al. [1] found inconsistent definitions of early specialization across 48 empirical studies, with 18 different methods used to classify athletes as early specializers. ‘Single sport participation’ was the most common indicator of early specialization with ~73% of the 129 papers included in the review using this marker. Comparing single sport versus multi-sport athletes is one of the more

common ways researchers have used to classify athletes as early specializers [e.g., 18]. Some have used a more comprehensive approach, collecting a complete history of an athlete's sporting background [e.g.,19]while others have used a single yes/no item to determine specialization [e.g., 20]. A popular classification system in sports medicine is the "Sport Specialization Scale" developed by Jayanthi et al.[4], which classifies athletes on a spectrum from low to high specialization based on specialization as "year-round intensive training in a single sport at the exclusion of other sports" (p. 795). This scale, while used in youth populations (ages 7–18), does not include a measure of age and, therefore, does not distinguish between *early* specialization and specialization more generally. This variation in methods used to determine specialization can lead to inconsistent classification of who is a specializer. The scientific value of measuring specialization based on a dichotomized definition using arbitrary nominal variables needs to be evaluated and researchers are advocating for more adequate approaches (e.g., measuring a variety of continuous variables) [21]. However, as it is common practice to define and measure specialization in this way, there is value in examining the implications of different methods.

Importantly, the lack of a consensus definition can change the relationship and severity of outcomes associated with specialization. For example, in a study on the prevalence of specialization and injury history, Bell and colleagues [22] had high school students in the United States complete two different specialization classification tools, including a self-report as a 'single sport' or 'multi-sport' athlete, and the Sport Specialization Scale; both methods have been used in prior research to distinguish specializers from non-specializers. They found little agreement between the classification methods, with only 12% of students being classified as both single-sport and highly specialized and 26% being classified as multi-sport and low specialization. More troubling, the method used to classify athletes affected whether there was an association found

between injury history and specialization. Athletes who self-classified as a single sport participant had no association to injury history, whereas those classified moderate or high specialization were more likely to report a history of injury [22].

The differing outcomes from different classification methods within the same study raise concerns about the reliability and validity of research examining specialization in general and early specialization in particular. While Bell and colleagues' [22] study indicates specialization rates appear to be dependent on the classification method used, their study is only one among a rapidly growing research base focused on both early specialization and specialization more generally, with little consistency in the definition of the construct. Further, Bell and colleagues' [22] study was cross-sectional in design, focused on athletes between the ages of 13 to 18. Given that much of the debate around specialization is concerned with *early* specialization and the dangers of specializing too soon, studies of this phenomenon in athletes before the age of 13 are needed. To this end, this investigation includes two studies, described below, examining the implications of varying classification methods for exploring both specialization and early specialization in sport.

Study 1

Given the recommendations from key organizations and athlete development models to avoid early specialization (e.g., American Academy of Pediatrics; Long Term Development Model) [7, 23] coupled with issues related to approaches for classifying athletes as specializers, greater examination of early specialization measurement in youth (12 years of age and under) samples appears to be warranted. In this first study, we had two objectives. First, we examined how different approaches to defining and measuring specialization affected the classification of athletes throughout development. Based on prior work, our hypothesis was that the method used to determine specialization status would affect the proportion of the overall sample classified as

'specializers'. Our second objective was to provide a 'profile' of the sample in terms of developmental milestones related to specialization. Few, if any, studies have provided individual milestones related to specialization, instead providing only the age at which specialization occurred. Examining the age that each component of specialization was met provides a more comprehensive picture of specialization patterns. Collectively, this study extends our understanding of the age at which youth meet different indicators of specialization and determines if *early* specialization is occurring in this sample.

Study 1 Materials and Methods

Participants

Participants included 362 athletes from one of the largest samples of athletes' developmental histories [24, 25]. In the original study, participants were recruited from all competition levels (e.g., local, regional, national, international) via advertisements on sport organization websites, social media and newsletters, or invitations from their coach. The sample was comprised of 203 females and 159 males with an age range of 14–42 (M = 20.8, *SD* = 4.7) from 10 different countries. The majority of participants were from Australia (*n* = 255) and Canada (*n* = 97). The athletes represented 36 different sports with the most popular being soccer (*n* = 77) and basketball (*n* = 46).

Measures

The indicators used in our studies were chosen mainly on their common use in the literature and not on their inherent value or evidence-based rationale. Data for this project came from a larger study of athlete development conducted in 2010–2011, where participants completed the Developmental History of Athletes Questionnaire (DHAQ) [26, 27]. The DHAQ is a comprehensive instrument that gathers quantitative information on several different areas of an

athlete's history including their main sport practice history, other sport participation, family sporting history, and attainment of sporting milestones. The DHAQ has been previously validated [26] and used in samples with both able-bodied and para-athletes [24, 28] While a number of measures included in the DHAQ were demonstrated to have questionable reliability or validity, the items analyzed for this study were deemed to have sufficient validity and reliability to provide valuable insights to the academic discussion of specialization in sport. A key strength of the DHAQ is that it allows collection and examination of key markers of specialization (outlined below) throughout athletes' development.

Single sport participation. As mentioned, single sport participation is the most commonly used indicator of specialization [1]. Subsequently, many studies have used this single qualifier as a method of classifying athletes as specializers [18, 29]. While the merit of this method is debatable [22], due to its frequency of use, single sport participation was the first method used for comparison in this study. To operationalize this indicator, drawing from the DHAQ variables, we used the number of sports participated in at each age between 5 and 18 years.

Year-round single sport. Another common indicator of specialization in previous work consists of year-round participation in one sport [1, 20], and reflects a two-indicator method focusing on the 'single sport participation' captured in method one, described above, but within a fixed time frame (i.e., over the full year). In the current study, we consider these two indicators together as a method of classifying athletes as specializers. The questions/variables drawn from the DHAQ to operationalize this indicator were: (a) age of first participation in year-round training in main sport and (b) number of other sports participated in at each age (5–18).

Sport Specialization Scale items. While the Sport Specialization Scale [4] was not explicitly used in the DHAQ, the three indicators that comprise the scale can be inferred from the

data collected [26]. Specifically, the Sport Specialization Scale consists of three self-reported questions pertaining to whether an athlete is engaged in: (a) year-round training, (b) exclusion of other sports, and (c) participation in one main sport. The aligning questions/variables drawn from the DHAQ were: (a) age of first participation in year-round training in main sport, (b) age of deliberate exclusion of other sports, and (c) number of sports participated in at each age (5–18). On the Sport Specialization Scale, an athlete responds 'yes' or 'no' to each of the three questions; specialization is then scored as low, moderate, or high (i.e., 'yes' to one, two, or three indicators). While the three similar items of the SSS were used as indicators of early specialization, our analysis was somewhat different from how these data have been typically considered, as described below.

Coding

Information collected from the DHAQ was used to classify athletes as specializers at each age of development based on the three methods described above (i.e., single sport participation, year-round single sport, and the Sport Specialization Scale items). The proportion of athletes meeting the criteria of specialization based on each method at each age from 5 to 18 years was calculated. Unlike Jayanthi and colleagues' [4] scale, which allowed for any one of the three indicators resulting in a score from one to three, this study used specific combinations of indicators (i.e., single sport alone; single sport and year-round training only; and single sport, year-round training, and exclusion of other sports). For a visual explanation of coding see Figure 1.

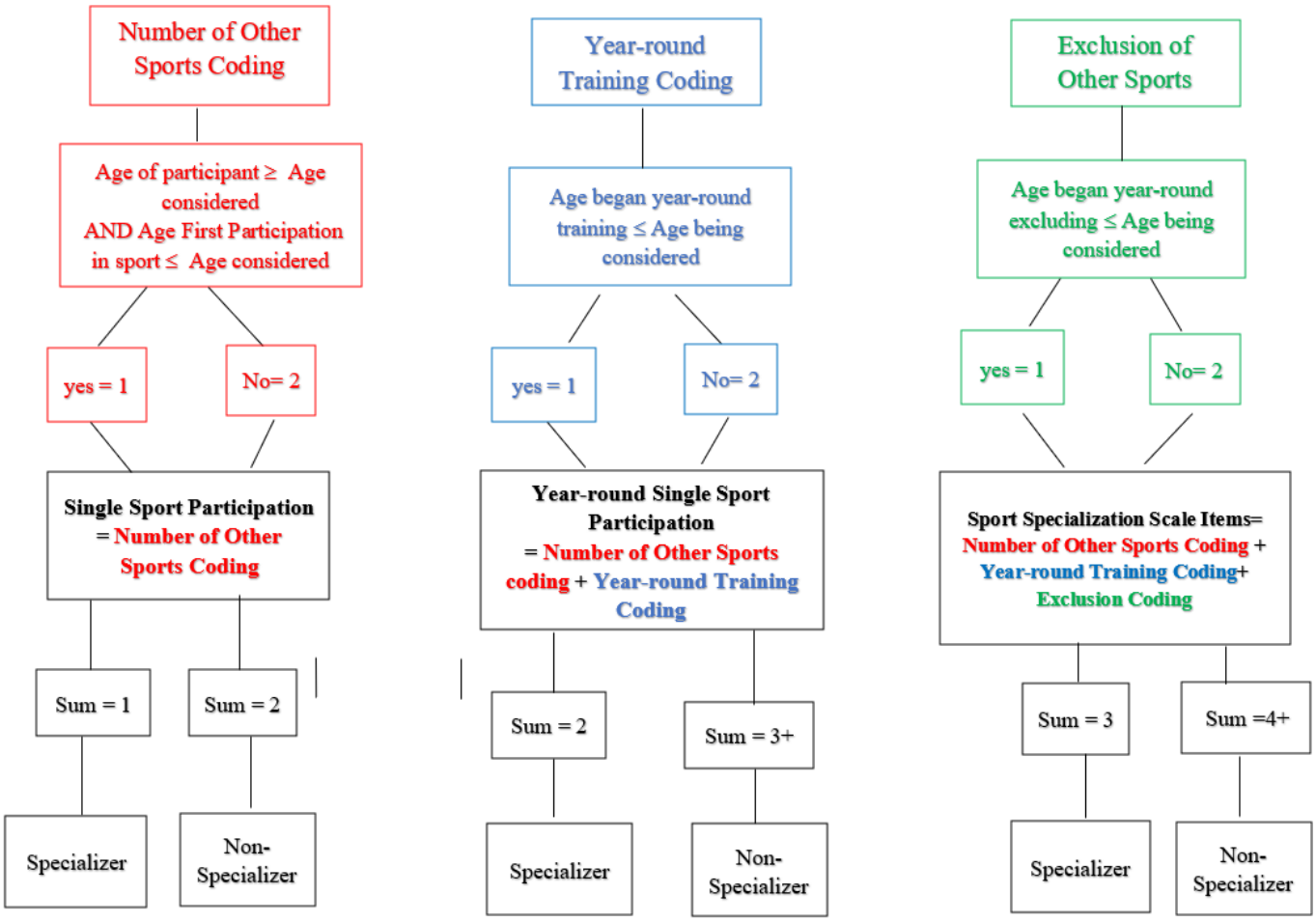


Figure 1. Breakdown of the coding for each variable and each method.

Single sport participation. The number of other sports in which an athlete participated was coded to indicate whether the athlete was a single sport participant and coded as 1 (i.e., response of zero additional sports) or participated in more than one sport (i.e., ≥1) coded as 2 for each age of development. In order to distinguish single-sport participation from data for years that participants had not yet started sport participation, athletes' age of first participation in their main sport was established. If, for example, an athlete did not start participating in any sports until age seven, the zero response for other sport participation at age 5 and age 6 was coded as a 2 rather than a 1. Additionally, in order to distinguish single sport participation from those who could not

fill out information because they were younger than the age of study (i.e., any age under 18), the age of the participant during the study was taken into consideration. This meant if an athlete was 15 years old at the time of the study, for the ages after 15 (16–18) a zero response for other sport participation was marked as 'N/A' rather than single sport participation. At each age of development, an athlete was deemed a specializer if they received a score of 1 on this measure and a non-specializer if they received a score of 2.

Year-round single sport. Year-round participation was coded similarly for each age of development. If the age of first participation in year-round training was equal to or less than the age being considered in the analysis (e.g., if the age of first participation in year-round training was 6 and the age being considered was 6 or higher), the athlete received a coding of 1. If the age of first participation in year-round training was greater than the age being considered for analysis (e.g., if age of first participation in year-round training was 7 and the age being considered in the analysis was 6), the athlete was coded as a 2. The same coding described above was applied to determine single sport participation. The two measures were then summed, and an athlete was deemed an early specializer if they received a total score of 2 (e.g., as it would indicate a coding of one for both criteria); they were classified a non-specializer if they received a score of 3 or 4, indicating they did not meet both criteria.

Sport Specialization Scale items. The same coding of 1 or 2 was applied to age of deliberate exclusion of other sports at each age of development. Similar to year-round participation, if the age of deliberate exclusion of other sports was equal to or less than the age being considered (e.g., if the age being considered in the analysis was 8 and the age of deliberate exclusion of other sports was 8), the athlete received a coding of 1. If the age of deliberate exclusion of other sports was greater than the age being considered (e.g., if age being considered

in the analysis was 8 and age of deliberate exclusion of other sports was 9) the athlete received a coding of 2. Year-round participation and single sport participation were coded as described above. After summing the three measures, an athlete was deemed a specializer if they received a total score of 3 (i.e., a coding of 1 for all three criteria).

Analyses

To address objective one, the proportions of athletes classified as specializers at each age were calculated using each of the methods described above. Objective two involved calculating the averages for the developmental milestones related to specialization. Averages were calculated for age of first participation in main sport, age of first participation in year-round training, and age of exclusion of other sports.

Study 1 Results

Analysis revealed athletes' average age of first participation in their main sport was 9.5 (*SD* = 5.1) years of age, the mean age of first participation in year-round training was 14.4 (*SD* = 3.9) years of age, and the mean age of exclusion of other sports was 15.1 (*SD* = 3.5) years of age. Only 16.3% of athletes began excluding participation in other sports by the age of 12, while 26.2% began year-round training by 12 years of age.

As expected, the number of athletes classified as specializers varied depending on the method used. Across every age, single sport participation resulted in the highest percentage of specializers. There was a large difference (20% or greater) between the proportion of specializers based on single sport participation compared to year-round single sport or the Sport Specialization Scale items between the ages of 5 to 12 (early specialization). By age thirteen (specialization), the differences between groups ranged from 20% to 6% with the greatest degree of convergence occurring at 18 years of age. Between the ages of 5 and 12 (early), the proportion of athletes

classified as early specializers remained low for the Sport Specialization Scale items and year-round single sport ranging from 0% to 12%, while the proportion of specializers based on single sport participation started at a higher percentage (19%) at 5 years of age and continued to increase (to 32%) up to 12 years of age. After age 13, there was an increase in the number of specializers based on year-round single sport and the Sport Specialization Scale items from 30% up to 46%, while the proportion of specializers for single sport participation fluctuated between 46% up to 54%. For a full break down of percentages by classification method, see Table 1.

Table 1. Proportion of athletes classified as early specializers by method.

	Single Sport Participation	**Year-Round Single Sport**	**Sport Specialization Scale items**
Age	% specializers (*n*)	% specializers (*n*)	% specializers (*n*)
Age 5	19.61 (71)	0.28 (1)	0.00(0)
Age 6	23.48 (85)	0.83(3)	0.55(2)
Age 7	25.69 (93)	1.10(4)	0.55(2)
Age 8	29.01(105)	2.21(8)	0.83(3)
Age 9	30.66(111)	4.97(18)	2.49(9)
Age 10	30.66(111)	7.73(28)	3.59(13)
Age 11	31.77(115)	9.39(34)	5.80(21)
Age 12	32.87(119)	12.43(45)	7.73(28)
Age 13	39.78(144)	19.61(71)	13.81(50)
Age 14	45.86(166)	30.11(109)	25.14(91)
Age 15	54.14(196)	40.88(148)	37.57(136)

Age 16	**54.42(197)**	45.58(165)	42.54(154)
Age 17	54.14(196)	**46.13(167)**	**45.30(164)**
Age 18	50.83(184)	44.48(161)	44.20(160)

Peak number of specializers indicated in bold .

Study 1 Discussion

Results from Study 1 highlight several implications for those studying early specialization. First, based on the average age of first participation in year-round training (~14 years), exclusion of other sports (~15 years) and the small percentage of athletes who met these milestones at 12 years of age or earlier, specialization (12 years of age or earlier) does not appear to be overly prevalent in this sample of athletes. This is in line with a study by Swindell et al. [30] that found approximately 17% of athletes had specialized at 12 years of age or earlier. While this is a meaningful minority and each athlete's experience and safety is important, these results suggest either the number of children meeting criteria for early specialization is not as large as the rhetoric would suggest [e.g., 7, 31, 32] or those who specialized early are no longer in the system at the age of this sample of athletes.

Second, our hypothesis suggesting differences in proportions of specializers based on method used was generally well supported, given large discrepancies found; the more indicators used, the lower the proportion of athletes classified as specializers.

At every age, using single sport participation as the sole indicator resulted in the highest number of athletes classified as specializers. Such variation in how early specialization is determined at younger ages [1] raises concerns regarding the methods used to generate the evidence for such strong condemnation of the dangers of early specialization [e.g., 33]The choice of method has clear implications for how study results are positioned in the discourse around early

specialization. At six years of age, for example, less than one percent of athletes were participating in *year-round-training* at the exclusion of other sports, yet approximately 23% were participating in only one sport. Our understanding of the appropriate level of sport engagement for youth participating in sport at this age is very limited. Many children at six years of age may simply be beginning sport participation, and it seems reasonable to attempt one sport at a time, yet these athletes would be classified as specializers according to the method used in many studies. The results from this study indicate that a measure with more indicators may be more suitable to classify athletes—particularly younger child-athletes—as specializers.

That the proportion of athletes categorized as specializers changes so dramatically based on the method used raises questions about the conclusions drawn from the evidence base on early specialization, particularly given the range of definitions reported in this literature [1] For example, how does the method used affect conclusions about the value of early specialization for becoming an elite athlete? We explore this issue in study 2.

Study 2

As a commonly agreed upon principle of early specialization is that it is a pathway often followed in pursuit of becoming an elite athlete [2], it is important to examine the relationship between athletes' sport development pathway (i.e., early specialization), and their attained skill level (i.e., elite). In this second study, we explored whether those who specialized in their youth became elite athletes in adulthood by examining the proportions of specializers (by each method used in Study 1) who achieved 'elite', 'pre-elite', and 'non-elite' status.

Study 2 Materials and Methods

Participants

A sub-sample of athletes from Study 1 was included in Study 2 (n = 237). Because this analysis focused on the highest level of skill attained, participants were limited to those *above* 18 years of age at the time of data collection. This age was chosen based on an assumption that generally, there is still room to improve and increase level of competition at age 16 or younger but by 18, if an athlete has not yet reached elite status, their chances of becoming elite decrease dramatically.

Measures

The same classification methods in Study 1 were used in Study 2 to determine specializers (i.e., single sport participation, year-round single sport, and the Sport Specialization Scale items). For single sport participation, athletes were either specializers meaning they met the single sport criterion (i.e., participated in one sport, sum of 1) or non-specializers (i.e., participated in more than one sport, sum of 2). For year-round single sport, athletes were considered specializers if they met both criteria (i.e., year-round and one sport, sum of 2) and non-specializers if they met one or none of the criteria (i.e., year-round or one sport or neither, sum of 3 or 4). Finally, in order to get a better understanding of the extremes of specialization compared to non-specialization, for the Sport Specialization Scale items, athletes had to meet all three criteria to be a specializer (i.e., year-round and exclusion of other sports and one main sport, sum of 3) but *none* of the criteria to be a non-specializer (as opposed to meeting some but not all criteria, sum of 6). This method provided a greater contrast than combining the remaining athletes (i.e., combining those who met one or two or none of the criteria) would have. Additionally, as there was overlap between all three methods (i.e., all use single sport, two use year-round), we felt much of the information would be provided by the other two methods and, therefore, the extreme comparisons for the Sport Specialization Scale items would be more valuable.

To determine highest level of competition and subsequently which skill group (elite, pre-elite, or non-elite) athletes belonged to, the milestones section of the DHAQ [24] was used. This section determines the age at which each athlete participated in different levels of competition (i.e., local, regional, national, international). Using the Athlete Development Triangle framework [24, 34] athletes were categorized into three groups: (a) '*elite'* athletes had competed at a senior international level, (b) '*pre-elite'* athletes had competed at a junior international or senior national level, and (c) *'non-elite'* athletes were all those who competed in remaining lower levels of competition.

Analyses

We determined the percentage of specializers across ages by each method described above who achieved elite, pre-elite, and non-elite status. The number of athletes (*n*) in each group varied across each age as the number of specializers varied, as described in Study 1.

Study 2 Results

Results indicated differences between the proportions of elite, pre-elite, and non-elite athletes classified as specializers across ages based on the method used. For a complete profile of percentages across the method used, see Table 2 and Figure 2. Across all skill levels, single sport participation resulted in the highest percentage of athletes classified as specializers for each age. The largest differences between percentages classified as specializers based on method used across skill level occurred in the earlier ages (i.e., 5–12), with the difference generally decreasing with age.

Table 2. Percentage of elite, pre-elite, and non-elite classified as specializers by method used.

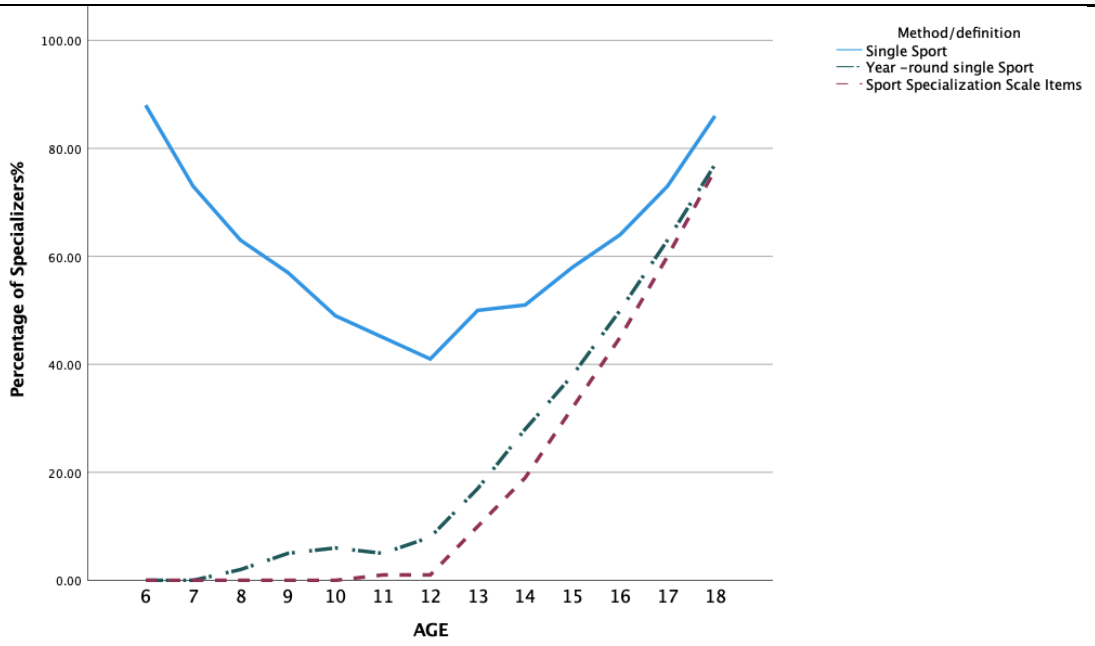
	% Elite (*n*)	% Pre-Elite (*n*)	% Non-Elite (*n*)

Age 5	*n* = 26	*n* = 13	*n* = 7
Single sport participation	88% (23)	77% (10)	71% (5)
Year-round single sport	n/a	n/a	n/a
SSS items	n/a	n/a	n/a
Age 6	*n* = 33	*n* = 17	*n* = 10
Single sport participation	88% (29)	59% (10)	60% (6)
Year-round single sport	0% (0)	0% (0)	20% (2)
SSS	0% (0)	0% (0)	20% (2)
Age 7	*n* = 41	*n* = 23	*n* = 11
Single sport participation	73% (30)	65% (15)	55% (6)
Year-round single sport	0% (0)	4% (1)	18% (2)
SSS items	0% (0)	0% (0)	18% (2)
Age 8	*n* = 52	*n* = 29	*n* = 23
Single sport participation	63% (33)	66% (19)	54% (7)
Year-round single sport	2% (1)	7% (2)	15% (2)
SSS items	0% (0)	3% (1)	15% (2)
Age 9	*n* = 61	*n* = 33	*n* = 15
Single sport participation	57% (35)	64% (21)	53% (8)

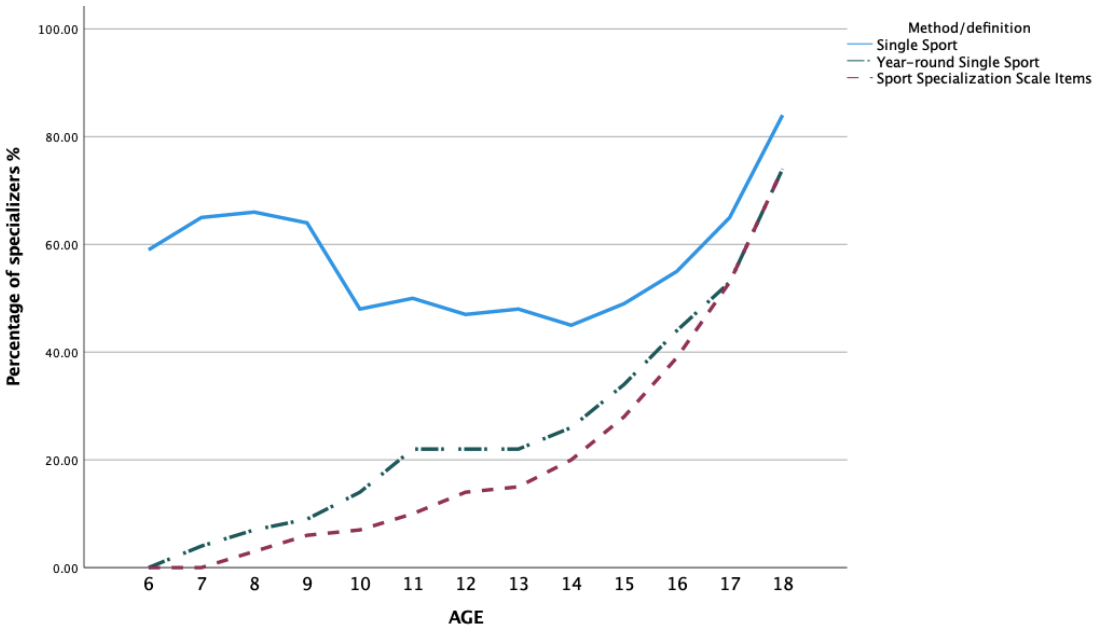
Year-round single sport	5% (3)	9% (3)	20% (3)
SSS items	0% (0)	6% (2)	20% (3)
Age 10	*n* = 71	*n* = 42	*n* = 20
Single sport participation	49% (35)	48% (20)	50% (10)
Year-round one sport	6% (4)	14% (6)	15% (3)
SSS	0% (0)	7% (3)	15% (3)
Age 11	*n* = 77	*n* = 46	*n* = 23
Single sport participation	45% (35)	50% (23)	52% (12)
Year-round single sport	5% (4)	22% (10)	13% (3)
SSS items	1% (1)	10% (5)	13% (3)
Age 12	*n* = 85	*n* = 51	*n* = 27
Single sport participation	41% (35)	47% (24)	48% (13)
Year-round single sport	8% (7)	22% (11)	11% (3)
SSS items	1% (1)	14% (7)	11% (3)
Age 13	*n* = 92	*n* = 58	*n* = 29
Single sport participation	50% (46)	48% (28)	41% (12)
Year-round single sport	17% (16)	22% (13)	10% (3)
SSS items	10% (9)	15% (9)	10% (3)

Age 14	*n* = 102	*n* = 62	*n* = 33
Single sport participation	51% (53)	45% (28)	39% (13)
Year-round single sport	28% (29)	26% (16)	15% (5)
SSS items	19% (20)	20% (13)	15% (5)
Age 15	*n* = 110	*n* = 65	*n* = 33
Single sport participation	58% (64)	49% (32)	36% (12)
Year-round single sport	38% (42)	34% (22)	18% (6)
SSS items	32% (35)	28% (18)	18% (6)
Age 16	*n* = 114	*n* = 67	*n* = 33
Single sport participation	64% (73)	55% (37)	36% (12)
Year-round single sport	50% (58)	44% (30)	21% (7)
SSS items	45% (51)	39% (26)	21% (7)
Age 17	*n* = 116	*n* = 68	*n* = 34
Single sport participation	73% (85)	65% (44)	47% (16)
Year-round single sport	63% (73)	53% (36)	26% (9)
SSS items	60% (70)	53% (36)	26% (9)
Age 18	*n* = 119	*n* = 69	*n* = 34
Single sport participation	86% (102)	84% (58)	70% (24)
Year-round single sport	77% (92)	74% (51)	53% (18)

SSS items	76% (91)	74% (51)	53% (18)



(**A**)



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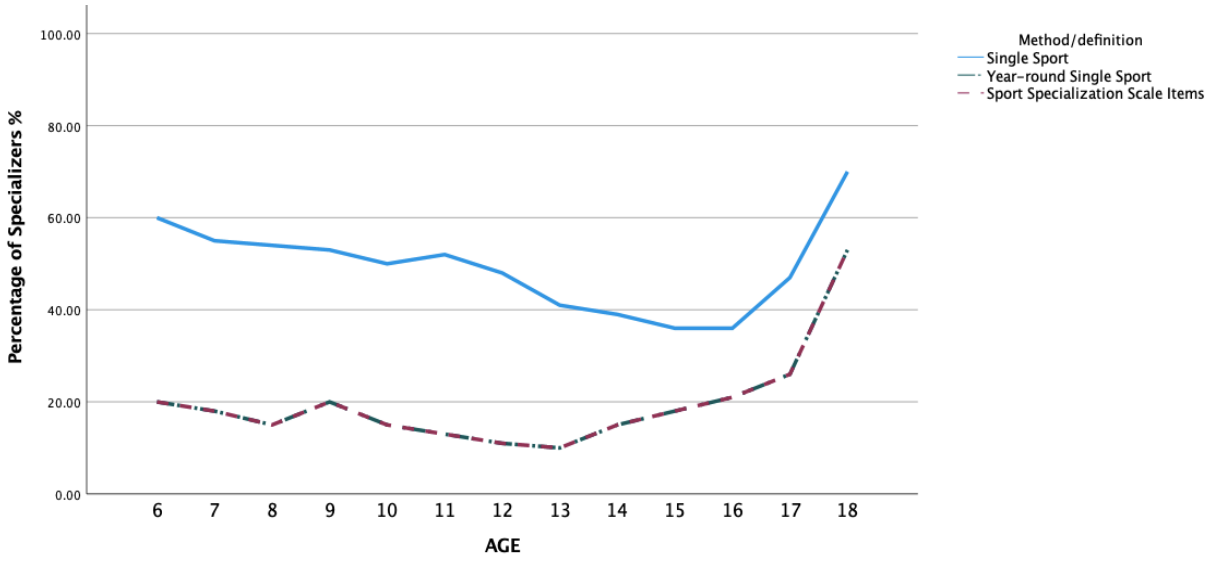

(C)

Figure 2. Percent of **(A)** Elite, **(B)** Pre-Elite, and **(C)** Non-Elite Defined as Specializers by Age and Method. Year-round single sport and the Sport Specialization Scale items have the same percentages and appear as one line .

Using the criterion of single sport participation, at the ages of 5–7, there was a higher percentage of specializers who became elite compared to pre-elite and non-elite, whereas when using both year-round single sport and the Sport Specialization Scale items, between the ages of 6 and 13 there was a higher percentage of specializers who became non-elite and pre-elite compared to elite. By all three methods, there was a higher percentage of athletes who were specializers at 18 who became elite compared to non-elite.

Study 2 Discussion

The assumptions underpinning the need to specialize are that it improves an athlete's performance [13] and helps their chances of playing at a higher level [12]. The results of this study challenge aspects of these assumptions and highlight a range of implications. First, reinforcing the

results from Study 1, there were large discrepancies between the proportion of athletes in each skill group based on the method used to classify athletes as specializers. As mentioned previously, single sport participation is not a nuanced measure of specialization status. However, even when using a more multi-dimensional measure (i.e., the Sport Specialization Scale items), the proportion of elite athletes versus pre-elite or non-elite was low until the age of fifteen. This suggests early specialization (i.e., specializing at 12 years of age or earlier) has limited benefit to performance and long-term elite attainment. This supports previous research by Wilhelm et al. [35] suggesting early sport specialization is *not a* requirement to compete at the most elite levels of sport. However, it is important to also recognize the large number of athletes who did go on to be elite, who had specialized before 18 (as measured by all three methods)—indicating that specialization in later adolescence is a common pathway to elite performance. More specifically, these results suggest specialization prior to 18 years of age may be required to become an elite athlete—but specialization does not need to or should not occur too early (i.e., not prior to 12–15 years). Further research is necessary to determine more precise optimal age(s) of specialization (and potential mitigating factors)—for athletes to reach top skill levels in adulthood.

General Discussion

Collectively, both studies demonstrate that single sport participation (i.e., the most commonly used indicator in prior research) resulted in the greatest proportion of the sample being classified as specializers. The large number of athletes classified as specializers based on the single sport participation method indicates there may be many athletes being classified as specializers who are not 'true' specializers (i.e., investing time and effort in one sport for the purpose of improving performance). There are many reasons a child may be participating in one sport, including parental time constraints, family financial constraints, and/or the child enjoying one sport over others. Simply asking the number of sports in which a child is participating fails to distinguish those who are deliberately choosing to play one sport to improve performance from those who participate in one sport for other reasons. The latter may be less of a concern as the child would likely be at a lower risk of injury associated with specializing for performance. Much of the increased injury risk associated with specialization is often attributed to the volume of training and overuse [36]. A child participating in one sport recreationally would likely not meet the volume of training that would warrant concern. In future work, if researchers choose to use single sport participation as a distinguishing factor it should be used in combination with other variables to ascertain why the athlete only participates in one sport in order to distinguish true specializers (i.e., the explicit decision to specialize to improve performance) from single sport athletes (e.g., those who may not be able to afford multiple sports or participate in low amounts in one sport at a recreational level).

When other variables were considered in addition to single sport participation (e.g., year-round participation), there were few to no athletes at the younger ages (i.e., 5–12 years) meeting the criteria for specialization. Much of the caution around specialization concerns the notion that

specializing too soon is dangerous to the physical health and well-being of the athlete [37]. Collectively, both studies indicate that specialization is not prevalent at younger ages, but rather, is more common beginning in the early adolescent years (i.e., 13–16). Further research should focus on specialization in early adolescence, given similar concerns may arise (e.g., related to physical maturation, psycho-social outcomes) despite specialization being deemed more acceptable at this stage of development.

Our ultimate goal for this series of studies was to examine the varying approaches to measuring specialization in the same group of athletes. The inconsistency of classifications across different methods raises important issues about the validity and reliability of prior work on early specialization. This is particularly important given the value of research synthesis approaches (e.g., systematic reviews, meta-analyses) for generating patterns of evidence to reflect conclusions in a field. Many practitioners advise against specialization for youth athletes, but without a consistent classification method for specializers, the evidence behind these recommendations is unclear.

One important next step could be increasing the accuracy of the measure used to classify athletes by increasing the number of criteria an athlete has to meet. As we note above, there are potentially important elements of specialized engagement that are not captured in current approaches (e.g., reason for specialization). It should be noted, however, that increasing the number of criteria does not guarantee a more accurate measure. A recent study on the Sport Specialization Scale [16], for example, found that 30% of athletes were misclassified as moderately specialized, because they had only ever participated in one sport and, therefore, failed to meet the criteria of exclusion of other sports, when they should have been considered highly specialized. A strong rationale for item inclusion and consideration to the way new items are best measured are necessary when attempting to increase the accuracy of future measures.

A final consideration is the common dichotomizing of specialization. By dividing athletes into one or two groups, researchers may miss important information that could help elucidate the links between specialization and negative outcomes. For instance, some researchers have operationalized specialization as a simple yes or no question, such as “are you a specializer or not?” [20]. This method provides little information about the indicators chosen as key markers of specialization and, thus, makes understanding which aspect(s) of specialization is(are) most harmful or beneficial more difficult. The same issue applies when asking an athlete whether they are a single or multi-sport athlete. While this provides some information about the breadth of their participation, it does little to illuminate areas of potential concern. It would be more valuable to collect information on hours spent in each sport or months spent training to identify where overtraining may occur, rather than a dichotomized single versus multisport variable. While the Sport Specialization Scale [4] aimed to move away from this trend by creating degrees of specialization (low, medium, high), some have questioned the validity of the scale [16, 17] as it does not account for volume of training and does not consider athletes who only ever played one sport. Overall, future research should move away from the simple single sport participation or dichotomous classification of early specialization and move towards a more comprehensive understanding of athletes’ full participation history.

While both studies in this paper have several strengths, it is important to also discuss potential limitations. The data collected was retrospective not prospective in nature and, therefore, only captures the responses from ‘survivors’ in the sport system. This a common issue in athlete development research but it means it is possible those who dropped out from sport may have different participation trajectories that are not captured in this analysis. Moreover, the retrospective design also raises concerns regarding the accuracy of recall by participants, with participants

attempting recall information from as far back as 30 years. Additionally, the specialization status of the sports was not considered; examining sports designed around early specialization (e.g., gymnastics, where peak performance can occur before 18 years for age) as well as later specializing sports (e.g., triathlon) is an important next step to gain more nuanced understanding of specialization. Moreover, our sample contained more elite athletes than pre-elite and non-elite athletes and, therefore, may not be generalizable to the average sporting population. Finally, development is best seen as a continuous process, which makes it hard to set 'cutoffs' for assessing development. We decided that having a cutoff would be more useful for analyses, and relevant for practitioners. Since the age of 18 is often used as an important marker of the transition from adolescent to adult, we felt this was an appropriate age to use as the cutoff in study two.

Despite these limitations, our results suggest important implications of the use of different definitions/measures for specialization in research studies. We are not alone in raising these concerns. Recently, there has been some progress towards a consensus definition of specialization [38] although whether this definition will be widely used remains to be seen [21]. While a consistent definition of specialization would be a positive step forward, this will need to be followed by addressing the methodological concerns highlighted in this study. Until there is a clear and consistent definition and aligning method used to classify specialization, position statements outlining risks should be interpreted with caution. In particular, future research should better measure and distinguish 'early' specialization from 'sport specialization'; this is essential when making specific and age-based recommendations. Despite the number of position statements and the passion of the rhetoric in this area, our understanding of the potential costs and benefits of early specialization is far from complete.

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Chapter Four: Understanding Sport Participation and Athlete Development: The Sport Exposure Scale

Introduction

The benefits of physical activity are well established (e.g., Reiner et al., 2013; Warburton et al., 2006). Sport, a form of physical activity, has been linked with benefits beyond physical fitness. Due to its unique context (e.g., team dynamics, coach-athlete relationships), sport participation is suggested to have a range of psychological and social benefits that go beyond the specific health-related stimuli of physical exercise. Sport participation has been linked to a number of positive outcomes including higher social functioning, more happiness, emotional control and confidence (Holt et al., 2011; Snyder et al., 2010). For a full review of psychological and social benefits of sport participation see Eime et al. (2013).

Despite these many benefits, there are risks associated with sport participation, the most prevalent being injury. Each year in the United States there are approximately 2.6 million emergency room visits due to sport related injuries (Merkel, 2013). Acute and overuse injuries in youth sport have been linked to several factors including puberty, athletic identity, and sport specialization (Caine et al., 2014; Mckay et al., 2019). Researchers have suggested that due to periods of increased growth velocity (i.e., growth spurts) and slowly elongating muscles, puberty leaves young athletes vulnerable to a variety of sports related injuries (Merkle, 2013). These issues are often compounded by increased training load encouraged during adolescents, making sport participation a higher risk activity for adolescent athletes.

Single Versus Multi-Sport Participation

Collectively, the above studies indicate youth athletes may be in a unique position to experience many benefits of sport participation while also facing increased risk of injury. A challenge for practitioners and policy makers is, therefore, promoting the many positive outcomes associated with sport participation (e.g., increased happiness, reduced social anxiety or

greater life satisfaction; Dimech et al., 2011; Snyder et al., 2010; Valois et al., 2004) while reducing the potential for negative outcomes (e.g., injury, dropout or compromised development; Butcher et al., 2002; Caine et al., 2014; McKay et al., 2019). Currently, much discussion focuses on the benefits and costs of different types of sport engagement during childhood and youth (e.g., Goodway et al., 2015; Meyer et al., 2016; Wojtys 2013). For instance, several researchers and organizations (e.g., American Orthopaedic Society for Sports Medicine; Bergeron et al., 2015; International Olympic Committee; LaPrade et al., 2016) have noted concerns with single sport participation - the act of dedicating the majority of one's leisure time, energy and resources into one sport during early sport participation. This type of sport exposure (often termed 'specialization') is linked to negative outcomes such as overuse injury and exhaustion (Jayanthi et al., 2015; Strachan et al., 2009). Usually presented as the superior alternative to specialization, is participation in multiple sports (often deemed 'diversification' or 'sampling'). A recent meta-analysis (Carder et al., 2020), for instance, found a decreased risk of injury for samplers compared to specializers, although this review only included six studies.

While the intention behind the promotion of multi-sport participation appears reasonable (i.e., to prevent the overtraining often occurring with specialization), diversification/sampling does not automatically equate to a lower training load (Hendricks et al., 2019). More specifically, multi-sport exposure could occur at a potentially higher total volume and/or intensity than single sport exposure. Concluding specialization is 'always bad' and diversification is 'always good' is problematic, given there may be situations where this is not the case. As such, more research is needed before practitioners and policy makers advise for or against a particular type of sport participation and/or athlete development pathway (Mosher et al., 2021).

Several practical questions remain, which serve as a foundation for further investigation. For example, if a child enjoys only one sport and has no desire to participate in a different one, is requiring them to play another sport a good thing for their development of intrinsic motivation or feelings of competency? Is determining a way of participating in their one sport in a healthy way a better approach? Due to the dichotomous nature of how specialization and diversification have been considered within the research, these questions of applied relevance and meaning have been left largely unexplored. Additionally, with the growing cost of youth sport (The Aspen Institute, 2019) the 'specialization is bad' narrative may marginalize families that can only afford to put their child into one sport or who have time for only one sport (Baker et al., 2021). Moreover, recent research has highlighted several challenges with participating in more than one competitive organized sport in today's sport structure (Larson et al., 2021). Ultimately, these challenges need to be considered when recommending for or against specialization over multi-sport participation. One of the key issues limiting the advancement of important practical questions and related research questions relates to how specialization and diversification/sampling are understood.

Defining Specialization and Diversification/Sampling

Recently, several research groups (Baker et al., 2021; Kliethermes et al., 2021; Larson et al., 2019; Swindell et al., 2019) have emphasized the inconsistencies in definitions used in defining specialization and diversification/sampling. Typically, the factors used to distinguish specialization from diversification/sampling differ depending on the model used or the researcher's own definition. The Developmental Model of Sport Participation (DMSP; Côté & Fraser-Thomas, 2016), for example, described specialization as engaging in high amounts of deliberate practice in one sport, while sampling is described as engaging in high amounts of

deliberate play in many sports. In this model, the distinguishing factor is not just the number of sports but also the type of activity in which the athletes partake (i.e., practice or play). Other researchers have suggested specialization refers to year-round intensive training in a single sport at the exclusion of other sports (e.g., Jayanti et al., 2015). Additional approaches taken by researchers include: (a) mentioning participation but not specifying the type of activity or training (Post et al., 2017), (b) considering the number of months per year athletes participate in a sport or considering whether participation is 'year round' (Padaki et al., 2017) and/or, (c) vary in whether exclusion of others sports is a necessary marker of specialization (Bell et al., 2018).

In a systematic review aimed at examining how specialization has been defined and measured in previous research, Mosher et al. (2020) found little consistency in the definitions used, concluding there is a need to establish the key markers of early specialization. They argued that at the very least, these variations in definitions make it difficult to discern what qualifies an athlete as a specializer, but also offers additional challenges of differentiating specializers from diversifiers/samplers. In 2021, a group of researchers created a consensus definition of specialization using a Delphi method, concluding specialization was "intentional and focused participation in a single sport for a majority of the year that restricts opportunities for engagement in other sports and activities" (Bell et al., 2021). While this is a comprehensive definition that addresses most of the key markers of specialization, the established evidence-base around specialization (i.e., prior to 2021) did not use this definition and it remains to be seen whether this definition will become widely adopted. Moreover, specialization represents just one element of the spectrum of how youth engage in sport. Posited to be on the opposite end of the spectrum to specialization is diversification/sampling.

The definition of diversification/sampling is equally, if not more, unclear than specialization. Not only is there little consistency between studies as shown in a systematic review by Ramsay et al. (2022), but the distinction between diversifiers and samplers is rarely explicitly made and the terms are often used interchangeably (e.g., Côté et al., 2009). Although the term sampling, based on the definition of a sample - "a representative part or a single item from a larger whole or group" (Merriam-Webster, n.d., Definition 1) - in the sport context could imply smaller amounts of many sports, few if any definitions of sport sampling include this marker. While there is some variation, most researchers use the term sampling to describe involvement in high amounts of deliberate play (i.e., activities that are inherently enjoyable and guided by flexible age-adapted rules) in multiple sports, as the key indicators of this sport participation pattern (e.g., Côté et al., 2007). Diversification, also inconsistently defined, typically refers to (a) participation in different sports (Travassos et al., 2017), (b) practicing, training, or playing in a variety of sports (Buhrow et al., 2017), and/or (c) engaging in a large number of hours in a number of sports (Ford et al., 2008). The key indicator appears to be multi-sport participation with no consistency between type of activity or amount. In addition to limited consistency on the type and amount of sampling/diversification, researchers have not provided details about how and when these multiple sports occur (i.e., sport timing). Few studies indicate whether multiple sports are occurring during the same season or same year - an important distinction when discussing overtraining (Kutz & Secrest, 2009). Because (a) "smaller amounts of many sports" is rarely used as a marker of sampling, (b) the terms sampling and diversification are often used interchangeably, (c) the definitions of diversification (albeit inconsistent) are more closely related to the opposite of specialization, and (d) a recent systematic review found that

diversification was used more commonly in the literature (Ramsay et al., 2022), for the purpose of this paper, we will be using the term diversification rather than sampling.

Measuring Specialization and Diversification

Another potentially more complicated flaw in the literature that makes understanding the mechanisms behind specialization or diversification difficult is the weak measurement precision underlying both constructs. In the study of specialization, 18 different methods have been used to classify specializers (Mosher et al., 2020). The most commonly used method is the three-item specialization scale developed by Jayanthi and colleagues (2015). This scale determines degree of specialization by giving a point for each 'yes' answered for each of the three questions: (a) Can you pick a main sport? (b) Did you quit other sports to focus on a main sport? and (c) Do you train more than 8 months in a year? A score of three (i.e., three "yes" responses) denotes high specialization, a score of two denotes moderate specialization and a score of one or zero indicates low specialization. While the scale is easy for participants to complete and clearly distinguishes athletes into three categories of specialization, there have been concerns raised around the scale's validity (e.g., Pasulka et al., 2017). For instance, in a study of 302 high school athletes, there was no significant association between self-classifying oneself as a specializer, and the three-item specialization scale, with agreement on only 38% of athletes (Bell et al., 2016). Furthermore, a study comparing the proportion of athletes classified as specializers based on different commonly used definitions/methods found that within the same sample of athletes, those classified as specializers changed depending on the method/definition used (Mosher et al., 2022).

Considerations for Moving Forward

Due to the lack of precision found in measures of specialization and diversification, there are substantial gaps in our understanding. First, because there is often *no measure of training volume or competition level*, athletes participating at different levels of intensity and time commitment are indistinguishable from one another. This means that within the research, an athlete playing recreationally for two hours a week could be categorized the same as an athlete on the national team training 14 hours a week. Researchers cannot determine whether overtraining is the driving mechanism behind negative effects of specialization, if we are not collecting information on these variables.

A second issue, related to the issue of training volume and competition level, is that current definitions and measures of specialization *do not distinguish underlying reasons for single sport participation*. Notably, athletes may engage in single sport participation due to a pursuit of elite status, but they may also engage in single sport by volition or due to other constraints (e.g., financial resources or time/availability). Risks association with single sport participation would likely be most concerning to practitioners when tied to the pursuit of elite status given greater potential for overtraining and overuse injuries. As a result, distinguishing the underlying reasons for single sport participation may be important for determining the impact and malleability of these factors on health and development.

Third, current measures may be *misclassifying certain groups of athletes*. For example, because a common definition of specialization includes the 'exclusion of other sports', athletes who only ever played one sport may be misclassified. In a study designed to determine the proportion of athletes misclassified, researchers found, 30% of athletes were misclassified as moderately specialized when they should be considered highly specialized for only ever playing one sport (Miller et al., 2019). Another group that may be missed or misclassified within existing

definitions and measures are “multi-specializers” - athletes who participate in more than one sport but dedicate potentially more time and resources into those multiple sports than many specializers do into one. Simply labeling these athletes as diversifiers/samplers fails to acknowledge the variation that exists within the group while ignoring the potential for negative outcomes that could occur from this type of participation. Evidently, if researchers’ aim is to assist practitioners in understanding which athletes may be at risk for negative outcomes through specialization, there is a need to ensure athletes are classified accurately.

Finally, there is *little understanding of the thresholds of constructs of specialization and/or diversification associated with positive or negative outcomes.* For example, researchers have questioned whether 8 months is an appropriate marker of year-round training, as studies looking specifically at the risk over and under 8 months have not been conducted (Bell et al., 2021). Additionally, there is no evidence indicating the optimal number of sports for positive outcomes. If multi-sport participation is beneficial, it is important to examine whether each additional sport increases athletes’ opportunities for positive outcomes, and what the threshold might be for too many different sports. In 2009, Baker and colleagues provided areas for future research on both specialization and diversification, with one area being a need to determine “what specific parameters of early specialization are harmful” (p. 84). Developing a precise tool that quantifies different variables will be an important first step to answering this question.

There is even less clarity in identifying meaningful constructs of diversification in the literature, as researchers often measure specialization and then simply classify all those not meeting these criteria as diversifiers. As the term implies, diversification should be determined by number of sports rather than other markers; if an athlete plays more than one sport they would be considered a diversifier. However, in line with the issues discussed above regarding

specialization, there is little information collected on amount or type of activity that diversifiers engage in, and there is no "diversification scale". The assumption that those who do not meet the arbitrary and inconsistent criteria of specialization are automatically diversifiers promotes an incomplete understanding of the breadth of sport participation, making it difficult to identify underlying mechanisms of positive and negative effects from both specialization and diversification.

In sum, the most common markers of specialization and by default diversification can be broken down into three categories: (a) number of sports (i.e., single or multiple), (b) amount of training (i.e., more than 8 months versus less than 8 months), and (c) type of activity (i.e., intense training versus deliberate play). At least two of these categories (i.e., number of sports, amount of training) should be measured as continuous variables and yet they are typically operationalized as dichotomous (i.e., yes/no). It is likely these dichotomous variables simplify more complex, possibly non-linear relationships between sport participation and potential outcomes. The issue of dichotomising and/or oversimplifying variables is not unique to the field of sport specialization research. As other sport researchers (e.g., Wattie et al., 2018) have suggested, if we want to understand the mechanisms that facilitate or impede athlete development, we need to avoid grouping athletes unless absolutely necessary.

Issues with defining and measuring specialization and diversification, and the limited understanding of the underlying mechanisms of positive and negative effects of different forms of participation on health, development and performance can be improved by creating a scale that measures markers of both specialization and diversification. The following sections provide a rationale and description for the "Sport Exposure Scale" (SES). The SES will provide a

uniform method for measuring sport exposure that can then be used to better investigate potential benefits or negative outcomes associated with different types and amounts of sport participation.

Conceptualizing and Creating the Sport Exposure Scale (SES)

In order to understand the relationship between different forms of sport participation (e.g., specialization, diversification) and positive and negative outcomes, there is a need for an instrument that measures these forms of sport participation, while addressing the gaps outlined above. The following section explains the conceptualization and operationalization of the Sport Exposure Scale (SES). For a schematic of the process that went into the creation of the scale, see Figure 1.

Based on prior work in the areas of athlete development, particularly related to the potential risks of early specialization and benefits of diversified forms of training, the fundamental assumption of this scale is that the quality and quantity of sport participation influence health, development and performance outcomes. Furthermore, due to the lack of precision in how issues related to sport participation have been considered in prior work on athlete development (Coutinho et al., 2016; Mosher et al., 2021; Smith et al., 2017), a key objective was to increase the clarity and precision of *how* participation is measured in sport settings. To this end, we considered approaches from various sub-domains of sport science to explore the various ways participation has been considered. For instance, approaches from health and injury epidemiology were considered since this research generally emphasizes: (a) clarity and ease of data collection, and (b) large, representative samples - two criticisms of prior work in this area (Wild, 2009). Similarly, approaches from exercise physiology were explored because of the long history of quantifying load in this field (e.g., for periodization of training, Turner, 2011)

Epidemiology considers the relationship between causal or predictive variables as risk factors, generally as they relate to 'exposure' (White et al., 2008). Given the types of outcomes at the forefront of discussions of athlete development (i.e., risks or costs of different forms of participation), positioning the relationships between variables from the perspective of 'risk' seems useful. Measuring exposure first involves determining the active agent (i.e., the component that causes the outcome). In the case of sport participation and particular outcomes related to specialization/diversification (e.g., burnout or injury), this is complicated to determine as there is no particular 'element' associated with sport participation and outcomes the same way that there would be within a medication, for example (i.e., there is no active 'agent'). However, given prior discussions and research in this and related areas, this scale is grounded in the assumption the most likely mechanism is related to *load*.

Examining and Measuring Sport Participation Load

Much of the research on load management assumes load is the driving factor in injury or improved athletic performance (Gabbett et al., 2016), inadvertently positioning it as the active agent in sport participation. Load management is a key factor in injury prevention (Bourdon et al., 2017) as well as for maximizing training-based adaptations (Baker et al., 2005; Hughes et al., 2018). Monitoring training load can be done broadly by measuring facets of training intensity, frequency, and duration (e.g., Gabbett et al., 2004; Gabbett et al., 2016). However, load has not been looked at across sports or from the perspective of overall exposure, mainly because most studies have focused on load management in samples of elite athletes who participate in one sport and have highly regimented training programs.

Although exposure to an active agent can be measured as a binary (i.e., Did exposure occur? yes/no), for more complex relationships, it is important to have precise measures of the

exposure dose. As discussed above, one of the biggest gaps in our understanding of specialization and diversification comes from positioning these variables as opposites of one another, rather than exploring them as separate, continuous variables - each with important nuances. Risks associated with specialization, for instance, may be related to more than single sport participation; it is important to know how much of a single sport an athlete is engaging in (i.e., load would reflect the *quantity of engagement*). An imbalance in the way different types of engagement or load are managed may be the mechanism driving negative outcomes (e.g., the quantity of engagement is not balanced with the time required for recovery from this engagement); however, current measures do not collect enough information to adequately determine training load.

Similarly, diversification is generally measured via number of sports; however, more information is needed to fully understand the mechanisms underlying participation in these sports. For instance, it would be important to understand whether (a) over-lapping sport seasons (i.e., engaging in three sports simultaneously) in a non-specialized athlete is better for health, development and performance than engaging in only one sport, (b) there is a linear relationship between number of sports and risk/reward (e.g., Does the potential for negative or positive effects increase with each additional sport?), and perhaps most importantly, (c) there is a threshold of overall engagement after which the risk of negative outcomes increases. Adding nuance to the way we measure sport participation will allow researchers to answer these and other questions.

In sport generally, and athlete development contexts in particular, exposure dose can be complicated. For instance, the appropriate dose to promote or inhibit a specific outcome will undoubtedly vary based on a range of factors that may change across development (e.g., what

dose is appropriate for a developing athlete and how is this affected by prior training history?). In order to capture this complexity, exposure can be captured in different ways, including cumulative dose, average dose, and dose rate. While each of these variables is calculated in a different way, and may vary in their potential value to researchers, creating these variables for sport participation generally involves elements of duration, frequency and intensity of different forms of participation.

Duration (i.e., the length of time the exposure lasts) can often carry more weight than other measures of exposure as it appears to be most closely related to the likelihood of a negative outcome (White et al., 2008). For example, an athlete participating for five years may be at an increased risk of injury compared to an athlete who has participated one year due to prolonged exposure. Frequency involves the number of occurrences of an exposure episode (White et al., 2008). In sport settings, this involves collecting information on how often an athlete engages in the activity/training. Finally, intensity reflects the dose of the active agent per episode, and in our context, will be important for distinguishing the *magnitude* of the training load. Determining these magnitudes may become important if increased risk only occurs above a certain level of intensity. The measure, however, is difficult to determine in sport as it will undoubtedly vary between, individuals, sports, and types of training activities among other variables.

Current Versus Historical Training Load

Athlete development in general, and sport training in particular, is grounded in principles of long-term adaptation to training stress (Cunanan et al., 2018). From this perspective, it was important to collect information not only on current sport exposure (e.g., in the last seven days) but on past sport exposure, to the extent this is possible. Sport participation does not occur in a vacuum and an athlete's capacity to manage levels of current exposure is influenced by patterns

of previous exposure. For this reason, this scale collects both retrospective/historical information as well as current data. Load management research has also stressed the importance of understanding both chronic (i.e., historical) and acute (i.e., current) loads (Gabbett et al., 2016). Collecting information on both allows for a more detailed calculation of whether load is increasing, decreasing or remaining the same over time. It also allows determination of the ratio between acute and chronic elements to explore situations such as when a high load is occurring acutely, and was not prepared for through progressive increases in loads over time (Hulin et al., 2016). Research has shown that increases in acute workload are more likely to lead to injury, whereas high chronic workloads may be protective (Gabbett et al., 2016; Hulin et al., 2014; Hulin et al., 2016). This research has implications for understanding the influence of sport exposure as we have conceptualized it in this tool (e.g., Are spikes in exposure similarly linked to adverse outcomes? What ratio of acute/current to chronic/historical exposure is optimal for an athlete?).

Determining the appropriate timeframe for measuring current workload (i.e., 'acute' load) varies across research areas, but studies of physical activity and exercise typically use the past seven days as a reasonable marker for the comprehensive recall of recent training (Blair et al., 1985). A study of children and adolescents' recall of physical activity found seven days to be the maximum for younger children's ability to recall (Sallis et al., 1993). This approach is also the norm in sport science; for instance, Gabbett (2016) noted this period "appears to be a logical and convenient unit" (p. 5). For these reasons, seven days is used as the time period for collecting 'current' information in the SES.

As noted by several researchers (e.g., Côté et al., 2005; Hendry et al., 2018; Hopwood, 2010), collection of athlete participation information, particularly retrospectively, is fraught with

challenges. Therefore, it was important to have items that were psychometrically sound with evidence to support their validity and/or reliability. To improve the measurement foundation for the SES, where possible, items were drawn from the Developmental History of Athletes Questionnaire (DHAQ; Hopwood, 2013). The DHAQ was created to be a psychometrically sound questionnaire for collecting retrospective/historical information from athletes across a variety of different areas related to their development. The scale has been used in several prior studies (Atefineya et al., 2021; Lemez et al., 2020; Wilson et al., 2017) and the information regarding its psychometric testing is readily available online (Hopwood, 2013).

For the SES, DHAQ items related to duration, frequency and intensity of participation in different forms of sport were considered – to capture both historical and current training load. It is important to note the DHAQ is a lengthy questionnaire, containing many items that were not relevant to exposure, as well as items that were relevant but did not provide sufficient detail for our purposes. As such, this led us to (a) select some items which we kept the same as in the DHAQ, and (b) expand some items from the DHAQ to better fit our purposes and provide the rationale for doing so.

Sport Exposure Scale (SES) Items

Below, we outline SES items aimed at collecting the duration, frequency and intensity of (a) practice, (b) competition and (c) play, three primary forms of sport participation (Ford et al., 2009).

Practice

Historical. To capture historical involvement in practice (i.e., chronic load), the scale collects number of sports participated in, level of participation (e.g., recreational, competitive), as well as months per year and days per week of each sport. Expanding on the relevant items

from the DHAQ, the scale collects number of hours per session and training sessions per day for each sport, as athletes may participate in more than one training session each day. These additional elements not currently captured in the DHAQ are relevant for understanding sport exposure, as well as a space to explain variation (e.g., some months followed one schedule while other months followed a different one). Additionally, the DHAQ measures the total number of months of engagement, which does not provide enough information to determine if/when sports were occurring simultaneously, which is relevant for diversification/specialization. Therefore, this scale allows participants to indicate which months each year they practiced in each sport (e.g., January to March in hockey). To get a comprehensive understanding of historical engagement in practice, the above items are completed for every age of participation, indicating how long participation lasted at each level (e.g., 2 years recreationally followed by 4 years competitively in hockey).

Current. Using particular DHAQ questions as a guide, current practice (i.e., acute load) includes items measuring practice for the past seven days for each sport an athlete has engaged in. More specifically, the scale collects days and hours practiced for the week, which days practice occurred and the number of sessions per day. Collecting this information is important for determining whether training occurs in multiple sports on the same day, as well as the duration and frequency of training load. We also include a novel item asking whether this is a regular practice week and space to explain whether this differed from the normal schedule (e.g., more or less training directly before an upcoming competition). Finally, to capture intensity the scale collects percentage of effort during practice for the week via a continuum between 0% to 100% effort a technique used by Côté and colleagues (2005) when collecting sport development history.

Competition

Historical. Athletes' sport exposure is not limited to their time spent in practice. Therefore, the scale collects relevant data about competition history; however, this type of data, at least when collected retrospectively, was found to be unreliable in the original DHAQ (Hopwood, 2010). Based on this limitation in recall ability and the importance of collecting competition data for determining exposure, only items with acceptable reliability are collected. In the DHAQ, only months in competition met acceptable reliability criterion (Hopwood, 2013). In order to establish if/when overlap occurred between sports, the scale includes an item to indicate the specific months competition took place. Additionally, to get a general understanding of competition frequency, an item asking overall how often competitions occurred is included to gauge whether the competition exposure was consistent (e.g., weekly) or intermittent (e.g., once in a while).

Current. Similar to the recall of current information for training/practice and again adapting relevant DHAQ items, the scale collects number of competitions (e.g., tournaments), number of events/matches within the competition, and hours of each event/match, for each sport over the most recent 7-day period. The scale also collects which specific days the event/matches took place to determine any potential overlap across sports. Collecting detailed competition data allows comparisons between amount of practice to competition, a ratio that has been suggested to be important (Sport for Life, 2019). Additionally, an item that measures average time actively competing for each event/match for each sport, as time spent actively engaged (as opposed to sitting on the bench) is included. Similar to the measure of intensity of practice, an item collects information about the intensity of effort during competitions (0 to 100%).

Play

Historical. Collecting information on retrospective engagement in play activities (i.e., non-organized, non-adult led sport activities that are inherently enjoyable; Côté et al., 2007) is challenging and unreliable (Hopwood, 2010; Soberlack & Côté, 2003) due to the inconsistent and often spontaneous nature of participation. For this reason, no information on historical play is collected.

Current. Current engagement in play activities (i.e., acute play) is more reliably recalled. Over the same 7-day period, respondent the scale collects hours in and which specific days they engaged in play. This allows researchers to determine whether play is occurring on the same days as practice and if there is a potential ratio of play to practice that relates to risk and/or benefit. Finally, as with both practice and competition, the same percentage of effort item is included to capture intensity of play.

Strengths and Limitations

Exposure measurement is complex, but collecting enough information on individual variables permits examination of relationships between exposure and health, developmental, and performance outcomes, as well as allows for the exploration of potential interaction effects - an element of analysis that has not been possible in most prior work. Being able to run more complex analyses will lead to a better understanding of the mechanisms behind potential harmful or beneficial outcomes of both specialization and diversification, and the ability to create specific guidelines for policy makers on sport participation among youth.

The final SES gathers information on duration, frequency and intensity of sport exposure (in the form of practice, competition, and play) for every age of an athlete's sporting history. Collecting this information allows for a more complete picture of the amount of sport an athlete

is exposed to and allows future researchers to investigate the relationship of different types of sport participation and individual variables of interest to different outcomes.

While we did our best to include all relevant items in the SES, the manner in which information is collected and the reliability of memory recall prevented the inclusion of several sections that may be important. Acute intensity, for instance, is better measured physiologically, via accelerometers or energy expenditure, and there are always limitations to the collection of this information via questionnaire. While our inability to capture measures of chronic intensity is reasonable given the limits of recall in this area, the loss of this information may not be as damaging as it appears. For instance, it may be reasonable to assume if someone is engaging in a certain activity for an extended period (e.g., many years in a sport) it occurred at a manageable level of intensity; too high of an intensity for too long would lead to stopping the activity. Similarly, if someone is progressing in their activity (e.g., increasing level of competition) it may be reasonable to assume the intensity is at a high enough level to allow for growth/improvement.

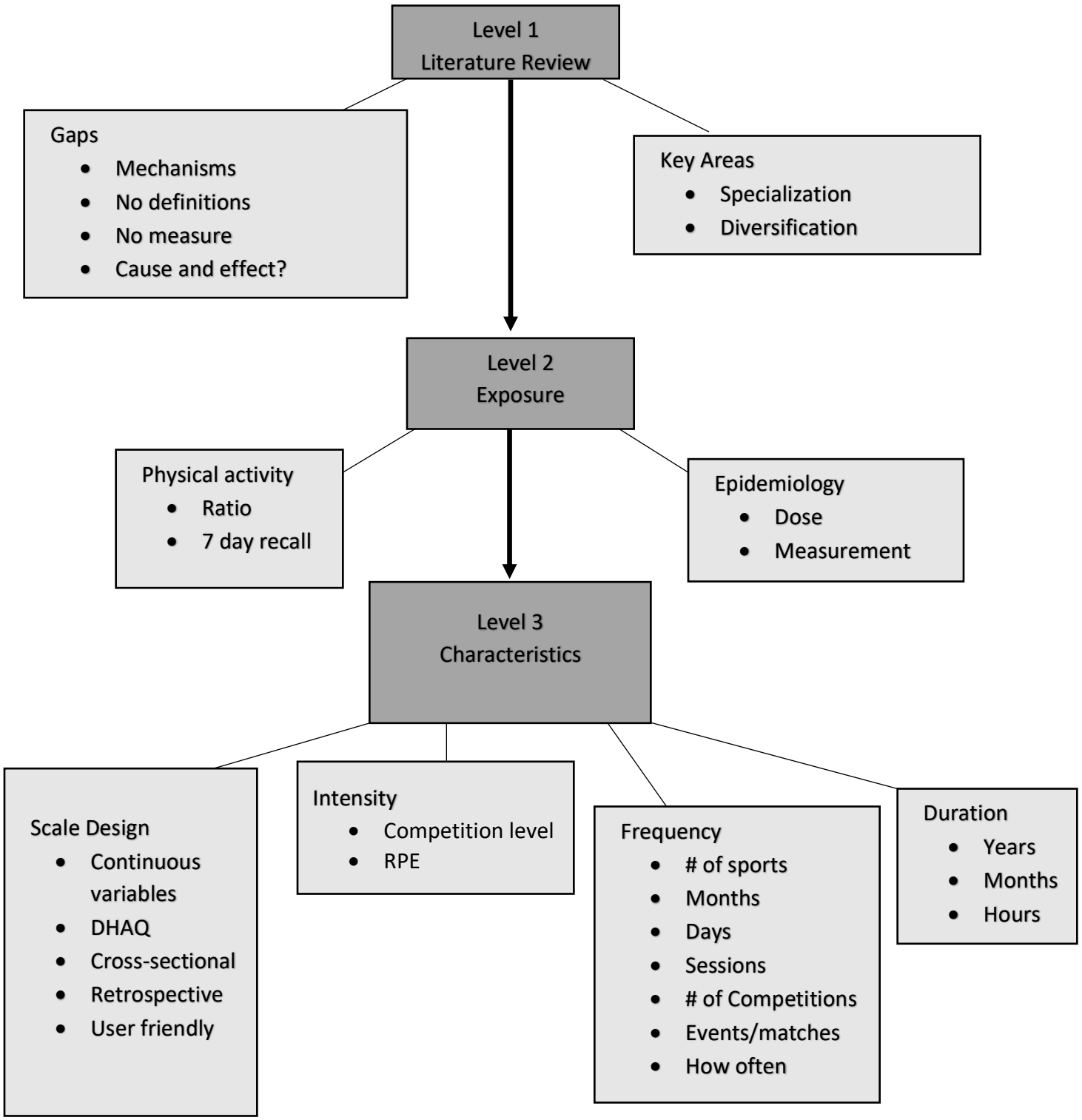
An additional challenge relates to practice and competition schedules not always being consistent; for example, some athletes may participate in two practices a day during some months and one session per day during others. While we did include items to collect whether this was a regular practice week and/or how often competition occurs, because we did not collect information for each week of each month of each year, we may have missed some variation in practice or competition amount. Although obviously time consuming, future work may wish to consider an in-depth investigation of the full schedule of athletes' training for each year, to capture all variation, as this variation may have value for understanding the complexity of load management across athlete development.

Perhaps most importantly, our scale chose to measure exposure from a physical load management perspective as the first step to understanding the mechanisms underpinning outcomes related to sport participation. It is possible this is not the most important mechanism; however, it is not possible to ascertain this without first measuring and ruling it out.

Conclusion

The SES has potential value for researchers in several areas of sport science. Despite some expected limitations, this is the first scale in athlete development research that measures sport participation from an exposure perspective. By drawing items from previously validated measures and expanding on identified gaps in measurement, we will be able to provide a reliable, and comprehensive method to capture the nuances of youth sport participation. These nuances are arguably important and have been generally missing from prior work in this area.

Figure 1. Concept Map.



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Chapter Five: Validating the Sport Exposure Scale: A Delphi Approach

Introduction

Discussions about youth sport participation pathways have seen a spike in activity in the last decade (Baker et al., 2021), mainly centered around the debate about the costs and benefits of specialized versus diversified training during early development (e.g., Ford & Williams, 2017; Myer et al., 2016) Despite this increased interest, the defining characteristics of sport specialization and diversification remain generally unclear, with several researchers noting inconsistencies in definitions and measurement (Baker et al., 2021; Kliethermes et al., 2021; Larson et al., 2019; Ramsay et al., 2022). A systematic review of specialization found numerous defining factors from single-sport participation to exclusion of other sports (Mosher et al. 2020). One recent and comprehensive definition proposed specialization was "intentional and focused participation in a single sport for a majority of the year that restricts opportunities for engagement in other sports and activities" (Bell et al., 2021, p. 1241).

By contrast, diversification in sport is not often explicitly defined, however, when it is, it is frequently described as multi-sport participation with little detail about when multiple sports are occurring (i.e., simultaneously, over the course of a year or over the lifetime) or what amount and type of activity is taking place (Ramsay et al., 2022). The lack of consistent definitions for both specialization and diversification make it difficult to accurately discern who qualifies as a specializer or diversifier (Mosher et al., 2020).

Interestingly, this lack of clarity and/or consistency has not prevented researchers and organizations from advising against early sport specialization (e.g., Brenner, 2016; Jayanthi et al., 2015); however, despite this earlier rhetoric there has been a shift in this narrative more recently. While it is widely held that specialization leads to negative psychological outcomes, little direct evidence of this relationship exists (Klietherme et al., 2021). In fact, recent research

has noted feelings of burnout were not related to markers of specialization in swimmers (Larson et al., 2019), and there was no association between feeling physically or mentally exhausted and early specialization in basketball players (Meisel et al., 2021). Additionally, there has been conflicting evidence around injury and specialization, with some studies finding an association between the two variables (Ahlquist et al., 2020; Jayanthi et al.,2020), others finding no association (Frome et al., 2019; Ross et al., 2021), and others finding associations that are only sport specific (Post et al., 2020). Importantly, diversification, at least in the vague manner it has been previously conceptualized, may not be a protective solution. Injury risk has been associated with participating on multiple sports teams at the same time (Post et al., 2021) as well as with overall training volume (Jayanthi et al., 2020). This mixed evidence has led some researchers to explore a more nuanced view of sport participation pathways. For instance, new models providing advice for how to properly train specialized athletes have emerged (Jayanthi et al., 2022; Mosher et al., 2021), and questions around the value of measuring specialization and diversification as a dichotomy are being raised (Baker et al 2021; Güllich et al., 2021).

Currently, there is no method for measuring diversification and arguably too many methods for measuring specialization, of which none have been shown to have appropriate reliability and validity (Mosher et al., 2020; Pasulka et al., 2017). It is difficult to provide evidence for or against specialization when the same athletes could be classified differently depending on the method researchers choose to use (Mosher et al., 2022). Furthermore, current methods fail to capture the nuances of sport participation by using categorical variables and dichotomies. Because of this measurement imprecision, researchers have suggested measuring specialization using a set of continuous variables would provide a more accurate representation of the phenomena (Baker et al., 2021; Güllich et al., 2021).

The lack of a consistent method for measuring specialization and diversification, discussed above, is partly to blame for the lack of understanding around specialization and diversification and a valid and reliable tool is needed. However, the inconclusive results on the issue of specialization and diversification could also suggest researchers are not addressing the real problem. As suggested by others (e.g., Baker et al., 2021; Mosher et al., 2021), rather than focusing on the debate around specialization and diversification, it may be more important to focus on the mechanism(s) driving any negative consequences of specialization. Researchers have proposed these could include the solitary focus in single movement domain, training intensity, and/or pressure (Baker et al., 2021), but there has been limited evidence exploring these hypotheses.

Emerging research (Jayanthi et al., 2020) emphasizes that current approaches to measuring specialization and diversification fail to consider several factors that could be important in understanding the underlying problematic mechanisms. For instance, if training intensity is a key mechanism for understanding risks of specialization, by failing to measure intensity of engagement, athletes participating in sport recreationally could be placed in the same group as athletes participating at an elite level. Similarly, by failing to measure training volume, it is not possible to distinguish between an athlete training for two hours a week and one training twenty hours a week. As a result, it is not possible to assess whether overtraining is the driving mechanism of risks or benefits associated with specialization. Furthermore, elements of participation and engagement do not occur in isolation and there is the potential for athletes to dedicate more time into multiple sports than specializers dedicate into one. Current methods do not provide information on *total* sport participation and, therefore, make it impossible to determine the risks associated with too much participation across multiple sports. Failing to

collectively measure these important aspects of sport participation make it difficult to understand the breadth of participation and/or explore the potential mechanisms behind any risks or benefits associated with either specialization or diversification.

With these limitations in mind, the Sport Exposure Scale (Mosher et al., 2022b) was developed to improve our understanding of the driving mechanisms of positive and negative outcomes related to sport participation and to improve the precision of measurement of key aspects of specialized and diversified engagement in sport. More specifically, a key objective of the Sport Exposure Scale was to improve the accuracy of how issues of sport participation are considered. A fundamental assumption of the Sport Exposure Scale is that aspects related to the quantity and quality of one's sport participation influence a range of health, performance and athlete development outcomes. Therefore, designing this scale involved an interdisciplinary perspective, drawing from various sub-domains of sport science including: (a) health and injury epidemiology, due to its use of large representative samples and ease of data collection (Wild, 2009) and (b) exercise physiology, due to its long history of quantifying load in sport (e.g., Turner, 2011). As most discussion around athlete development has focused on the risks of different types of sport participation pathways (e.g., specialization versus diversification), epidemiology was particularly useful since it considers exposure as it relates to risk (White et al., 2008).

In order to measure exposure, one must first determine the elements of the exposure that cause the outcome (White et al., 2008). Athlete training research suggests the main contributor to both injury and improved optimal performance is 'load' (Gabbett et al., 2016). Load management has been shown to be a key factor in maximizing training-based adaptations and preventing injury (Bourdon et al., 2017; Hughes et al., 2018)- suggesting load may be an

important component of exposure and/or a driving mechanism behind different outcomes. Because load management research is heavily focused on highly regimented single sport training programs, load has yet to be looked at across multiple sports or from the perspective of overall exposure. To capture this exposure (i.e., total load), the Sport Exposure Scale gathers information on duration, frequency and intensity (White et al., 2008) for every sport an athlete is currently participating in or has participated in. This allows researchers to understand how much exposure to sport an athlete is currently getting, regardless of whether they are participating in a single sport (i.e., specializer) or multiple sports (i.e., diversifier), and how current load relates to chronic exposure.

In order to gather the full breadth of sport exposure, information on the three primary categories of sport participation (i.e., practice, play, and competition) are needed. While definitions for each vary, it is generally agreed that practice involves structured activities (e.g., coach-led drills) designed to improve aspects of current performance (Ford et al., 2009). In comparison, play reflects engagement in non-structured activities that are inherently enjoyable (e.g., a youth-led pick-up game; Côté et al., 2007). There are conflicting opinions about the importance of practice versus play in the development of an athlete. While some studies have found play to be a distinguishing factor between elite and non-elite athletes (e.g., Ford et al., 2009) others have found play to have negligible effects (e.g., Güllich et al., 2021). Despite this ambiguity, measuring both practice and play is important to gain a full understanding of load. Finally, competition involves structured activities that are against an opponent and governed by pre-determined rules (Ward et al., 2007), such as a coach-led game or event with referees or judges where the result has a pre-determined social meaning (e.g., rankings, medals). Research has shown that injury rates are higher during competition than practice (Tirabassi et al., 2016)

and athletes who report higher volumes of competition are more likely to have a previous injury than those with lower competition volume (Post et al., 2017). Collecting information on competition, in addition to practice and play, may help to further understand whether load is the mechanism behind specialization and diversification. Each of the three above activities are different in terms of their structure and purpose, and are, therefore, important in order to fully understand elements of training load in developing athletes, as well as to determine what quantity/pattern of each aspect of sport participation may be beneficial or harmful. All of the above considerations (i.e., measurement precision, understanding mechanisms, capturing exposure, measuring load, and the three forms of participation) went into the construction of the Sport Exposure Scale.

The purpose of this study was to assess elements of validity for the Sport Exposure Scale (Mosher et al., 2022b). Generally, validity relates to the "extent to which a test measures what it is supposed to measure" (Berg & Latin 1994, p.152). While there are several kinds of validity, each reflecting the degree of support for a measure, this study focused on establishing content validity and face validity using a modified Delphi approach (Vernon, 2009). Content validity describes "the extent to which the items or questions are capable of accurately measuring the desired information" (Berg & Latin 1994, p.153) while face validity is when "it appears obvious that the test or device is measuring what it is supposed to" (Berg & Latin 1994, p.152). In the case of the Sport Exposure Scale, content validity relates to whether the proposed items accurately measure exposure while face validity is reflected in whether the scale logically appears to measure overall exposure. While more advanced and robust elements of validity (e.g., criterion or predictive validity) can only be established through on-going research conducted over extensive time, if experts on the Delphi panel agree that the proposed items are a

comprehensive, accurate and logical measure of exposure, then preliminary validity of the Sport Exposure Scale will be established, justifying its use in further research.

Methods

Participants

Study participants included researchers currently active in the field of youth sport participation, to ensure scholars' area of work was aligned with the purpose of the proposed scale (Powell, 2003). To be included in the study participants had to have published an article on sport specialization in a peer reviewed journal in the last 15 years (as determined by systematic review, Mosher et al., 2020). The first author of each publication was invited to participate. If the first author could not be contacted, then the second author was contacted; if the first author was a graduate student, then the supervising author was contacted. After receiving ethics approval from the Institution Review Board, invitation emails were sent out to 74 researchers whose emails were publicly available, requesting their participation in our study. Fifty researchers did not respond, 5 declined due to time constraints, and 19 consented to be a part of the study. Of the 19 who consented to participate, at the end of data collection, one participant only completed Round One, one person completed two rounds but not all three, and, one person skipped all of the questions in Round Three. The remaining participants (n=16) completed the study in full. Of the sample who completed all three rounds, 6 were female, 14 were PhDs and two were practicing medical doctors.

Study Design

To test the validity of the proposed Sport Exposure Scale (Appendix A), a modified Delphi approach was used. The original Delphi project was undertaken in the 1950s by the Research and Development (RAND) corporation to estimate potential targets and effects of an atomic bomb

attack on the United States (Vernon, 2009). While the Delphi method has evolved in many ways since its original conception, the main premise remains. A Delphi is an iterative process designed to collect the opinion of experts on a topic that has little evidence or has conflicting evidence, and could benefit from the subjective judgements of individuals (Hsu & Sanford, 2007). This approach can also be used to investigate something that does not yet exist (Skulmoski, 2007)-as is the case of the Sport Exposure Scale.

According to Rowe and Wright (1999), the Delphi method is comprised of four key elements: (a) anonymity of participants, (b) iteration, (c) controlled feedback, and (d) statistical aggregation of responses. In this method, participants are free to express their opinions without pressure to conform and can change their views based on the feedback of other participants and the quantitative interpretation of the data. The Delphi method has been used in sport science in a variety of ways, including to define self-care and determine barriers and facilitators for implementing self-care in sport psychology practitioners (Quartiroli et al., 2021), to determine considerations and definitions of performance tests in exercise and sport science (Robertson et al., 2017) and most relevant to this study, to define sport specialization (Bell et al., 2021).

A modified Delphi approach was conducted to achieve consensus on the items included in the Sport Exposure Scale. There are different modifications that can be made to the Delphi method depending on the research question. For instance, there is no set number of participants on a panel or rounds of questions in a modified Delphi, and all decisions should be based on the research question (Sklumoski, 2007). Often a Delphi study will begin with open-ended questions being asked of participants to generate the initial survey. However, it is both common and acceptable to use an extensive review of the literature as the basis for the Delphi questionnaire (Hsu & Sandford, 2007). The Sport Exposure Scale was created based on multiple systematic

reviews (Mosher et al., 2020; Ramsay et al., 2022) and an extensive understanding of the relevant literature. Therefore, proposed scale items served as an appropriate first iteration for the Delphi study (Appendix A).

Procedure

Similar to a classic Delphi method, participants were asked to engage in three rounds of review and feedback. Participants were given two weeks to complete each round as suggested by Delbecq and colleagues (1975). Consensus was determined *a priori* as when more than 70% of participants responding 3 or higher on a four-point Likert scale (Green, 1982). An item was modified if it did not receive this a priori consensus. If suggestions for improvement were made, items were also modified to improve clarity, even if consensus was reached in the first round.

During Round One, participants were given the proposed Sport Exposure Scale to read in full. They were then asked to rate the clarity and relevance of each proposed item on a 4-point Likert-scale. Participants were also asked to provide comments for each item and any general comments on the scale as a whole. After participants completed Round One, responses were aggregated and modifications were made. To begin Round Two, participants were shown the combined results of Round One and any common themes that arose in the comments. They were then asked to rate the modified items again on the same four-point Likert scale for clarity and relevance. Participants were also asked whether they felt modifications made after Round One had improved the scale. Finally, open ended questions about how to improve the scale more generally and the potential uses of the finished product were added. Once again, scores were calculated, themes were discovered, and information was shared with participants. On the third and final round, participants were asked to rate any items that had still not achieved consensus on

the same four-point-Likert scale for clarity and/or relevance. Opened ended questions about how to balance recall bias, participant burden and how best to measure intensity were also included. Below are the results of each round.

Results

Round One

For the complete list of scores for each item see Table 1. Of the 38 items in the scale, all but 11 items achieved consensus for relevance. The items that did not achieve consensus were not excluded from the scale; instead participants were given a rationale in Round Two for why these items were included in the scale and then asked to rate the relevance again.

The biggest concern for participants in Round One was around clarity. Twenty-two items achieved consensus for clarity but only 9 were well above (more than 10% above) the 70% threshold. For this reason, every item in the scale was modified for clarity. Items were changed from short labels to question format (e.g., "Number of hours" was changed to "How many hours did you participate in practice?"). Some of the main themes of participants' comments noted the need for "more explanations of terms" or to "revise [the item] to reflect the statistics and analytical tools you wish to use". Therefore, all introduction items and instructions were modified and "select all" options were provided instead of open-ended answer blanks (e.g., select all, or Monday to Sunday, instead of 'which day did you practice?'). In an attempt to shorten participant burden in Round One only one example of the Sport Exposure Scale was provided in each section, which left participants confused about the ability of multi-sport athletes to complete the scale. To address these concerns, a longer example of the Sport Exposure Scale was provided in Round Two. Finally, there were questions around the intended audience and purpose of the tool, and, therefore, open-ended questions were added in Round Two to obtain information from the participants regarding who they thought the tool would be useful for.

Round Two

For a complete list of scores for each item see Table 2. In Round Two, only one item did not reach consensus for relevance. However, comments suggested there were concerns around the validity of the item, not the relevance (i.e., is this the best way to measure intensity, as opposed to why are you measuring intensity). Given the importance of this item to the issue of exposure and load (i.e., it focused on the amount of 'effort' an athlete put into their training), rather than removing the item, in Round Three the experts were asked how they would measure intensity. Participants reported the items were clearer in this round, with only three items not achieving consensus for clarity. Once again, items were amended based on suggestions to improve clarity. The biggest concern from participants in this round was related to participant burden and recall bias. In the comment section under specific items, participants voiced their concern about the length of the scale, how long it may take participants to complete the scale, and the ability to recall specific information requested within the scale, from many years back.

Given the concerns raised by participants in Round Two, we asked open-ended questions about how to collect the information required by the scale while reducing participant burden and recall bias, in Round Three. Respondents agreed that changing the items to question format, adding definitions to the introduction, and adding "select all that apply" when applicable, improved the scale from the original version. There were still concerns around the clarity of instructions and respondents did not feel the expanded instructions improved the scale. Therefore, additional modifications were made to the instructions based on this feedback, in the hopes of achieving consensus for clarity. Based on the open-ended questions, most (n=10) respondents felt the scale would be applicable for high school aged youth, and that it could capture the experiences of athletes in most sports, but that the scale could be simplified and that

it was missing sections on time off and cross-training. Finally, participants found the time frame of reference confusing because the scale was organized by type of participation (i.e., practice, competition or play) rather than current or retrospective timing.

Round Three

The biggest change after feedback from Round Two was separating the Sport Exposure Scale into two separate sections, one for historical participation and one for current participation. In Round 3, participants agreed that separating the scale into current and historical participation provided more clarity with three stating "I like this idea" and others stating, "good move" or "good idea". For a complete list of scores for Round Three, see Table 3. After the third round, all items achieved consensus for clarity. One item was removed as participants felt the information was collected in other questions included in the scale. To address the concerns with validity on the item related to intensity that did not achieve consensus, we asked participants how to improve this measure. There were mixed responses, with four feeling the existing measure and wording was appropriate, three indicating the item was still not a good measure of intensity and should be removed, and two suggesting the item would be improved by providing examples. There was no consensus on how to improve the question, but this element of exposure remained important to capture athletes' global patterns of participation. As a result, the item was retained, but further assessment will determine whether it should remain in future versions.

In this round, we also asked additional open-ended questions to examine some of the bigger concerns participants noted with the scale. For instance, participants were concerned with recall bias, therefore we asked them for suggestions on how to collect the amount of precise data we needed while not succumbing to recall bias. Four suggested limiting the time frame in some way so that there are fewer years to complete the scale for, while three acknowledged the

information was important and recall bias was an accepted limitation in retrospective data collection. One participant even provided references to studies that had shown there is recall accuracy for recurrent and salient lifetime activity such as sport.

Participants were also concerned with participant burden in Round Two, therefore, we asked for suggestions on how to reduce burden. Four participants advised us to take advantage of online methods that can use autofill and logic to reduce the time, and two suggested providing more flexibility in which items needed to be used for each participant or research question. Finally, we asked participants for any final thoughts on the scale. Responses were generally positive with eight participants providing encouraging feedback such as "much improved", "worthy project" and "this is a creative and novel idea".

The Final Scale

The three rounds resulted in a revised version of the Sport Exposure Scale containing two sections that can be used together or separately, depending on researchers' needs. The "Historical" participation section contains 13 items that are to be repeated for each age of participation and each sport. The "Current" participation section contains 20 items to be repeated for each sport. See Appendix A, B and C for the scale's evolution and final version.

Discussion

The purpose of this study was to assess the content and face validity of the Sport Exposure Scale (Mosher et al., 2022) using a modified Delphi approach. The experts on the Delphi panel agreed the proposed items were a comprehensive, logical and reasonably accurate measure of sport exposure, establishing the preliminary validity of the scale.

The Delphi method began with feedback on the scale as originally conceived by Mosher and colleagues (2022). After experts' feedback in Round One, several changes were made to

increase clarity, resulting in significant and comprehensive changes to the scale. In Round Two, consensus was achieved for both clarity and relevance on most items, indicating participants were satisfied with the individual items; however, there were still concerns about the scale as a whole. Round Three focused on gaining experts' thoughts on these larger concerns. The consistency in positive responses across the three rounds of feedback from the Delphi panel and the consensus at the end of the process provide evidence of both content and face validity. While some concerns remain (e.g., participant burden or recall bias), they do not relate to content or face validity and can only be addressed through future empirical testing.

In the final scale, all items reached consensus for clarity and relevance. However, it is important to note that the Sport Exposure Scale may undergo further changes as testing begins and research questions evolve. For instance, there were differences of opinion regarding our question on intensity. There were concerns with the term used (i.e., 'intensity' - versus 'effort' or other suggestions), as well as concerns as to whether the question offered an appropriate measure of intensity. Given the key role of intensity of participation for determining an athlete's exposure or load, future research is needed to determine the most appropriate way to measure intensity of sport participation in a survey (i.e., using self-report). Future work should explore the predictive and criterion validity of the items proposed in the Sport Exposure Scale as well, to determine their ultimate value for researchers.

Several times during the three rounds of the Delphi, participants highlighted the need to collect information on supportive training activities such as strength and conditioning or cross-training activities. These types of activities are clearly important for athlete training, but after discussions amongst the research team, it was decided these would not be included for two reasons. First, an objective of the scale was to improve the precision of measurement of key

aspects of specialized and diversified engagement in sport. It is difficult to capture all possible supportive training activities that athletes engage in (e.g., strength and conditioning or yoga) in one survey. Moreover, this would increase the participant burden significantly. Therefore, rather than trying to include all of these activities in our scale- potentially reducing the precision of the measure, we decided to be very specific in the activities we collected (i.e., detailed information about engagement in practice, play and competition). Second, the scale was designed to improve our understanding of the driving mechanisms of positive and negative outcomes related to sport participation. Adding items related to supportive training activities would shift the focus from isolating sport exposure as the underlying mechanism. While our focus has been on overall sport exposure, future research should consider the influence of engagement in different supportive training activities to determine whether they are linked to specialization and negative (or positive) outcomes.

While this study had many strengths, including its flexible design and the quality of the experts involved in the scale's creation, there were limitations. For example, by the end of the study only 16 experts remained out of an original pool of 74. While this may be a relatively small sample size, there is no prescribed number of panelists in a Delphi study with previous Delphis having as little as four experts (Vernon, 2008). A Delphi examining early specialization had 17 participants (Bell et al., 2021), and, ultimately, we felt 16 was reasonable number. Additionally, our panel consisted of a fairly even distribution of females and males, from a variety of institutions who had all completed a PhD or Medical degree. Therefore, we felt this was a good representation of the those who would potentially have use for the scale.

The use of a four-point Likert-scale could be seen as a limitation in our design as it limits the number of response options for participants. However, this was a conscious decision. As the

goal of a Delphi is to achieve consensus (Holey et al., 2007), we did not want to provide participants with a neutral option (as is the case with a five-point scale). Instead, the four-point scale forces panelists to decide one way or the other as this increased the likelihood of reaching consensus.

Conclusion

This study was the first step in establishing the validity of the Sport Exposure Scale, but further empirical testing is vital for determining the value of the scale moving forward. Many of the participants emphasized the significance in attempting to create this scale and for tackling an issue that has limited further understanding of specialization. The responses from the panel indicate that the scale is on the right track and they look forward to seeing where it goes next.

This investigation was also an important step in our understanding of specialization and youth sport participation more broadly. Once overall sport exposure can be more precisely and accurately measured, researchers will be better able to determine the relationships between this exposure, engagement in specialization patterns of participation, and negative (or positive) effects on health or development. This will advance our understanding of the driving mechanisms of both positive and negative outcomes related to sport participation, and enhance our ability to design programs aimed at promoting or preventing these outcomes, respectively.

Table 1. Round One scores for each item.

Item	% Clear or Very Clear (median score)	% Relevant or Very Relevant (median score)
Historical practice intro sentence	42.1% (2.0)	89.4% (4.0)
Number of total sports you were doing at this age	36.9% (2.0)	94.7% (4.0)
Sport 1	79.0% (3.5)	89.5% (4.0)
Level competed	5.3% (2.0)	84.2% (3.0)
Number of months per year	69.5% (3.0)	89.5% (4.0)
Specific months (e.g. March to June)	73.7% (3.0)	63.2% (3.5)
Number of sessions per day	52.7% (3.0)	68.5% (3.0)
Number of hours per session	89.5% (3.0)	84.2% (4.0)
Current practice intro sentence	78.9% (3.0)	73.6% (3.0)
Sport 1	73.7% (3.5)	84.2% (4.0)
Specific days (e.g. Monday and Wednesday)	100% (4.0)	52.6% (3.0)
Number of hours total	78.9% (3.0)	84.2% (4.0)
Number of sessions per day	84.2% (3.0)	79.0% (3.0)
Number of hours per session	84.2% (3.0)	73.7% (3.5)
Is this a typical training week for you: Y/N	100% (4.0)	79.0% (3.5)
If you answered "No" what's the different about this week	84.2% (3.0)	84.2% (3.5)
Think of the most effortful activity you have ever done, this is 100%.	52.7% (3.0)	52.6% (3.0)
Think of an activity where the effort level is non-existent this is 0%		
Rate your effort during practice this past week from 0% to 100%	79.0% (3.0)	47.4% (3.0)
Comp intro	57.9% (3.0)	89.4% (4.0)
Sport 1	73.7% (3.5)	84.2% (4.0)
How many months were you in competition	79.0% (3.0)	84.2% (3.0)
In what months did you have competitions (e.g. March to June)	84.2% (3.0)	63.2% (3.0)
How often do you have competitions: weekly/Monthly/Less than one a month/once every so often	47.4% (3.0)	84.2% (3.0)
Comp current intro	78.9% (3.0)	84.2% (3.0)
Sport 1	73.7% (3.5)	78.9% (4.0)
Number of competitions	68.5% (3.0)	79.0% (4.0)
Specific days (e.g. Saturday and Sunday)	89.5% (3.5)	57.9% (3.0)
Number of event/matches per competition	52.6% (3.0)	73.7% (3.0)
Average time of event/match	73.7% (3.0)	68.5% (3.0)
Average time actively competing (e.g. playing time)	68.4% (3.0)	79.0% (3.0)
Think of the most effortful activity you have ever done, this is 100%.	63.1% (3.0)	63.1% (3.0)
Think of an activity where the effort level is non-existent this is 0%		
Rate your effort during competitions this past week from 0% to 100%	63.2% (3.0)	63.2% (3.0)
Play intro	84.2% (3.0)	89.5% (4.0)
Sport 1	63.2% (3.0)	79.0% (3.5)
Number of hours per day	68.4% (3.0)	79.0% (3.5)
Specific days (e.g. ,Monday)	78.9% (3.0)	52.7% (3.0)
Think of the most effortful activity you have ever done, this is 100%.	57.9% (3.0)	63.1% (3.0)
Think of an activity where the effort level is non-existent this is 0%		
Rate your effort during play this past week from 0% to 100%	73.7% (3.0)	68.4% (3.0)

Comment themes:

- revise to reflect the statistics and analytical tools you wish to use
- categorize sport experiences into team vs individual

- need to know the intended audience
- ask about enjoyment of activity and stress/pressure
- don't know if the effort aspect is something that adds value
- don’t use open-ended questions
- high participant burden given the length and detail of the measure
- needs more explanation of terms

Table 2. Round Two scores for each item

Item	% Clear or Very Clear (median)	% Relevant or Very Relevant (median)	% Agree-Improved Scale
Defining practice, competition and play			88.9
New instructions	66.6 (3.0)		61.1
Use “select all that apply”			94.4
Word items as a question			94.4
How many organized sports were you practicing in at this age?____	94.5 (3.0)		
Which months were you practicing in this sport? Select all that apply (Jan to Dec)	100 (4.0)	94.4 (3.0)	
How many practices did you have on average each day?_____	94.4 (3.0)		
How many hours on average was each practice?_____	100 (4.0)		
Let’s shift to more recent practice experiences you’ve had. The following section refers to organized sport practices in the last 7 days. Once again, if you are currently playing multiple sports, please fill it out for each sport.	94.4 (4.0)		
Which days did you participate in this sport? Select all that apply (Monday to Sunday)	94.4 (4.0)	77.8	
How many organized practices of this sport did you have per day?	94.5 (4.0)	88.9	
How many hours on average was each practice of this sport? _____	94.4 (4.0)		
How many hours of organized practice total did you do in this sport? _____	77.8 (3.0)		
If you answered “No” was this week less or more than a typical week ? Less / More	83.3(3.0)		
Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all	88.9 (3.0)		
Rate your average effort during practice in this sport this past 7 days from 100% to 0%:	77.8 (3.0)	66.6 (3.0)	
We want to understand the amount of organized sport competition (e.g. games, meets, tournaments, matches, etc.) you have engaged in during your sport participation. Same as above, complete the questions for every age from	77.8 (3.0)		

when you began competing up to and including now. Again, please answer for each sport at that age as well.		
Level competed: (Select one) Recreational or Competitive	55.6 (3.0)	
How often did you have competitions? Weekly/Several times per month/Monthly/Less than once per month/Once per year	83.3 (3.0)	
How many competitions did you have in this sport in the last 7 days?(e.g. tournaments or meets) ____	88.9 (3.0)	
How many games, matches, races, or events were in each competition in this sport?	55.6 (3.0)	
Finally, I want you to focus on your participation in unorganized youth-led sport play (e.g., pick-up basketball or street hockey) in the past 7 days:	83.4 (3.0)	
How many hours on average was each event/match?_____		72.3 (3.0)

Comments:

- concerned about the overall length of survey completion
- worried about recall bias
- confused about the time frame
- “effort” may not be the best word
- use logic and autofill

Table 3. Round Three scores for each item that had not achieved consensus.

Item	% Clear or Very Clear (median)	% Relevant or Very Relevant (median)
New instructions	94.1 (3)	
What level were you competing at?	76.5 (3)	
How many games, matches, races, or events were in each competition in this sport?		Item removed
Rate your average effort during practice in this sport this past 7 days from 100% to 0%:		Open-ended question asked

Comments:

- concerned about participant burden
- concerned about recall bias
- reduce the years collected
- much improved
- excited to see where it goes

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Chapter Six: General Discussion

General Discussion

Collectively this dissertation aimed to advance our understanding of early specialization in youth sport. At the onset of the first study, specialization was thought to be a relatively simple concept, and the plan was to create a novel tool that could measure it precisely. However, as the project progressed (from Chapters Two and Three) and from involvement in additional projects related to the topic (e.g., a systematic review of diversification; Ramsay et al., 2022; an editorial on the challenging issues of specialization, with key area researchers; Baker et al., 2021), it became evident the concept of specialization was more complicated and complex than originally perceived. For this reason, in Chapters Four and Five, there was a conscious shift to (a) developing a tool that could also capture diversification, and (b) focusing on underlying mechanisms of specialization, rather than the muddied concept of specialization. This general discussion revisits the guiding framework and reviews important findings from each Chapter, as well as exploring key themes that emerged across studies. Potential implications of this work are also discussed, followed by limitations, future directions, and key strengths of the dissertation. Finally, a conclusion to the dissertation is presented.

Guiding Framework Revisited

This dissertation was guided by the Knowledge to Action (KTA) framework (Graham et al., 2006). Specifically, the Knowledge Creation Funnel of the KTA was the thread connecting all four studies of the dissertation. The Knowledge Creation Funnel is comprised of three levels: (a) Knowledge Inquiry, (b) Knowledge Synthesis, and (c) Knowledge Tools/Products. The first level, *Knowledge Inquiry*, is comprised of first-generation knowledge – essentially all research studies and information available on the topic. This was covered in Chapter Two of the dissertation through the systematic review. The second level, *Knowledge Synthesis*, is where one

attempts to make sense of the relevant knowledge from the first level. This involves the aggregation and amalgamation of knowledge, which was covered in Chapter Three, by highlighting the impact of measurement imprecision, and part of Chapter Four, by combining the information to form the rationale for the Sport Exposure Scale. The final level, *Knowledge Tools/Products*, offers a generally tangible solution to the identified problem by presenting the knowledge in a clear and concise format, which was covered in part of Chapter Four and all of Chapter Five, where the Sport Exposure Scale (tool/product) was created and its validity was tested.

Important Findings

Chapter Two: Study One

The first study of this dissertation was a systematic review of research to understand the types, characteristics, and content of the literature on specialization and to examine how early specialization had been defined and measured (Mosher et al., 2020). The main objective was to advance knowledge towards a clear and consistent definition of early specialization. After searching four different databases, a considerable number of articles (n=129) were included in the final review. However, a large proportion (~ 43%) were non-data driven, which indicates that much of the discussion around early specialization is not as evidence-based as one might think. When examining the data driven studies, only a minority explicitly examined the relationship between early specialization and a particular outcome. Based on this information, I argue there is insufficient evidence to conclude that early specialization is harmful or beneficial to psychosocial, physical, and sport-specific outcomes.

The second objective of the study examined how early specialization had been defined and measured, with results showing highly inconsistent and varied definitions of specialization.

Importantly, there was often a conflating of “early specialization” and “specialization”. This distinction needs to be made to determine whether the timing of specialization is the problem (i.e., if too early causes negative outcomes) or if it is a facet of specialization that is the problem (i.e., timing has little to no effect). Finally, the review noted there was often misalignment between the definition of specialization and method used to explore this definition, which raised concerns around the validity and reliability of previous findings.

Chapter Three: Study Two

The second study of this dissertation was a two-part study that took the findings from Study One and sought to determine potential research implications of these findings (Mosher et al., 2022). Part one of this investigation had two objectives. The first was to provide a snapshot of a large sample of diverse athletes, in terms of developmental milestones related to specialization. The second was an examination of how the proportions of athletes classified as ‘specializers’ changed depending on the method used. Three hundred and sixty-two athletes were classified as specializers or non-specializers depending on three different indicators of specialization. Interestingly, the results indicated that athletes were not engaging in “early” specialization and that the number of athletes classified as specializers varied depending on the method used, with single sport participation resulting in the highest percentage of specializers.

In the second part of this study, results from Part 1 were applied to an analysis of skill level, specifically to determine whether those who specialized (determined by each method in part 1) in youth became elite athletes in adulthood.

There were large discrepancies in the proportions of elite, pre-elite and non-elite athletes classified as specializers across all ages based on the method used, as well as a higher percentage of athletes who were specializers at age 18 who became elite compared to those who became

non-elite. Results indicated specialization before 18 years of age may be required to become an elite athlete, but may not need to occur prior to 12-15 years of age.

Chapter Four: Study Three

Based on the findings from the first two investigations, the third study of this dissertation marked a shift in the way the research question was examined. Rather than focusing on the term specialization and the inconsistencies in definitions and methods used to classify specialization, it became evident that focusing on potential mechanisms underlying specialization could offer more important insight on understanding outcomes associated with specialization. For this reason, Chapter Four describes and conceptualizes the creation of the Sport Exposure Scale. The scale was grounded in the assumption that quality and quantity of sport participation influence different sport and developmental outcomes, and, therefore, a key objective of the scale was to increase the precision of how sport participation is measured. Using approaches from health and injury epidemiology, exercise physiology, and athlete development research, the scale was designed to measure exposure from the perspective that an athlete's participation 'load' (e.g., frequency, duration and intensity of different types of sport participation) is the most likely mechanism behind any differences between specialized and diversified participation. By expanding on identified gaps in measurement and using items from previously validated measures (i.e., DHAQ; Hopwood et al., 2010), the Sport Exposure Scale is the first attempt at a reliable and valid measure designed to capture the nuances of sport participation.

Chapter Five: Study Four

The final study of this dissertation took the Sport Exposure Scale developed in Chapter Four and aimed to validate it using a modified Delphi approach (Vernon, 2009). The three rounds of feedback from experts in the field, resulted in the Sport Exposure Scale being

separated into two sections that could be used jointly or independently. Consensus for clarity was reached for all items after three rounds, and all but one item achieved consensus for relevance. As some bigger picture concerns remained within the final version of the scale, open-ended questions offered valuable additional insights and suggestions. The resulting version of the Sport Exposure Scale will need to undergo rigorous psychometric testing in order to establish it as a robust and useful tool; however this study took an important first step in establishing the content and face validity of the scale.

Key Themes in This Dissertation

As shown in the first chapter of this dissertation, there is a lot of negative rhetoric concerning specialization. Researchers and organizations are advising against specialization based on the conclusion that it leads to negative outcomes such as injury or burnout (Brenner et al., 2016; LaPrade et al., 2016; Jayanthi et al., 2020). However, the results of the first two studies indicate these conclusions are based on evidence found by inconsistent, unreliable and potentially non-valid methods. The systematic review indicated researchers do not necessarily agree on what constitutes a specializer, as there are many different definitions being used, with equally diverse markers. In order to make strong recommendations regarding specialization, the field needs to first agree what specialization is. Additionally, the systematic review showed a lack of evidence in general to support these negative outcomes. For example, only 14 studies in the systematic review empirically examined the relationship between injury and specialization and not all 14 studies found an association between these constructs (e.g., Moseid et al., 2018). This indicates a lack of evidence and inconsistent findings, which consensus statements fail to acknowledge. These studies support the conclusions of a recent editorial (Baker et al., 2021) arguing ***it is premature to condemn early specialization based on current evidence***.

Furthermore, similar to Bell and colleagues' (2016) findings, findings from Chapter Three noted that the number of athletes deemed specializers varied based on the method used for classification, thereby raising concerns about the reliability of previous results. If athletes have the potential to be labeled specializers in some studies and non-specializers in others, this undermines the validity of any evidence against specialization. Combined, these studies showed that while the strength of the rhetoric suggests the debate around specialization is closed, and that evidence is overwhelming supportive that specialization leads to negative outcomes, the reality is that the debate is far from over, and there are issues within the field that need to be further explored and resolved, before any conclusions can be made to guide policy documents, programmers, coaches, and athletes.

The next theme, centred around a ***need for empirical testing of any new methods***. Both Chapters Two and Three highlighted the lack of rigour that has gone into current measures of specialization. For example, a major criticism of the three-item sport specialization scale (Jayanthi et al., 2015) is that there have been no attempts to validate the measure (Miller et al., 2019). In order for a tool to establish its value, validity (i.e., measuring what it is designed to measure) needs to be confirmed, not assumed. Despite the lack of validity, researchers continue to use this tool; Chapter Two noted over 30% of data driven studies on specialization used this scale. Together, the first two studies of the dissertation showed that in order for a new tool to improve upon current measures, it needs to undergo rigorous validity and reliability testing. Chapter Five marked the beginning of the testing that will need to be done on the Sport Exposure Scale to ensure it improves measurement precision. As one expert (participant) stated, "The way the authors will make it [the Sport Exposure Scale] stand out and be relevant to researchers, is by conducting extensive validity and reliability studies." Chapter Five was the first step in

validating the scale, establishing content and face validity. Although more testing is required, findings indicate that the Sport Exposure Scale has established the important first steps towards becoming a valid and reliable means of identifying specialization.

The final theme centered around ***participation is more than the differences between specialization and diversification***. As it was shown that the evidence around specialization was faulty, and the concept and measurement of specialization was imprecise, the final two studies of this dissertation moved beyond the debate around specialization, towards an understanding of the underlying mechanisms that may affect youth outcomes in sport. Rather than simply developing a scale that was a valid and/or reliable indicator of specialization, the aim became developing a scale that would be able to answer latent questions around specialization: (a) what elements of sport participation lead to negative outcomes, (b) what elements of sport participation leads to positive outcomes, and (c) what patterns of sport participation lead to elite attainment? To explore these questions, a scale that measures more than the concept of specialization was required (i.e., the Sport Exposure Scale). Perhaps most importantly, more detailed examinations of elements of participation would help to uncover 'why' these effects occur, an element that has not been possible in previous retrospective or correlational studies. While this dissertation cannot provide the answers to these questions, it provides the first step in a series of many.

Practical Implications

From a practical standpoint, this dissertation led to the creation of a tangible knowledge tool/product (Graham et al., 2006). While the Sport Exposure Scale needs to undergo further testing and validation, it is plausible that it will become a useful tool for youth sport research. To our knowledge, this will be the first comprehensive tool to be used in athlete development research that collects information on both historical and current sport exposure across a variety

of sports. In addition to researchers who need a tool like this to advance their research, the simplicity and clarity of the Sport Exposure Scale may lend itself to use by coaches wanting to understand their athlete and plan appropriate training environments.

Further, the results from Chapters Two and Three provide the ability for coaches to challenge current recommendations about early specialization. As mentioned throughout this dissertation, many coaches in Canada use the Long-Term Development in Sport and Physical Activity Model (LTD; Sport for life, 2019) to guide their programs. This model strongly advises against early specialization. The lack and poor quality of evidence noted in Chapters Two and Three, and the consequences of these recommendations discussed elsewhere (Baker et al., 2021), challenge these recommendations and may allow coaches flexibility to revaluate and adjust their beliefs around early specialization. If coaches are able to challenge the rhetoric that early specialization is always harmful, then they may be able to design more appropriate training environments for their athletes.

As the tool collects information on duration, frequency and intensity of sport participation, in future, it could be used to calculate how much sport is too much for youth athletes, potential thresholds of sport tied to certain outcomes, and which types of exposure are optimal for youth development. The Sport Exposure Scale may also have some value for preventing injury in youth athletes, predicting potential negative outcomes, and ensuring maximal benefits from sport participation. This information may provide critical data for developing evidence-informed models of athlete development. If sport exposure is found to be the underlying mechanism behind negative outcomes in sport participation, then determining which patterns of historical or current sport exposure (via the Sport Exposure Scale) can aid in designing training programs or development models aimed at delivering appropriate levels of

sport exposure. If we can determine safe levels and parameters of sport exposure, then sport stakeholders can develop policies to promote adherence to these standards, thereby creating a safter sport experience for all.

Research Implications

In addition to the practical implications of this dissertation, there are also implications for research in the areas of specialization, diversification, and youth sport more broadly. At the onset of this dissertation, the goal was to develop a scale that could more precisely measure the construct of early specialization in sport. While the project has evolved beyond that aim, the objective of helping answer questions around specialization has remained. The creation of a scale that measures sport exposure offers a means to test the underlying mechanism(s) behind specialization. As such, this project directly advanced research around specialisation. While the Sport Exposure Scale collects more information than current measures of specialization (e.g., Jayanthi et al., 2015), it still collects the information necessary to determine specialization as it was previously measured. For example, if specialization is defined as intensive training, year-round, in a single sport at the exclusion of other sports in a particular study, the Sport Exposure Scale collects information about this pattern of participation; however, the scale collects this information as continuous data rather than a dichotomous yes/no response, which allows more comprehensive and thorough analysis of exposure in relation to outcomes. Additionally, the Sport Exposure Scale is able to measure elements of diversification more explicitly rather than simply positioning it as the default of non-specialization, as is the current method (see Ramsay et al., 2022). This will allow researchers to progress in understanding diversification and its associated potential benefits or risks.

Finally, this dissertation serves as a call to action to other researchers to improve their measurement and conceptual understanding of sport participation pathways. The field of youth sport has seen rapid growth in recent decades (Gould, 2019); however, much of the research on sport participation pathways is built on a foundation of overly simplistic and narrow understanding of specialization. This dissertation has highlighted some of the areas of concern in current literature. In order for the field to move forward, researchers need to be more critical of how they are choosing to define and measure these concepts. While some researchers are choosing to contest the status quo (e.g., Gullich et al., 2021), many are still using the same flawed methods and definitions. The hope in publishing this dissertation is that more researchers become aware of these concerns and limitations to in turn (drawing upon a popular sports reference) - 'up their game'.

Societal Implications

From a broad lens, this dissertation highlights the need to have a more nuanced discussion around youth sport participation. First, policy makers and other stakeholders should stop advising against the practice of early specialization while simultaneously promoting multi-sport participation, without considering broader societal implications. In Chapter Three we suggested new measures of specialization need to differentiate *why* someone is participating in one sport (i.e., pursuit of elite performance, or constraints of not being able to participate in more than one sport). Sport is becoming increasingly expensive (The Aspen Institute, 2021), and advising against specialization in favour of multi-sport participation may indirectly marginalize those who cannot afford to participate in multiple sports. This recommendation is particularly problematic when considering the potential (likely unintended) message received by young athletes – to not participate in *any* sports, if they cannot participate in many. Rather than

suggesting to parents who are already struggling to afford one sport for their child, or communities that may not have multiple sport organizations available to offer diverse programs, that children must engage in multi-sport, we need to find a way to inform parents and stakeholders how to train single sport athletes in a safe, healthy, and beneficial manner. Instead of simply focusing on whether specialization is bad, there needs to be a shift in perspective towards creating single sport training environments that are designed around avoiding the underlying potentially problematic mechanisms behind specialization (Jayanthi et al., 2022). This approach would allow athletes who only participate in one sport for any reason (e.g., by choice, financial constraints, time constraints) to still reap the benefits of sport participation, while avoiding the potential harm (i.e., healthy specialization).

Second, there needs to be more consideration of individual needs and preferences when discussing youth sport participation. A one-size-fits-all model of sport participation can be harmful to youth who do not fit the model. In Chapter Three we highlighted the difficulties in consistently classifying athletes as specializers. These inconsistencies and difficulties make it difficult to advise athletes on what pathway would be optimal for their sport journey. Rather than forcing a child who only wants to play one sport to play multiple sports because of blanket statements concluding specialization is bad, parents and coaches should attend to the individual needs of each. child. For instance, evidence indicates lack of enjoyment is more strongly correlated with burnout or dropout from sport than markers of specialization (Larson et al., 2019). If removing or limiting a child's participation in the sport they love reduces their enjoyment, then it may be more harmful in certain situations to promote multi-sport participation. As highlighted throughout this dissertation, there needs to be more nuanced

assessment of whether specialization is harmful for all athletes in all circumstances, as the rhetoric suggests, before practitioners advise parents to ignore the individual needs of their child.

Finally, coming down too strongly against specialization could conceivably prevent youth from participating in sport all together. When an athlete is only able to participate in one sport, but parents are told how dangerous specialization can be, this may deter parents from enrolling their child in sport to begin with. With so much rhetoric advising against specialization, it is possible parents adopt the belief 'if my child can't play more than one sport, then it is safer for them to play none'. This could have large societal implications as sport involvement is shown to have a number of benefits on overall health and development (Holt et al., 2011; Reiner et al., 2013). If youth (or their parents) stop participation in sport because of statements against specialization, this could exacerbate already rising health costs and childhood obesity (Weintraub et al., 2008). A more nuanced discussion around youth sport participation would allow parents to see that some sport participation is better than no sport participation.

Limitations and Future Directions

Despite the many strengths of this dissertation, there were limitations that should be considered for future research. First, this dissertation and the Sport Exposure Scale specifically examined sport from the lens of 'Western' sport participation. In the systematic review in Chapter Two availability in English was an inclusion-criteria which limited the studies from non-western countries. In the analysis in Chapter Three the majority of participants were from Canada or Australia (i.e., Western nations). This indicated a lack of variety in the countries considered in the rationale for the scale written in Chapter Four. During the Delphi study in Chapter Five, a participant raised concerns about some of the language used and whether it would translate in other countries. For example, 'shinny' is a common word used to describe a

type of ice hockey play in Canada, however participants from other countries were unaware what the word meant. Future studies should look into the generalizability of the scale and potential translations for other languages.

More importantly, a 'Western' focus meant the scale was based on western sport systems. Sport systems around the world vary in their delivery of youth sport (De Bosscher et al., 2010), and even within the western world there is variation. Therefore, future research should examine sport exposure from a variety of different sporting systems to test generalizability and/or adapt the scale to a knowledge tool/product that is useful to individual systems.

Second, the focus on 'mainstream' sports and how they are delivered may be a limitation to our design. Very few niche or fringe sports were included in the multiple studies in this dissertation. In developing the scale in particular, the goal was to capture sport exposure; however it did not fully take into account sports that do not follow a typical (i.e., practice, competition, play) schedule. For example, one participant in the Delphi indicated it may be difficult for mountain bikers to complete the scale as the lines between practice and play are quite blurred in an individual 'extreme' sport. Future research should examine the scale in different sports to confirm its validity and reliability across all sports.

Finally, by assessing specialization and creating a scale that measures sport exposure, this dissertation at times falls into the 'one-size-fits-all' approach to sport that is often criticized (e.g., Geisler, 2019). Sport participation should always be based on the individual and situation, and should avoid being given as a blanket recommendation when possible. While this tool has the ability to be used on an individual basis, there is a possibility it will be used to dictate general policy moving forward. Determining appropriate thresholds and parameters of participation

frequency, duration and intensity, to guide individual decision making will be important area for future research.

Key Strengths

The key strength of the dissertation was its capacity to extend this area of research into different perspectives. Rather than maintaining current research in the field, this program of research was critical of the literature and sought to better understand the issue. Instead of summarizing previous findings on specialization, the systematic review in Chapter Two examined the composition of the literature and highlighted gaps and flaws. In Chapter Three, instead of choosing a method to analyze specialization and skill level, the implications of having inconsistent methods was shown. Moreover, instead of merely pointing out the area's shortcomings, Chapters Four and Five attempted to provide a solution. In addition, a multidisciplinary approach was used to build the rationale for this solution. By drawing from epidemiology, for example, the scale took on a different meaning and the end knowledge tool/product was strengthened. Moreover, the ability to view the research question from a different perspective resulted in a novel an innovative solution, which was the key strength of this dissertation.

Conclusion

This dissertation set out to better understand the implications of early specialization in youth sport. First, research gaps in the existing literature and areas for future research were outlined. During the process of highlighting gaps, this dissertation became about more than just understanding specialization; it became an effort to improve a number of aspects of specialization research, particularly in how potential mechanisms of effect are measured. This dissertation as a whole should be seen as an initial step to improvement in this field as a whole.

As an ancient Chinese proverb states, “A journey of a thousand miles begins with a single step”. Creating the Sport Exposure Scale is the first step in a long journey towards better understanding sport participation pathways and improving how youth sport is delivered and experienced.

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Appendices

Appendix A

The Sport Exposure Scale

Practice

We want to understand the amount of organized sport practice you have engaged in during your sport journey. For each age please complete the following questions:

Age ____ number of total sports you were doing at this age _____

Sport 1 _____(e.g. Basketball) Level competed_____

Number of months per year____ Specific months (e.g. March to June)_____

Number of days per week _____

Number of sessions per day_____

Number of hours per session_____

Notes to explain variation

Let's shift to more recent practice experiences you've had. The following section refers to practices in the last 7 days.

Sport 1 _____

Specific Days (e.g. Monday and Wednesday)_____

Number of hours of practice total _____

Number of sessions of practice per day_____

Number of hours of practice per session_____

Is this a typical training week for you (select one) Yes /No

If you answered "No" what's different about this week?
_____

Think of the most effortful activity you have ever done, this is 100%. Think of an activity where the effort level is non-existent, this is 0%

Rate your effort during practice this past week from 0% to 100% _____%

Competition

We want to understand the amount of organized sport competition you have engaged in during your sport journey. For each age please complete the following questions

Age_____

Sport 1_____

How many months were you in competition_____

In what months did you have competitions (e.g. March to June)_____

How often do you have competitions?

Weekly Monthly Less than once a month Once every so often

Now I want you to focus on your competitions in the past 7 days (e.g., game, tournament, matches)

Sport 1_____

Number of competitions_____ Specific days (e.g. Saturday and Sunday)_____

Number of events/matches per competition _____

Average time of event/match _____

Average time actively competing (e.g. playing time) _____

Think of the most effortful activity you have ever done, this is 100%. Think of an activity where the effort level is non-existent, this is 0%

Rate your effort during competition this past week from 0% to 100% _____%

Play

Finally, I want you to focus on your engagement in unorganized play (e.g., pick-up basketball or street hockey) in the past 7 days :

Sport 1 _____

Number of hours of play per day _____

Specific days of play (e.g. Monday)_____

Think of the most effortful activity you have ever done, this is 100%. Think of an activity where the effort level is non-existent, this is 0%

Rate your effort during play this past week from 0% to 100% _____%

Appendix B

Round Two version of the Sport Exposure Scale

We are going to ask you a series of questions about your previous and current sport participation. We will be asking you about three types of participation:

Practice- organized, coach-led, training
Competition- organized, coach present, tournaments or meets etc.
Play- unorganized, youth-led sport activity (e.g. pickup or shinny)

Practice

We want to understand the amount of organized sport practice you engaged in during your sport participation.

Beginning with the youngest age you began practicing organized sports, fill out the following section for every sport you participated in. Then complete the questions again for the next age and each sport you participated in at that age. Continue this up to and including your current age. Please, fill out every age you were participating and every sport you were participating in.

Age ____ How many organized sports were you practicing in at this age_____

Sport 1 _____(e.g. Soccer)

Which months were you practicing in this sport? Select all that apply (Jan to Dec)

Which days were you practicing in this sport? Select all that apply (Monday to Sunday)

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Sport 2 _____(e.g. Basketball)

Which months were you participating in this sport? Select all that apply (Jan to Dec)

Which days were you practicing in this sport? Select all that apply (Monday to Sunday)

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Age ____ How many organized sports were you practicing in at this age?_____

Sport 1 _____(e.g. Soccer)

Which months were you participating in this sport? Select all that apply (Jan to Dec)

How many days were you practicing in this sport?_____

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Let's shift to more recent practice experiences you've had. The following section refers to organized sport practices in the last 7 days. Once again, if you are currently playing multiple sports, please fill it out for each sport.

Sport 1 _____

Which days did you participate in this sport? Select all that apply (Monday to Sunday)

How many organized practices of this sport did you have per day?_____

How many hours on average was each practice of this sport? _____

How many hours of organized practice total did you do in this sport? _____

Is this a typical training week for you (select one) Yes /No

If you answered "No" was this week less or more than a typical week ? Less / More

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during practice in this sport this past 7 days from 100% to 0%: _____%

Sport 2_____

Which days did you participate in this sport? Select all that apply (Monday to Sunday)

How many organized practices of this sport did you have per day?_____

How many hours on average was each practice of this sport? _____

How many hours of organized practice total did you do in this sport this week? _____

Is this a typical training week for you (select one) Yes /No

If you answered “No” was this week less or more than a typical week? Less / More

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during practice in this sport this past 7 days from 100% to 0%: _____%

Competition

We want to understand the amount of organized sport competition (e.g. games, meets, tournaments, matches, etc.) you have engaged in during your sport participation.

Same as above, complete the questions for every age from when you began competing up to and including now. Again, please answer for each sport at that age as well.

Age_____ Level competed: Recreational or competitive_____

Sport 1_____

Which months did you have competitions? Select all that apply (Jan to Dec)

How often did you have competitions?

Weekly Several times per month Monthly Less than once per month Once per year

Sport 2_____

Which months did you have competitions? Select all that apply (Jan to Dec)

How often did you have competitions?____

Weekly Several times per month Monthly Less than once per month Once per year

Age_____ Level competed: Recreational or competitive (select one)

Sport 1_____

Which months did you have competitions? Select all that apply (Jan to Dec_____

How often did you have competitions?

Weekly Several times per month Monthly Less than once per month Once per year

Now I want you to focus on your competitions in the past 7 days (e.g., game, tournament, matches, meets etc.)

Sport 1_____

How many competitions did you have in this sport in the last 7 days?(e.g. tournaments or meets) ____

Which days were your competitions in this sport? Select all that apply (Monday to Sunday)?

How many games, matches, races, or events were in each competition in this sport? _____

How much time on average was each game, match, race or event ?_____

How much time on average were you actively competing? (e.g. playing time)_____

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during competitions in this sport this past 7 days from 100% to 0%: _____%

Sport 2_____

How many competitions did you have in this sport in the last 7 days?(e.g. tournaments or meets) _____

Which days were your competitions in this sport? Select all that apply (Monday to Sunday)?

How many games, matches, races, or events were in each competition in this sport? _____

How much time on average was each game, match, race or event ?_____

How much time on average were you actively competing (e.g. playing time) ?_____

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during competitions in this sport this past 7 days from 100% to 0%: _____%

Play

Finally, I want you to focus on your participation in unorganized youth-led sport play (e.g., pick-up basketball or street hockey) in the past 7 days:

Sport 1 _____

Which days did you play this sport: Select all that apply (Monday to Sunday)

How many hours did you play on average each day ?

How many total hours of this sport did you play in the past 7 days ?

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during play in this sport this past 7 days from 100% to 0%: _____%

Sport 2 _____

Which days did you play this sport: Select all that apply (Monday to Sunday)

How many hours did you play on average each day ?

How many total hours of this sport did you play in the past 7 days ?

Think of 100% as the most effort you have ever put into an activity and 0% as no effort at all

Rate your average effort during play in this sport this past 7 days from 100% to 0%: _____%

Appendix C

Round Three version of the Sport Exposure Scale

The Sport Exposure Scale: Historical

We are going to ask you a series of questions about your previous sport participation. We will be asking you about three types of participation:

Practice is *structured, coach-led, activities, designed to improve performance (e.g. basketball practice where a coach runs drills)*

Competition is *structured, coach present activities designed to test performance (e.g. tournaments, meets games, matches etc.)*

Historical Practice

We want to understand the amount of organized sport practice you engaged in during your sport participation. *Remember, practice is structured, coach-led, activities, designed to improve performance (e.g. basketball practice where a coach runs drills)*

At what age did you begin your participation in organized sports? _____

Beginning at the above age, fill out the following section for every sport you participated in. For each subsequent year of age, up to and including your current age, complete the questions again, detailing each sport you participated in. Please, fill out every age you participated in organized sport and every sport you participated in.

Age ____ How many organized sports were you practicing in at this age_____

Sport 1 _____(e.g. Soccer)

Which months were you practicing in this sport? Select all that apply (Jan to Dec)

How many days per week were you practicing? (select) 1-7

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Sport 2 _____(e.g. Basketball)

Which months were you practicing in this sport? Select all that apply (Jan to Dec)

How many days per week were you practicing? (select) 1-7

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Age ____ How many organized sports were you practicing in at this age?_____

Sport 1 _____(e.g. Soccer)

Which months were you practicing in this sport? Select all that apply (Jan to Dec)

How many days per week were you practicing? (select) 1-7

How many practices did you have on average each day?_____

How many hours on average was each practice?_____

Notes to explain variation (e.g., 2-a-days for one month then 1 a day for the others)

Historical Competition

We want to understand the amount of competition you have engaged in during your sport participation. *Remember, competition is structured, coach present activities designed to test performance (e.g. tournaments, meets games, matches etc.)*

Same as above, beginning with the first age you began participating in competitions in sport fill out the following section for every sport you participated in. For each subsequent year of age, up to and including your current age, complete the questions again, detailing each sport you were competing in. Please, fill out every age you participated in organized sport and every sport you participated in.

Age_____

Sport 1_____

What level were you competing at ?

Which months did you have competitions? Select all that apply (Jan to Dec)

How often did you have competitions?

Weekly Several times per month Monthly Less than once per month Once per year

Sport 2_____

Which months did you have competitions? Select all that apply (Jan to Dec)

How often did you have competitions?____

Weekly Several times per month Monthly Less than once per month Once per year

Age_____

Sport 1_____

What level were you competing at ?_____

Which months did you have competitions? Select all that apply (Jan to Dec)

How often did you have competitions?

Weekly Several times per month Monthly Less than once per month Once per year

The Sport Exposure Scale: Current

We are going to ask you a series of questions about your current sport participation. We will be asking you about three types of participation:

Practice is structured, coach-led, activities, designed to improve performance (e.g. basketball practice where a coach runs drills)

Competition is structured, coach present activities designed to test performance (e.g. tournaments, meets games, matches etc.)

Play is unstructured, peer-led sport activities designed for fun (e.g. pickup basketball or street hockey)

Current Practice

Think about more recent practice experiences you've had. *Remember, practice is structured, coach-led, activities, designed to improve performance (e.g. basketball practice where a coach runs drills)*

The following section refers to structured sport practices in the past 7 days. If you are currently playing multiple sports, please fill it out for each sport.

Sport 1 _____

Which days did you participate in this sport? Select all that apply (Monday to Sunday)

How many organized practices of this sport did you have per day?_____

How many hours on average was each practice of this sport? _____

How many hours total of structured practice did you do in this sport? _____

Is this a typical training week for you (select one) Yes /No

If "No", was this week less or more than a typical week ? Less / More

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during practices in this sport over the past 7 days from 0% to 100%: _____%

Sport 2_____

Which days did you participate in this sport? Select all that apply (Monday to Sunday)

How many organized practices of this sport did you have per day?_____

How many hours on average was each practice of this sport? _____

How many hours total of structured practice did you do in this sport? _____

Is this a typical training week for you (select one) Yes /No

If "No", was this week less or more than a typical week ? Less / More

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during practices in this sport over the past 7 days from 0% to 100%: _____%

Current Competition

Now I want you to focus on your competitions in the past 7 days. *Remember, competition is structured, coach present activities designed to test performance (e.g. tournaments, meets games, matches etc.)*

Sport 1_____

What level are you competing at?_____

How many tournaments or meets did you have in this sport in the last 7 days ?

Which days were your competitions in this sport? Select all that apply (Monday to Sunday)?

How many games, matches, races, or events did you participate in? _____

How much time on average were you actively competing? (e.g. playing time)_____

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during competitions in this sport over the past 7 days from 0% to 100%: _____%

Sport 2_____

What level are you competing at ?_____

How many tournaments or meets did you have in this sport in the last 7 days ?

Which days were your competitions in this sport? Select all that apply (Monday to Sunday)?

How many games, matches, races, or events did you participate in? _____

How much time on average were you actively competing? (e.g. playing time)_____

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during competitions in this sport over the past 7 days from 0% to 100%: _____%

Current Play

Finally, I want you to focus on your participation in sport play in the past 7 days. Play is *unstructured, peer-led sport activities designed for fun (e.g. pickup basketball or street hockey)*

Sport 1 _____

Which days did you play this sport: Select all that apply (Monday to Sunday)

How many hours did you play on average each day ?

How many total hours of this sport did you play in the past 7 days ?

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during play in this sport over the past 7 days from 0% to 100%: _____%

Sport 2 _____

Which days did you play this sport: Select all that apply (Monday to Sunday)

How many hours did you play on average each day ?

How many total hours of this sport did you play in the past 7 days ?

Think of 100% as the most physical intensity you have ever put into any activity and think of 0% as no physical intensity

Rate your average physical intensity during play in this sport over the past 7 days from 0% to 100%: _____%

Appendix D
Email Invitation to Participate

Subject Line: Participation in Research Study

Hello Dr. x,

My name is Alexandra (Sandy) Mosher and I am a PhD candidate with Joe Baker and Jessica Fraser-Thomas at York University in Ontario Canada. My dissertation aims to develop a measure of overall sport exposure. For one of my studies, I am attempting to test elements of validity of my scale (The Sport Exposure Scale) via a Delphi survey.

As an expert in the field of youth sport, I am hoping to recruit you to take part in my Delphi Study. If you agree to participate, you will be asked to provide feedback on the "Sport Exposure Scale" three separate times. Each round will have a two-week window for completion. I know you are a busy individual and I appreciate you considering this. I anticipate each round of feedback should take about a half hour of your time. Our goal is to design a scale capable of measuring the breadth and depth of sport exposure in youth. Having experts like you provide feedback will ensure the Sport Exposure Scale provides a useful method for capturing sport participation.

Below is the link to the Delphi survey. All information will be collected anonymously and presented via average rating or anonymous comment.

https://www.surveymonkey.com/r/CZLFV8R

If you choose to participate in the first round, I will email you again when it is time for the second and third rounds.

I would really appreciate your help on this project and thank you for your time.

Best,
Sandy

Appendix E

Online Informed Consent Form

Date: April– June, 2022

Study Name: Validating the Sport Exposure Scale: A Delphi approach

Investigator: Alexandra Mosher, Doctoral Student. School of Kinesiology & Health Science, York University, Chemistry Building, Room 158, moshera@yorku.ca

Purpose of the Research: The purpose of this project is to validate the Sport Exposure Scale. The purpose of the scale is to measure the duration, frequency, and intensity of sport participation. To validate the scale, we will use a Delphi approach, which involves sending the proposed scale to experts in the field and having them provide feedback. For instance, experts could identify items to remove or add to the scale. There will be three rounds of feedback. For each round, feedback will be collected using a survey provided via an online platform (SurveyMonkey).The objective after the three rounds is to arrive at a finished scale that experts agree measures sport exposure in a valid and useful way**.** Results will be presented in the principal investigator's dissertation as well as in future publications and presentations.

What You Will Be Asked to Do in the Research: You will be asked to help validate the Sport Exposure Scale via an online platform (SurveyMonkey) First you will be given the proposed Sport Exposure Scale and asked to read it through in full. Next you will be asked to indicate any items you feel should be removed, providing your rationale. You will also be asked if there are any items you feel should be added or were missed, again providing your rationale. Finally, you will be asked to indicate the clarity of each item using a three-point Likert scale (i.e., clear, somewhat clear, unclear). At the end of the scale, you will be asked to include any additional comments or concerns. All information will be collected anonymously. The PI will then revise the scale according to the feedback collected and the survey will be sent back to you for the next round. The estimated time commitment is one hour for each round (i.e., 3 hours total).

Risks and Discomforts: We do not foresee any risks or discomfort from your participation in the research.

Benefits of the Research and Benefits to You: Currently there is no valid way to measure sport exposure in athletes. This means we are unable to predict or prevent negative outcomes associated with sport exposure. Developing a valid measure of sport exposure is an important first step in being able to understand the mechanism(s) behind negative outcomes of sport participation and to develop policy/programs designed to avoid triggering the mechanism.

Through your participation, you will help to create a new scale that will allow for more accurate measurement of sport exposure.

Voluntary Participation and Withdrawal: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer, to stop participating, or to refuse to answer any questions will not influence the nature of the ongoing relationship you may have with the researchers or study staff, or the nature of your relationship with York University either now, or in the future.

In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality:

Participants will not be matched to their responses and all responses will be anonymous. The online platform provides the ability to collect information anonymously. All information will be stored on a password protected computer that only the PI has access too. Consent forms will be stored on a password protected external hard drive. The external hard drive will be stored in a locked desk drawer that only the PI can access. Data will be saved for three years (01/01/2025) at which time data will be deleted from the computer and the trash emptied. Data will also be deleted from the external hard drive and the trash emptied.

Unless you choose otherwise, all information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Confidentiality will be provided to the fullest extent possible by law.

The researcher(s) acknowledge that the host of the online survey (SurveyMonkey) may automatically collect participant data without their knowledge (i.e., IP addresses). Although this information may be provided or made accessible to the researchers, it will not be used or saved without participant's consent on the researchers' system. Further, because this project employs e-based collection techniques, data may be subject to access by third parties as a result of various security legislation now in place in many countries and thus *the confidentiality and privacy of data cannot be guaranteed during web-based transmission.*

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact the PI at moshera@yorku.ca or her supervisors, Joseph Baker at bakerj@yorku.ca or Jessica Fraser-Thomas at jft@yorku.ca and/or by phone at 416 736 2100 Ext. 20952. You may also contact the Graduate Program in Kinesiology and Health Science at kahs@yorku.ca and/or 416-736-5807.

This research has received ethics review and approval by the Delegated Ethics Review Committee, which is delegated authority to review research ethics protocols by the

Human Participants Review Sub-Committee, York University's Ethics Review Board, and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, Kaneff Tower, York University (telephone 416-736-5914 or e-mail ore@yorku.ca).

Legal Rights and Signatures:

I_____ consent to participate in "Validating the Sport Exposure Scale: A Delphi approach" conducted by Alexandra Mosher. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

Participant Name	**Date**
(To be filled in online)	**(To be filled in online)**