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Influence of Sport Specialization on Athletic Performance and Injury Risk in Collegiate Swimmers

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ABSTRACT

To assess the effect of swimming specialization on performance and injury risk in collegiate swimmers, thirty collegiate swimmers (20.1 ± 0.9 years [18.5 – 22.3 years]) were asked to complete an anonymous survey to provide information regarding their sports participation history, success in swimming, and the occurrence and quantity of swimming-related injuries. Specialization status was determined by the swimmers claiming they had specialized and by the number of months (≥ 8 months) they participated in swimming each year. Correlation analysis revealed several significant ($p < 0.05$) relationships between all determinants of specialization, swimming success, and swimming injuries. Stepwise regression analysis revealed that the age at which an athlete specialized was the best predictor of the occurrence of a swimming-related injury ($R^2 = 0.34$, $p = 0.004$) and the number of injuries sustained ($R^2 = 0.25$, $p = 0.019$). Years of competitive swimming experience was the best predictor ($p < 0.008$) of performance in the freestyle stroke at 50-yards ($R^2 = 0.47$), 100-yards ($R^2 = 0.53$), and 500-yards ($R^2 = 0.43$), the back stroke at 200-yards ($R^2 = 0.41$), and the 100-yard butterfly ($R^2 = 0.55$). The age at which the athlete specialized in swimming was the best predictor of the 200-yard individual medley ($R^2 = 0.30$, $p = 0.037$). Our data suggests that swimming specialization may be beneficial for success in select swimming events but is not as important as years of competitive experience and may also lead to a greater number of swimming-related injuries.

Keywords: injury prevention, youth sports, early diversification

Sport specialization occurs when an athlete has made the decision to concentrate on a single sport for competitive purposes. While several definitions may exist, athletes are generally considered specialists if they decide to quit participating in other sports, devote at least eight months per year to the sport, or both (Bell et al., 2016; Myer et al., 2015). Specialization has become a popular trend within youth athletics, particularly amongst swimmers. Athletes who specialize typically compete on multiple teams within the same sport throughout the year, and as a result, accumulate more practice hours and guidance from coaches (Baker, Horton, Robertson-Wilson, & Wall, 2003; Brenner, 2016). These deliberate practices may enhance development of sport-specific skills and potentially lead to greater athletic success in the specific sport. Teams and coaches may promote specialization to increase the athletes' chances of winning, obtaining a scholarship or financial award, or being invited to elite camps, clinics, and off-season programs. However, specialization may also increase the incidence of "burnout"

(i.e., decreased interest in a specific sport) and the risk of an overuse injury (Brenner, 2016; Malina, 2010; Myer et al., 2015). Further, it may inhibit the development of athletic traits that are not the primary focus of the specific sport yet still important for success, such as intrinsic motivation. Less than 12% (3.3-11.3%) of high school athletes compete in the National Collegiate Athletic Association (NCAA). Of those athletes only 1% receive an athletic scholarship, and 0.5% or less compete at the professional level (Brenner, 2016). Given the likelihood that obtaining elite-level status is small, the pressure placed on youth athletes to succeed by focusing on a single sport appears to be overwhelming and potentially unnecessary. Thus, it is unclear whether specialized athletes experience greater sports-specific performance improvements over individuals who participate in multiple sports.

Children who specialize in a sport are thought to surpass the performance levels of their peers due to the refinement of sport-specific skills, potential of improved performance, better preparedness, and elimination of injury from other activities (Hill & Hansen, 1988; Hill & Simons, 1989; Malina, 2010). In one survey of late-teenaged soccer players, those who were chosen as professionals began supervised practice at 5 years old, competing at 7 or 8 years old, and elite training at 10 to 11 years old. Their highly skilled, but non-professional counterparts did not begin supervised soccer practices until the age of 6, and accumulated fewer hours in soccer (Livingston, Schmidt, & Lehman, 2016). However, simply specializing in a sport does not guarantee success. Studies supporting specialization emphasize the importance of accumulated practice hours and the structure of practices. To obtain expert level status in a domain, Macnamara, Hambrick, and Oswald (2014) suggested that one must have at least 10,000 hours of practice gathered over time, while Baker et al. (2003) stated that expert status is achieved after a minimum of 10 years of training. A key component to these hypotheses is the structure of the practices; that is, practice time should be deliberate. Deliberate practices are motivated by the potential for great success, and require more effort and attention from the participant (Baker et al., 2003).

Expert and specialized swimmers tend to train at a more intense level and possess the technique for faster swimming results. For example, high stroke length is believed to be indicative of stroking efficiency and could distinguish between expert and recreational swimmers (Schnitzler, Seifert, Alberty, & Chollet, 2010). Likewise, amongst highly trained athletes, the effect of specialization on performance is apparent. Previously, a greater increase in the propulsive phase of a swimming stroke was found in elite swimmers compared to triathletes. The triathletes also had a greater recovery time in the stroke at high velocities, greater vertical and lateral displacement, and lower stroke symmetry, which can slow down performance times and increase risk of injury (Millet, Chollet, Chalies, & Chatard, 2002). These findings suggest that increased focus on swimming technique may improve swimming performance, and thus, specialization may be beneficial for success in swimming.

Early specialization does not guarantee success. Moesch, Elbe, Hauge, and Wikman (2011) concluded that early adroitness of a sport did not correlate with long-term success. In that study, a comparison between the practice habits of elite and near-elite athletes indicated that elite athletes spent fewer hours per week practicing at a younger age (12 and under), the same amount of time practicing by the age

of 18, and more practice hours by the age of 21. In another study, it was reported that out of the 35,000 students at a Russian sports school, only 0.14% (n = 49) reached a high-level status (Myer et al., 2016). Most importantly, however, it was observed that athletes who compete in the NCAA at the Division I level were more likely to have competed in multiple sports throughout their high school athletic career. In fact, the first organized sport that these athletes ever played was often different from the sport that they competed in for the NCAA (Brenner, 2016). When looking at the NCAA Division I athletes at a single university, 70% of the athletes did not specialize until 12 years of age, which was later than their non-NCAA athlete counterparts (Myer et al., 2016). These findings suggest that later specialization and early diversification in sports may be the better option for a young athlete's career and health.

Specialization in sports also appears to increase the risks associated with social isolation, overdependence, burnout, injury, and compromised growth and maturation (Brenner, 2016; Hill & Hansen, 1988; Hill & Simons, 1989; Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2013; Malina, 2010; Myer et al., 2015). Practicing more than 16 hours a week increases the athletes' chances of obtaining an overuse injury (Myer et al., 2015). Once an athlete is injured, lower levels of physical activity and mental health have been reported within the year of injury occurrence. This decrease in physical activity can continue into adulthood. Brenner (2016) suggests that 46% to 50% of athletic injuries are due to overuse injuries. Specialization may also lead to musculoskeletal and psychological complications, the female athlete triad, along with iron, calcium, and vitamin D deficiencies (Hill & Hansen, 1988; Malina, 2010). Some of the social consequences associated with specialization include arrested behavioral development, socially maladaptive behaviors, performance pressures, lack of autonomy, psychological stress, and premature withdrawal from the sport (Jayanthi et al., 2013; Myer et al., 2015).

Exposing athletes to a variety of sports that focus on fun (i.e. early diversification), tends to be more enjoyable for young athletes, reduces the risk of burnout, and exposes them to a reduced risk of injury (Moesch et al., 2011). Playing multiple sports integrates programs that strengthen and condition children's bodies for health- and skill-related fitness while creating a positive social environment (Myer et al., 2016). It also develops transferable physical and social skills and the intrinsic motivation needed to become a highly motivated, self-determined, and committed adult athlete (Baker, 2003; Moesch et al., 2011). In fact, early diversification has been associated with longer competitive athletic careers and increased longevity of participation in leisurely physical activity compared to early specialization (Côté, Lidor, & Hackfort, 2009). For instance, since the adoption of the age eligibility rule (i.e., the age of a player limits the number of tournaments they can compete in a year), the average player's career has been increased by two years and the rate of premature dropout has decreased from 7% to 1% (Baker et al., 2003). Thus, a variety of athlete development models have been suggested to limit premature specialization. These architypes are designed to develop fundamental skills while creating a positive experience before progressing to more advanced skills and learning to train, typically, not until high school or approximately 15 years of age (Brenner, 2016; Casto & Edwards, 2016). Eventually, older adolescent or adult athletes will shift mindsets towards winning and excelling at high performance levels

(Brenner, 2016). Nevertheless, little is known regarding the success of this strategy across a variety of sports. Therefore, the purpose of this research was to determine the influence of sport specialization during childhood on success and the occurrence of injury in collegiate swimmers.

Methods

Participants

Coaches from 72 colleges and universities in the southeastern United States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia) received an introductory email describing the present investigation. Coaches were requested to forward the introductory email to members of their respective swimming teams. The introductory email also contained a link to an anonymous survey hosted by a password-protected website via Google Docs. The survey asked swimmers to provide information regarding personal athletic history, swimming performance times, and injuries related to swimming competition. Relationships were determined between athletic history and swimming performance, as well as between athletic history and injuries sustained.

Thirty collegiate swimmers, seven males and 23 females (20.1 ± 0.9 years [18.5 – 22.3 years]), volunteered to participate in this investigation. Following an explanation of all procedures, risks, and benefits, each participant provided his or her informed consent to participate in the study by completing and submitting the online survey. All participants were current members of the swim team for their respective school and competed at the NCAA level (i.e. Division I [D1], Division II [D2], or Division III [D3]). This investigation was approved by the Kennesaw State University Institutional Review Board.

Protocol

The online survey is presented in Table 1. Briefly, the survey requested information regarding the experiences of the athlete in swimming and other sports from two types of dependent variables: 1) swimming success, and 2) occurrence and number of injuries sustained while participating in (or practicing for) swimming competition. Swimming success was defined by the competitive level of the athlete in college, and best personal swimming performance times in freestyle (FS; 50 - 1650 yards), backstroke (BKS 100 – 200 yards), butterfly (BFS; 100 – 200 yards), breaststroke (BRST; 100 – 200 yards), and the individual medley (IM; 200 – 400 yards). Additionally, qualifying for Olympic Trials and the Olympics were considered measures of success.

Table 1. *Online Survey*

Section	Description
Athletic participation	
Questions 1 - 4	Consent, age, and sex.
Questions 5 - 19	History with swimming including the age they learned to swim, competitive level in college, and best performance times in 50 freestyle, 100 freestyle, 200 freestyle, 500 freestyle, 1650 freestyle, 100 backstroke, 200 backstroke, 100 butterfly, 200 butterfly, 100 breaststroke, 200 breaststroke, 200 individual medley, and 400 individual medley.
Questions 20 - 23	Have you qualified for Olympic Trials in an individual event? How many individual events did you qualify for Olympic Trials in, during your last/most current season? Have you qualified for the Olympics in an individual event? How many individual events did you qualify for the Olympics in, during your last/most current season?
Questions 24 - 28	How many years have you competed in swimming? Have you stopped participating in any other sports to focus on swimming? At what age did you discontinue other sports to focus on swimming? Have you sustained any injuries that have caused you to miss at least one week of practice time or a competitive event while participating in this sport? How many injuries meeting the criteria above have you sustained from this sport? (If an injury is reoccurring, please count it as one single injury.)
Competitive swimming by grade level	
Questions 29 - 65	Questions asking if the athlete had competed in swimming that grade year, how many months they devoted to swimming that year, the types of teams they participated on, and if they competed in other sports during that year. Questions were repeated from third grade to senior year of high school.
Athletic participation in other sports	
Questions 69 - 124	Questions asking the athlete if they had competed in this sport, what age they began to compete, what age they discontinued the sport, and if they discontinued the sport to focus on swimming. Sports included in survey: football, cheerleading, baseball/softball, basketball, volleyball, lacrosse, soccer, tennis, wrestling, cross country, track and field, and other.

Our primary independent variable, swimming specialization, was characterized by the age at which the athlete learned how to swim, their swimming competition experience (in years), and if they had ever quit other sports to specialize in swimming. The athlete's decision to specialize was determined both explicitly and implicitly. If the athlete answered "Yes" to quitting other sports to specialize in swimming, they were asked to indicate the age they decided to focus on swimming. Additionally, the athletes were considered swimming specialists based on the number of months

they devoted to swimming from 3rd through 12th grade. Athletes were considered specialists if they indicated that they had devoted eight months or greater to swimming within a single year (Bell et al., 2016). For analysis, we identified the grade in which the athlete became a specialist, the number of years of specialization, and the grade (up to 12th) they stopped being a specialist. Further, the number of years that the athlete competed in multiple sports throughout the entire specialization period, specifically in high school, were also identified.

Statistical Analysis

Relationships were examined between all dependent variables (swimming success, injury history) and all swimming experience and specialization variables for all participants. Pearson's (r) product-moment correlation coefficients were calculated for all relationships containing continuous-normal variables (e.g., experience, specialization period, performance scores, and quantity of injuries), whereas Spearman's Rho (ρ) correlation coefficients were used to assess relationships containing nominal (e.g., decision to specialize, incidence of swimming-related injury) and ordinal (e.g., collegiate level) variables. Subsequently, the contribution of each significantly-related independent variable to swimming success and injury was then evaluated using a stepwise regression analysis. A criterion alpha level of $p \leq 0.05$ was used to determine statistical significance. Statistical Software (v.24.0, SPSS Inc., Chicago, IL) was used for all analyses.

Results

A table reporting the mean performance scores for respondents in the events they swam for the 2016-2017 season is presented in Table 2.

Table 2. *Performance scores for each event [mean ± standard deviation (range)]*

	Males (n = 7)	Females (n = 23)	Total (n = 30)
Freestyle (sec)			
50 yards	21.5 ± 0.8 (20.7 - 22.7)	25.9 ± 2.0 (22.3 - 30.6)	24.8 ± 2.6 (20.7 - 30.6)
100 yards	46.4 ± 0.9 (45.6 - 47.8)	57.1 ± 5.3 (48.4 - 70.8)	54.6 ± 6.5 (45.6 - 70.8)
200 yards	106 ± 2 (103 - 110)	125 ± 12 (109 - 152)	120 ± 13 (103 - 152)
500 yards	275 ± 12 (263 - 287.1)	348 ± 41 (290 - 430)	337 ± 46 (263 - 430)
1650 yards	980 ± 55 (917 - 1020)	1140 ± 114 (1005 - 1352)	1106 ± 123 (917 - 1352)
Backstroke (sec)			
100 yards	51.9 ± 3.0 (48.1 - 56.3)	67.5 ± 6.7 (55.8 – 78.0)	62.8 ± 9.4 (48.1 – 78.0)
200 yards	114 ± 10 (107 - 126)	142 ± 12 (122 - 166)	132 ± 18 (107 - 166)
Butterfly (sec)			
100 yards	50.9 ± 1.7 (49.5 - 53.6)	63.6 ± 7.0 (52.4 - 73.4)	59.6 ± 8.4 (49.5 - 73.4)
200 yards	118 ± 5 (112 - 123)	144 ± 18 (124 - 173)	136 ± 20 (112 - 173)

Breaststroke (sec)			
100 yards	61.7 ± 4.4 (58.2 - 68.2)	78.4 ± 10.5 (66.3 – 105.0)	74.5 ± 11.8 (58.2 – 105.0)
200 yards	145 ± 22 (130 - 160.1)	167 ± 14 (146 - 185)	163 ± 17 (130 - 185)
Individual Medley (sec)			
200 yards	120 ± 3 (115 - 124)	142 ± 14 (125 - 178)	134 ± 15 (115 - 178)
200 yards	254 ± 23 (229 - 273.3)	280 ± 19 (241 - 304)	275 ± 22 (229 - 304)

Note: sec= seconds

Collegiate Competitive Level

Responses were obtained from swimmers at the D1 (n = 2), D2 (n = 11), and D3 (n = 17) levels of competition. A negative relationship was found between the competitive level of the swimmers in college and the number of years of competitive swimming experience (ρ = -0.45, p = 0.015), whereas positive relationships were found between the competitive level of swimmers and the age they decided to focus on swimming (ρ = 0.52, p = 0.012). Of these, stepwise regression analysis revealed the number of years of competitive swimming experience to be the best predictor of competitive level in college (R^2 = 0.23, p = 0.025).

Freestyle Events

The relationships between performance in the free-style swimming events and measures of swimming experience, specialization, and sports performance are presented in Table 3. Negative relationships were found between FS (50, 100, and 500), the number of years of competitive swimming experience (r = -0.68, to -0.76, $p < 0.001$) and the numbers of years spent specializing (r = -0.53 to -0.66, $p < 0.01$), as well as between FS_{50} and the grade the athlete stopped specializing (r = -0.44, p = 0.032). Positive relationships were found between FS (100 and 500) and the grade the athlete became a specialist (r = 0.48 to 0.60, $p < 0.032$). Of these, stepwise regression analysis indicated that the years of competitive swimming experience was the best predictor (p = 0.008) for FS_{50} (R^2 = 0.47, SEE = 1.83 sec), FS_{100} (R^2 = 0.53, SEE = 4.21sec), and FS_{500} (R^2 = 0.43, SEE = 35.6 sec). No other significant relationships were observed.

Non-Freestyle Events

The relationships between performance in non-freestyle swimming events and measures of swimming experience, specialization, and sports performance are presented in Table 3. Negative relationships were found between years of swimming competition experience and BKS_{200} (r = -0.63, p = 0.022), BFS_{100} (r = -0.65, p = 0.003), $BRST_{100}$ (r = -0.50, p = 0.039), and IM_{200} (r = -0.58, p = 0.008). Additionally, the grade in which an athlete decided to quit specializing was negatively related to BKS_{200} (r = -0.58, p = 0.050). No other significant relationships were observed. According to stepwise regression analysis, years of swimming competition experience was the best predicator of BKS_{200} (R^2 = 0.41, SEE = 12.7 sec, p = 0.034) and BFS_{100} (R^2 = 0.55, SEE = 5.78 sec, p = 0.001), while the age the athlete decided to focus on swimming

was the best predictor of IM_{200} (R^2 = 0.30, SEE = 10.3 sec, p = 0.037).

Olympic Trials and Olympic Qualifiers

Two participants reported qualifying for the Olympic Trials with one qualifying in three events and the other in a single event. However, neither of these individuals qualified for the Olympics. Due to this small sample size, the relationships between swimming specialization and success at the national and international levels could not be determined.

Injuries

The relationships between swimming-related injury history and measures of swimming experience, specialization, and sports performance are presented in Table 3. Twenty respondents reported sustaining a swimming-related injury (1.67±1.60 injuries) over the course of their career. Among all variables the age an athlete decided to focus on swimming was related to the occurrence of a swimming-related injury (ρ = 0.64, p < 0.001) and the number of injuries sustained (r = -0.53, p = 0.010). Participating in multiple sports during high school was also positively related to the occurrence of a swimming-related injury (ρ = 0.43, p = 0.024) but not the number of injuries sustained. Stepwise regression analysis indicated that 34.4% of variance in the occurrence of an injury (p = 0.004) and 24.6% of variance in the number of injuries sustained (SEE = 1.52 injures, p = 0.019) was best predicted by the age a swimmer decided to focus primarily on swimming.

Table 3. *Relationships between measures of swimming experience, specialization, sports participation, and swimming performance [correlation coefficient (p-value)]*

	Experience		Stated Specialization		Implied Specialization			Participation in multiple sports	
	Swim	Compete	Decision	Age	Grade started	Grade stopped	Time span	As specialist	In High School
Freestyle									
50 yards	0.01 (0.994)	-0.68 (0.001)	0.23 (0.268)	0.29 (0.215)	0.39 (0.062)	-0.44 (0.032)	-0.53 (0.008)	0.20 (0.361)	0.17 (0.420)
100 yards	-0.01 (0.957)	-0.71 (0.001)	0.09 (0.679)	0.30 (0.195)	0.48 (0.018)	-0.26 (0.226)	-0.55 (0.006)	0.32 (0.128)	0.33 (0.120)
200 yards	-0.01 (0.980)	-0.32 (0.147)	0.15 (0.520)	0.26 (0.340)	0.23 (0.328)	-0.27 (0.249)	-0.29 (0.223)	0.08 (0.751)	0.29 (0.224)
500 yards	0.04 (0.866)	-0.76 (0.001)	0.02 (0.940)	0.26 (0.348)	0.60 (0.005)	-0.39 (0.092)	-0.66 (0.002)	0.19 (0.435)	0.15 (0.530)
1650 yards	0.27 (0.359)	0.39 (0.168)	0.15 (0.606)	-0.31 (0.351)	-0.46 (0.096)	-0.02 (0.960)	0.37 (0.191)	0.07 (0.807)	-0.18 (0.541)
Backstroke									
100 yards	0.30 (0.228)	-0.05 (0.850)	-0.09 (0.701)	-0.14 (0.632)	0.02 (0.932)	0.02 (0.951)	-0.02 (0.954)	0.19 (0.470)	-0.01 (0.967)
200 yards	0.02 (0.938)	-0.63 (0.022)	-0.51 (0.065)	0.22 (0.485)	0.38 (0.221)	-0.58 (0.050)	-0.52 (0.080)	0.15 (0.653)	-0.22 (0.495)
Butterfly									
100 yards	-0.14 (0.560)	-0.65 (0.003)	-0.25 (0.301)	0.23 (0.385)	0.31 (0.214)	-0.09 (0.715)	-0.33 (0.187)	0.32 (0.194)	0.15 (0.547)

200 yards	-0.29 (0.443)	-0.38 (0.317)	-0.41 (0.268)	-0.31 (0.497)	0.24 (0.567)	N/A	-0.24 (0.567)	0.05 (0.907)	-0.36 (0.384)
Breaststroke									
100 yards	-0.16 (0.528)	-0.50 (0.039)	0.21 (0.429)	0.05 (0.869)	0.46 (0.075)	-0.01 (0.962)	-0.46 (0.074)	0.06 (0.835)	0.23 (0.403)
200 yards	-0.52 (0.104)	-0.37 (0.260)	0.45 (0.167)	-0.26 (0.494)	0.25 (0.494)	-0.03 (0.942)	-0.23 (0.515)	0.23 (0.525)	0.40 (0.257)
Individual Medley									
200 yards	-0.18 (0.461)	-0.58 (0.008)	0.22 (0.358)	0.45 (0.084)	0.41 (0.094)	0.01 (0.981)	-0.39 (0.113)	0.39 (0.112)	0.43 (0.077)
400 yards	-0.08 (0.774)	-0.38 (0.185)	-0.17 (0.555)	0.07 (0.819)	0.09 (0.754)	-0.29 (0.323)	-0.19 (0.510)	0.16 (0.597)	0.06 (0.848)
Swimming-related injuries									
Incidence	0.22 (0.253)	-0.05 (0.818)	-0.06 (0.770)	0.64 (0.001)	0.25 (0.204)	-0.01 (0.962)	-0.19 (0.337)	0.07 (0.733)	0.43 (0.024)
Quantity	-0.30 (0.121)	0.29 (0.132)	0.05 (0.814)	-0.53 (0.010)	-0.37 (0.058)	0.01 (0.949)	0.35 (0.071)	-0.14 (0.472)	-0.36 (0.067)

Discussion

This study surveyed the athletic participation history of collegiate swimmers to determine if early swimming specialization leads to success, injury, or both. The data suggest that the best predictor for swimming success was the number of years a swimmer had competed in swimming, while age and number of years of specialization were also strong predictors. Specifically, swimmers who had more experience in swimming competition and those who focused on the sport at an earlier age performed better. However, early specialization also led to more swim-related injuries. These findings suggest a potential benefit of early specialization albeit at the risk of sustaining more injuries. The data coincide with previous studies on the possible advantages and consequences associated with sport specialization. However, we examined a very specific population and investigated success and injury within the same study.

Sports specialization had a positive effect on performance for freestyle and backstroke, but was not as important as years of competitive experience which helped all four strokes. Specialization may be beneficial because athletes who specialize accumulate more detail-oriented and focused practices, and thus refine their technique, which is likely to improve performance (Macnamara, Hambrick, & Oswald, 2014). However, according to the data, the length of time an athlete was exposed to competitive swimming was more indicative of success than being a specialist. It is possible that repeated exposure to physical activity (e.g., years of practices or competition) induces neurological adaptations (Del Olmo, Reimunde, Viana, Acero, & Cudeiro, 2006), resulting in improvements in technique (e.g., stroke length, pacing ability, starts, and turns) over time. Furthermore, although the competitive environment may be stressful (Arruda et al., 2014; Casto & Edwards, 2016), the exposure would likely occur over a much shorter duration throughout the year compared to that of a specialist (Brenner, 2016; Jayanthi et al., 2013). Though speculative, gradual exposure to intense practices and elite competition could prolong the swimmer's career and still allow them to

be successful. Thus, an investigation into specific practice habits (e.g., frequency, intensity, duration), coaching quality, and their relation to success may be warranted.

In addition to being influential to performance, specialization age was also related to the likelihood of and the amount of swim-related injuries. Competitive swimmers may swim over 10,000 meters in a day (Costill et al., 1991), and practices appear to be the likeliest place where injuries may occur (Wolf, Ebinger, Lawler, & Britton, 2009). Though not investigated in the present study, the repetitive motion occurring over these long distances may have contributed to the occurrence of injury and possibly caused some overuse injuries. It is also possible that the greater number of injuries sustained may simply be a function of the longer period of specialization providing more opportunities for injuries to occur. This hypothesis may not be limited to specialization alone. The data also suggested that participation in multiple sports was related to the occurrence of a swimming-related injury but not the number of injuries. Thus, sustained competitive activity throughout the entire year may also appear to increase the likelihood that a swimming-related injury will occur. Further research should investigate the types of injuries most likely to occur with swimmers.

Previous classification criteria considers athletes who devote more than eight months in a single year to a single sport as specialists (Bell et al., 2016). In the present study, swimmers were asked to identify the number of months they devoted to swimming from 3rd to 12th grade. Those who reported having devoted eight months or more to swimming were considered specialists during those specific periods. However, the relationships between measures of success and specialization variables created using this classification criteria were limited. Further, this manner of classification resulted in different specialization periods between the age an athlete decided to focus on swimming and the grade the athlete decided to focus on swimming, where the age and grade a swimmer decided to focus on swimming did not correspond to the same time period. It is possible that other factors, such as motivation, may be responsible for this difference. For example, swimming to stay healthy and swimming to compete have different training approaches. Alternatively, these differences may be related to the participant's ability to recall their athletic participation history over an extended period of time. In this study, participants were asked to recall their entire athletic participation history from 3rd through 12th grade. It is possible that discrepancies exist between the participants' self-reported participation and the actual number of participation months in each sport or year, the actual age they decided to specialize, or both. Consequently, a longitudinal approach documenting sports participation from an early age may best answer these hypotheses.

The findings of this study suggest that specialization may benefit swimmers' performance; however, not to the same extent as competitive experiences. Further, specialization also seems to lead to more injuries. Young athletes who are considering swimming should obtain competitive experience early, but specialize later, if at all. Though competing in multiple sports throughout the year may also increase the likelihood of sustaining an injury. Within the sport, coaches should pay attention to swimming technique to ensure that the athlete's stroke does not increase the risk of musculoskeletal injury, and diversify training to help athletes avoid the occurrence of an overuse injury. While accumulating yardage can be advantageous to performance, it can

increase the risk of injury and potentially hinder a future swimming career.

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