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Original Research

Sport Specialization and Fitness and Functional Task Performance Among Youth Competitive Gymnasts

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Context: Gymnastics trains fundamental movement skills but has high rates of early sport specialization. Early specialization is associated with increased injury risk. Gymnasts devote time to developing technical skill, but whether specialization status influences performance is unknown.

Objective: To describe the participation and specialization characteristics of youth club gymnastics participants and determine whether the level of specialization is associated with fitness and functional task performance.

Design: Retrospective cross-sectional study.

Setting: A single gymnastics facility.

Patients or Other Participants: Data on youth gymnasts (n = 131; 84 females, 47 males; age = 10.9 ± 2.9 years, height = 142.14 ± 16.23 cm, mass = 38.15 ± 12.93 kg) were reviewed.

Main Outcome Measure(s): Specialization was assessed using a 3-tiered classification. Fitness measurements consisted of the Gymnastics Functional Measurement Tool, Men's Gymnastics Functional Measurement Tool, and core strength. Functional tasks evaluated hop performance, dynamic balance, and jump-landing technique. Separate analyses of covariance, covaried by age, hours of training, and years of gymnastics participation, were used to identify differences in fitness and functional performance among specialization groups. Pearson product correlations were calculated to evaluate the relationships between training hours per week and years in gymnastics with fitness and functional performance.

Results: Most gymnasts were classified as moderately (50.4%, n = 66) or highly (35.1%, n = 46) specialized. Only 14.5% (n = 19) were classified as having a low level of specialization. Weak to moderate correlations were present between years in gymnastics and most fitness tasks. Moderate to strong correlations were noted between training hours per week and most fitness tasks. Low-specialization gymnasts scored lower on right lower extremity Y-balance ($P = .004$), upper left extremity Y-balance ($P = .033$), and right hop performance ($P = .039$) tests.

Conclusions: Gymnasts reported high proportions of moderate to high specialization, and many exceeded guidelines for hours participating in gymnastics per week. We did not observe clinically meaningful group differences among specialization status and fitness or functional movement tasks, indicating no clear benefit of gymnastics training to the exclusion of other sports for increased performance.

Key Words: fundamental movement skills, adolescent, training, gymnastics

Key Points

- Most gymnasts were classified as moderately or highly specialized, and some gymnasts reported specializing as early as 5 years of age.
- More than half of the gymnasts 11 years of age or older described high levels of weekly training volume that exceeded the recommendations of the American Academy of Pediatrics.
- Most fitness and functional task performance variables did not differ by specialization level when adjusted for age, suggesting that specialization alone did not lead to improved performance outcomes.

Gymnastics is an increasingly popular sport among youths, and United States (USA) Gymnastics, the national governing body for the sport organization, estimated that in 2016, approximately 164 000 youth gymnasts participated in the junior elite and elite programs.[1] Gymnastics demands a high level of specific posturing, movement quality, and coordination with apparatuses to compete and, therefore, gymnasts must use a combination of motor control, balance, and strength. However, due to the skill and apparatus specificity required, concerns have been raised regarding sport specialization and the risk of overuse injury in gymnasts.

Researchers[2] reported that children started participating in gymnastics earlier than other sports (~7 years) and began specializing at the youngest age (~9 years) compared with all other individual and team sports. In conjunction with higher rates of early specialization,

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gymnasts tend to have a higher training volume (~15 hours/week) than athletes in other individual and team sports[2] and often train 12 months of the year, with elite-level female gymnasts training up to 36 hours per week.[3] Peak performance in gymnastics typically occurs during adolescence, and participation in Olympic gymnastics can begin at age 16.[4] As young gymnasts enter gymnastics early and prepare to compete and excel at higher levels, training demands and the required skills increase, which may contribute to tendencies toward earlier specialization.

Due in part to the aerial task demands as well as an increased tendency toward early specialization, rates of injury in club gymnasts are significant, with estimates for acute and overuse injuries of 1.3 and 1.8 injuries per 1000 hours, respectively.[5] An injury estimate over a longer, 3-year study in club gymnasts demonstrated an even higher rate of 2.5 injuries per 1000 hours.[3] Although reinjury in gymnastics occurs at a lower rate than initial injury (0.61 per 1000 hours), these rates warrant attention from an injury-prevention perspective.[3]

In response to the greater risk of overuse injury,[6] as well as burnout and sport dropout, numerous medical organizations[7–9] have raised concerns regarding early sport specialization and promoted models of long-term athlete development that serve as a framework for fostering skills, improving physical literacy, and engaging individuals in physical activity for life.[8,10] Although each development model differed slightly in the specific age ranges and nomenclature for each level, all models suggested a foundational level in which children learn fundamental movement skills and develop physical literacy, as well as rest periods between sports to aid in physical and psychological recovery.

Despite emerging evidence regarding early sport specialization and its association with injury,[6] a gap in the literature exists regarding the advantages and disadvantages of early specialization in sports that have year-round participation, such as gymnastics.[4] One reason that gymnasts participate year-round is to spend time outside of the competition season learning new skills and upgrading the difficulty of their skills.[4] However, whether those specializing in gymnastics have better general fitness and functional movement patterns as a result of these practices is unknown.

Little is known about the sport-specialization characteristics of gymnasts and whether the level of specialization is related to fitness or functional-movement parameters. Thus, we had 2 aims for this study: (1) to describe the participation and specialization characteristics of youth gymnasts and (2) to determine if the level of specialization was associated with fitness and functional-movement tasks. We hypothesized that highly specialized athletes would perform better in gymnastics-specific movements but that foundational-movement patterns would not differ across levels of specialization.

METHODS

Experimental Design

A retrospective analysis was used to evaluate the relationships between sport-specialization characteristics and fitness and functional tasks in youth gymnasts. Data from records on recreational and competitive gymnasts at a local gym were reviewed and collected as part of the annual preseason screening process.

Participants

Preseason athlete assessment data from 131 youth athletes participating in club gymnastics (84 females, 47 males; age = 10.9 ± 2.9 years, height = 142.14 ± 16.23 cm, mass = 38.15 ± 12.93 kg) were reviewed. Gymnasts were included if they participated in artistic gymnastics, acrobatic gymnastics, or tumbling and trampoline. Recruits with existing concussion, musculoskeletal injury, or illness prohibiting them from participating on the day of testing were excluded. The A.T. Still University Institutional Review Board considered this retrospective study exempt from review.

Procedures

Data were collected as part of a single gym's preseason screening during 1 season. Although the gym accommodated athletes of all ages and levels, from baby and toddler tumble classes through collegiate gymnastics teams, the preseason screening was specifically targeted at the middle and high school–aged athletes participating in club-level (eg, Junior Olympic Development and Xcel) gymnastics. Coaches of that athlete cohort reached out to a local physical therapist for the preseason screening to better inform athlete-specific strength and conditioning goals. All screenings were conducted during a single session lasting approximately 45 minutes in length; gymnasts were required to complete a sport-specialization scale, as well as a battery of tests related to fitness measurements and functional movements. Measurements were obtained in a station approach, and the same clinician staffed the same station throughout testing. Screenings were performed during the gymnasts' usual practice times, and the data were used by the physical therapist and coaching staff to determine areas for improvement in fitness and movement capacity. Deidentified data were provided to the research team for analysis.

Sport-Specialization Scale

A 3-tiered classification scale was used to evaluate sport-specialization status.[11] Respondents were asked the following questions: (1) Have you quit other sports to focus on 1 main sport? (2) Do you train more than 8 months out of the year in 1 main sport? (3) Do you consider your main sport more important than other sports? (4) Do you train more than 75% of the time in the primary sport? (5) Do you train to improve skill and miss time with friends as a result? and (6) Do you regularly travel out of state for your primary sport? Responses were binary (*yes* = 1, *no* = 0). Answers to the first 3 questions were summed, and the scores were used to categorize the gymnasts as *low specialization* (0–1 point), *moderate specialization* (2 points), or *high specialization* (3 points).

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Table 1. Preseason Assessment Fitness Components

Task	Targeted Area of Assessment	Procedure	Task Origin
Vertical jump	Power	Gymnast stands with the dominant side facing a wall and jumps for maximum height. Gymnast stands flat footed and reaches upward. The distance between the maximum reach and the height reached during the jump is measured.	GFMT MGFMT
Hanging pike	Strength, flexibility	Gymnast starts in a dead hang position on a horizontal bar. Gymnast then flexes at the hip with the knees extended and attempts to touch the toes to the bar. The number of pikes completed is recorded.	GFMT MGFMT
Shoulder flexion	Flexibility	Gymnast lies prone while holding a dowel in both hands with the shoulders flexed to 90°. Gymnast then flexes the shoulders while maintaining the wrists in neutral position.	GFMT MGFMT
Agility	Agility	Gymnast sprints diagonally on a 12- × 12-m gymnastics floor from 1 corner to the other and back 5 times.	GFMT MGFMT
Pull-up	Strength, endurance	Gymnast starts in a hanging position from a horizonal bar and completes as many pull-ups as possible (from full shoulder extension to the chin clearing the bar).	GFMT MGFMT
Push-up	Strength, endurance	Gymnast starts with the hands shoulder-width apart on a low beam and completes as many push-ups as possible (chest touches a 1-in [2.54-cm]-high block to full elbow extension).	GFMT
Handstand	Strength, endurance, balance	Gymnast starts with the hands on a low beam. Timing starts when the gymnast's feet leave the ground and stops when the hands change positions or any other body part touches the floor. Two trials are completed, and the best time is used.	GFMT MGFMT
Plank (right and left)	Core strength, endurance	Gymnast lies on 1 side with the feet stacked and the elbow directly under the shoulder. The hips are lifted to form a straight line from feet to neck.	NA
Hollow hold	Core strength, endurance	Gymnast lies supine with the arms overhead. The hips and knees are extended in the air. Time in the correct position is recorded up to 1 min.	NA
Double-legged lower down	Core strength, endurance	Gymnast lies supine with the arms across the chest and the legs straight up toward the ceiling. The examiner places 1 hand under the athlete's back. The athlete lies with the back flat and slowly lowers the legs until the spine extends beyond a neutral position. The position of the legs above horizontal (°) is recorded.	NA
Bridge (right and left)	Core strength, endurance	Gymnast lies supine on the ground with the knees bent and feet flat on the ground. Athlete bridges the hips upward to form a straight line from the knees to the neck. Athlete extends 1 knee out straight while maintaining a neutral pelvis. Time in the correct position is recorded up to 1 min.	NA

Abbreviations: GFMT, Gymnastics Functional Measurement Tool; MGFMT, Men's Gymnastics Functional Measurement Tool; NA, not applicable.

Fitness Measurements

Preseason fitness measurements consisted of components of the Gymnastics Functional Measurement Tool (GFMT),[12] Men's GFMT,[13] and additional core-strength measures (Table 1). The GFMT is a series of 10 field-based physical fitness tasks used to assess a gymnast's overall fitness level and has demonstrated appropriate construct validity and test-retest reliability in female gymnasts,[12] whereas the Men's GFMT includes 10 physical fitness tasks specifically developed to assess the physical abilities of male gymnasts.[13] Only data for the fitness tasks completed by both male and female athletes were included for analyses. The raw scores for the following components of the GFMT and Men's GFMT were analyzed: vertical jump (cm), hanging pike test (repetitions), normalized shoulder flexibility test (cm/arm length), agility test (seconds), pull-up test (repetitions), push-up test (repetitions), and handstand test (seconds). Preseason screening also incorporated a series of core-strength measures, including the left and right planks (seconds), double-legged lower-down test (degrees from vertical), left and right planks (seconds), hollow hold (seconds), and left and right bridge (seconds).

Functional Assessments

Functional tasks were also performed during the preseason screening for evaluation of dynamic balance using a more generalized measure as well as a clinical measure of neuromuscular control. These tasks were the right and left single-legged hop-for-distance tests,[14] right and left upper and lower Y-balance tests (normalized to arm or leg length),[15] and the Landing Error Scoring System (LESS) test.[16] A description of each task is provided in Table 2.

Statistical Analysis

We completed a retrospective analysis of the athletes' preseason screening data. Summary descriptive statistics are provided as means ± standard deviations or counts (percentages), as appropriate. Means and 95% confidence intervals, as well as *P* values, are supplied for inferential

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Table 2. Preseason Assessment Functional and Movement Tasks

Task	Targeted Area of Assessment	Procedure
Hop (right and left)	Power	Gymnast stands with the hands behind the back and the toes just behind the starting line. Athlete hops forward and "sticks" the landing. Distance from the start line to the back of the heel on the landing leg is measured. The best of 2 trials is recorded.
Y-balance upper (right and left)	Dynamic postural control	Gymnast is in the push-up position at the center of 3 lines marked by tape on the floor: the anterior line is directly in front, and the 2 posterior lines are 120° from the center line. While maintaining single-arm stance, the gymnast reaches as far as possible in the 3 directions.
Y-balance lower (right and left)	Dynamic postural control	Gymnast places the hands on the hips. Maintaining single-legged balance on the involved side, the athlete reaches forward as far as possible, non–weight bearing. Athlete must return to the start position with control. Distance is recorded to the nearest 0.5 cm. The best of 3 trials is recorded.
Landing Error Scoring System	Neuromuscular control	Gymnast stands on a 30-cm box and jumps a distance approximately half his or her height away from the box and immediately rebounds to perform a vertical jump for maximum height. Trials are recorded using standard digital cameras in the frontal and sagittal planes. A single rater blinded to specialization status retrospectively grades the jump-landing movement quality using the Landing Error Scoring System.

tests. Bivariate Pearson correlations were conducted to estimate the strength of the relationships between both years participating in gymnastics and weekly training hours and fitness and function. Correlation coefficients were categorized as *low* ($r = 0.0$–0.25), *fair* ($r = 0.26$–0.50), *moderate* ($r = 0.51$–0.75), or *good* ($r > 0.75$).[17] Preliminary analyses indicated that age, height, hours of training, and years of gymnastics participation were, generally, correlated with performance on fitness and functional-movement tasks. To determine if the level of specialization was associated with fitness and functional movement, we attempted to control the potentially confounding effects of these 4 variables before evaluating the relationships between specialization and performance. Specialization was first dummy coded and then entered into a multiple linear regression, along with age, height, hours of training, and years of gymnastics participation as predictor variables to evaluate multicollinearity. A separate analysis was conducted with each of the fitness and functional-movement tasks serving as criterion variables. Multicollinearity was evaluated by examining tolerance and the variance inflation factor (VIF) for each equation. The substantial correlation between age and height ($r = 0.88$) yielded unacceptable VIF (>6.0) and tolerance (<0.15) values. Therefore, height was removed from the equations, yielding acceptable VIF (<2.5) and tolerance (>0.35) values for all equations. After removing height, we used a series of generalized linear models to provide final marginal mean estimates and 95% confidence intervals. Pairwise comparisons were conducted using Bonferroni corrections only if the omnibus test was significant. The significance level was set a priori at $P \leq .05$. No adjustments were made for multiplicity. All analyses were conducted in SPSS (version 24; IBM Corp, Armonk, NY).

RESULTS

Participant and Specialization Characteristics

The majority of gymnasts were classified as moderately (50.4%, n = 66) or highly (35.1%, n = 46) specialized, with only 14.5% (n = 19) classified as having a low level of specialization. The percentage of endorsement for each question on the sport-specialization scale by specialization group is provided in Table 3. Compliance with the American Academy of Pediatrics recommendation[8] for training hours per week to not exceed the athlete's age in years is illustrated in Figure 1. Larger positive numbers indicated that the athlete trained that many hours more than his or her age in years. Conversely, lower negative values indicated the athlete trained that many hours less than his or her age in years. When the figure was divided by the median sample age of 11 years, a higher percentage of athletes 11 years of age and older were training a greater number of hours than their age compared with those younger than 11 years (Figure 2).

The gymnasts' demographics by specialization level are presented in Table 4. The low-specialization group was younger and smaller, spent fewer hours per week training, and had been involved in gymnastics for fewer years than the moderate- and high-specialization groups. Overall, 34.4% of gymnasts indicated they were participating with a current injury; however, those percentages did not differ by specialization level ($\chi^2 = .708$, low = 26.3%, moderate = 34.8%, high = 37.0%).

Table 3. Responses to the Specialization Questionnaire Items by Level of Specialization, % (Frequency)

Item	Level of Specialization		
	Low (n = 19)	Moderate (n = 66)	High (n = 46)
Trains more than 75% of time in primary sport	31.6 (6)	95.5 (63)	93.5 (43)
Trains to improve skill and misses time with friends	26.3 (5)	50 (33)	50 (23)
Quit another sport to focus on 1 sport[a]	0 (0)	1 (1.5)	100 (46)
Considers primary sport more important than other sports[a]	0 (0)	98.5 (65)	100 (46)
Regularly travels out of state for primary sport	5.3 (1)	51.5 (34)	45.7 (21)
Trains >8 mo/y in primary sport[a]	63.2 (12)	100 (66)	100 (46)

[a] Denotes questions used to calculate specialization level.

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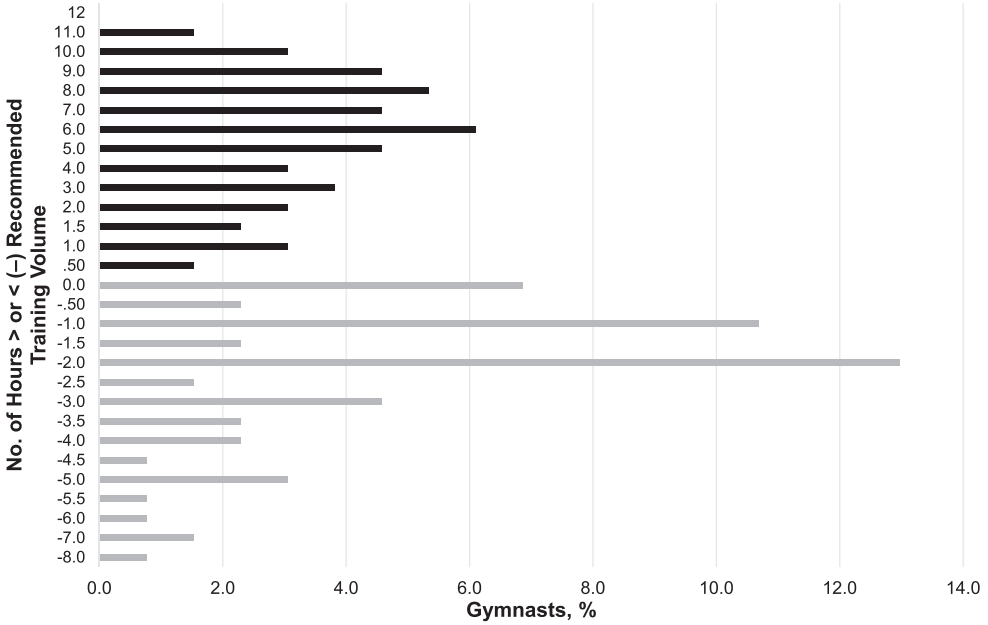

Figure 1. Training volume (hours per week) compared with the American Academy of Pediatrics recommendation[8] that training hours per week should not exceed the athlete's years of age.

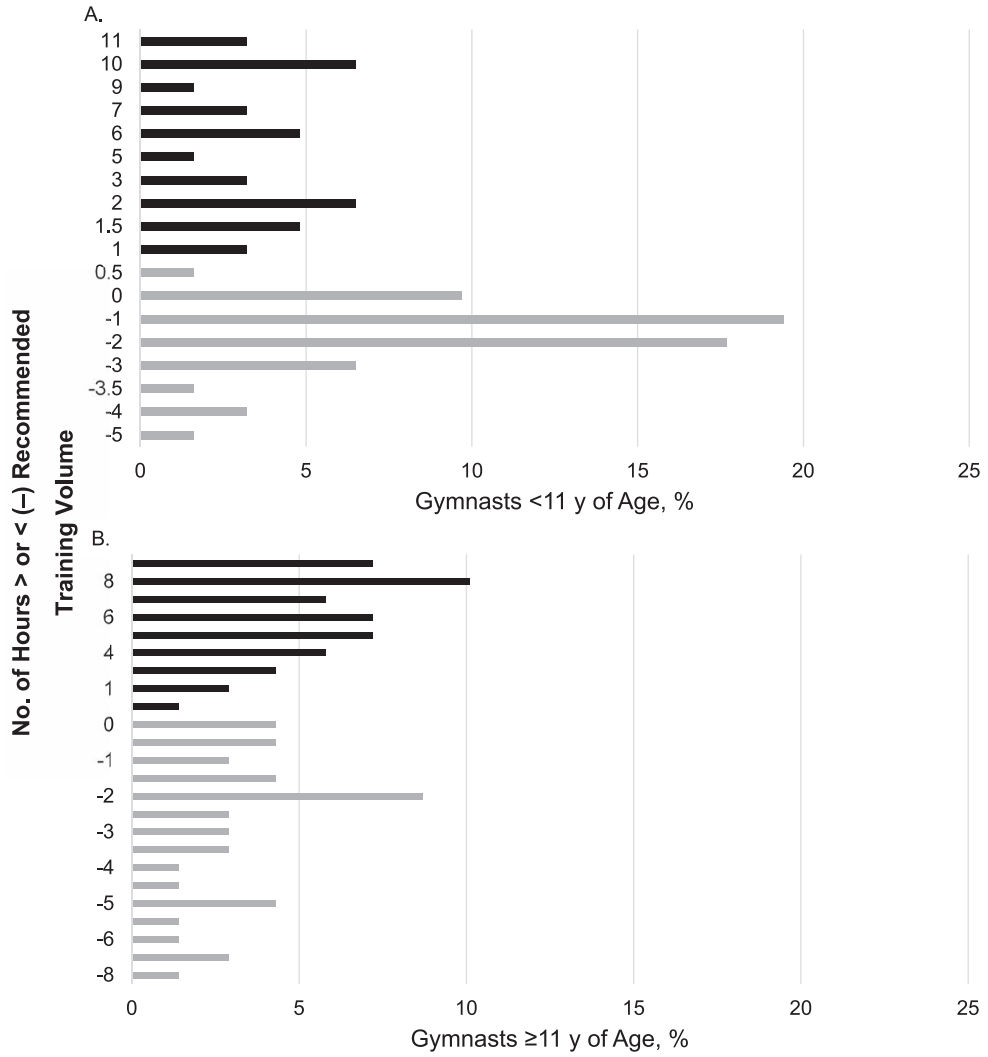

Figure 2. Training volume (hours per week) compared with the American Academy of Pediatrics recommendation[8] that training hours per week should not exceed the athlete's age among (A) those less than 11 years of age and (B) those 11 years of age or older.

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Table 4. Gymnasts' Demographic Characteristics and Training Volume by Level of Specialization

Characteristic	Level of Specialization		
	Low (n = 19)	Moderate (n = 66)	High (n = 46)
	Percentage		
Sex, females/males	42.1/57.9	72.7/27.3	60.9/39.1
Side dominance. right/left	77.8/22.2	52.4/47.6	48.9/51.1
	Mean ± SD		
Age, y	7.95 ± 2.64[a,b]	11.67 ± 2.78	10.87 ± 2.63
Height, cm	129.62 ± 14.38[a,b]	145.99 ± 16.48	141.33 ± 14.13
Mass, kg	30.83 ± 10.58[a]	40.97 ± 13.68	37.03 ± 11.52
Training, h/wk	7.66 ± 4.79[a]	13.31 ± 5.38	12.61 ± 5.42
Years in gymnastics	3.26 ± 2.92[a]	6.36 ± 3.21	5.01 ± 2.80
Started gymnastics, age	4.69 ± 1.76	5.31 ± 2.40	5.86 ± 2.83
	Percentage (n)		
Gymnastics type			
Artistic	94.7 (18)	66.7 (44)	80.4 (37)
Acrobatic	5.4 (1)	25.8 (17)	6.5 (3)
Trampoline and tumbling	0 (0)	7.6 (5)	13 (6)

[a] Lower than the moderate-specialization group.
[b] Lower than the high-specialization group.

Gymnastics Fitness Tests

No differences by specialization level were noted for most of the gymnastics fitness tasks ($P > .05$) as outlined in Table 5. Weak to moderate correlations were found between years participating in gymnastics and each fitness task, except for the shoulder-flexibility test, which was normalized to arm length and showed no relationship (Table 6). Moderate to strong correlations were noted between training hours per week and each fitness task, with no relationship found for the normalized shoulder-flexibility test.

Functional and Movement Assessments

Gymnasts in the low-specialization group scored lower ($P = .004$) on the Y-balance test for the right lower extremity compared with the moderate- and high-specialization groups. The low-specialization group also scored lower ($P = .033$) on the Y-balance test for the left upper extremity and the right-sided hop ($P = .039$) compared with the high-specialization group (Table 7). Moderate correlations were found between both years participating and training hours per week and the normalized right and left hop tests (Table 8). No relationships were noted between either years participating or training hours per week with any of the Y-balance tasks or the LESS.

DISCUSSION

In this retrospective analysis of preseason assessment of youth gymnasts, the majority of gymnasts were classified as moderately or highly specialized; however, most fitness and functional measures did not differ by specialization level when adjusted for age. Therefore, sport specialization by itself did not lead to improved performance outcomes. Given the concerns regarding the relationship between sport specialization and injury, among other negative side effects, athletes and parents should exercise caution when

Table 5. Scores on the Gymnastics Fitness Tasks Adjusted for Age, Hours of Training, and Years of Gymnastics Participation, Mean (95% Confidence Interval)

Task	Level of Specialization			*P* Value
	Low	Moderate	High	
Vertical jump, cm	35.0 (32.0, 38.0)	33.10 (31.56, 34.60)	33.33 (31.56, 35.11)	.551
Hanging pike, repetitions	6.95 (4.57, 9.32)	5.34 (4.12, 6.56)	6.24 (4.84, 7.64)	.440
Normalized shoulder flexibility, cm/arm length	0.51 (0.41, 0.61)	0.65 (0.60, 0.70)	0.66 (0.60, 0.71)	.035[a]
Agility, s	22.32 (21.42, 23.22)	21.92 (21.46, 22.37)	21.88 (21.34, 22.42)	.700
Pull-ups, repetitions	4.28 (2.87, 5.70)	2.75 (2.03, 3.48)	3.53 (2.70, 4.37)	.138
Push-ups, repetitions	16.69 (10.75, 22.62)	14.87 (12.79, 16.94)	13.82 (10.95, 16.69)	.654
Handstand, s	10.85 (4.32, 17.37)	10.01 (6.70, 13.33)	10.07 (6.17, 13.98)	.976
Plank right, s	83.82 (69.49, 98.14)	71.14 (63.77, 78.51)	76.10 (67.51, 84.69)	.306
Plank left, s	72.11 (57.03, 87.19)	72.57 (64.79, 80.35)	79.53 (70.31, 88.76)	.479
Hollow hold, s	41.80 (33.47, 50.13)	31.45 (27.39, 35.50)	35.39 (30.65, 40.14)	.091
Double-legged lower-down test, °	28.21 (19.84, 36.58)	27.73 (23.59, 31.86)	24.42 (19.56, 29.27)	.542
Bridge right, s	34.78 (26.67, 42.88)	40.60 (36.59, 44.60)	42.26 (37.55, 46.96)	.296
Bridge left, s	34.20 (26.55, 41.86)	40.33 (36.55, 44.12)	42.90 (38.45, 47.34)	.155

[a] $P < .05$.

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Table 6. Age, Years of Participation, and Training Volume Correlations With Fitness Tasks

Task	Age	Years of Participation	Training, h/wk
Vertical jump	0.775[a]	0.498[a]	0.609[a]
Hanging pike	0.353[a]	0.262[b]	0.646[a]
Normalized shoulder flexibility	0.055	−0.011	−0.004
Agility	−0.702[a]	−0.442[a]	−0.531[a]
Pull-ups	0.495[a]	0.361[a]	0.699[a]
Push-ups	0.457[a]	0.364[a]	0.511[a]
Handstand	0.408[a]	0.275[b]	0.541[a]
Plank right	0.577[a]	0.373[a]	0.530[a]
Plank left	0.497[a]	0.322[a]	0.538[a]
Hollow hold	0.636[a]	0.434[a]	0.623[a]
Double-legged lower-down test	−0.393[a]	−0.234[b]	−0.459[a]
Bridge right	0.408[a]	0.302[a]	0.373[a]
Bridge left	0.448[a]	0.250[b]	0.359[a]

[a] $P < .001$.
[b] $P < .01$.

Table 8. Age, Years of Participation, and Training Volume Correlations With Functional Movement Assessments

Assessment	Age	Years of Participation	Training, h/wk
Normalized test			
Hop right	0.425[a]	0.316[a]	0.390[a]
Hop left	0.371[a]	0.251[b]	0.352[a]
Y-balance upper right	0.072	0.094	0.114
Y-balance upper left	0.126	0.089	0.194
Y-balance lower right	0.130	0.079	0.073
Y-balance lower left	0.132	0.129	0.104
Landing Error Scoring System average	−0.083	−0.105	−0.006

[a] $P < .001$.
[b] $P < .01$.

deciding whether to focus on a single sport, such as gymnastics, at an early age.

In this sample of athletes at 1 gym, more than 85% of gymnasts were categorized as either moderately or highly specialized, and just under 15% were categorized as having a low level of specialization. The small proportion of low-specialization athletes was unsurprising, as gymnastics historically has a high level of early specialization due to the relative advantage of focused training in the very technical aspects of the sport.[2] Although sports participation and specialization characteristics have not been evaluated in a large sample of gymnasts at multiple sites, the authors of several descriptive studies have provided data with which we can compare our findings. Feeley et al[4] reported that gymnasts described participating in gymnastics at about 7 years of age, which was the youngest among all the sports surveyed. Across specialization groups, the gymnasts in our sample reported starting gymnastics even earlier, at about 5 years of age. In an evaluation of specialization patterns across youth sports,[2] gymnastics had the second-highest proportion of single-sport specialization, second only to tennis, and gymnasts reported the highest mean number of weekly training hours. The moderately and highly specialized groups in this sample demonstrated a high volume of specific training: more than 90% of participants in both groups stated that over 75% of their training was spent in gymnastics. Similarly, of the 3 questions on specialization status, all moderately and highly specialized athletes responded *yes* to the question, "Do you train more than 8 months out of the year in 1 main sport?" However, the 3-tiered system for specialization likely underrepresents highly specialized athletes, as many of the moderately-specialized athletes responded *no* to the third question, "Have you quit other sports to focus on 1 sport?" possibly because they never participated in another sport.

Regardless of whether they were classified as moderately or highly specialized, the gymnasts in our sample had high training volumes that exceeded recommendations from several medical organizations. All of the moderately and highly specialized gymnasts reported that they trained more than 8 months of the year, which was higher than the 60% described by youth athletes participating in other sports,[18] perhaps demonstrating the early specialization often required in gymnastics. The American Academy of Pediatrics recommended that regardless of sport, youth athletes should take at least 3 months off from their primary sport to allow for physical and psychological recovery; however, they can still be involved in other physical activities.[8] Furthermore, although the average hours of training per week exceeded the age recommendation by about 2 hours in the moderately and highly specialized gymnasts, analysis of the individual training hours showed that 46.6% of gymnasts trained for more hours than their ages, with about 30% exceeding their ages by at least 5 hours per week and just under 5% of those training at least 10 hours

Table 7. Functional and Movement Assessment Scores Across the Specialization Groups Adjusted for Age, Hours of Training, and Years of Gymnastics Participation, Mean (95% Confidence Interval)

Assessment	Level of Specialization			*P* Value
	Low	Moderate	High	
Normalized test, cm/cm leg or arm length				
Hop right	0.75 (0.69, 0.81)	0.71[b] (0.68, 0.74)	0.77 (0.74, 0.81)	.039
Hop left	0.74 (0.67, 0.80)	0.72 (0.68, 0.77)	0.76 (0.71, 0.80)	.364
Y-balance upper right	0.73 (0.67, 0.79)	0.77 (0.74, 0.80)	0.79 (0.75, 0.82)	.247
Y-balance upper left	0.70[b] (0.64, 0.76)	0.77 (0.74, 0.79)	0.79 (0.76, 0.82)	.033
Y-balance lower right	0.81[a] (0.73, 0.88)	0.93 (0.90, 0.96)	0.96 (0.92, 1.00)	.004
Y-balance lower left	0.89 (0.83, 0.94)	0.94 (0.92, 0.96)	0.96 (0.93, 0.98)	.055
Landing Error Scoring System average, errors	5.38 (4.44, 6.32)	5.62 (5.15, 6.08)	5.37 (4.82, 5.91)	.774

[a] Lower than the moderate- and high-specialization groups.
[b] Lower than the high-specialization group.

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more per week than their ages. The level of specialization, high training volume, and limited time off are all concerns as possible risk factors for sport-related injury.[6,19] Of this sample, 35% indicated they were currently participating with an injury, which was similar to the results of observational studies[3,5] that showed 23.5% to 43.5% of gymnasts participated while injured. However, we found no differences among specialization levels in the percentages of athletes participating with an injury. This finding differs from the higher rate of injury noted among those who were highly specialized.[19] Collectively, these gymnasts had high proportions of moderate- and high-specialization status and were starting gymnastics at earlier ages than previously reported, and many were participating with existing injuries.

It has been suggested[20] that athletes who sampled a variety of sports possessed better neuromuscular control than sport-specialized athletes. As such, the neuromuscular control of athletes who were previously exposed to other sports and quit those sports to focus on gymnastics may be different than that of those who only participated in gymnastics. The differential neuromuscular-control development between gymnasts with or without exposure to other sports supports the tenets of the long-term *athlete-development model*, in which well-rounded sport and physical activity training includes elements of strength training to improve balance, motor control, and global sport performance (eg, speed and agility), with appropriate periods of rest,[10] as a means to diversify development and reduce the risk of injury. As a foundational activity in the context of athlete-development models,[10] gymnastics may result in better agility, balance, coordination, and strength, leading to improved neuromuscular control. However, as we found no differences between sport-specialization status and performance, specializing exclusively in gymnastics does not appear to confer a clear benefit. To optimize the benefits of gymnastics training and long-term athlete development, such training should follow current recommendations and guidelines, be age appropriate, provide rest breaks throughout the year, and periodically expose gymnasts to other sports or activities.

Interestingly, no differences among specialization levels were evident for most of the functional-movement tasks, suggesting that increased focused training in gymnastics was not advantageous to clinical measures of function and movement quality. For the Y-balance upper left and lower right tasks, the low-specialization group demonstrated poorer performance than the high-specialization group. Previous researchers[21] who compared adult gymnasts with adult nongymnasts found that the former performed better on postural-control tasks, including unipedal stance. Gymnasts also used different stabilizing strategies compared with nongymnast peers.[22] Yet the group differences for Y-balance upper and lower performance between specialization tiers in this study were within the standard error of the measure.[23,24] Further, participation in gymnastics or weekly training load and the normalized Y-balance variables were not associated.

Jump-landing technique revealed no differences in average total LESS score among specialization groups, which aligns with findings[25] in low-, moderate-, and high-specialization high school athletes. The LESS is used to evaluate movement quality during a jump-landing task through the observation of variables such as stance width at landing and range-of-motion displacement in preparation for a maximum vertical jump postlanding. Athletes are instructed to jump forward from the box and upon landing, immediately jump straight up in the air as high as they can.[16] The LESS has been used in youth athletes but is perhaps less appropriate for gymnasts, who are trained to "stick" landings with their feet together, typically with limited ranges of motion.[26] Many athletes landed with limited hip and knee flexion and their feet positioned together during the task, which added to their total number of LESS errors. Although this landing style was consistent among specialization levels, it may predispose gymnasts to injury.[27] Interestingly, in an evaluation of 15 collegiate sports, gymnasts had the highest incidence rate of anterior cruciate ligament (ACL) injuries.[28] Previous authors who evaluated landing patterns on the LESS in a youth athlete population showed that an average total LESS score <5 was associated with a decreased risk of ACL injury[16] and that athletes who had been exposed to a variety of sport experiences had better movement techniques.[20] Gymnasts in this sample had average total LESS scores >5, regardless of specialization group, indicating that increased time in the sport did not improve their neuromuscular control according to the LESS. Gymnasts must be strong and exhibit sound body coordination to perform various techniques, but early sport specialization can lead to overdevelopment or underdevelopment of muscle groups due to repeated movement patterns. Recent evidence[29] demonstrated that collegiate gymnasts may have muscular imbalances that predispose them to ACL injury. Focused neuromuscular-control training in the form of preventive training programs could be beneficial for gymnasts as a means to enhance specific motor skills and reduce their lower extremity injury risk. Such training is consistent with the recommendations of long-term athlete-development models.[7,9,10,30]

Gymnastics-specific fitness tasks reflected no group differences when we controlled for age. We did observe moderate to strong correlations between the tasks and training hours per week and years in gymnastics, whereby increased training and years in gymnastics were associated with improved performance in gymnastics-specific fitness measures. Thus, training volume and sport-participation history may be important factors that influence sport-specific performance and should be explored in future studies. Although the athlete-development models encourage sport sampling and diversification, that advice may be suboptimal for gymnasts, whose training techniques and skill sets are unique. Some organizations[8,9] have acknowledged that certain sports, such as diving, figure skating, and gymnastics, may require early specialization. Although increased training volume and time in sport may positively influence gymnastics performance, they may put gymnasts at a particular increased risk of injury due to repetitive tasks. Clinicians, coaches, and parents should be cognizant of this dynamic, encourage adequate rest periods, and monitor gymnasts for signs of overuse injury and burnout.

A limitation of this study was that our sample attended a single gym. As such, the coaching staff may share similar

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training philosophies, and the sample may not represent all competitive youth gymnasts. Our smallest group consisted of only 19 participants, so the study was not well powered to identify small changes among groups. Further, no differences were present among specialization groups, which could be a function of the low sensitivity of the scale used to classify specialization. The 3-tiered scale may be insufficient, in that many of our athletes categorized as moderately specialized responded *no* to the question, "Have you quit other sports to focus on 1 main sport?" because they may have only participated in gymnastics, thereby underrepresenting the number of highly specialized athletes. Future investigators should prospectively measure sport-specialization levels along with other athlete characteristics, such as age at onset of sport specialization, sport and injury history, and additional details surrounding training volume.

CONCLUSIONS

Our results broadly characterized the sport-specialization and training-volume status of youth gymnasts and the influence of specialization and training on fitness and functional performance. With respect to specialization, it was not surprising to find that most gymnasts were moderately or highly specialized and participating in high training volumes with respect to training hours per week and participating more than 8 months of the year. However, we did not observe clinically meaningful group differences between specialization status and gymnastics fitness tasks or functional-movement tasks, indicating no clear relationship existed with training in gymnastics to the exclusion of other sports and increased sport performance.

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