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Original Research

Sport Specialization and Single-Legged–Squat Performance Among Youth Baseball and Softball Athletes

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Context: Previous research has indicated that throwing sports expose athletes to overuse injuries and that specialization in sport is linked to injury. However, the effect of overexposure to a throwing sport on a dynamic movement task is unknown.

Objective: To determine if sport specialization in youth throwing athletes affected performance on the single-legged squat (SLS).

Design: Descriptive laboratory study.

Setting: University research laboratory.

Patients or Other Participants: A total of 49 youth baseball and softball athletes (23 baseball, 26 softball; age = 12.96 ± 2.32 years, height = 165.01 ± 13.05 cm, mass = 61.42 ± 13.04 kg) were recruited.

Main Outcome Measure(s): Participants were grouped into 3 categories based on specialization definitions: (1) 8 months or longer in season, (2) 8 months or longer in training, or (3) 8 months or longer in season and previously quit another sport. We measured SLS kinematics and used a set of 1-way multivariate analyses of variances to determine if trunk kinematics differed by group.

Results: Athletes who spent 8 months or more in sport-specific training exhibited significantly more trunk control, revealed by less trunk lateral flexion ($\Lambda = 0.69$, $F_{6,38} = 2.89$, $P = .020$) and less trunk flexion ($\Lambda = 0.69$, $F_{6,38} = 2.88$, $P = .021$) throughout an SLS.

Conclusions: These results agree with the principle of specific adaptation to imposed demands. Surprisingly, athletes who spent 8 months or more playing a unilateral sport showed no differences in SLS performance. Clinicians should emphasize that neuromuscular adaptations of the lumbopelvic-hip complex for dynamic movement, such as an SLS, may be achieved through training instead of strict sport participation. Future researchers should consider how much of the training protocol is actually specialized for sport training.

Key Words: overhead throwing, pitching, single-sport athletes

Key Points

- Youth athletes who spent more than 8 months of the year training for baseball or softball displayed greater trunk control as demonstrated by an increased ability to stabilize their lumbopelvic hip complex during the single-legged squat.
- Clinicians should emphasize that neuromuscular adaptations of the lumbopelvic hip complex for dynamic motion such as a single-legged squat can be achieved through training instead of strict sport participation.
- More attention is needed to the intersection of sport-specific training programs, sport specialization, and injury.

Sport specialization is a topic of interest among clinicians because of the documented increase in youth propensity to injury.[1–4] According to the American Academy of Orthopaedic Surgeons,[5] *sport specialization in youth* is defined by engaging in a sport for at least 3 seasons per year to the exclusion of other sports. Anecdotally, specialization is believed to assist in sport performance; however, other fitness aspects are commonly neglected. Youth athletes who specialized in sport were at greater risk of sustaining an injury.[2,3,6–8] Specifically, female youths who participated in a single sport were at greater risk of developing anterior knee pain and other chronic knee injuries than those who played 2 sports.[9] Among high school athletes, even moderate sport specialization led to an increased likelihood of lower extremity injury.[2] Additionally, the increased volume of sport-specific movement patterns and the lack of variety in movement patterns because of sport specialization were associated with a history of injury.[3,7,9–11] Comparing specialization across sports, baseball and softball athletes were more likely to specialize in their sport and to sustain some of the highest rates of overuse injuries.[8] Increasing the volume of a unilateral rotational motion, such as that seen in baseball and softball, in relation to other movement patterns is postulated to predispose an athlete to injury.[2,12,13]

Much attention regarding youth sport is currently focused on the association of sport specialization and injury,[1–4,7,8] yet a link has also been established between injury prevention and functional movement. Specifically, the efficient and effective use of the body as a kinetic chain working in a proximal (lower extremity) to distal (upper extremity) manner seems to aid in injury prevention.[6,11,12,14,15] The kinetic chain concept of efficient movement and stability of the lower extremity for the ultimate production of upper extremity mobility and optimal performance has been emphasized in examinations of the overhead throw.[15–18] For sequential movement patterns such as the overhand throw, maximum ball velocity is achieved via successful transfer of energy from the ground through the kinetic chain and to the ball.

The efficiency of the kinetic chain's ability to transfer energy from the lower to the upper extremity is critically dependent on the stability of the *lumbopelvic-hip complex* (LPHC).[14,16–19] The LPHC has been defined as the area encompassing the spine, torso, hips, pelvis, proximal lower limbs, and associated musculature of the abdomen and gluteals.[14] The ability to maintain LPHC control throughout dynamic movement is paramount not only to injury prevention but also to performance enhancement.[14] Chaudhari et al[18] defined *LPHC control* as a person's ability to actively mobilize or stabilize (or both) the LPHC in response to internal or external stress on the human body. Extensive efforts have been focused on determining the underlying pathomechanics and risk factors that increase the injury susceptibility of baseball and softball athletes. Two underlying mechanisms that are commonly referenced are overuse due to sport specialization and faulty mechanics.[20,21] Although the discussion of overuse injuries focuses on sport specialization, the association of faulty throwing mechanics with LPHC instability should be considered. With mechanical concerns such as reduced postural control being highly prevalent in those with LPHC instability,[12,16,17,20] an increased incidence of these pathomechanics becomes a characteristic of sport specialization. Given this conundrum of overuse, pathomechanics, and sport specialization, we need to examine the throwing athlete's ability to maintain LPHC stability throughout dynamic movement. One such method is the single-legged–squat (SLS) assessment. Using an SLS assessment, one can gain insight into LPHC stability as characterized by postural control.[14,22]

The ability to maintain a stable LPHC throughout dynamic movement allows an athlete to instantaneously adapt to postural changes from the demands of the movement.[23] To prevent injury in the throwing athlete, a dynamic assessment of postural control, LPHC stability, and mobility (such as the SLS) to identify biomechanical deficiencies has proven reliable.[16,17,19,24,25] Additionally, the SLS has been used and validated in general populations, as well as in baseball and softball athletes, as a clinical test of postural control and LPHC stability.[19,25] The SLS offers clinicians the opportunity to measure LPHC stability as demonstrated through postural control of trunk and lower extremity kinematics. Ultimately, the goal of the SLS is to maintain neutral posture, or minimal deviation from neutral posture, throughout the movement. For this study, we chose to analyze trunk lateral flexion, trunk axial rotation, and trunk flexion in order to assess overall trunk control and LPHC stability. The influence of postural control and LPHC stability on injury prevention is known.[14,15] Although awareness of sport specialization and subsequent overuse injury is increasing, clinicians must establish the effect of specialization on LPHC stability. Therefore, the purpose of our study was to determine if sport specialization in youth throwing athletes (baseball and softball) affected performance on the SLS. We hypothesized that throwing youths who specialized in sport (ie, those who spent 8 months or more in season, 8 months or more training for baseball or softball, or 8 months or more in season and previously quit another sport) would demonstrate less LPHC stability in regard to trunk control, which would be evident in less trunk lateral flexion, trunk axial rotation, and trunk flexion.

METHODS

Participants

A total of 49 youth baseball (n = 23) and softball (n = 26) athletes (age = 12.96 ± 2.32 years, height = 165.01 ± 13.05 cm, mass = 61.42 ± 13.04 kg) were recruited to participate. All recruits were in good physical condition, and none had been injured in the previous 6 months. Participants completed a health history form immediately before the study. We grouped them based on sport specialization, which was divided into 3 categories: (1) 8 months or longer in baseball or softball season (months in season),[5] (2) 8 months or longer in baseball or softball training (months in training),[4,5,26] or (3) 8 months or longer in baseball or softball season and previously quit another sport (specialized).[26] The institutional review board of Auburn University approved the testing protocols. Informed written consent was obtained from each participant's parents and written assent from each participant before testing.

Procedures

The kinematic data were collected at 100 Hz using an electromagnetic tracking system (trakSTAR; Ascension Technologies, Inc, Burlington, VT) synchronized with the MotionMonitor (Innovative Sports Training, Chicago, IL). Fourteen electromagnetic sensors were attached at the following locations: (1) posterior aspect of the torso at the first thoracic vertebrae (T1) spinous process; (2) posterior aspect of the pelvis at the first sacral vertebra (S1); (3, 4) flat, broad portion of the acromion on the scapula bilaterally; (5, 6) lateral aspect of the bilateral upper arm at the deltoid tuberosity; (7, 8) posterior aspect of the bilateral distal forearm, centered between the radial and ulnar styloid processes; (9) dorsal aspect of the second metatarsal of the nondominant foot; (10, 11) lateral aspect of the bilateral upper leg, centered between the greater trochanter and the lateral condyle of the knee; (12, 13) lateral aspect of the bilateral lower leg, centered between the head of the fibula and the lateral malleolus; and (14) dorsal aspect of the third metacarpal of the dominant hand. A 15th, movable sensor was attached to a plastic stylus for the digitization of bony landmarks.[23,27] Errors in determining the position and orientation of the electromagnetic sensors with the current calibrated world axis system were less than 0.01 m and 3°, respectively. After the sensors were attached and digitized, each participant performed an SLS using the right and left leg in random order. For the SLS, participants were instructed not to touch the ground with the back foot and not to rest the leg that was in the air against the stance leg (Figure). Cadence for the SLS was self-selected. Participants were allowed to practice the task until they were comfortable performing it correctly.

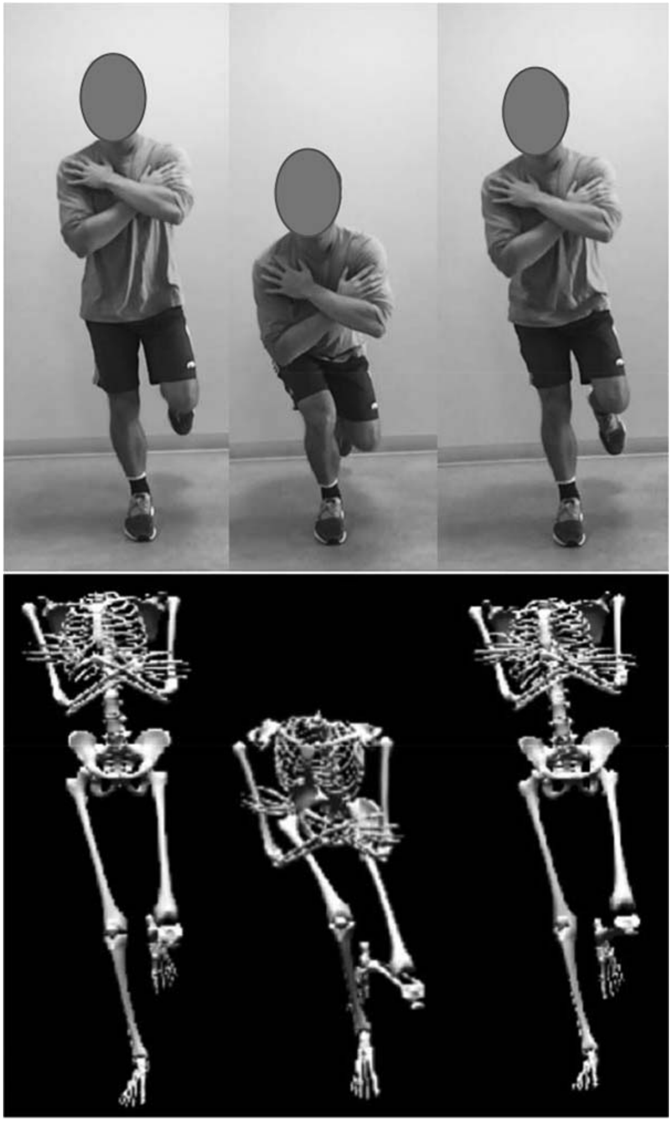

Figure. Single-legged squat at start, peak knee flexion, and finish.

Once the participant was acclimated to the setup and procedure, data from 1 SLS were collected for analysis.[16,19] A *failed trial* consisted of the back leg touching the ground or resting on the stance leg; in that event, the participant was asked to repeat the trial.

Data Processing

For the world axis, the positive y-axis represented the vertical direction, the positive x-axis was anterior to the participant, and the positive z-axis was orthogonal to the x- and y-axes. Position and orientation of the body segments were obtained using Euler angle sequences that were consistent with the International Society of Biomechanics standards and joint conventions.[27] All trunk motion was captured in reference to the world axis. All raw data were independently filtered along each global axis using a fourth-order Butterworth filter with a cutoff frequency of 13.4 Hz.[23] All data were time stamped by the MotionMonitor and passively synchronized using a data-acquisition board. Kinematic data of the SLS were marked at 3 points: 45° of knee flexion (during the eccentric phase or descent in the squat), peak knee flexion, and 45° of knee flexion (during the concentric phase or ascent in the squat). All data were processed using MATLAB (The MathWorks, Inc, Natick, MA), stratified by throwing-arm side or glove side, and analyzed using SPSS (version 21; IBM Corp, Armonk, NY).

Statistical Analysis

Univariate normality was assessed using skew and kurtosis values. We calculated 1-way multivariate analyses of variance (MANOVAs) to determine if trunk kinematics differed based on sport-specialization group. Testwise error for the multivariate tests was set at $\alpha = .05$. To follow up on significant multivariate test values, we conducted univariate analyses of variance (ANOVAs). Effect size was reported as partial η^2 for all MANOVAs and follow-up ANOVAs. To adjust for multiple comparisons, we used the Bonferroni inequality for all follow-up tests, setting testwise error at $\alpha = .008$.

RESULTS

Descriptive statistics can be found in Tables 1 through 3. Trunk–lateral-flexion dependent variables did not differ based on months in season ($\Lambda = 0.85$, $F_{6,38} = 1.09$, $P = .383$, $\eta^2 = 0.15$) or specialization ($\Lambda = 0.94$, $F_{6,38} = 0.38$, $P = .888$, $\eta^2 = 0.06$). However, a difference was found for the months-in-training group ($\Lambda = 0.69$, $F_{6,38} = 2.89$, $P = .020$): about 31% of the variance in trunk lateral flexion ($\eta^2 = 0.31$) occurred because of the time

Table 1. Trunk Flexion by Group,°[a]

	Group, Mean ± Standard Error					
	Months in Season		Months Training		Specialized?	
Variable	≥8 (n = 29)	<8 (n = 20)	≥8 (n = 28)	<8 (n = 21)	Yes (n = 16)	No (n = 33)
Throwing-arm side						
Descent	−1.42 ± 1.92	−5.6 ± 2.16	−1.75 ± 1.71	−3.86 ± 2.39	−6.15 ± 2.68	−1.14 ± 1.75
Peak knee flexion	−16.77 ± 2.88	−18.92 ± 3.24	−12.11 ± 2.57	−22.86 ± 3.58	−24.25 ± 4.02	−14.1 ± 2.62
Ascent	−7.14 ± 2.43	−7.87 ± 2.73	−3.32 ± 2.16	−11.45 ± 3.02	−11.1 ± 3.39	−5.53 ± 2.21
Glove side						
Descent	−3.68 ± 2.22	−3.17 ± 2.5	−2.24 ± 1.98	−4.79 ± 2.76	−7.12 ± 3.1	−1.71 ± 2.02
Peak knee flexion	−18.36 ± 3	−17.1 ± 3.38	−12.51 ± 2.68	−23.37 ± 3.74	−26.08 ± 4.19	−13.87 ± 2.74
Ascent	−9.46 ± 2.78	−7.05 ± 3.13	−4.04 ± 2.48	−13.27 ± 3.46	−15.09 ± 3.88	−5.43 ± 2.54

Abbreviations: ascent, upward portion of the single-legged squat; descent, downward portion of the single-legged squat.

[a] Positive values represent extension; negative values represent flexion.

Table 2. Trunk Axial Rotation by Group,°[a]

Variable	Months in Season ≥8 (n = 29)	Months in Season <8 (n = 20)	Months Training ≥8 (n = 28)	Months Training <8 (n = 21)	Specialized? Yes (n = 16)	Specialized? No (n = 33)
Throwing-arm side						
Descent	10.25 ± 8.46	8.95 ± 9.52	−0.86 ± 7.54	20.49 ± 10.52	−6.99 ± 11.81	18.22 ± 7.71
Peak knee flexion	6.71 ± 8.58	7.56 ± 9.65	−3.12 ± 7.65	17.11 ± 10.66	−10.4 ± 11.96	15.7 ± 7.81
Ascent	9.72 ± 8.47	11.78 ± 9.53	0.85 ± 7.55	19.96 ± 10.53	−6.26 ± 11.82	18.74 ± 7.72
Glove side						
Descent	15.36 ± 8.61	16.3 ± 9.69	5.38 ± 7.68	25.97 ± 10.71	−2.99 ± 12.01	25.01 ± 7.85
Peak knee flexion	17.6 ± 8.56	17.75 ± 9.63	6.77 ± 7.63	28.52 ± 10.65	−1.15 ± 11.94	27.04 ± 7.8
Ascent	13.88 ± 8.77	14.72 ± 9.87	3.41 ± 7.82	24.9 ± 10.91	−3.97 ± 12.24	23.22 ± 7.99

Group, Mean ± Standard Error

Abbreviations: ascent, upward portion of the single-legged squat; descent, downward portion of the single-legged squat.

[a] Positive values indicate rotation toward the glove side; negative values indicate rotation toward the throwing-arm side.

spent in training. Results from the univariate ANOVAs are shown in Table 4. The group that spent 8 months of the year or more training for an overhead sport showed less trunk lateral lean toward the leg performing the SLS.

For trunk axial rotation, no differences were present in the months-in-season ($\Lambda = 0.86$, $F_{6,38} = 1.01$, $P = .433$, $\eta^2 = 0.14$), months-in-training ($\Lambda = 0.92$, $F_{6,38} = 0.53$, $P = .780$, $\eta^2 = 0.08$), or specialized ($\Lambda = 0.84$ $F_{6,38} = 1.17$, $P = .343$, $\eta^2 = 0.16$) dependent variables.

Trunk-flexion dependent variables differed based on months in training ($\Lambda = 0.69$, $F_{6,38} = 2.88$, $P = .021$). About 31% of the variance in trunk flexion ($\eta^2 = 0.31$) occurred because of the time spent in training. However, the trunk-flexion dependent variables were not different based on months in season ($\Lambda = 0.76$, $F_{6,38} = 1.97$, $P = .094$, $\eta^2 = 0.24$) or specialization ($\Lambda = 0.78$, $F_{6,38} = 1.82$, $P = .120$, $\eta^2 = 0.22$). Descriptive statistics indicated that the group that spent 8 months or more training displayed less trunk flexion than their counterparts. Results from the univariate ANOVA for trunk flexion and months in training are presented in Table 5.

DISCUSSION

The purpose of our study was to determine if youth sport specialization in baseball or softball influenced SLS kinematics. Our hypothesis that a youth throwing athlete specializing in sport would demonstrate less trunk control during the SLS was rejected. Youth athletes who spent more than 8 months in the year training for baseball or softball actually displayed greater trunk control as demonstrated by an increased ability to stabilize their LPHC, as seen in less trunk flexion, trunk axial rotation, and trunk lateral flexion, when experiencing internal or external perturbations during the SLS.[18] Specifically, athletes who spent more than 8 months training exhibited less trunk flexion and trunk lateral flexion but no difference in trunk axial rotation during the SLS compared with athletes who did not pursue lengthy training. However, no differences were noted in SLS kinematics between overhead athletes who spent 8 months or more in season and those who spent 8 months or more in season after quitting another sport.

In choosing trunk lateral flexion, trunk axial rotation, and trunk flexion as our measures, we were able to examine LPHC control via the SLS. Previous authors[19] suggested that LPHC musculature detriments may contribute to altered SLS kinematics. In an examination of SLS among females with excessive knee valgus and patellofemoral pain, trunk lateral flexion was greater toward the stance-leg side for the pain group.[28] We observed that trunk lateral flexion was in the direction of the stance leg, regardless of which leg was used. Therefore, our findings for trunk lateral flexion in baseball and softball athletes appeared to be consistent with the findings in other populations. Athletes who spent more than 8 months in sport-specific training demonstrated less trunk lateral flexion, which could have implications for reducing knee pain.[29] In an examination[29] of SLS mechanics between those classified as good or poor

Table 3. Trunk Lateral Flexion by Group,°[a]

Variable	Months in Season ≥8 (n = 29)	Months in Season <8 (n = 20)	Months Training ≥8 (n = 28)	Months Training <8 (n = 21)	Specialized? Yes (n = 16)	Specialized? No (n = 33)
Throwing arm side						
Descent	0.33 ± 1.7	4.07 ± 1.91	1.44 ± 1.51	1.71 ± 2.11	−0.08 ± 2.36	2.4 ± 1.54
Peak knee flexion	0.54 ± 2.07	5.63 ± 2.33	1.87 ± 1.84	2.61 ± 2.57	−0.02 ± 2.88	3.37 ± 1.88
Ascent	2.62 ± 2.71	6.21 ± 3.04	2.93 ± 2.41	4.7 ± 3.36	0.63 ± 3.77	5.41 ± 2.47
Glove side						
Descent	−4.78 ± 1.75	−0.38 ± 1.96	−1.69 ± 1.56	−4.94 ± 2.17	−6.12 ± 2.44	−1.91 ± 1.59
Peak knee flexion	−4.62 ± 1.88	0.02 ± 2.12	−0.08 ± 1.68	−6.08 ± 2.35	−5.09 ± 2.64	−2.07 ± 1.72
Ascent	−4.28 ± 1.63	2.24 ± 1.84	0.76 ± 1.46	−4.98 ± 2.03	−5.4 ± 2.28	−0.47 ± 1.49

Group, Mean ± Standard Error

Abbreviations: ascent, upward portion of the single-legged squat; descent, downward portion of the single-legged squat.

[a] Positive values indicate toward the throwing-arm side; negative values indicate toward the glove side.

Table 4. **Univariate Analysis of Variance Results for Trunk Lateral Flexion Across 3 Events for the Months-in-Training Group**

Trunk Lateral Flexion	Sum of Squares	Degrees of Freedom	Mean Square	*F* Value	*P* Value[a]	η^2
Throwing-arm side						
Descent	0.584	1	0.584	0.01	.918	<0.01
Peak knee flexion	4.55	1	4.55	0.06	.814	<0.01
Ascent	25.25	1	25.25	0.18	.672	<0.01
Glove side						
Descent	85.95	1	85.95	1.49	.230	0.03
Peak knee flexion	292.15	1	292.15	4.32	.044	0.09
Ascent	267.06	1	267.06	5.28	.027	0.11

Abbreviations: ascent, upward portion of the single-legged squat; descent, downward portion of the single-legged squat.

[a] Significance was set at $\alpha \leq .008$. Events are 45° of knee flexion on the way down, peak knee flexion, and 45° of knee flexion on the way up.

SLS performers, trunk axial rotation was the primary kinematic difference between groups. Specifically, when performing SLS using the dominant leg as the stance leg, poor performers demonstrated greater trunk axial rotation toward the stance leg compared with good SLS performers.[29] Although trunk axial rotation was not significantly different in the current study, athletes in the months-in-training and specialized groups displayed trunk axial rotation toward their glove-arm side, regardless of the stance leg. To further expand on the implications of specialization, follow-up studies should be conducted to examine the differences between a specialized group of throwing athletes and an inactive population.

Our findings that those who trained for baseball or softball 8 months or more in the year had greater trunk control implies that the specific adaptations to imposed demands (SAID) principle was at work among these athletes. In theory, if one can display LPHC stability via the SLS, then the propensity to use an efficient kinetic chain during a ballistic skill such as throwing is greater. We grouped baseball and softball athletes together based on sport similarities. Although baseball and softball pitching are different, both sports include sequential pitching motions using the entire kinetic chain and a large number of overhead throws. For baseball and softball athletes to achieve LPHC stability and an efficient kinetic chain during a ballistic movement such as throwing, they should focus on developing an efficient kinetic chain during dynamic movements, such as the SLS. Previous investigators[19,29] showed that muscle compensations occurred among athletes with SLS deficiencies. If baseball and softball athletes exhibit LPHC deficiencies during the SLS, researchers should determine what these deficiencies and compensations mean to the dynamic throwing motion. Coupling the known links between LPHC control and injury in a throwing sport[18] and the amount of specialization and injury risk could prove beneficial for the sports medicine world.[2] However, more detail regarding the actual amount of sport-specific training throughout the year could be useful. Because the link between sport specialization and injury was only modest with limited evidence,[30] more focus needs to be placed on the intersection of sport-specific training programs, sport specialization, and injury.

Without knowing the exact training protocol that the youth athletes in our study were performing, the question of true sport specialization is speculative and based on the time spent training. Athletes who train specifically for baseball or softball 8 months or more in the year could spend 4 months or less developing a more rounded athletic base or resting. Future authors should obtain details about training protocols from sport-specialized athletes. Also, it is important to examine injury history to determine if injury, sport specialization, and LPHC stability in SLS performance are related. Additionally, assessing SLS performance and segmental sequencing in the ballistic movement of throwing could prove beneficial.

The lack of a significant finding with respect to SLS kinematics and the 2 sport-specialization groups, with playing 8 months or more in season as a characteristic, among youth throwing athletes (baseball and softball) in our study should interest clinicians. To influence neuromuscular control of the LPHC, as seen in dynamic movements such as the SLS, more direct methods such as sport-specific training should be used instead of relying strictly on sport participation. Clinicians should acknowledge the importance of athletes training for sport, especially

Table 5. **Univariate Analysis of Variance Results for Trunk Flexion Across 3 Events for the Months-in-Training Group**

Trunk Flexion	Sum of Squares	Degrees of Freedom	Mean Square	*F* Value	*P* Value[a]	η^2
Throwing-arm side						
Descent	36.14	1	36.14	0.52	.476	0.01
Peak knee flexion	936.35	1	936.35	5.95	.019	0.12
Ascent	535.86	1	535.86	4.79	.034	0.10
Glove side						
Descent	52.60	1	52.60	0.56	.457	0.01
Peak knee flexion	957.13	1	957.13	5.59	.023	0.12
Ascent	689.83	1	689.83	4.69	.036	0.10

Abbreviations: ascent, upward portion of the single-legged squat; descent, downward portion of the single-legged squat.

[a] Significance was set at $\alpha \leq .008$. Events are 45° of knee flexion on the way down, peak knee flexion, and 45° of knee flexion on the way up.

those who specialize. Also, the lack of SLS kinematic differences among the 2 sport-specialization groups playing 8 months or more in season deserves further research consideration. Although the SAID principle implies that unilateral loading to the LPHC such as that seen in a throwing sport with throws and swings would alter LPHC control, we did not find any difference in these 2 specialization groups. Perhaps future authors should separate baseball- or softball-specialized athletes who train for sport from those who do not train. Given the link between LPHC control and injury susceptibility, our results of no difference between sport-specialized groups, based on time spent in season and SLS kinematics, are interesting. After examining LPHC and time missed during the season among professional baseball players, Chaudhari et al[18] determined that LPHC control is desirable because it is associated with decreased injury rates. For youth athletes who participate in baseball or softball for 8 months or greater throughout the year, such as those examined in this study, staying healthy and injury free should be priorities. In regard to being in season for baseball or softball, we did not consider the position played, how many throws or swings were made, the number of practices, or the number of games throughout the year. Perhaps these variables of interest contributed to the lack of differences in SLS kinematics. Based on the SAID principle, we would expect baseball and softball athletes to demonstrate greater LPHC control only if proper demands were placed on their LPHC; thus, future studies of sport specialization and SLS kinematics should be conducted to quantify the volume of throws and swings per year.

Limitations to this study included the sample size. Most investigations of sport specialization have a large number of participants. However, using a G-Power (version 3.1.9.2; Heinrich-Heine-Universität Düsseldorf, Germany) postcollection analysis of sample size set at a power of 0.8 and the lowest effect size seen in this study based on the MANOVA for the specialized group (effect size = 0.06), 40 participants were needed. Therefore, the sample size was adequate. Because baseball and softball athletes perform different pitching motions, separating them into groups for analysis may have altered the results. To ensure adequate power, we chose to group the athletes because softball athletes warm up and play defense with an overhand throwing motion. Other limitations were the reliance on a health history questionnaire to determine specialization, potential equipment error, and the specialization definition selected. Because specialization is hard to define,[10] we used 3 criteria for specialized athletes. Previous researchers[10] documented the difficulty in determining an all-encompassing definition for specialization. Another limitation was the age discrepancy among participants. Chronologic age and maturation should be considered when examining SLS performance.[24]

In conclusion, the group that spent 8 months or more pursuing sport-specialized training demonstrated greater LPHC control by means of less trunk flexion and less trunk lateral flexion. Clinicians should emphasize that neuromuscular adaptations of the LPHC for dynamic motion such as that in an SLS can be achieved through training instead of strictly through sport participation. Differences in SLS trunk kinematics between this population and other samples are apparent and should be identified in follow-up studies to determine the full effect of sport specialization on dynamic movement.

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