Multidirectional Instability of the Shoulder in Elite Female Gymnasts

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Abstract

Multidirectional instability (MDI) of the shoulder is symptomatic laxity in 2 or more directions, 1 of which is inferior. MDI is well described in overhead athletes (eg, baseball players, tennis players, swimmers) but not in gymnasts. We conducted this study to estimate the incidence of any type of shoulder pathology in elite gymnasts, to estimate MDI incidence in this population, and to determine which if any circumstances place these gymnasts at higher risk for developing MDI.

An 18-question multiple-choice questionnaire was administered to 70 female US collegiate gymnastics teams. Potential risk factors were cross-matched against those gymnasts with traumatic shoulder injuries and again against those gymnasts who met MDI study inclusion criteria.

Of the 1115 questionnaires distributed, 457 (34 teams) were returned. Twenty-two percent of gymnasts suffered from a traumatic shoulder injury, and 11% met study inclusion criteria. There was a statistically significant (P = .02) relationship between generalized ligamentous laxity and traumatic shoulder instability but not MDI. Incidence of atraumatic or traumatic shoulder injuries in gymnasts is higher than previously recognized. Although this study did not reveal any potential risk factors, it does provide several avenues for more specific research.

In 1980, Neer and Foster[1] described multidirectional instability (MDI) as symptomatic laxity of the shoulder in 2 or more directions, 1 of which is inferior. Although the literature on MDI has grown since then, the exact pathophysiology of MDI remains elusive. Most clinicians speculate that MDI is the cumulative result of repetitive microtrauma to a shoulder capsule under stress.[2,3] MDI is well described in overhead athletes (eg, baseball players, tennis players, swimmers) but not in gymnasts. Despite the recognition[2-6] that gymnasts are at increased risk for developing MDI, none of the literature has addressed which gymnasts are at risk and, more important, why they are at risk.

We conducted this study to estimate the incidence of any type of shoulder pathology in elite gymnasts, to estimate MDI incidence in this population, and to determine which if any circumstances place these gymnasts at higher risk for developing MDI.

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Materials and Methods

After obtaining institutional review board approval, we created 18 multiple-choice questions for a survey (Appendix) of US elite female collegiate gymnasts. The questions covered duration of participation in gymnastics, number of workout hours per week both before and during college, details of past and present shoulder problems and pain, and generalized ligamentous laxity.

Female collegiate gymnasts in National Collegiate Athletic Association (NCAA) Division I and II programs were selected as the study population for several reasons: They are all roughly the same age and have similar training hours; they are of the age and educational level that help them answer survey questions more accurately than younger gymnasts do; and Division I and II gymnasts represent a group of elite female athletes who are exposed to many years of long practice hours before college.

Mailing addresses and e-mail addresses of NCAA Division I and II collegiate gymnastics teams were obtained from an up-to-date directory on the Internet. Number of gymnasts per team was estimated from the rosters posted on the teams' Web pages. To try to increase survey completion, we sent the head coach of each program an individual, personalized e-mail detailing the aims of the study before survey distribution. In addition, a cover letter cowritten by Dr. Caplan and the head coach of the George Washington University gymnastics team was included with the questionnaires. First-class postage was used for the mailing, and self-addressed stamped envelopes were included. Questionnaires (N = 1115) were distributed to 70 NCAA Division I and II gymnastics programs across

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the United States—66 Division I teams and 4 Division II teams. Division III gymnastics teams were excluded, as their skill levels and practice hours are not comparable to those of the elite teams.

Survey answers were entered into a computerized database. Categorical data obtained from the questionnaire were analyzed with χ^2 tests and the Fisher exact test. Continuous data (eg, age) were not normally distributed, so comparisons were made with the Mann-Whitney test. All statistics were computed with SPSS (Version 12; SPSS Inc, Chicago, IL). Potential risk factors were cross-matched against those gymnasts with traumatic shoulder injuries and again against those gymnasts who met MDI study inclusion criteria. For the purposes of this study, MDI was defined as having no previous history of traumatic injury yet reporting symptoms of instability in 2 or more activities that put different directions of stress on the shoulder (from question 18) or in simply carrying books (which was thought to be indicative of inferior shoulder instability).

Results

Of the 1115 surveys distributed to 70 NCAA Women's Division I and II collegiate gymnastics teams, 457 (34 teams) were returned. Thirty-two of the 66 Division I teams and 2 of the 4 Division II teams completed and returned their questionnaires. Every year, the top 36 Women's Division I teams qualify for regional championships, and the top 6 teams from the regional competition advance to the national championship. Of these top 36 teams, 17 returned questionnaires, and 4 of the top 6 collegiate teams participated in the study (including the reigning national champions).

One hundred two (22%) of the 457 gymnasts suffered a traumatic shoulder injury, including rotator cuff injury (56), anterior shoulder dislocation (9), posterior shoulder dislocation (2), anterior shoulder subluxation (10), posterior shoulder subluxation (10), and labral pathology (12). Many of these gymnasts reported more than 1 type of injury (Table I). Approximately 70% had practiced 20 to 30 hours before college, and 88% currently practice 15 to 24 hours in college. More than 80% of the gymnasts exercise outside the gym; 66% engage in weight training. Twenty-nine percent reported at least 1 sign of ligamentous laxity, and an additional 19% reported having more than 1 such sign. Although only 102 gymnasts reported a traumatic injury, 271 (59%) reported shoulder pain. More than 25% of gymnasts (127/457) reported the sensation of excess shoulder motion. Of those who experienced a sensation of excess motion, 72 noticed symptoms in the gym as well as during activities of daily living. According to the predetermined definition, 52 (11%) of the 457 gymnasts met the MDI inclusion criteria.

In the examination of the relationships between traumatic shoulder injuries and potential risk factors, there was no statistical significance in terms of number of years of gymnastics participation, number of practice hours before college, number of practice hours during college, extra exercise outside gymnastics practice, shoulder strengthening outside gymnastics, participating in all 4 events, or having only 1 type of hyperlaxity motion (Table II). However, the relationship between time dedicated to shoulder stretching and shoulder injury was statistically significant ($P<.001$), In addition, having 2 or more signs of hyperlaxity ($P = .003$) and having the sensation of shoulder instability ($P<.001$) both reached statistical significance.

For gymnasts with MDI (as previously defined), there was no relationship between developing MDI and age at start of gymnastics or number of years of participation in gymnastics. Furthermore, there was no association with having at least 1 sign of ligamentous laxity or having 2 or more signs of ligamentous laxity (Table III). There was no relationship between MDI and time spent stretching shoulders and no correlation with MDI and gymnastics practice hours. For gymnasts who did additional exercise and weight training, there was no apparent relationship with MDI. Of all the potential risk factors, only shoulder pain had a statistically significant ($P<.01$) association with MDI.

Discussion

A major goal of this study was to estimate the incidence of shoulder pathology and/or pain in collegiate gymnasts. Twenty-two percent of the 457 gymnasts surveyed suffered from some type of traumatic shoulder injury, and 59% had shoulder pain while practicing. These percentages are in stark contrast to the 4% of elite gymnasts (N = 151) who suffered from shoulder injuries, as determined in an epidemiologic study prospectively and retrospectively identifying number of injuries by location and gymnastics level.[7] In another prospective study of injury patterns, 26 female collegiate gymnasts had a total of 106 injuries, only 4 of which involved the shoulder (0.9%), and these were described as atraumatic impingement injuries.[8] Nevertheless, findings similar to ours were noted in a 5-year prospective study of collegiate gymnasts in a very successful Division I women's team.[9] The investigators defined an injury as "any damaged body part that would interfere with training." The leading body part injured was the shoulder (18% of injuries); however, type of shoulder pathology was not specified.

A second goal of this study was to estimate MDI incidence in elite female gymnasts. MDI incidence was 11% (52/457). Although the study design (ie, using a nonvalidated questionnaire) precluded determining exact incidence, it allowed us to determine a number of gymnasts who suffered shoulder pathology, and some of this pathology included MDI.

Most have speculated that MDI occurs in athletes in the setting of repetitive microtrauma to the shoulder joint. The forces acting on the shoulder, though not significant enough to cause frank dislocation, can cause microdamage in the capsule. The cumulative effect of repetitive microtrauma leads to plastic deformation of the ligamentous structures and, eventually, acquired laxity and possible instability.[10,11]

Several authors have reasoned that the demands of elite gymnastics place these athletes at increased risk for developing MDI.[2,4] Often, the most flexible athletes are the ones who succeed in the sport, but this acquired or congenital laxity may also make these gymnasts more susceptible to shoulder injury. The more difficult skills in elite gymnastics are often performed with the shoulders placed repeatedly in extreme ranges of motion in which the glenohumeral ligaments are under maximal tension. Usually, the rotator cuff muscles are strong enough to withstand the shear forces that can plastically deform the capsule. Under repetitive motion, the muscles may become fatigued and no longer capable of overcoming these forces. Without the protection of the surrounding musculature, the capsular ligaments must bear all the shear stress, and ultimately they can fail. As gymnasts execute their skills through all shoulder ranges of motion, these multiple, microtraumatic injuries occur along all points of the capsule, over time resulting in acquired laxity.[2] If this laxity becomes symptomatic, then the athlete may be diagnosed with MDI.

The third and last goal of this study was to determine which if any circumstances place elite female gymnasts at higher risk for developing MDI. The study failed to identify any potential risk factors. Although a significant relationship was found between pain and MDI, one would

Table I. Types of Shoulder Injuries Reported

Injury	No. of Gymnasts
Rotator cuff pathology	45
Anterior shoulder dislocation	2
Posterior shoulder dislocation	0
Anterior shoulder subluxation	10
Posterior shoulder subluxation	10
Labral pathology	12
Other	9
More than 1 injury	15

Table II. Potential Risk Factor Associated With Shoulder Injuries

Risk Factor	n	No. of Gymnasts		*P*
		With Injury	Without Injury	
Shoulder stretching				<.001
1 min	263	42	221	
3 min	154	38	116	
5 min	35	21	14	
1 hyperlaxity sign				.02
Yes	226	60	166	
No	231	42	189	
≤2 hyperlaxity signs				.003
Yes	91	31	60	
No	366	71	295	
Sensation of instability				<.001
No	318	41	277	
Yes, but rarely	64	19	45	
Yes, but only at practice	27	17	10	
Yes, in and out of practice	36	21	15	

Table III. Potential Risk Factors Associated With Multidirectional Instability (MDI)

Risk Factor	n*	No. of Gymnasts		*P*
		With MDI	Without MDI	
Shoulder stretching				.1
1 min	221	33	188	
3 min	116	14	102	
5 min	14	5	9	
1 hyperlaxity sign				.1
Yes	166	30	136	
No	189	22	167	
≥2 hyperlaxity signs				.4
Yes	60	11	49	
No	295	41	254	
Shoulder pain				<.001
No	140	3	137	
Yes, but rarely	94	12	82	
Yes, but only at practice	47	7	40	
Yes, in and out of practice	55	26	29	

*As multidirectional instability is defined as an atraumatic shoulder process, the 102 gymnasts with an injury were excluded from these statistics, reducing the number of gymnasts from 457 to 355

expect MDI to be painful, as by definition it is symptomatic (ie, painful) laxity. For the gymnasts who met our inclusion criteria, we did not find any association with number of practice hours or number of years of participation in gymnastics—contradicting research reported to show a direct association between injury and number of practice hours.[12,13]

Furthermore, there was no apparent protection afforded by exercise and weight training outside the gym. Indeed, although there was no significant negative association between shoulder strengthening and MDI apparent in this study, there was no place on the survey for gymnasts to specify type and frequency of shoulder- strengthening activities.

Type and frequency of shoulder-strengthening activities are important because limitations in proprioception may be a risk factor for shoulder instability. Mechanoreceptors are damaged with increasing plastic deformation of the capsule, and this damage limits the ability of these receptors to respond appropriately when the capsuloligamentous structures are being stretched.[14] Most patients, including athletes, respond well to conservative treatment[15] because therapy programs are designed to improve muscle strength and coordination as well as proprioception. Nevertheless, some patients do not improve with conservative therapy; their capsular pathology may exceed the ability of the newly coordinated muscles to compensate. Thus, although this study did not show a statistically significant relationship between shoulder strengthening and MDI, shoulder strengthening may still have a protective role in a structured shoulder program and may help in decreasing the incidence of atraumatic and traumatic shoulder instability. Studies on the effects of shoulder strengthening on MDI development are necessary.

When Neer and Foster[1] first defined MDI, they noted *generalized ligamentous laxity* (their phrase for "hypermobility of the fingers, thumb, elbow, and knees") in almost half their patients. Other investigators have also noted a high incidence of generalized ligamentous laxity in their study populations.[16,17] Carter and Wilkinson[18] and Beighton and colleagues,[19] on the other hand, developed stricter criteria for defining generalized ligamentous laxity. Carter and Wilkinson defined it as being able to perform 4 of 5 maneuvers: (1) passive thumb apposition to forearm, (2) passive finger hyperextension so finger is parallel to forearm, (3) elbow hyperextension of more than 10°, (4) knee hyperextension of more than 10°, and (5) excessive ankle dorsiflexion and foot eversion. Question 15 of our survey was our attempt to determine whether a gymnast had generalized ligamentous laxity. Instead of following the strict criteria of Carter and Wilkinson, we broke our analysis down into whether gymnasts met at least 1 of the criteria or met 2 or more criteria. Even with this more generous definition of generalized ligamentous laxity, there was still no statistically significant association with shoulder MDI (Table III). Nevertheless, as shown in Table II, gymnasts who suffered from traumatic shoulder injuries were more likely to have evidence of ligamentous laxity, at least 1 of the criteria ($P = .02$), and this relationship became even more apparent with increased numbers of laxity signs ($P = .003$).

It is difficult to explain why gymnasts with traumatic shoulder injuries had more instances of increased laxity while those with MDI did not. Some may argue that our study results are flawed because the gymnasts may not have been able to answer the questions on the survey appropriately, and therefore estimates may be incorrect about which gymnasts have evidence of ligamentous laxity. However, we recognized this weakness in the study design before administering the surveys and took steps in the study design and in the statistical analysis to minimize its effects. For example, we selected older (college) gymnasts, who we believed could answer survey questions more accurately than younger gymnasts could, and we phrased the questions for ease of understanding. As already mentioned, we did not follow the generalized ligamentous laxity criteria of Carter and Wilkinson[18] because we thought that some gymnasts might not understand all the responses for survey question 15. For our analysis, the gymnasts were divided into 2 groups: those who had 1 sign of generalized laxity and those who had 2 or more signs. The validity of the laxity data may be called into question because they were not derived from direct physician examination. Nevertheless, the data most likely overestimated incidence of generalized laxity in this population. As a result, we would have expected a higher number of gymnasts with both laxity and MDI, but this was not the case. Although laxity is not a predictor of clinical signs of MDI ($P = .1$), there is a significant relationship between traumatic shoulder injuries and laxity ($P = .02$). This association may not be completely understood, but it should be recognized.

Aside from the possibility of overestimating ligamentous laxity, there were other study limitations, mostly a consequence of study design. Our review relied on female gymnasts' answering a 1-page questionnaire. As already mentioned, though attempts were made to increase participation, the survey response rate could have been better. However, whereas the response rate was 41% (457/1115), the absolute number of surveys returned (457) was high, giving the study strong statistical power. Furthermore, with half the teams being regional qualifiers, and the other half nonqualifiers, the study represents a diverse cross-section of elite female collegiate gymnasts.

Conclusions

Given the study design limitations, our goals were simplified: to determine the incidence of shoulder pathology in elite gymnasts, to estimate the incidence of MDI in this same population, and to discover any potential risk factors for development of this shoulder disorder.

We discovered that, in gymnastics, both atraumatic and traumatic shoulder injuries (especially rotator cuff pathology) may be more prevalent than previously recognized. Although risk factors for developing MDI were not clear, we found potential risk factors (eg, lack of stretching, having several signs of generalized laxity) for developing a traumatic

shoulder injury. Furthermore, that MDI would develop with increased number of practice hours and/or with increased number of practice years was also not observed.

With the number of children participating in gymnastics increasing, the number of female gymnasts developing shoulder MDI will naturally increase as well. This injury could be detrimental to elite gymnasts, who rely on stable yet flexible shoulders to perform some of their maneuvers. Our research only touches on a pathology previously unrecognized in the gymnastics population. Although this research provides a framework for answering some basic questions regarding MDI, it also leaves many more questions unanswered. Certainly, more investigation is needed so that preventive measures can be incorporated into training programs.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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Appendix

Multidirectional Instability (MDI) Questionnaire

The goal of our research is to determine risks of shoulder injuries in gymnasts. Even if you have never had a shoulder problem, your participation is still very helpful. Please answer all questions (by circling the most appropriate answer) as honestly as possible. If your answer is not provided in the answer choices, please write in a brief answer on the side. Your participation is greatly appreciated.

1. How old are you now?
a. 17
b. 18
c. 19
d. 20
e. 21
f. 22

2. How old were you when you began gymnastics?
a. 4
b. 5
c. 6
d. 7
e. 8
f. 9

3. Have you ever had a major, traumatic shoulder injury?
a. Yes
b. No (If no, please move on to question 8)

4. Did your shoulder injury occur on the same or opposite hand that you write with?
a. Same side
b. Opposite side

5. If yes, which kind have you had?
a. Rotator cuff injury
b. Anterior shoulder dislocation (shoulder went completely out of place forward)
c. Posterior shoulder dislocation (shoulder went completely out of place backward)
d. Anterior shoulder subluxation (shoulder went partially out of place forward)
e. Posterior shoulder subluxation (shoulder went partially out of place backward)
f. Other _____

6. Did this injury force you to stop training gymnastics at any time?
a. Yes
b. No

7. How was this injury treated?
a. Ignored it, and it got better
b. Physical therapy
c. Surgery (If surgery, which type?)

8. For how long do you stretch your shoulders before practice?
a. 1 minute
b. 3 minutes
c. 5 minutes

9. Roughly how many hours per week did you practice gymnastics before college?
a. 15-19 hours
b. 20-24 hours
c. 25-29 hours
d. >30 hours

10. How many hours per week do you practice gymnastics in college now?
a. 10-14 hours
b. 15-19 hours
c. 20-24 hours
d. >25 hours

11. Do you exercise outside the gym as well?
a. Yes
b. No

12. Does this exercise include weightlifting?
a. Yes, and this includes shoulder strengthening
b. Yes, but I do not do shoulder strength
c. No

13. Do you practice all 4 events?
a. Yes (If yes, skip question 14)
b. No

14. Choose the 2 events you practice the most.
a. Vault
b. Bars
c. Beam
d. Floor

15. Please circle below if you are able to do the following:
a. Hyperextend your knees more than 10 degrees
b. Hyperextend your elbows more than 10 degrees
c. Bend your thumb and wrist forward so that it touches your wrist (on the same side as your palm)
d. Bend your fingers back so they are parallel to your forearm

16. Even if you have never had a shoulder injury, do you still experience shoulder pain?
a. No
b. Yes, but rarely
c. Yes, but only at gymnastics practice
d. Yes, both inside and outside gymnastics practice

17. Do you ever have the sensation, or experience your shoulder moving out of place (instability)?
a. No (If no, skip question 18)
b. Yes, but rarely
c. Yes, but only at gymnastics practice
d. Yes, both inside and outside gymnastics practice

18. If you do experience shoulder instability, please circle all the following activities in which your symptoms develop
a. Vault
b. Bars
c. Beam
d. Floor
e. Pushing open doors
f. Carrying a heavy load, like books
g. Other _____

This paper will be judged for the Resident Writer's Award.