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Authors

Talutis, Stephanie D
Ulloa, Jesus G
Gelabert, Hugh A

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The impact of competitive level of high school and collegiate athletes on outcomes of thoracic outlet syndrome

Stephanie D. Talutis, MD, MPH,[a] Jesus G. Ulloa, MD, MBA,[b] *and* Hugh A. Gelabert, MD,[b] *Boston, MA; and Los Angeles, CA*

ABSTRACT

Objective: Thoracic outlet syndrome (TOS) has life-changing impacts on young athletes. As the level of competition increases between the high school (HS) and collegiate (CO) stage of athletics, the impact of TOS may differ. Our objective is to compare surgical outcomes of TOS in HS and CO athletes.

Methods: This was a retrospective review of HS and CO athletes within a prospective surgical TOS database. The primary outcome was postoperative return to sport. Secondary outcomes were resolution of symptoms assessed with somatic pain scale (SPS), QuickDASH, and Derkash scores. Categorical and continuous variables were compared using χ^2 and analysis of variance, respectively. Significance was defined as $P < .05$.

Results: Thirty-two HS and 52 CO athletes were identified. Females comprised 82.9% HS and 61.5% CO athletes ($P = .08$). Primary diagnoses were similar between groups (venous TOS: HS 50.0% vs CO 42.3%; neurogenic TOS: 43.9% vs 57.7%; pectoralis minor syndrome: 6.3% vs 0.0%) ($P = .12$). Pectoralis minor syndrome was a secondary diagnosis in 3.1% and 3.8% of HS and CO athletes, respectively ($P = 1.00$). The most common sports were those with overhead motion, specifically baseball/softball (39.3%), volleyball (12.4%), and water polo (10.1%), and did not differ between groups ($P = .145$). Distribution of TOS operations were similar in HS and CO (First rib resection: 94.3% vs 98.1%; scalenectomy: 0.0% vs 1.9%, pectoralis minor tenotomy: 6.3% vs 0.0%) ($P = .15$). Operating room time was 90.0 vs 105.3 minutes for HS and CO athletes, respectively ($P = .14$). Mean length of stay was 2.0 vs 1.9 days for HS and CO athletes ($P = .91$). Mean follow-up was 6.9 months for HS athletes and 10.5 months for CO athletes ($P = .39$). The majority of patients experienced symptom resolution (HS 80.0% vs CO 77.8%; $P = 1.00$), as well as improvement in SPS, QuickDASH, and Derkash scores. Return to sport was similar between HS and CO athletes (72.4% vs 73.3%; $P = .93$). Medical disability was reported in 100% HS athletes and 58.3% CO athletes who did not return to sport ($P = .035$).

Conclusions: Despite increased level of competition, HS and CO athletes demonstrate similar rates of symptom resolution and return to competition. Of those that did not return to their sport, HS athletes reported higher rates of medical disability as a reason for not returning to sport compared with CO athletes. (J Vasc Surg 2024;79:388-96.)

Keywords: Neurogenic; Outcomes; Paget-Schroetter; Pain; Thoracic outlet

Thoracic outlet syndrome (TOS) is a constellation of symptoms caused by compression of major structures by the scalene triangle.[1-3] Compression may be the result of scalene muscle hypertrophy[4-6] or structural abnormalities such as cervical ribs or fibrous bands.[6-8]

There are three distinct types of TOS, which are defined by the compressed structure within the scalene triangle. Neurogenic TOS (NTOS) is the most common form and is caused by brachial plexus compression.[1,4] Pectoralis minor syndrome (PMS) is a subset of NTOS caused by compression of the brachial plexus in the retro-pectoral space.[9,10] In both NTOS and PMS, patients present with pain and paresthesia radiating down the arm,[9,11] which may progress to weakness and motor deficits with prolonged compression.[1,2,7,12,13] Venous TOS (VTOS) is caused by subclavian vein compression and results in upper extremity deep vein thrombosis (Paget-Schroetter) or positional swelling without thrombosis (McCleery syndrome).[1] Arterial TOS (ATOS) is the least frequent variant and occurs with subclavian artery compression resulting in either symptomatic upper extremity ischemia or aneurysmal changes within the artery, which may also result in upper extremity ischemia from embolization.[1,4]

TOS has been reported in athlete populations due to anatomical compression of nervous and vascular structures following recurring activity or trauma,[3,14] especially among those engaging in with repetitive overhead activity.[15] TOS may have a life-changing impact on young athletes in particular when considering high physical performance demands, coupled with social pressures to return to pre-injury peak performance.[2] Organized

From the Division of Vascular Surgery, Cardiovascular Center, Tufts Medical Center, Boston[a]; and the Division of Vascular and Endovascular Surgery, David Geffen School of Medicine at UCLA, Ronald Reagan Medical Center, University of California Los Angeles, Los Angeles.[b]

Correspondence: Stephanie D. Talutis, MD, MPH, Tufts Medical Center Department of Vascular Surgery, 200 Medical Plaza, Ste 526, Los Angeles, CA 90095 (e-mail: stephanie.talutis@tuftsmedicine.org).

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athletics are characterized by progressive increase in competitive level as athletes mature into their sport and grow in both strength and skill. The time in training and enhanced muscular development of collegiate (CO) athletes are hallmarks of athletic progression. These same characteristics might be anticipated to improve the CO athlete ability to return to competition after developing TOS. We hypothesize that as the level of competition increases, the impact of TOS may also increase, and outcomes may differ. Our objective is to compare surgical outcomes of TOS in high school (HS) and CO athletes.

METHODS

A prospective surgical database was reviewed for HS and CO athletes who required surgical care for disabling TOS between 1997 and 2022. HS vs CO athlete status was determined by the patients' academic sport level at the time of consultation. Demographic, clinical, and pathologic data were reviewed.

Diagnosis of TOS. The Society for Vascular Surgery TOS reporting standards were used in establishing a diagnosis of each patient.[1] The diagnosis of NTOS was based on symptoms of radicular pain, paresthesia, and weakness in conjunction with physical exam findings consistent with the diagnosis of TOS. A combination of cervical spine x rays, cervical magnetic resonance imaging (MRI), nerve conduction testing, and anterior scalene muscle blocks (ASMBs) were used to confirm the diagnosis. After a trial of TOS-targeted physical therapy, patients with persistent and severe symptoms were offered treatment with Botox for chemical denervation or surgical decompression. Surgery was reserved for patients with intractable, severe, disabling symptoms.

Pectoralis minor syndrome (PMS) is a distinct diagnosis of brachial plexus compression by the pectoralis minor muscle in the sub-coracoid space. Diagnosis of PMS is based on symptoms of pectoralis minor pain, along with pain, paresthesia, and weakness that radiate down the arm. These symptoms are exacerbated with maneuvers that elicit compression by the pectoralis minor muscle.[9] Although these symptoms may overlap with those of NTOS, diagnosis is confirmed by pectoralis minor block. Surgery is reserved for debilitating and severe symptoms.

VTOS cases were diagnosed based on symptoms of upper extremity swelling, pain, and discoloration in addition to confirmation of subclavian vein thrombosis by ultrasonography and venography. Thrombolysis was routinely utilized in acute (within 2 weeks of symptom onset) presentations. First rib resection (FRR) was offered to patients with extrinsic venous compression and persistent congestive symptoms. Venography is routinely performed for patients with VTOS at the time of FRR. Postoperatively, patients with VTOS resume anticoagulation on postoperative day 5. Routine post-rib resection venography was performed 2 to 3 weeks after surgery to assess surgical results and provide venoplasty as needed. If venoplasty is performed, anticoagulation is continued for an additional 4 weeks.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center, retrospective cohort study
- **Key Findings:** We found that high school (HS) and collegiate (CO) athletes experience similar rates of resolution of symptoms (80% vs 77.8%) and a similar overall rate of return to competition (72.4% vs 73.3%) after thoracic outlet decompression. Secondary injuries were more frequent in HS athletes (75% of HS and 18% of CO athletes), and secondary operations were required to treat thoracic outlet syndrome in 26% of our athletes.
- **Take Home Message:** Regardless of the level of competition, both HS and CO athletes return to their sports at similar rates following thoracic outlet decompression.

TOS decompression was achieved in most patients by means of transaxillary resection of FRR and/or cervical rib with subtotal scalenectomy.[16-18] Supraclavicular scalene muscle resection was reserved primarily for recurrent NTOS symptoms in the setting of a prior transaxillary FRR.

Routine postoperative visits were conducted at 2 weeks, 6 weeks, and then every 3 months until symptoms resolved. Patients are given instructions on range of motion exercises at the time of discharge and are given a prescription for physical therapy after their first postoperative appointment, 2 weeks after surgery. Postoperative physical therapy consists of graduated massage, stretching, and strengthening. The duration of physical therapy is determined by individual patient recovery, and on average lasts 6 to 8 weeks.

Analysis of outcomes. Outcomes were assessed based on Society for Vascular Surgery reporting standards,[1] including somatic pain scale (SPS), Quick DASH scores (QuickDASH), and Derkash scores (Derkash) and were compared between HS and CO athletes. Each of these scores was also compared preoperatively vs postoperatively within the NTOS and VTOS groups.

Return to sport and resolution of symptoms were recorded for all patients at all clinic visits. Medical disability included both unrelated injuries and medical conditions impeding the athlete's return to competition. Approval for this work was granted by the UCLA Institutional Review Board (protocol no. 13-000,624).

Statistical analysis. The χ^2 test and analysis of variance were used to evaluate categorical and continuous variables respectively. The paired *t*-test was used to compare

Table I. Demographics and preoperative characteristics

	All	HS	CO	
	N = 84	N = 32	N = 52	*P* Value[a]
Age, years	18.2 ± 2.3	15.7 ± 1.0	19.7 ± 1.4	**<.001**
Female	69.0	81.3	61.5	.06
Primary diagnosis				.12
VTOS	45.2	50.0	42.3	
NTOS	52.4	43.9	57.7	
PMS	2.4	6.3	0.0	
Secondary diagnosis-PMS	3.6	3.1	3.8	1.00
Symptoms in dominant hand	69.3	67.9	70.2	.83
Prior TOS operation	2.4	3.1	1.9	.73
Other neck/arm/shoulder/hand pathology	17.9	21.9	15.4	.45

CO, Collegiate; *HS*, high school; *NTOS*, neurogenic thoracic outlet syndrome; *PMS*, pectoralis minor syndrome; *TOS*, thoracic outlet syndrome; *VTOS*, venous thoracic outlet syndrome.
Data are presented as percent or mean ± standard deviation.
[a]Boldface *P* values indicate statistical significance, defined as $P < .05$.

preoperative and postoperative metrics. Significance was defined as $P < .05$.

RESULTS

During the study period, 1800 operations for TOS were performed. Of these, a total of 32 HS and 52 CO athletes were identified. Demographic and clinical presentation data are presented in Table I. HS athletes were younger (15.7 vs 19.7 years; $P < .001$) and had a higher percentage of females (81.3% vs 61.5%; $P = .08$). There was no difference in distribution of VTOS, NTOS, or PMS between groups ($P = .12$). In both groups, symptoms were more likely to be present in the dominant hand (67.9% vs 70.2%; $P = 1.00$). At the time of consultation, 3.1% of HS and 1.9% of CO athletes reported having undergone a prior TOS operation ($P = .73$). Diagnosis of an unrelated neck, arm, shoulder, or hand pathology was present in 21.9% of HS and 15.4% of CO athletes at the time of consultation ($P = .45$). Mean time from symptom onset was 11.6 months. Although this did not differ between HS and CO athletes, there was a longer time from symptom onset to consultation when comparing VTOS (2.8 ± 4.8 months) vs NTOS (19.0 ± 18.5 months) ($P < .001$).

Preoperative diagnosis. Preoperative workup consisted of ASMB, cervical x rays, MRI, and computerized tomography angiography, as well as electromyography. There was a higher percentage of CO athletes undergoing MRI cervical spine (25.0% vs 50.0%; $P = .04$), with no difference in the remaining diagnostic modalities. The majority of imaging studies were ordered by referring physicians prior to referral to vascular surgery.

Few patients with VTOS presented acutely with subclavian vein thrombosis (HS 12.5% vs CO 22.7%; $P = .30$). Preoperative management of patients with VTOS did not differ between the HS and CO groups. The majority of patients with VTOS underwent thrombolysis (68.8% vs 54.5%), with the remaining patients undergoing receiving anticoagulation alone (18.8% vs 27.3%), or other treatment (12.5% vs 13.6%) ($P = .72$).

Sports. Sports data are represented in Fig 1. The majority of HS and CO athletes played one sport; however, there were eight athletes who played two sports (5 HS and 3 CO athletes), and one HS athlete who played three sports. The most frequently reported sports were those with overhead activity, including baseball/softball (35.5%), volleyball (11.8%), water polo (9.7%), and swimming (8.6%).

Operative details. FRR was performed in 96.4% of patients, with 1.2% undergoing scalenectomy, and 2.4% PMT alone (Table II). Of those undergoing FRR, concurrent operations included cervical rib resection in 4.8% and PMT in 2.4%. All patients with VTOS underwent venogram at the time of FRR. There were no differences in the distribution of primary ($P = .14$) or concurrent operations ($P = .55$) between groups. Mean operative time was similar between groups (90.0 vs 105.3 minutes; $P = .15$). Mean length of stay was 2.0 days for HS and 1.9 days for CO athletes ($P = .91$).

There were no differences in outcomes between HS and CO athletes on postoperative venogram for patients with VTOS ($P = .55$). Patent subclavian vein was found in 31.3% of HS and 22.2% of CO athletes. Venoplasty of subclavian stenosis was performed in 18.0% of HS and 44.4% of CO athletes. Subclavian thrombus, either persistent or recurrent, was treated with either Penumbra catheter-directed mechanical aspiration (6.3% vs 0.0%) or catheter-directed chemical thrombolysis (12.5% vs 11.1%) except in cases with robust collateralization (6.3% vs

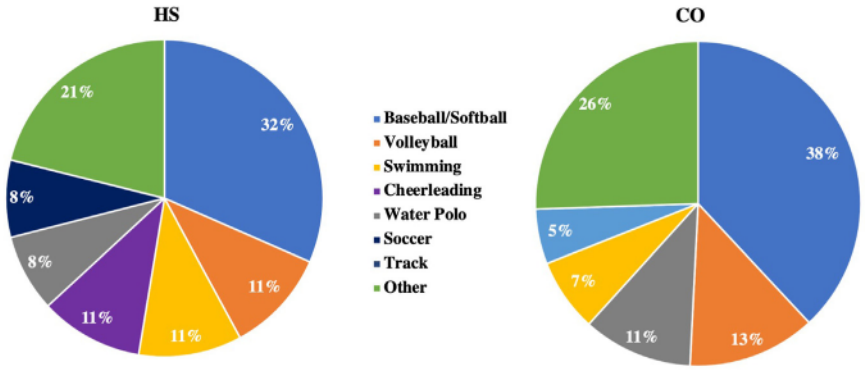

Fig 1. Athletic details. *CO*, Collegiate; *HS*, high school.

Table II. Operative details

	All n = 84	HS n = 32	CO n = 52	*P* value
Primary operation				.14
FRR	81 (96.4)	30 (93.8)	51 (98.1)	
Scalenectomy	1 (1.2)	0 (0.0)	1 (1.9)	
PMT	2 (2.4)	2 (6.3)	0 (0.0)	
Concurrent operation				.55
CRR	4 (4.8)	2 (6.3)	2 (3.8)	
PMT	2 (2.4)	0 (0.0)	2 (3.8)	
Venogram	20 (23.8)	6 (18.8)	14 (26.9)	
Secondary operation				.72
Contralateral FRR	12 (14.4)	4 (12.5)	8 (15.4)	
Ipsilateral scalenectomy	13 (15.5)	6 (18.8)	7 (13.5)	
Contralateral scalenectomy	2 (2.4)	1 (3.1)	1 (1.9)	
Ipsilateral PMT	2 (2.4)	2 (6.3)	0 (0.0)	

CO, Collegiate; *CRR*, cervical rib resection; *FRR*, first rib resection; *HS*, high school; *PMT*, pectoralis minor tenotomy.
Data are presented as number (%).
Secondary operations indicate those not performed at the time of the index (primary operation).

5.6%). Repeat venogram was not performed in patients with McCleery syndrome (0.0% vs 5.6%). Some venograms were performed at outside referring facilities due to patients living remotely from our institution (25.0% vs 11.1%).

Symptom relief and standardized outcomes. Mean follow-up was 6.9 months for HS and 10.5 months for CO athletes ($P = .39$). Eighty percent of HS and 77.8% CO athletes experienced complete symptom resolution postoperatively ($P = 1.00$). SPS, QuickDASH, and Derkash scores improved for both groups between preoperative score and postoperative score ($P < .001$ for HS and CO for all metrics).

Standardized outcomes are presented in Table III. There were no differences in SPS. QuickDash, or Derkash scores between HS and CO athletes.

Standardized outcomes of NTOS and VTOS were compared within groups (Fig 2). HS and CO athletes with VTOS did not experience significant change in SPS ($P = .026$); however, HS and CO athletes with NTOS experienced significant improvement in SPS ($P < .001$). Similarly, there was no significant change in QuickDASH score in HS or CO athletes with VTOS. HS and CO athletes with NTOS experienced significant reduction in QuickDASH (HS, $P = .002$; CO, $P < .001$). Derkash score, however, improved in HS and CO athletes with both VTOS and NTOS ($P < .001$ for all groups).

Standardized outcomes of NTOS and VTOS were also compared between the HS and CO groups. SPS were higher for CO athletes with VTOS preoperatively (0.0 vs 2.1; $P = .013$) and postoperatively (0.3 vs 0.5; $P = .019$) compared with HS athletes with VTOS. However, there were no significant difference in comparing QuickDASH scores preoperatively ($P = .46$) or postoperatively ($P = .86$), or in comparing Derkash scores preoperatively ($P = .40$) or postoperatively ($P = .15$) between HS and CO athletes with VTOS.

Table III. Standardized outcomes

	All	HS	CO	*P* value
SPS				
Preoperative	4.1	3.5	4.6	.18
Postoperative	0.9	0.9	0.8	.89
Delta	2.7	1.9	3.2	.14
% change	56.4	42.6	63.9	.16
QuickDASH				
Preoperative	21.1	50.0	43.7	.34
Postoperative	18.7	24.8	15.4	.07
Delta	50.2	34.3	59.5	.54
% change	66.7	60.5	70.8	.23
Derkash				
Preoperative	2.7	2.7	2.7	.89
Postoperative	3.6	3.5	3.6	.24
Delta	0.9	0.9	1.0	.44
% change	40.5	41.6	39.8	.83

CO, Collegiate; *HS*, high school; *SPS*, somatic pain scale.

In comparing HS and CO athletes with NTOS, there were no differences in SPS preoperatively ($P = .51$) or postoperatively ($P = .95$); QuickDASH scores preoperatively ($P = .12$) or postoperatively ($P = .17$); or Derkash scores preoperatively ($P = .23$) or postoperatively ($P = .34$).

Return to sport and medical disability. There was no significant difference in return to sport in HS or CO athletes (73.3% vs 79.6%; $P = .52$). Medical disability was a reason for not returning to sport in 100% of HS and 58.3% of CO athletes ($P = .035$) (Table IV).

Return to sport was higher in athletes with VTOS compared with those with NTOS (VTOS: 94.6% vs NTOS: 62.5%; $P = .002$). There was no difference in return to sport between HS and CO athletes with VTOS (93.3% vs 95.2%; $P = .84$). Medical disability was reported in 100% of HS and 50% of CO athletes that did not return to sport.

There was no difference in return to sport between HS and CO athletes with NTOS (50.0% vs 67.9%; $P = .29$). Medical disability was reported among 100% of HS and 60% of CO athletes who did not return to sport ($P = .07$).

Medical disability included both unrelated injuries and medical conditions. Overall, HS athletes reported a higher incidence of unrelated injuries as the reason for not returning to sport (87.5% vs 16.7%; $P = .009$). When stratified by diagnosis, the difference was not significant among athletes with VTOS (HS: 100% vs CO: 50%; $P = .39$) but persisted among athletes with NTOS (83.3% vs 10.0%; $P = .003$). Reported unrelated injuries included cubital tunnel syndrome, shoulder injury, and spine injuries. The remaining athletes who did not return to sport cited medical conditions, including migraines, chronic regional pain syndrome, and positional orthostatic tachycardia syndrome. These were all among athletes with NTOS, with no difference between HS and CO athletes (16.7% vs 20.0%; $P = .87$). There was no association between preoperative neck, arm, shoulder, and hand pathology and postoperative medical disability ($P = .20$), even when stratifying by HS or CO groups.

Additional operations. Twenty-seven additional operations were performed in 22 patients (26%) (Table II). Contralateral FRR was performed in 12 patients (14%): four HS athletes (3 NTOS, 1 VTOS) and eight CO athletes (7 NTOS, 1 VTOS). Thirteen athletes (16%) (6 HS and 7 CO) with recurrent NTOS symptoms were evaluated with ASMB prior to undergoing a supraclavicular completion scalene muscle resection. Late pectoralis minor tenotomy was required in two patients (3%): (2 HS and 0 CO).

Athletes who required additional operations were less likely to experience complete resolution of symptoms ($P = .028$). However, the need for additional operations did not affect return to sport ($P = .26$).

DISCUSSION

Of the 84 athletes in the cohort who underwent TOS decompression, 73% returned to athletics, and 80% experienced symptom resolution. Despite the increased level of athletic competition, there is no difference in the rate of returning to sport between HS and CO athletes. All athletes, HS and CO, experienced reductions in SPS and QuickDASH scores, as well as improvement in Derkash scores. Twenty-six percent of athletes required at least one additional operation. Athletes who required at least one additional operation had lower resolution of symptoms, but no difference in return to sport.

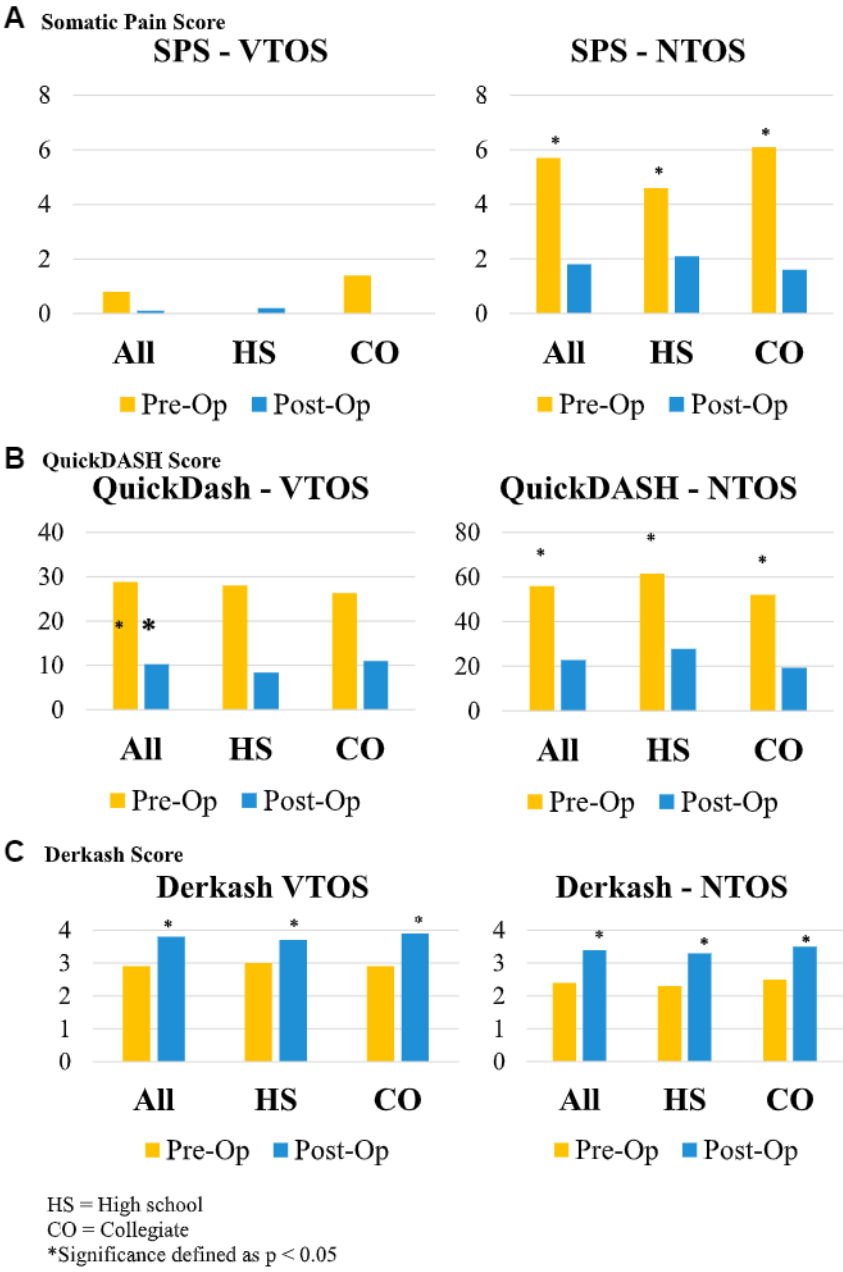

Fig 2. Standardized outcome metrics stratified by neurogenic thoracic outlet syndrome (*NTOS*) and venous thoracic outlet syndrome (*VTOS*). **A,** Somatic Pain Score (*SPS*); **B,** QuickDASH Score; **C,** Derkash Score. *CO*, Collegiate; *HS*, high school. *Significance defined as $P < .05$.

Several factors converge on both HS and CO athletes to impact their return to athletic competition. The level of training and coaching will differ between amateur and professional levels, and as such, the pressure to return. The cumulative impact of injuries may gradually degrade an athlete's competitive ability. The motivations, both personal reward from competition as well as potential financial and career outlook, certainly play a role in the decision as to whether to attempt return to sports. Life transitions, from school and college to working the general economy, certainly impact the desire and opportunity to continue in organized sports. Very few collegiate athletes will progress into professional sports. Additionally, loss of one's identity as an athlete, either as a result of injury or transition, can put additional strain on an athlete's well-being.[19]

Return to athletic competition was successfully achieved in 73% of our patients. This is similar to other reports on TOS in athletes; a high percentage of disabled athletes may return to competition following TOS

Table IV. Symptom resolution and return to sport

All athletes	All n = 84	HS n = 32	CO n = 52	*P* value[a]
Symptom resolution	78.8	80.0	77.8	1.00
Return to sport	73.0	72.4	73.3	.93
Non-return				
Medically disabled	75.0 (15/20)	100.0 (8/8)	58.3 (7/12)	**.035**
Athletes with VTOS	**Total n = 29**	**HS n = 16**	**CO n = 22**	***P* Value[a]**
Symptom resolution	97.1	92.9	100.0	.41
Return to sport	94.6	93.3	95.2	.84
Non-return				
Medically disabled	66.7 (2/3)	100.0 (1/1)	50.0 (1/2)	.39
Athletes with NTOS	**Total n = 44**	**HS n = 16**	**CO n = 30**	***P* value[a]**
Symptom resolution	65.9	71.4	63.6	.738
Return to sport	62.5	50.0	67.9	.29
Non-return				
Medically disabled	75.0 (13/17)	100.0 (7/7)	60.0 (6/10)	.07

CO, Collegiate; *HS*, high school; *NTOS*, neurogenic thoracic outlet syndrome; *VTOS*, venous thoracic outlet syndrome.
Data are presented as percent or percent (n/N).
[a]Boldface *P* values indicate statistical significance, defined as $P < .05$.

decompression.[2,4,15,20-24] Melby[23] reported 32 athletes with VTOS, all of whom (100%) were able to resume athletic competition.[23] Chandra reported a series of 41 patients (27 NTOS and 14 VTOS) who underwent surgery for TOS. They noted that 82% of patients with NTOS and 93% of patients with VTOS patients were able to return to competition.[2] Shutze reported a questionnaire survey of their athletes who had undergone TOS surgery. Of those who replied, 70% returned to competition.[15]

Relief of symptoms following TOS decompression was experienced by most athletes. In our series, we noted that overall, 79% experienced resolution of TOS symptoms. Shutze noted that 96% were improved in pain medication use and 82% had resolution of symptoms.[15] In a later report comparing athletes with non-athletes, Beteck noted that 87% were improved in pain medication use (athletes 93% vs nonathletes 80%) and 73% had resolution of TOS symptoms (athletes 80% vs non-athletes 65%).[21]

Secondary operations were required to treat TOS in 26% of our athletes. These operations included contralateral FRR for contralateral symptoms, completion scalenectomies for recurrent or persistent symptoms, and pectoralis minor tenotomies. In their series of patients with VTOS, Melby noted that 21% (7/32) required secondary operations in the perioperative period: three graft thrombectomies for subclavian vein graft thrombosis, two evacuations of hemothorax, and two explorations for control of lymph leak. Additionally, 43% (14/32) required late ligation of arteriovenous fistulas.[23] Among patients with NTOS, Chandra reported that 10% of patients (2/27) experienced return of symptoms, and one required reoperation.[2]

Standardized outcome metrics were used to assess the result of surgical care. In our series, we noted the average QuickDash score reduced from 55.9 to 22.7, representing a 60% reduction in the QuickDash score. In a similar manner, average SPS scores were reduced by 70%, and Derkash scores improved by 35%. Similarly, other reports indicate symptomatic improvement confirmed by QuickDash reduction[2,14,20] and decreased pain,[20,21] as well as satisfaction with postoperative results.[15,21]

We noted significant difference in outcomes of patients with NTOS and VTOS, with patients with VTOS having better outcomes overall. We found that return to competition was achieved in 50% of patients with NTOS and 93% of patients with VTOS. Similarly, relief of symptoms was noted in 71% of patients with NTOS and 93% of patients with VTOS. This is similar to the observation by Chandra et al, in a series of 41 patients (27 with NTOS and 14 with VTOS) who underwent surgery for TOS, where 93% of patients with VTOS and 82% of patients with NTOS were able to return to competition.[2] In our cohort, 77.2% overall returned to sport, including 94.6% with VTOS and 62.5% with NTOS, with no difference in HS vs CO athletes across groups. Medical disability was the primary reason for not returning to sport, reported by 75% of those who did not return to sport. Reasons

for not returning to sport are not frequently reported in the literature but can highlight the complexity of treating athletes. Our return to sport rate is lower for athletes with NTOS than other cohorts. This could be explained by the limited follow-up for some of the athletes due to distance from our institution.

Reasons for not returning to competition included secondary injuries, other medical conditions, and graduation. The most frequently reported reason for not returning to sport was an unrelated, non-TOS related injury. Unrelated injuries were more prevalent in HS athletes compared with CO athletes. Similar findings have been reported in other athletic literature, with up to one-third of athletes requiring additional sports-related operations.[15] Many young athletes may push themselves through injuries due to the limited age window for competition,[15] as well as high physical performance demands and pressures to return to peak athletic performance while coping with injuries.[2] Many HS athletes may feel pressured to "power through" injuries due to the prospect of obtaining college scholarships, and CO athletes may similarly feel compelled to play while injured to maintain those scholarships.

Limitations. Our study is limited by its design as a retrospective review of a single-institution prospective surgical database. With return to sport as our primary outcome, we relied on patient follow-up and self-report of this metric. Although outcome data is available for most patients, longer-term follow-up was limited for those athletes who lived remotely from our institution. This may mean that return to sport may be underestimated, as some athletes may have later returned to sport if we had followed them for a longer duration. Although virtually all athletes participated in weight training as part of sports conditioning, the details regarding the impact of weight training were not collected for this study. Additionally, we do not have data regarding preoperative duration of sport disability, which likely impacts postoperative return to sport.

Race and ethnicity data points were not included in our surgical dataset, and therefore cannot be analyzed in this study. Our population was also predominantly female with a higher composition of VTOS, which may be more reflective of the athletic population with TOS but may not be representative of the general population with TOS.

CONCLUSIONS

Our study is unique in comparing outcomes between HS and CO athletes and highlights the difference between resolution of symptoms and return to competition. HS and CO athletes with TOS return to sports at similar rates following thoracic outlet decompression. Relief of TOS symptoms was experienced by most of our athletes. A significant number of athletes in our cohort (14%) required a secondary operation to treat TOS in their contralateral limb as well as secondary operations for recurrent TOS (12%). Our results may aid in guiding expectations around surgery for both athletes and surgeons pursuing thoracic outlet decompression in the management of severe, disabling TOS, despite increased level of competition.

AUTHOR CONTRIBUTIONS

Conception and design: ST, JU, HG
Analysis and interpretation: ST, HG
Data collection: ST, HG
Writing the article: ST, HG
Critical revision of the article: ST, JU, HG
Final approval of the article: ST, JU, HG
Statistical analysis: ST
Obtained funding: Not applicable
Overall responsibility: ST

DISCLOSURES

None.

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