ORIGINAL ARTICLE

Quantification of the weakness and fatigue in thoracic outlet syndrome with isokinetic measurements

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Objectives: Patients with thoracic outlet syndrome (TOS) complain of many subjective symptoms that are difficult to measure and quantify. In this study we have tried to assess the weakness (muscle strength) and fatigue (endurance) of these patients with an objective measurement method, isokinetic muscle testing.
Methods: Twenty three TOS patients and 15 age matched healthy controls were enrolled in the study. Detailed histories of the patients were taken and the patients underwent complete physical examinations. Cervical radiographies, Doppler ultrasonography, electromyography, and isokinetic measurements were carried out. The isokinetic measurements were carried using the Biodex System 3 dynamometer during concentric shoulder flexions and extensions at velocities of 60˚/s, 180˚/s, and 240˚/s.
Results: Although the muscle strengths of both groups seemed to be similar, the fatigue ratios of TOS patients at 60˚/s and 180˚/s were found to be higher compared with those of healthy controls ($p = 0.029$, $p = 0.007$).
Conclusions: TOS patients were found to have muscular performance similar to controls, but their upper extremities developed fatigue more easily than those of healthy individuals.

The complex of signs and symptoms caused by compression of brachial plexus and subclavian vessels in the cervicoaxillary region is known as thoracic outlet syndrome (TOS). Although there is much debate about its classification, TOS is usually divided into three groups: vascular (vTOS), neurogenic (nTOS), and disputed neurogenic TOS (dnTOS). Bones and the surrounding soft tissues are the two main factors which play an important role in the etiology of TOS. The bony factors, responsible for 30% of all cases,[1] are usually the long transverse process of the seventh cervical vertebra (C7), a cervical rib, an anomalous first rib, and fractures of the clavicle or first rib. The soft tissue factors are either nearby congenital bands and ligaments or scalene muscle problems which may be congenital or acquired. In addition, any trauma or mechanical stress to the neck, shoulders, or upper extremities may either predispose the individual to TOS or can aggravate an established clinical scenario.[2]

TOS can easily be misdiagnosed unless considered in the differential diagnosis. The most common symptoms—no matter which type of TOS is present—are pain and paraesthesias which are present in 90–95% of patients,[3] usually in the supraclavicular, interscapular, subscapular, and cervical regions or in the upper extremities. The pain is often described as blunt and radiating towards the arm; paraesthesias are segmental and usually on the ulnar side of the upper limb. Feelings of weakness, fatigue, coldness, and swelling in the upper extremities are other common findings. Rarely, some patients also experience symptoms such as tachycardia, dyspnea, dysphagia, angina-like chest pain, occipital headache, and Raynaud-like vasomotor changes in the upper extremity, all of which can reasonably be explained with reference to different types of pathophysiological mechanisms.[4 5]

Symptoms occurring particularly when patients are using their arms overhead or are carrying heavy objects—and getting relief once they cease doing so—point to a diagnosis of TOS. However, weakness and fatigue, which can be due to either neurogenic or vascular compression,[6 7] are not always clearly differentiated or interpreted in TOS patients. Thus, focusing particularly on these muscular symptoms, in this study our aim was to demonstrate and quantify the actual functional changes in the upper limbs of these patients. To the best of our knowledge, subjective complaints of weakness or fatigue in TOS patients have not yet been clarified with any objective data in the literature.

Isokinetic systems are appropriate tools for quantitative measurement of the musculoskeletal system and have been used for muscular evaluation. Endurance studies are specific isokinetic measurements for assessing fatigue and are carried out at high rates of repetition ranging from 10 to 150 repetitions[8–10] where the decline in peak torque values[11 12] or in the work done[9 10] is taken into consideration. We have undertaken such a study to substitute for the lack of objective data for TOS patients with regard to their subjective complaints of weakness and fatigue.

METHODS

Twenty three patients (17 female, six male) and 15 (11 female, four male) healthy control volunteers were enrolled in the study. All individuals were informed of the study procedure and gave informed consent.

Clinical history

The age, height, body weight, sex, and occupation of the patients were noted. The patients then completed a questionnaire to ascertain the following: primary complaint; dominant side; side and duration of the complaint; any history of smoking; previous upper extremity or thorax surgery; fracture in the costaclavicular region; shoulder dislocation or any accident involving the same area; previous subclavian catheterisation; and any tachycardia, dyspnea, dysphagia, vertigo, tinnitus, headache, sleeping disturbances, or malaise. The patients then answered questions as to whether in each upper extremity the pain was felt in the

Abbreviations: CTS, carpal tunnel syndrome; dnTOS, disputed neurogenic TOS; D-USG, Doppler ultrasonography; FRs, fatigue ratios; nTOS, neurogenic TOS; PT/BW, peak torque/body weight; TOS, thoracic outlet syndrome; vTOS, vascular TOS

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limb, in the overhead limb, and with or after heavy lifting; whether it was intermittent or steady, and experienced during rest, at night, or during valsalva manoeuvre; and whether the limb was easily fatigued and there was any swelling in the morning, discoloration, coldness, paraesthesia, or weakness. Pain intensity was assessed using a 10 cm visual analogue scale.

Physical examination
Detailed neurological and musculoskeletal evaluations were carried out in addition to a thorough physical examination. Tender or trigger points, any skin changes, oedema, and heat discrepancies between the upper extremities were examined. Muscular strengths were recorded using the Lowett scale. Supraclavicular Tinel's sign, Adson, hyperabduction (Wright), costaclavicular (Halstead), and Roos tests were also performed.

Radiological evaluation
Cervical radiographs (anteroposterior, lateral, oblique views) were evaluated for the presence of a long C7 transverse process or cervical ribs and were also used to differentially diagnose any concurrent problems such as cervical spondylosis. Doppler ultrasonography (D-USG) was performed, first when the patient was lying supine and then during two provocative manoeuvres as follows: (i) while hyperabducting the arm whilst in the supine position; and (ii) after inserting a pillow beneath the midscapular area with simultaneous extension and lateral rotation of the patient's neck.

Electrophysiological evaluation
Bilateral segmental motor nerve conduction studies of the ulnar and median nerves were performed using a Synergy monitoring system (Medelec, Vickers Medical, Woking, Surrey, UK). For the median nerve, recording from the abductor pollicis brevis muscle, stimulations were applied to the wrist, antecubital region, axilla, and Erb's point. Likewise for the ulnar nerve, recording from the abductor digiti minimi muscle, stimulations were applied to the wrist, 5 cm distal and 5 cm proximal to the elbow, axilla, and Erb's point. F wave measurements via both ulnar nerves were carried out with the arms in a neutral position and also at maximum abduction. Antidromic sensory nerve conduction studies of ulnar, median, and median antecubital nerves were also performed. Ring electrodes were used during the measurements on the third finger for the median nerve and the fifth finger for the ulnar nerve. Median antecubital nerve studies were also conducted using superficial electrodes with the active electrode placed 18 cm distal to the mid point of the upper arm and the reference electrode 4–5 cm distal to the active electrode.

After assessment, patients were clinically diagnosed to have TOS if they had experienced the above symptoms (especially weakness and fatigue) with the prerequisite that their symptoms also emerged during the provocative manoeuvres (Adson, hyperabduction, costaclavicular, and Roos). D-USG was used to confirm vascular compromise and cervical *x* rays were used to confirm an underlying bony etiology or to rule out other likely pathologies. Patients with a

Table 1 Demographics of the patients

	TOS	Control	p
Age (years)	41.57 (11.96)	38.40 (13.92)	0.30
Height (m)	1.65 (0.10)	1.65 (0.09)	0.85
Body weight (kg)	71.26 (13.04)	66.47 (11.77)	0.37

Values in parentheses are standard deviations.

Table 2 Most common complaints of the patients

Symptom	Extremity n	Extremity %
Pain when limb overhead	20	60.60
Pain with heavy lifting	25	75.75
Pain when carrying objects	27	81.81
Intermittent pain	25	75.75
Paraesthesia	30	90.90
Fatigue	30	90.90
Weakness	20	60.60

%, Percentage of the complaint among 33 extremities.

diagnosis of fibromyalgia, cervical radiculopathy, or cardiovascular problems were excluded.

Isokinetic muscle measurement
Isokinetic muscle testing was performed using the Biodex System 3 (Biodex Medical System, Shirley, NY) dynamometer with the shoulder and elbow attachment connected. Orientation of the dynamometer was kept at 0°, tilt at 0°, and seat orientation at 15°. Before testing, patients were exercised on a treadmill for 5 min and then performed 30–40 rotations with a shoulder wheel to warm up. Patients were excluded if they had exercise intolerance due to cardiopulmonary instability or any polyneuropathy affecting muscular performance. After explanation of the procedure, the patients were seated and the dynamometer adjusted. Bilateral isokinetic (concentric/concentric) shoulder flexion and extension studies at 60°/s (five repetitions), 180°/s (10 repetitions), and 240°/s (25 repetitions) were carried out. Patients had a 30 s period of rest between the three sessions. Isokinetic measurement results—peak torque (PT), peak torque/body weight (PT/BW), and fatigue ratios (FRs)—of the upper extremities were noted; FRs were estimated using the ratio of the first third of work (Wf) to the last third of work (Wl) ($[(Wf-Wl)/Wf]\times100$). The control group was also evaluated in an identical manner except that D-USG was not performed.

Statistical analysis was carried using the Statistical Package for Social Sciences (SPSS) 10.0 for Windows using Student's *t* test and the Mann-Whitney U test, and p values less than 0.05 were considered significant. Comparisons were made both between the two groups and within the TOS group, comparing the symptomatic and healthy sides of the same individuals.

RESULTS
The TOS patients consisted of 17 (73.9%) females and six (26.1%) males, while the control group contained 11 (73.3%) females and four (26.7%) males. The ages of the TOS and control groups ranged from 22 to 72 years and from 23 to 71 years, respectively, and were statistically similar (table 1). The average heights and body weights were also similar between the two groups (table 1). Twenty one (91.3%) TOS patients and all the control patients were right handed. Two patients (8.7%) had a history of upper extremity surgery and two patients (8.7%) had a history of upper extremity trauma.

The most common symptoms of the patients are summarised in table 2. Symptom duration ranged from 2 to 240 months with a mean (standard deviation) of 52.0 (58.9) months. One patient (4.3%) had mild hyperaemia and minimal temperature increase on her right forearm and one patient (4.3%) had oedema in the left hand. Five (21.7%) patients complained of symptoms on their right side and eight (34.8%) on their left side, while 10 (43.5%) had bilateral symptoms. Thus, there were 33 symptomatic extremities (15 right, 18 left) and another group of 30 healthy extremities.

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Table 3 Comparison of isokinetic measurements (TOS *v* control)

	TOS*	Control	p
60˚/s angular velocity PT/BW (Nm/kg)	56.68 (19.84)	66.35 (19.65)	0.13
180˚/s angular velocity PT/BW (Nm/kg)	42.69 (10.56)	44.42 (9.46)	0.49
240˚/s angular velocity PT/BW (Nm/kg)	42.59 (19.67)	42.04 (8.57)	0.89
60˚/s angular velocity FR (%)	35.43 (28.20)	22.39 (12.81)	0.03
180˚/s angular velocity FR (%)	28.74 (19.71)	10.11 (24.67)	0.01
240˚/s angular velocity FR (%)	45.18 (27.64)	40.81 (30.28)	0.58

*33 extremities of 23 TOS patients.
FR, fatigue ratio; PT/BW, peak torque/body weight.

The comparisons were made both between the two groups and between the symptomatic and healthy sides of the same individuals. The extremities were also classified according to clinical, radiological, and electrophysiological evaluation as follows: 1 nTOS, 15 vTOS, and 17 dnTOS.

Isokinetic measurement results—PT, PT/BW, and FRs—of the upper extremities were again compared by two different methods and both tests yielded statistically similar results (tables 3 and 4). FRs between the groups were found to be higher in the symptomatic sides in all velocities, but the differences were significant only at the 60˚/s and 180˚/s velocities but not at 240˚/s (tables 3 and 4).

Electrophysiological measurements were found to be similar both between the groups and when comparing individuals bilaterally. Of the TOS patients, one had bilateral, two had unilateral carpal tunnel syndrome (CTS), and one had ulnar entrapment at the elbow.

DISCUSSION

Weakness or fatigue, which are not always clearly differentiated in TOS patients, can be either due to neurogenic or vascular compression.[6 7] These two symptoms are very commonly observed in TOS patients and are also noted in our study (table 2); however, there are no supportive objective data in the literature. In our study we aimed to demonstrate and quantify any decrease in muscle strength or increase in fatigue in the upper limbs of TOS patients. Isokinetic measurements were used to assess the PT and FRs. The peak torque values did not seem to differ either between the TOS and control groups or between the symptomatic and asymptomatic extremities of the same individuals (tables 3 and 4). Although the FRs were found to be different in both comparisons, this difference did not reach significance at the 240˚/s velocity (tables 3 and 4). These findings are relevant with the understanding that though their maximum voluntary muscle strengths (power) are not affected, TOS patients do have decreased upper limb muscle endurance. The lack of expected statistical significance for the measurements in the last 25 repetitions at 240˚/s was assumed to be due to the naturally tiring nature of the work for healthy individuals.

Although TOS has been recognised for a long time, it is still treated with scepticism.[13 14] Its symptomatology varies and it has many features in common with other conditions. The most common symptoms mentioned in the literature are pain and paraesthesias.[3] Likewise, in our study our patients complained of paraesthesias, fatigue, and pain (table 2). The pain occurred while carrying heavy objects, was intermittent, and occurred when the arms were raised overhead (table 2). The pain and paraesthesias in these patients are usually are intermittent and are often evoked by certain positions of the extremities. Irritation of the superficial sensory fibres is mainly responsible for paraesthesias, whereas insults to deep pain fibres are blamed for blunt and radiating pain.[4] ''Double crush'' lesions have been reported to occur in 40–50% of TOS patients.[15] Interestingly, patients may even complain of distal symptoms for the first time at examination, suggesting the incidence of TOS may be underestimated. In our TOS patients we have diagnosed one patient with bilateral CTS, two with unilateral CTS, and one with cubital tunnel syndrome, an incidence of 15% among our TOS patients.

In performing the isokinetic measurements during shoulder flexions and extensions we sought to simulate the actual daily activities during which TOS patients claimed their symptoms were most evident, that is, when their arms were raised overhead. Perhaps intrinsic hand muscles should have been evaluated since the C8–T1 roots are mostly affected in TOS patients. However, we only had one nTOS patient with such involved hand musculature and in any case we did not wish to examine the contribution of the neuropathy to the isokinetic test results but rather to illuminate the patients' experience during daily activity. We assume that the decreased endurance in the limbs of TOS patients is temporary since according to our data the muscle strengths of both groups were similar. We believe that had there been persistent changes in the upper extremity musculature, muscle strengths would have been decreased. However, further studies are needed to evaluate the endurance of the upper extremity muscles in neutral non-provocative positions before we can be sure that the decrease is only temporary.

Overall, in light of this current study, we encourage the use of isokinetic testing for the quantitative analysis of weakness and fatigue in TOS patients. In this way, we believe not only that a dynamic simulation of the patients' symptomatology will be achieved but also that a likely diagnosis can be confirmed objectively.

Table 4 Comparison of isokinetic measurements (symptomatic *v* asymptomatic sides)

	Symptomatic	Asymptomatic	p
60˚/s angular velocity PT/BW (Nm/kg)	60.27 (21.04)	61.28 (22.23)	0.89
180˚/s angular velocity PT/BW (Nm/kg)	37.56 (9.21)	39.78 (14.12)	0.79
240˚/s angular velocity PT/BW (Nm/kg)	32.35 (9.52)	33.73 (15.29)	0.79
60˚/s angular velocity FR (%)	35.52 (28.79)	16.91 (7.10)	0.01
180˚/s angular velocity FR (%)	37.62 (17.84)	24.05 (12.19)	0.03
240˚/s angular velocity FR (%)	39.95 (20.44)	27.16 (11.55)	0.12

The measurements refer to 10 patients with unilateral TOS. FR, fatigue ratio; PT/BW, peak torque/body weight.

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What is already known on this topic

Pain and paraesthesias are the most common symptoms of thoracic outlet syndrome. However, weakness and fatigue are not always clearly differentiated or interpreted in TOS patients.

What this study adds

The decreased upper limb endurance found in TOS patients is assumed to be temporary since the muscle strengths of both groups were found to be similar.

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REFERENCES

1 **Urschel HC**, Razzuk MA. Thoracic outlet syndrome. In: Sabiston DC, Spencer FC, eds. In: *Surgery of the chest.* 5th ed. Philadelphia: WB Saunders, 1990:536–53.

2 **Sanders RJ**. *Thoracic outlet syndrome–A common sequela of neck injuries.* Philadelphia: JB Lippincott, 1991.

3 **Urschel HC**, Hylan JW, Solis RM, *et al.* Thoracic outlet syndrome masquerading as coronary artery disease (pseudoangina). *Ann Thoracic Surg* 1973;**16**:239–48.

4 **Atasoy E**. Thoracic outlet compression syndrome. *Orthop Clin North Am* 1996;**27**:265–303.

5 **KaymakB**, Ozcakar L, Oguz AK, *et al.* A novel finding in thoracic outlet syndrome: tachycardia. *Joint Bone Spine* 2004;**71**:430–2.

6 **Dorazio RA**, Ezzel F. Arterial complications of the thoracic outlet syndrome. *Am J Surg* 1979;**138**:246–50.

7 **Etheredge S**, Wilber B, Stoney RJ. Thoracic outlet syndrome. *Am J Surg* 1979;**138**:175–82.

8 **Barnes WS**. Isokinetic fatigue curves at different contractile velocities. *Arch Phys Med Rehabil* 1981;**62**:66–9.

9 **Elert J**, Gerdle B. The relationship between contraction and relaxation during fatiguing isokinetic shoulder flexions. An electromyographic study. *Eur J Appl Physiol* 1989;**59**:303–9.

10 **Gerdle B**, Elert J, Hendriksson-Larsen K. Muscular fatigue during repeated isokinetic shoulder forward flexions in young females. *Eur J Appl Physiol* 1989;**59**:666–73.

11 **Gray JC**, Chandler JM. Percent decline in peak torque production during repeated concentric and eccentric contractions of the quadriceps femoris muscle. *J Orthop Sports Phys Ther* 1989;**10**:309–13.

12 **Thorstensson A**, Karlsson J. Fatiguability and fibre composition of human skeletal muscle. *Acta Physiol Scand* 1976;**98**:318–22.

13 **Roos DB**. Thoracic outlet syndrome is underdiagnosed. *Muscle Nerve* 1999;**22**(1):126–9.

14 **Wilbourn AJ**. Thoracic outlet syndrome is overdiagnosed. *Muscle Nerve* 1999;**22**(1):130–8.

15 **Wood VE**, Twito R, Verska JM. Thoracic outlet syndrome - the results of first rib resection in 100 patients. *Orthop Clin North Am* 1988;**19**:131–46.

Clinical Evidence article

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