Jacques Forestier's *vanished* bowstring sign in ankylosing spondylitis: A call to test its validity and possible relation to spinal myofascial hypertonicity

A.T. Masi, S. Sierakowski, J.M. Kim

Alfonse T. Masi, MD, DrPH, Professor of Medicine, University of Illinois College of Medicine at Peoria (UICOMP), One Illini Drive, Peoria, Illinois 61656, USA. E-mail: amasi@uic.edu
Stanislaw Sierakowski, MD, PhD, DSc(Med.), Professor & Chairman, Department of Rheumatology and Internal Diseases, Medical University in Bialystok, Poland. E-mail: stanspl@amb.edu.pl
Jeehun Michael Kim, BA, Senior Medical Student, UICOMP.
E-mail: jkim126@uic.edu
Corresponding Author

ABSTRACT

Jacques Forestier's bowstring sign (signe de la "corde de l'arc") in ankylosing spondylitis (AS) was described by him in his 1951 book (French). In free lateral bending, the early AS patient has palpably firm, contracted dorsolumbar muscles on the concave side, opposite to the findings in normals. Forestier described this sign as a common and characteristic finding in AS. Perplexingly, the sign is essentially unknown in the rheumatologic field. A single report (Polish) on electromyographic (EMG) findings in AS and control subjects documented the electromotor component of the bowstring sign as well as its diagnostic utility in early AS patients.

In this paper, the literature on EMG studies in series of AS patients is reviewed as well as kinesiologic EMG studies of normals in lateral bending. Paravertebral and other muscle pathology in AS was reviewed in relation to the EMG findings. Critical, controlled assessment of Forestier's bowstring sign and biomechanical investigations of the dorsolumbar muscles in AS promise to offer new insights into the early physiopathogenesis of this unique disease.

Introduction

A historical vignette

Jacques Forestier *et al.* (1) described clinical, radiological, pathological, and therapeutic experiences on 200 ankylosing spondylitis (AS) patients in a book published in 1951 in French – *La Spondylarthrite Ankylosante: Clinique, Radiologie, Anatomie Pathologique, Traitement* – which received high acclaim (2). In this book, the *Signe de la corde de l'arc* (Bowstring Sign) was briefly described as a diagnostic physical examination finding for AS. The sign was mentioned in a short section, "II. The Back Muscles, Contracture, Atrophy" [1, pp. 22, 23 (French)] as having been previously described by Forestier. Dorsolumbar (paravertebral) muscle atrophy was also properly recognized as occurring in the course of ankylosis of the spine (1), and has since been amply documented (3-5). The section (1) further stated that paraverte-

bral muscles in AS are hard, but muscular contracture is never very evident during physical examination due to the atrophy.

The Bowstring Sign of Forestier
(Fig. 1)

The sign is elicited in a standing subject with his back turned toward the examiner and freely bending the trunk laterally to one side, then to the other (1). In cases of early AS, the muscles of the concavity (i.e., flexed side) contract ("bowstring"), and on delicate palpation are under greater tension (firmness) than the muscles on the convex side. Normal subjects were stated to show opposite findings, i.e., the dorsolumbar muscles were more relaxed and soft on the concave side, but more tensed and firm on the convexity (i.e.,

Fig. 1. Reproduction of Figure 108a (1), originally photographed by Francois Forestier. The 51-year-old AS patient, who has essentially normal spinal mobility, is performing the exact lateral flexion of the thoracolumbar spine described by the author. In this maneuver, Forestier's bowstring sign is stated to reveal palpably contracted muscles of the concavity, which have greater firmness than the muscles of the convex side. Normal subjects are described as showing opposite findings (1).

the counter-balancing, stretched side). The bowstring sign was said to be rather common and altogether characteristic of AS (1). It was also said not to be observed in mechanical back processes (i.e., degenerative) or Pott's disease, but that validation will require further research, along with a certain technical expertise (finesse) (1).

In PubMed, bowstring (or bow-string) sign is not a MeSH term. When this term was searched as a key word, a 1968 citation (Polish) was retrieved on the subject of electromyographic (EMG) investigations on the bowstring sign in patients with AS (6). Surface EMG was used to test the bowstring sign in AS patients and two sets of control subjects (6). Only one other article was retrieved in which the bowstring sign was an indexed key word (7). However, it referred to a different physical examination maneuver and sign by that name, which is employed to test for sciatic nerve tension in the diagnosis of lumbar disc herniation (7-12).

The purpose of this review and commentary is to salvage awareness of Forestier's bowstring sign in AS and attempt to interpret its clinical (1) and EMG (6) features. In addition, the literature on EMG studies of AS patients was specifically reviewed, in order to assess its relevance to recent perspectives on the role of axial (spinal) myofascial hypertonicity in AS (13, 14). The EMG search was integrated with a previous review of paravertebral and other muscle pathology in AS (5).

Methods

Literature search for EMG studies in AS patients and control subjects

A search of the English and non-English literature was conducted in the MEDLINE database (1966 – June 2005). Search parameters were set to find articles with combined mentions of ankylosing spondylitis (AS) and electromyography (EMG). The medical subject headings searched were: ankylosing spondylitis (including the idiopathic and secondary forms), as either a MeSH term or a key word. Articles were excluded in which EMG was used to evaluate the neuropathy of cauda equina syndrome (CES). This

late stage CES complication in advanced AS patients is not believed to be related to the paralumbar muscles. Case reports of AS patients in which EMG studies were performed as part of diagnostic evaluations of myopathy (4, 5) were separately analyzed. Emphasis was given to reports of quantitative EMG studies on series of AS patients. Accordingly, the functional relevance of quantitative and kinesiologic EMG studies were emphasized, rather than studies of pathological patterns of motor unit potentials (MUPs) in search of myopathy (4,5). Since only one article was retrieved on EMG studies of the bowstring sign in AS (6), the literature on EMG findings in lateral bending of normal subjects was also reviewed.

Results

The single EMG study on Forestier's bow-string sign in AS retrieved in Pub-Med (6) utilized surface electrodes to measure bilateral simultaneous paravertebral myoelectric activity on lateral bending. Integrated bioelectrical acti-

vity was recorded while study subjects performed a modified lateral bending maneuver (i.e., in a seated position). Twenty (19 M, 1 F) patients with definite AS, and 3 with sacroiliitis, were compared to 20 (9 M, 11 F) patients with spinal osteoarthritis (OA) and to 20 normals of comparable age.

The contact electrodes were placed symmetrically on the paravertebral muscles at the L3-L4 level (6). Subjects were seated on a horizontal surface, and inclined freely to each side, in the direction of the force of gravity. Separately, they performed lateral bending against resistance of the investigator's hand placed against the examinee's shoulder. Under the assumption that muscular "isometric tensions" are linearly correlated with integrated muscle action potentials (15), the bowstring sign was tested utilizing defined EMG criteria. The sign was considered to be positive when bioelectrical activity on the inclined (concave) side was greater than on the extended (convex) side. The overall EMG findings (6) were considered to be supportive of the clin-

Table I. Myoelectric criteria for a positive bow-string sign in ankylosing spondylitis (AS), spinal osteoarthritis (OA) and normal (NL) subjects[1].

Myoelectric criteria	AS (n = 20)*	OA (n = 20)*	NL (n = 20)*
Positive[2]	15	4	1
Equivocal[3]	4	1	1
Negative	1	15	18
Total number	20	20	20

[1]Three sacroiliitis patients were also studied, two having equivocal and one negative myoelectric activity.

[2]Positive myoelectric criterion for the bowstring sign was defined as greater activity occurring on the inclined (concave) than the extended (convex) side during free lateral bending to either one side or the other.

[3]Equivocal EMG criterion was defined as equivalent activity on both sides during free lateral bending to either one side or the other.

* p values: AS vs OA p < 0.0001, OA vs NL p = 0.167.

Table II. Jacques Forestier's bowstring sign for early ankylosing spondylitis (AS).

The patient stands with his/her back turned toward the examiner.
He/she is asked to bend directly laterally to one side, then to the other.
In early AS patients, muscles are palpably tensed in the inclined concavity.
Muscle tension is greater in the inclined concavity than on the stretched side.
In normals, delicate palpation senses relaxed, soft muscles in the concavity.
The findings of muscle firmness vs softness are opposite in AS vs normals.
In AS, dorsolumbar muscles show greater EMG activity on the concave side.

ical descriptions by Forestier *et al.* (1), as reviewed below.

In the 20 AS patients, 15 (75%) were considered to have greater activity on the concave side, i.e., a positive "bowstring sign", whereas only one (5%) showed the opposite, expected normal findings (Table I). Four (20%) of the 20 OA patients showed positive myoelectric indication of the bowstring sign. In the 20 normals, only one (5%) was reported to show greater activity on the inclined (concave) than the extended (convex) side. The observed difference in frequencies of the EMG results supporting a positive bowstring sign between AS and OA patients (as well as normals) is highly (p < 0.0001) significant. The difference was not explained by degree of mobility in the sagittal plane, i.e., the Schober maneuver (16, 17), nor by the radiological stage of disease of the AS vs OA patients (6). No difference (p = 0.167) was observed

between the OA vs normal subjects in the frequency of a positive "bowstring sign" (Table I). Based upon their studies, the authors considered the bowstring sign to be an early indicator of AS (6). Forestier's description of this sign and its correlated EMG findings are summarized in Table II.

Dorsolumbar muscle atrophy in AS
Case studies of muscle pathology in AS patients were previously reviewed (4, 5, 18-26). Most of those reports also revealed EMG findings mainly consistent with the histologically observed muscle atrophy, fibrosis, or myopathy, as opposed to changes of inflammatory myositis (Table III). The EMG changes were suggested to be secondary to pain inhibition and limited usage (26). Another group reviewed and commented upon the previous reports of myopathy in AS, but without performing biopsy (27). They studied quantitative

EMG features of shoulder muscles in 8 full-time workers with AS compared to 10 healthy male controls (27). The descending part of the trapezius muscles of the AS subjects showed faster development of EMG signs of fatigue vis-à-vis the referents, which was considered to be suggestive of functional disturbances in the muscle (27). No physical difference in shoulder muscle strength, power grip, endurance or recovery measures was found between the groups. However, the authors cautioned against the possible risk of hazardous effects from prolonged static exercise by AS patients (27).

Quantitative EMG studies in series of AS patients
Except for the kinesiologic EMG study of shoulder muscles in full-time workers with AS (27), all retrieved reports of EMG findings in series of AS patients were published before 1970 (6,

Table III. Paravertebral and other muscle pathology in ankylosing spondylitis*.

First author, year (Ref.)	Atrophy	Other pathology	EMG findings
Pohl, 1974 (18)	Major finding was single fiber atrophy	Interstitial fibrosis also in a minority of biopsies	Not described
Roux, 1975 (19)**	In lumbar region and quadricepts muscle	Hyperplasia, neuropathic features	Null EMG activity of paralumbar muscles at rest. Studied lateral bending in 3/14 cases
Berman, 1976 (20)	Decreased type II fibers	"Moth-eaten" type I fibers, "targetoid core" or "target" fibers	Not described
Gonzalez-A, 1981 (21)†	Loss of myofibrils on EM	Capillary abnormalities, normal light microscopy	Surface EMG mean power frequency reduced in quadriceps m.
Hopkins, 1983 (22)†	Fiber size reduced in 40%, mainly type II	Non-specific myopathic changes found in all patients	Quadriceps m. mean power freq. was lower in 3/10 AS pts. than the lower range in 16 normals.
Carrabba, 1984 (23)	Angulated and atrophic fibers	"Targetoid core" fibers, constant, early involvement	Not described
Wattiaux, 1985 (24)†	Equivocal degree	No specific myopathy, denervation changes	Very modest myogenic pattern
Kakulas, 1987 (25)	Varying degrees	Z-band streaming, "targetoid core" fibers	Not described
Faus-Riera, 1991 (26)†	Not found on needle biopsies	Type I fiber predominance, mild changes in 16/24 pts.	Mild "myopathic" EMG pattern in quadriceps m. in 13 (46%) of 28 AS patients. None had a neuropathic pattern.
Cooper, 1991 (4)	Marked type II fiber atrophy	Perimuscular fibrosis without evidence of inflammation	No abnormality on needle EMG of superficial erector spinae m. in 6 AS pts.

* Adapted from Table 8 in ref. 5.** Quadriceps or other muscles also studied. † Quadriceps or other non-paraspinal muscles only studied.

28-33). The first dorsal interosseous muscle was studied by needle electrode sampling in 59 male AS patients of ages 17 to 59 years (29, 30). Only 12 (20%) of the AS subjects had normal durations of action potentials. Decreased durations (i.e., greater than 20% below normal) were seen in the majority, i.e. 35 (59%) (29, 30). However, no AS patient showed spontaneous EMG activity, e.g., fibrillation potentials, associated with active myopathic or myositis processes (29, 30). These two reports, i.e., in 1966 (29, in Polish) and in 1967 (30, in English), were uncontrolled studies on the same series of AS patients. The authors concluded that the EMG findings were not closely related to the stage of AS. They interpreted the abnormalities as being that of a rather weaker myopathic character than those described for RA. Electromyographic (34, 35) and biopsy (34) studies of muscle tissue in RA patients revealed evidence of myogenic (34) and neurogenic (35) changes.

Time-integrated muscle action potentials (MAPs) of lumbar erectores spinae (ES) were analyzed quantitatively using surface EMG in 36 AS patients (mean age 37.5 years) and 26 normals (mean age 34.1 years), both in full relaxation (prone) and on voluntary contraction (31). In a later paper (32), those preceding study subjects were further compared to 39 patients with degenerative disease of the spine (mean age 52 years). At rest, the values for integrated MAPs were approximately equal in the three groups. However, during voluntary contraction, the mean value of integrated activity over a one-minute interval was nearly twice as great in normals as in AS patients (p < 0.0001). The degenerative spine group had a mean value on contraction intermediate between that of the AS and normal subjects (32).

A quotient (ratio) of the integrated myoelectrical activity recorded in contraction over that in relaxation was derived (31, 32). This ratio was again approximately twice as great in normals as in the AS patients. The ratio in AS patients was positively and highly (p < 0.0001) correlated with the degree of spinal mobility in the Schober test

(31, 32), i.e., greater contractility was seen in those with greater spinal mobility. In the degenerative spine patients, the resting integrated MAP activity over a five-minute duration was markedly (p < 0.0001) less in those who had longer durations of disease, i.e., six years or more, than shorter intervals (32), indicating greater ES muscle atrophy in the more chronic patients. The authors interpreted the EMG findings as being related to muscle atrophy as well as to the severity and duration of spinal disease. Decreased myoelectric activity was not specific to the AS patients.

The same lead investigator who tested the bowstring sign using EMG techniques (6), reported a detailed study (33) of myoelectric activity in the sacrospinal muscles of 50 AS patients (ages 20-63 years). The biceps brachii was also studied in 43, and the first dorsal interosseous muscles in 38 of the 50 patients (33). Shortening of the durations of MAPs suggestive of myopathy was observed in 19 (38%) of the sacrospinal muscles, and in 7 (8.6%) of the 81 upper extremity muscles tested (p < 0.001) (33). The EMG changes suggestive of myopathy were significantly (p < 0.001) more frequent in the AS patients with a disease duration of over 10 years [16 (66.7%) of 24] vs shorter durations [5 (19.2%) of 26]. Increased numbers of polyphasic potentials (i.e., over 12% of all potentials) were noted in 10 (20%) of the 50 sacrospinal muscles vs 2 (2.5%) of the 81 extremity muscles (p < 0.001). During maximum contractions, the EMG amplitude (voltage) of MUPs was low in the sacrospinal muscles (2,474μV), and was impressively less than those in the biceps brachii (4,848μV) and dorsal interossei (6,880 μV). The low sacrospinalis potentials are consistent with the above-mentioned EMG findings (31, 32). The myopathic changes were not related to the clinical activity of AS. Interestingly, the author mentioned muscle "hypertonus" in spondylitis (33).

Kinesiologic EMG studies in normals

The EMG activity of paravertebral muscles of back pain patients may be

difficult to interpret and may be non-diagnostic because of reflex pain effects (14, 36) and variability in degrees of voluntary relaxation (37-39). Back muscles serve the important functions of maintaining static equilibrium postures and providing for smooth movement as well as resistance to deviations from external loads (37-45). Thus, proper interpretation of EMG findings in any group of paravertebral muscles must also consider the interacting effects of both postures and muscle loadings (45).

In the relaxed, "standing at ease" equilibrium posture, little or no surface EMG activity was observed in the extensor spinae (ES) muscles, at the mid-lumbar (L3) level (40-44, 46). Minimal extra energy is utilized in such a standing position, compared to resting horizontally (47), which is estimated at circa 7% greater expenditure (48). In such an erect, relaxed, equilibrium stance, low-level activity is observed in the posterior calf and lower thoracic paravertebral muscles (42, 46).

In free slow anterior flexion of the lumbar spine, EMG activity increases in relation to the sine angle of bending up to circa 60°, when full flexion is achieved (36, 49). The EMG is silent in this full trunk flexion position, i.e., the flexion-relaxation response (36, 37, 41, 42, 49). In the fully flexed position, the moment load of the trunk is supported by the intrinsic ligaments and intervertebral discs of the spine. In addition, the ES muscles are extended or stretched beyond their normal length compared to the relaxed, erect stance. Nevertheless, they are electrically inactive, since a static equilibrium posture is achieved (albeit stretched), without proprioceptive signals for active muscle contractions (36, 37, 41, 42, 49).

The normal EMG activity of dorsolumbar muscles in free lateral (coronal) bending has been studied less than in forward bending. Free lateral bending elicits minimal EMG activity of the ipsilateral erector spinae muscles, when initiating movement in the direction of the force of gravity (38, 41, 43). Slightly greater activity is seen on the contralateral, stabilizing side in normals. Loading was studied on EMG

activation of back muscles in lateral bending of 15 young (19 to 35 years) normal males (45). Four maneuvers were performed while holding a load (20.4 Kg) in either hand at one time, and bending laterally 20º from an erect stance to both the ipsilateral and contralateral sides (45). Consistent patterns of surface EMG activity were observed at the L3 and L5 levels. When flexing in the direction of the load held in one hand, i.e., in the direction of gravity, no or minimal activity was detected in the ipsilateral (concave) dorsolumbar muscles. On the contrary, the contralateral equilibrium-stabilizing (convex) dorsolumbar muscles showed significant myoelectric activity. The latter results are analogous to the findings in normal subjects in the EMG study of the bowstring sign (6), even though free bending was not performed in this loading study (45). Both studies (6, 45) concur in demonstrating that normals have quiet ipsilateral (concave) muscles during direct lateral bending, unlike the opposite results found in most of the AS patients (1, Table I).

Discussion

A proposed interpretation of Forestier's bowstring sign in AS patients

The biomechanics of human dorsolumbar muscles are profoundly complex and our understanding is limited, both in health and AS (13, 14). Forestier et al. (1) believed that the bowstring sign is due to the resistance which the muscles in the concavity encounter during the movement of lateral flexion, and which forces the patient into active contraction in order to carry it out. He also stated that validation of the bowstring sign will require further research and a measure of finesse (technical expertise). If the clinical (1) and EMG (6) phenomena are indeed validated as an early, useful physical finding in AS, then its underlying basis will deserve critical investigation. Dorsolumbar muscle atrophy and myopathy are recognized as later-stage secondary abnormalities in AS and were reviewed previously (4, 5, 18-26, Table III). Also, forms of spinal muscular dystrophy, e.g., rigid spine syndrome (50) and paralytic disorders (14, 51-53), can cause

varying degrees of immobilization and secondary spondylosis, misdiagnosed as AS. Recently, early physiological spinal myofascial hypertonicity was proposed to occur in AS (13, 14) and deserves further study. Physiological alterations of ES muscles in AS may possibly contribute to Forestier's bowstring sign in early-stage patients (see below).

Forestier et al. (1) did not specifically interpret the physiological basis of the bowstring sign, but stated that the dorsolumbar muscles showed contracture, which may have been related to back pain. An English interpretation of the French term "contracture" is ambiguous. It may imply either chronic shortening of myofascial tissues or active contraction. The EMG study (6) would argue against the former interpretation of contracture, i.e., passive shortening on the concave side. Muscle shortening and fibrosis on the concave side, without increased active contraction, would be expected to cause less, rather than more, EMG activity. To the contrary, if the concave dorsolumbar muscles were in spasm or actively contracted, then EMG potentials would be increased. However, muscle spasm or cramp is typically associated with localized pain, which was not mentioned in the clinical (1) or EMG (6) descriptions of the bowstring sign. Also, an explanation would be needed for engendering the alternating dorsolumbar spasm in AS patients in free lateral bending to each side. Normally, such maneuver is nearly effortless and not straining (38, 41, 43).

Notably, when lateral bending was performed against resistance of the EMG investigator's hand (6), a positive bowstring sign could be induced in all AS, OA, and normal subjects. The investigator's hand acted to resist the subject's lateral bending, requiring a greater force of ipsilateral contraction. Thereby, greater EMG activity occurred on the concave vs convex side, as would be physiologically expected. However, external resistance did not apply to the free lateral bending, and cannot explain the differentiated findings of the AS patients (1, 6, Table I).

Forestier et al. (1) described the dorso-

lumbar muscles of AS patients as being hard and contracted. The data on AS patients with respect to their EMG activity of fully relaxed ES muscles revealed normally low integrated myoelectric potentials (31, 32). Nevertheless, inordinate firmness to palpation of the dorsolumbar muscles is observed when early-stage AS patients are placed in a relaxed, anterior lumbar flexion position, with the trunk fully-supported on an examination table (13, 14). Such firmness in a relaxed posture suggests intrinsic axial myofascial hypertonicity (13, 14). Controlled studies of such a maneuver in a comfortably supported, prone position are needed in AS, with particular attention given to the possible influence of any associated back pain upon muscle tightening (14, 36).

Dorsolumbar myofascial hypertonicity may be a possible contributor to the bowstring sign

If the recently proposed concept of intrinsic axial musculoligamentous hypertonicity in AS (13, 14) is confirmed, then presumably an increased contractile effort is required by the agonistic (concave side) muscles to bend laterally, against an increased myofascial (and other tissues) stiffness on the contralateral (convex) side. Normally, contraction of one muscle group causes the antagonistic group to relax, i.e., reciprocal inhibition. This reflex may be physiologically altered in AS, particularly as related to pain pathways (14, 36). Since the bow-string sign may be an early and frequent finding in AS (1, 6), its basis may be physiological, rather than a secondary pathological manifestation. Also, this sign is said to be infrequent in OA of the spine (1, 6). Thus, it may not be strictly explained on the basis of pain mechanisms.

Lateral flexion is one of the earliest movements to become restricted in AS (54). Of various spinal maneuvers tested, it was the only one that was significantly reduced over a 12- to 18-month follow-up interval in AS patients initially selected to have mild disease and relatively good spinal mobility (55). However, EMG studies were not performed in that study to correlate with movement limitations (55).

Since the 1968 controlled study (6), no kinesiological EMG research on paravertebral muscles of AS patients was retrieved. Such technology has considerably advanced and critical modern investigations now promise to provide important basic understanding on functional electromotor activity in various stages of this disease (14). Besides a critical test of the bow-string sign (1, 6), AS patients and control subjects can be studied with correlated EMG findings in relation to: 1) balanced, static, equilibrium postures; 2) various other positions; and 3) under varied mobility and load conditions, always accounting for reported degrees of pain and severity of spinal deformity (14, 36).

Jacques Forestier: An internationally recognized spondylitis investigator
Dr. Jacques Forestier (July 27, 1890 – March 15, 1978) was a widely acclaimed world leader in rheumatology, both during his life and for many years after his death (2, 56, 57). He was an accomplished physician and scientist, having particular clinical interest in the study of the spine. His book describing the various ankylosing conditions affecting the back (1) was characterized as "remarkable" (2). An English translation of this book was also published (1). Space does not permit a properly thorough review of Forestier's extraordinary contributions to medicine or his personal accomplishments in his younger life (2, 56, 57). For undiscovered reasons, his bowstring sign in AS (1, 6) seems to have been essentially lost to posterity. A reference to this sign was found in a textbook on orthopedic physical assessment published in 1994 (9), but was not again included in the subsequent edition published in 2001 (12).
Forestier's clinical description of this sign is simple and specific, although admittedly requiring a certain degree of technical expertise. Because of his recognized proficiency in spondylitis and his confidence in the diagnostic value of the bowstring sign in AS, critical research promises to provide further information on altered kinesiologic and myoelectric patterns in this disease of unknown etiology.

Theoretical links may be drawn between Forestier's statements that the ES muscles in AS patients are often contracted and found to be hard (1) and recent perspectives on underlying, intrinsic spinal myofascial hypertonicity in this disease (13, 14). If such links can be validated, the role of the paravertebral muscles in AS will likely receive enhanced focus and permit new lines of biomechanical investigation in this unique disease (13, 14).

Conclusions
1. Forestier's bowstring sign may serve as a useful clinical examination test of dorsolumbar muscle changes in the early stages of AS, and help in the diagnosis.
2. The diagnostic utility of this sign was supported by EMG studies demonstrating greater activity of the dorsolumbar muscles on the inclined vs. extended side, in free lateral bending of AS patients.
3. Later stages of the disease, however, reveal muscle changes consistent with atrophy and subtle myopathy, particularly of the dorsolumbar group.
4. Controlled studies of the dorsolumbar muscles in the earliest stages of AS are needed, addressing: physical/palpatory consistency (i.e., firmness) in full relaxation; quantitative measures of flexibility vs stiffness in movement; EMG correlates in such clinical protocols; and currently refined histological/ultrastructural characteristics of the tissues.
5. Confounding effects from relevant factors in AS require critical analyses in the above-suggested studies, e.g., degree and type of pain, limitations of movement, and any structural deformities.
6. Forestier's bowstring sign and biomechanical analyses of the stability vis-à-vis movement functions of the spinal muscles promise to offer new insights into AS, a unique disease of unknown etiology.

Acknowledgments

References
1. FORESTIER J, JACQUELINE F, ROTES-QUEROL J: *La Spondylarthrite Ankylosante: Clinique, Radiologie Anatomie Pathologique*, Traitement, Masson & Cie, Paris, 1951 (in French) (English translation, A.U. Desjardins. Thomas, Springfield, IL, 1956).
2. JAYSON MIV, MENKES CJ: Historical perspective: Jacques Forestier. *Spine* 1995; 20: 111-5.
3. GORDON TP, SAGE MR, BERTOUCH JV, BROOKS PM: Computed tomography of paraspinal musculature in ankylosing spondylitis. *J Rheumatol* 1984; 11: 794-7.
4. COOPER RG, FREEMONT AJ, FITZMAURICE R, ALANI SM, JAYSON MI: Paraspinal muscle fibrosis: a specific pathological component in ankylosing spondylitis. *Ann Rheum Dis* 1991; 50: 755-9.
5. MASI AT: Do sex hormones play a role in ankylosing spondylitis? *Rheum Dis Clin North Am* 1992; 18: 153-76.
6. SADOWSKA-WROBLEWSKA M, GARWOLINSKA H, SUWALSKA M: Electromyographic investigations on the bow-string sign in patients with ankylosing spondylitis and with degenerative joint disease of the spine. *Reumatologia* 1968; 6: 275-82 (in Polish).
7. SUPICK LF, BROOM MJ: Sciatic tension signs and lumbar disc herniation. *Spine* 1994; 19: 1066-9.
8. MAZION JM: *Illustrated Manual of, Part II, Orthopedic Signs/Tests/Maneuvers for Office Procedure*. 2nd ed. Orlando, Daniels Publishing, 1980, pp. 232.
9. EVANS RC: *Illustrated Essentials in Orthopedic Physical Assessment*. St Louis, Mosby Yearbook, 1994, pp. 232, 233 (Forestier's bowstring sign), pp. 262, 263 (bowstring sign).
10. HAWKINS RJ: A*n Organized Approach to Musculoskeletal Examination and History Taking*. St. Louis, Mosby, 1995, pp 264, 265.
11. MCCOLLOCH J, TRANSFELDT E: *MacNab's Backache*. 3rd ed. Baltimore, Williams & Wilkins, 1997, p. 271.
12. EVANS RC: *Illustrated Orthopedic Physical Assessment*. St. Louis, Mosby, 2001, pp. 504, 505 (Bowstring sign).
13. MASI AT, WALSH EG: Ankylosing spondylitis: Integrated clinical and physiological perspectives. *Clin Exp Rheumatol* 2003; 21: 1-8.

14. MASI AT, BENJAMIN M, VLEEMING A: Anatomical, biomechanical, and clinical perspectives on sacroiliac joints: An integrative synthesis of biodynamic mechanisms related to ankylosing spondylitis. *In* VLEEMING A, STOECKART R, MOONEY V (Eds): *Movement, Stability, and Lumbopelvic Pain: A Multidisciplinary Approach*, 2nd ed. Elsevier Limited, Edinburgh (in press).

15. LIPPOLD OCJ: The relation between integrated action potentials in a human muscle and its isometric tension. *J Physiol* 1952; 117: 492-9.

16. SCHOBER P: The lumbar vertebral column and backache. *Munch Med Wochenschr* 1937; 84: 336-8.

17. WILLIAMS R, BINKLEY J, BLOCH R *et al.*: Reliability of the modified-modified Schöber and double inclinometer methods for measuring lumbar flexion and extension. *Phys Ther* 1993; 73: 26-37.

18. POHL W, SIEVERS B-U: Veranderungen der muskulatur bei spondylitis ankylopoetica. *Z Rheumatol* 1974; 33: 249-53.

19. ROUX H, SERRATRICE G, MAESTRACCI D *et al.*: Les atteintes musculaires au cours de la pelvi-spondylite rhumatismale. *Rev Rhum Mal Osteoartic* 1975; 42: 231-8.

20. BERMAN L, ISAACS H, PICKERING A: Structural abnormalities of muscle tissue in ankylosing spondylitis. *S Afr Med J* 1976; 50: 1238-40.

21. GONZALEZ-ANGULO A, FERNANDEZ-DIEZ J, ROBLES E *et al.*: Ultrastructural abnormalities of striated muscle in ankylosing spondylitis. *Arch Invest Med (Mex)* 1982; 13: 51-8.

22. HOPKINS GO, McDOUGALL J, MILLS KR, ISENBERG DA, ERBRINGER A: Muscle changes in ankylosing spondylitis. *Br J Rheumatol* 1983; 22: 151-7.

23. CARRABBA M, CHEVALLARD M, COLOMBO B *et al.*: Muscle pathology in ankylosing spondylitis. *Clin Exp Rheumatol* 1984; 2: 139-44.

24. WATTIAUX MJ, RONDIER J, BLETRY O, GODEAU P, CAYLA J: Unusual muscular involvement in ankylosing spondylitis. *Rev Rhum Mal Osteoartic* 1985; 52: 151-5.

25. KAKULAS BA, MORRISON I, OWEN ET, KITRIDOU R: Unusual paraspinal muscle lesions in ankylosing spondylitis. *Clin Exper Neurol* 1987; 23: 23-9.

26. FAUS-RIERA S, MARTINEZ-PARDO S, BLANCH-RUBIO J *et al.*: Muscle pathology in ankylosing spondylitis: Clinical, enzymatic, electromyographic and histologic correlation. *J Rheumatol* 1991; 18: 1368-71.

27. HAGBERG M, HAGNER IM, BJELLE A: Shoulder muscle strength, endurance and electromyographic fatigue in ankylosing spondylitis. *Scand J Rheumatol* 1987; 16: 161-5.

28. SCHMIDT K, PODZICH M: Surface electromyographic studies in ankylosing spondylitis. *Congress of the German and Austrian Societies of Physical Medicine*, Salzburg-Hallein 1966; 9:12-14.4 (in German).

29. KOCZOCIK-PRZEDPELSKA J, TOMASZEWSKA J, DZIERZYNSKI M, STRABURZYNSKI G: Electromyographic studies and neuromuscular excitability curves in patients with ankylosing spondylitis. *Chir Narzadow Ruchu Ortop Pol* 1966; 31: 673-9 (in Polish).

30. KOCZOCIK-PRZEDPELSKA J, TOMASZEWSKA J, DZIERZYNSKI M, STRABURZYNSKI G: Electromyographic studies and strength-duration curves in patients with spondyloarthritis ankylopoetica. *Rheumatism* 1967; 23: 14-20.

31. SCHMIDT K, PODZICH M: Surface electromyography studies in ankylosing spondylitis. *Arch Phys Ther (Leipz)* 1967; 19: 129-33 (in German).

32. SCHMIDT K, PODZICH M: Electromyographic studies of inflammatory and degenerative rheumatism of the spine. *Z Rheumaforsch* 1967; 26: 376-82 (in German).

33. SADOWSKA-WROBLEWSKA M: Electromyographic investigations in ankylosing spondylitis. *Reumatologia* 1968; 6: 265-74 (in Polish).

34. HALLA JT, KOOPMAN WJ, FALLAHI S, OH SJ, GAY RE, SCHROHENLOHER RE: Rheumatoid myositis. Clinical and histological features and possible pathogenesis. *Arthritis Rheum* 1984; 27: 737-43.

35. BEKKELUND SI, TORBERGSEN T, HUSBY G, MELLGREN SI: Myopathy and neuropathy in rheumatoid arthritis. A quantitative controlled electromyographic study. *J Rheumatol* 1999; 26: 2348-51.

36. ZEDKA M, PROCHAZKA A, KNIGHT B, GILLARD D, GAUTHIER M: Voluntary and reflex control of human back muscles during induced pain. *J Physiol* 1999; 520 pt. 2: 591-604.

37. FLOYD WF, SILVER PHS: The function of the erectores spinae muscles in certain movements and postures in man. *J Physiol* 1955; 129: 184-203.

38. JOSEPH J, McCOLL I: Electromyography of muscles of posture: posterior vertebral muscles in males. *J Physiol* 1961; 157: 33-7.

39. BASMAJIAN JV: Control and training of individual motor units. *Science* 1963; 141: 440-1.

40. FLOYD WF, SILVER PHS: Function of erectores spinae in flexion of the trunk. *Lancet* 1951; 1: 133-4.

41. PORTNOY H, MORIN F: Electromyographic study of postural muscles in various positions and movements. *Am J Physiol* 1956; 186: 122-6.

42. MORRIS JM, BENNER G, LUCAS DB: An electromyographic study of the intrinsic muscles of the back in man. *J Anat* 1962; 96: 509-20.

43. PAULY JE: An electromyographic analysis of certain movements and exercises. I. Some deep muscles of the back. *Anat Rec* 1966; 155: 223-34.

44. DONISCH EW, BASMAJIAN JV: Electromyography of deep back muscles in man. *Am J Anat* 1972; 133: 25-36.

45. ANDERSSON GBJ, ORTENGREN R, HERBERTS P: Quantitative electromyographic studies of back muscle activity related to posture and loading. *Orthop Clin North Am* 1977; 8: 85-96.

46. JOSEPH J: *Man's Posture. Electromyographic Studies*. Charles C. Thomas, Springfield, Illinois, 1960.

47. BOOYENS J, McCANCE RA: Individual variations in expenditure of energy. *Lancet* 1957; 273: 225-9.

48. ABITBOL MM: Effect of posture and locomotion on energy expenditure. *Am J Phys Anthropol* 1988; 77: 191-9.

49. SOLOMONOW M, BARATTA RV, BANKS A, FREUDENBERGER C, ZHOU BH: Flexion-relaxation response to static lumbar flexion in males and females. *Clin Biomech* 2003; 18: 273-9.

50. UITZ E, AGLAS F, HERMANN J, RAINER F, KLEINHART R, KREJS GJ: Possible diagnostic error of "Bechterew disease". *Wien Med Wochenschr* 1996; 146: 468-471 (in German).

51. WRIGHT V, CATTERALL RD, COOK JB: Bone and joint changes in paraplegic men. *Ann Rheum Dis* 1965; 24: 419-31.

52. KHAN MA, KUSHNER I, FREEHAFER AA: Sacroiliac joint abnormalities in paraplegics. *Ann Rheum Dis* 1979; 38: 317-9.

53. FISKE DN, BUSH CH, EDWARDS NL: Axial skeletal changes in paralysed patients may mimic ankylosing spondylitis. *Br J Rheumatol* 1995; 34: 174-7.

54. JENKINSON TR, MALLORIE PA, WHITELOCK HC *et al.*: Defining spinal mobility in ankylosing spondylitis (AS): the Bath AS Metrology Index. *J Rheumatol* 1994; 21: 1694-8.

55. SWINKELS A, DOLAN P: Spinal position sense and disease progression in ankylosing spondylitis: a longitudinal study. *Spine* 2004; 29: 1240-5.

56. KERSLEY GD: Obituary, Dr. Jacques Forestier. *Ann Rheum Dis* 1978; 37: 388.

57. RAKIC M: Dr. Jacques Forestier July 27, 1890-March 15, 1978. *Arthritis Rheum* 1978; 21: 989-90.

Discovery Prize of $750.00

The "Bowstring Sign" was stated to be an already classic sign described by J. Forestier in his 1951 book (1). However, an original reference was not cited. Therefore, a prize of $750.00 will be given to the first person who discovers the original reference and sends it to Dr. A.T. Masi by certified or registered mail, in the year 2006.

The Judging Committee will be composed of the following persons:

Dr. Francois Forestier (*Aix Les Bains, France*)

Dr. Alfonse T. Masi (*Peoria, Illinois, USA*)

Dr. Henri A. Ménard (*Montreal, Canada*)

Dr. Klaus Louis Schmidt (*Bad Nauheim, Germany*)