Neuromuscular and Musculoskeletal Problems in Instrumentalists

Richard J. Lederman, MD, PhD
Department of Neurology and Medical Center for Performing Artists,
Neurological Institute, Cleveland Clinic Foundation
9500 Euclid Avenue
Cleveland, OH 44195 USA

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2621 Superior Dr NW
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Department of Neurology and Medical Center for Performing Artists
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EDUCATIONAL OBJECTIVES  Upon completion of this monograph, the reader will acquire skills to: (1) recognize the spectrum of medical problems which may result from or impact on the playing of a musical instrument. (2) distinguish the factors which may contribute to the likelihood of an instrumentalist developing a playing-related problem. (3) define the clinical approach to the performing artist, with particular attention to the differences that may exist between this group and others. (4) discuss the multiple ways in which electrodiagnostic techniques may be helpful in the investigation of playing-related disorders. (5) apply various therapeutic approaches which may be helpful in returning the instrumentalist to full and pain-free performance.

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ABSTRACT: Instrumentalists are at risk of occupational health problems that can significantly interfere with their ability to perform. If not recognized and properly treated, many of these problems can limit, interrupt, or end an individual’s performing career. Among 1872 instrumentalists evaluated, musculoskeletal disorders were identified in 63%, peripheral nerve disorders in 18%, and focal dystonia in 9%. Focal dystonia involving the upper limb, or in some woodwind and most brass players the muscles of embouchure, is being recognized with increasing frequency. Symptoms and signs are related to the stresses inherent in playing. Electrodiagnostic studies are an important part of the evaluation of these disorders, particularly nerve entrapments. With carefully designed treatment, the majority of instrumentalists can return to full and pain-free playing. Treatment success is highest in nerve entrapment syndromes, followed by musculoskeletal syndromes. Despite some recent innovative approaches and increased understanding of pathophysiology, focal dystonia remains largely resistant to therapy.

NEUROMUSCULAR AND MUSCULOSKELETAL PROBLEMS IN INSTRUMENTALISTS

RICHARD J. LEDERMAN, MD, PHD

Department of Neurology and Medical Center for Performing Artists, Neurological Institute, Cleveland Clinic Foundation
9500 Euclid Avenue, Cleveland, OH 44195 USA

The performing arts have been an integral part of the human experience since the beginning of recorded history, serving as an expression of emotion, a means of paying homage to deities, and a reflection of man’s awe of the environment. Music, dance, and dramatic arts are prominent features of all cultures; indeed these activities are nurtured among the youngest members of society. It is perhaps because the performing arts are so much a part of everyday experience that society generally has failed to perceive them as an occupation. Even the words chosen to describe these activities—playing, dancing, singing, or acting—convey a sense of leisure and relaxation rather than labor.

Until recently, with a few exceptions, little attention was focused on the health problems of performers as a group. The development of sports medicine as a discipline helped set the stage for performing arts medicine. Initially this area of medicine dealt with the health disorders of dancers and vocalists. The focus on instrumentalists is more recent. This review will focus specifically on the scope and extent of neuromuscular and musculo-skeletal problems observed in instrumentalists as well as the clinical approach to the musician-patient.

All instrumentalists are at risk for neuromuscular and musculoskeletal disorders, including professional performers and teachers, students, and amateurs. However, professionals and students in conservatories or schools of dance or music comprise the large majority of those referred to this author’s center for performance-related health problems.

Attempts to determine the prevalence of performance-related disorders have dealt primarily with professional and student groups of instrumentalists, as it is difficult to identify a large enough and representative cohort of amateur
instrumentalists to survey. A relatively small survey of 79 amateur instrumentalists attending a chamber music workshop was carried out by Newmark and Lederman to assess the incidence of regional pain syndromes during that week of intensive playing (average 7-8 hours per day). Of the 79, 57 (72%) developed a new playing-related problem, mostly regional pain. Caldron and colleagues surveyed 250 non-wind instrumentalists via questionnaire; 59% reported some musculoskeletal problem related to playing. Within this group, 58% were students, 41% professional instrumentalists or teachers, and 1% amateurs. Fry, interviewing and examining 485 professional symphony orchestra musicians, found that 312 (64%) suffered recurrent or persistent playing-related pain. A questionnaire survey of 48 symphony orchestras carried out by the International Conference of Symphony and Opera Musicians showed that 58% of 2,212 respondents had a musculoskeletal problem characterized as severe at some time in their career. In all of these studies, women were more likely to report musculoskeletal symptoms than men. This is not a phenomenon unique to instrumentalists. Players of certain instrument groups, particularly keyboard and strings, have been shown to be more susceptible to musculoskeletal problems than others. Not surprisingly, the likelihood of developing a problem appears to correlate with the amount of playing or practicing. Studies focusing on student populations have yielded prevalence rates approaching those of professionals.

Zaza reviewed seven eligible studies looking at the prevalence of musculoskeletal disorders among instrumentalists and found that they were comparable to the prevalence of work-related problems in other occupational groups, including those associated with a high level of repetitive tasks. Prevalence data are, unfortunately, widely divergent, as might be expected, given the diversity and number of such studies; factors considered in the acquisition of data also influence the results. For example, a review of the frequency of upper extremity disorders worldwide yielded a 12-month prevalence ranging from 2.3% to 41%, obviously difficult numbers to use for comparison. Data compiled by the National Institute for Occupational Safety and Health was reviewed critically regarding specific work-related disorders, including shoulder pain, epicondylitis, carpal tunnel syndrome (CTS), and hand/wrist tendinitis. An interesting reported statistic is that, among injuries attributed to repetitive motion, 55% affected the wrist, 7% the shoulder, and 6% the back. Injuries attributed to “overexertion,” however, involved the back in 50-65% of cases. A survey published more than 25 years ago by the National Center for Health Statistics regarding prevalence of musculoskeletal symptoms and signs in the general population indicated shoulder and finger symptoms in 6.7% and 7.8%, respectively, with physical signs of impairment in 3.0% and 4.4%, respectively. Prevalence in specific occupations has been investigated in a number of studies as well, with widely varying results. However, the overall data suggest that instrumentalists, as well as members of other selected occupational groups, suffer a considerable excess of musculoskeletal problems that may tentatively be attributed to their work-related activities.

What are the risk factors that seem to predispose instrumentalists to this high prevalence of musculoskeletal problems? These have included age, gender, and physical characteristics (e.g., hand size, joint laxity, and muscle conditioning), as well as music-related factors (e.g., technique, playing posture, methods of instrument support, practice/playing time and “intensity,” and even the music itself). These various risk factors have been reviewed comprehensively by Brandonbrener.

ARE MUSICIANS INHERENTLY DIFFERENT FROM NONMUSICIANS?

It seems intuitive that there might be some difference in the brains of those with extraordinary musical talent and accomplishment, as well as those of genius in any other field, compared to the general population. Until recently, with the development of sophisticated and noninvasive techniques, investigation of such differences has been largely restricted to examination of the morphological characteristics of individual brains postmortem. For an interesting review of such studies in musicians and others, see Meyer. The application of neuroimaging and powerful physiologic techniques to such studies has yielded information that does suggest that musicians and nonmusicians may differ, whether inherently or perhaps only as the result of early training and musical experience.
Schlaug and colleagues have used magnetic resonance imaging (MRI) to compare brain morphology in musicians and nonmusicians.\textsuperscript{24-27} They have identified significant differences in the configuration of the primary sensorimotor cortex, Heschl’s gyrus (primary auditory cortex), and some additional areas that may underly the particular skills required in musicians. A critical question is whether these differences are inborn, accounting perhaps for the early recognition of talents leading to the decision to pursue musical training, or are acquired as the result of the many years of intensive training that it takes to develop those necessary skills. Norton and colleagues\textsuperscript{28} compared neuropsychological testing results and MRI studies in two groups of 5-7 year-old children before about half of them began taking music lessons (piano or strings). They found no significant differences in cognitive, motor, or brain structure between the groups. Longitudinal study of these subjects may allow the question to be answered as to whether their subsequent musical training truly produces the changes noted in the accomplished musician, as a reflection of brain plasticity.

Electrophysiologic techniques, such as electroencephalogram activation with musical stimuli, may also show differences between populations of musically trained and naive subjects.\textsuperscript{29,30} Altenmueller and colleagues showed that musical stimulation in musicians could produce some “spill over” from sensory to motor control areas of brain, perhaps indicating a tendency for musicians to mentally image finger movements in response to musical input.\textsuperscript{29}

There is also evidence to suggest that nonmusical hand skills may differ between musicians and nonmusicians and that musical training may influence one’s ability to carry out other skilled motor acts. Jäncke and colleagues found that musicians showed less hand skill asymmetry than non-musicians, perhaps suggesting that early musical training might reduce the otherwise expected superiority of the dominant hand.\textsuperscript{31} In a widely quoted study, Elbert and colleagues used magnetoencephalography (MEG) to map the cortical representation of the left hand in string players compared to a control group of nonmusicians and found that there was a shift and increase in representation of the index through little fingers of the string players.\textsuperscript{32} Furthermore, there was a correlation between the age at onset of musical training and the degree of altered cortical organization. In another MEG study, Lappe and colleagues\textsuperscript{33} reported training two groups of nonmusicians over 2 weeks. One group learned to play a musical sequence on piano, whereas the other group only listened to the sequences and analyzed them. Post-training, there were cortical response changes in both groups, but there was evidence of greater enhancement of musical representation in auditory cortex in the subjects who actually played the sequences, suggesting additive effects of sensorimotor and auditory training. All of these studies relate to cortical plasticity and the likelihood that the brains of musicians do indeed differ in significant although rather subtle ways from those of nonmusicians. Just how important and how lasting these effects are remains to be determined.

**CLINICAL APPROACH TO THE PERFORMER**

Performing artists who present for clinical evaluation are similar to other patients, with some notable differences.\textsuperscript{34} The patient’s history may be punctuated by terms unfamiliar to some physicians, as the performer describes the problem and its effect on playing, singing, or dancing. Some knowledge of the physical requirements of the specific performing art is desirable, including the age at which serious training begins as well as insight into the rigors of the training process. It is important that the examining physicians understand the extraordinary demands which many aspects of performance place upon the neuromuscular apparatus. As part of the history, it is necessary to obtain a detailed description of the symptoms and circumstances under which they have developed. This may include a review of time spent in practice, rehearsal, and performance as well as details of practice techniques and repertoire. The examining physician should inquire about specific stresses that may play a role in the development of neuromuscular problems, including not only the physical rigors of intense pre-audition or performance activities but also the psychological and socioeconomic aspects. While this review necessarily focuses on “physical” symptoms and
signs in the instrumentalist, the impact of psychological factors contributing to the clinical syndrome should always be among the most important considerations in the diagnostic and therapeutic formulation.35

The examination of a performer, including the neurological and musculoskeletal examination, is again similar to that of other patients.34 It is often important, and at times crucial, to observe the patient while performing. This may, of course, present logistic problems (e.g., when examining the pianist or double bass player) and may stress the capabilities of the examiner as well. No one realistically can be expected to be an expert in analyzing performance techniques of all instrumentalists. What can be recognized, however, is the inefficient posture, excessive tension, and extraneous movement that may over time lead to a breakdown of the neuromuscular and musculoskeletal systems.

SPECTRUM OF CLINICAL NEUROMUSCULAR AND MUSCULOSKELETAL DISORDERS

Among instrumentalists, pain is the most frequent symptom leading to medical consultation. In this author’s performing arts medicine practice, 80% of patients indicate pain as the main complaint. Among the 1872 instrumentalists evaluated by this author through the end of 2009, a total of 2173 diagnoses were rendered. Of these, 1367 or 63% could be characterized as musculoskeletal disorders, 393 (18%) as peripheral nerve problems, and 201 (9%) as representing focal dystonia or occupational cramp. The remaining diagnoses (212, 10%) include a variety of central nervous system and miscellaneous problems. The distribution among the various instrument groups is shown in Table 1. Since a variety of factors may influence referral of patients for evaluation, it is difficult to draw any conclusions regarding the prevalence of these disorders among instrumentalists from this one patient group. Females represented 57% of the group evaluated. The average age of all patients at the time of evaluation was 37 years (male) and 30 years (females).

Approximately one-third of instrumentalists with musculoskeletal disorders can be assigned a relatively specific diagnosis such as shoulder impingement or rotator cuff disruption, ligament sprain (including those with joint hyperlaxity, tendinitis, or tenosynovitis), arthritis, and epicondylitis.36 The remaining two-thirds can best be classified as having a regional pain syndrome often characterized in the performing arts medicine literature as “overuse.” This controversial term, which performing arts medicine often shares with sports medicine, has been defined as a group of disorders characterized by symptoms and signs of presumed injury to tissues subjected to stresses exceeding their biological limits.37 The concept of overuse has been criticized, and to some extent appropriately, as simplistic and at worst misleading.58 However, the term remains firmly entrenched in the lexicon, despite its imprecision and vagueness, although attempts have been made to provide a more acceptable definition.39 It does imply knowledge of the mechanism or pathogenesis, which may or may not be justified, similar to other commonly utilized terms such as repetitive motion disorders and cumulative trauma syndromes.

In this review, the diagnosis of overuse refers primarily to regional muscle pain syndromes. The clinical diagnosis is based on the presence of pain and tenderness, which may be uni- or multifocal, but which is primarily localized to muscle or muscle-tendon complexes rather than to joints or tendons themselves. Accompanying symptoms include tightness, stiffness, cramping, fatigue, swelling, and numbness. Sometimes there may be a perception of impaired motor control and perhaps an actual degradation in motor performance.40 Pain usually can be elicited by stretching or activating the affected muscle-tendon unit against resistance, often providing the impression to both the patient and the examiner that weakness is present. Generally, however, no actual impairment of strength can be demonstrated or separated from the effects of pain. Furthermore, the neurological examination is characteristically normal, with no sensory or reflex abnormalities. In general, the diagnosis of regional pain syndrome or overuse is not utilized if a more specific or “better” diagnosis can be made.41 Among instrumentalists, pain in the hand, wrist, and forearm are most common,
although shoulder, neck, and back pain are by no means infrequent.

The lateralization of symptoms and signs in the neuromuscular disorders of instrument-talists tends to demonstrate instrument-specific patterns, as shown in Table 2. Violinists and violists, particularly, show a preponderance of left arm problems whereas the right arm and hand are more frequently affected in keyboard players. The weight-bearing right thumb and hand of oboists and clarinetists is more commonly symptomatic whereas, if brass players have upper extremity symptoms, they are more likely to be on the left.

**PERIPHERAL NERVE DISORDERS**

Because pain is commonly associated with specific disorders of peripheral nerve, these must be carefully assessed among the large number of musician patients presenting with upper limb symptoms. Comprehensive clinical and electrodiagnostic (EDX) evaluation often will identify the majority of these disorders. The peripheral nerve diagnoses identified in this author’s instrumentalist population are shown in Table 3. The majority of these represent compression neuropathies (predominantly entrapment neuropathies). These are defined as disorders of peripheral nerve function associated with a lesion at a predictable anatomical site at which the nerve is subject to compression, stretch, or friction. Entrapment neuropathies are, of course, common in the general population and there is no evidence to suggest that they are more common in performers than in others. There are some data, however, to suggest that the posture and position of playing certain instruments may predispose to the development of an entrapment neuropathy (see below). Among performers seeking medical consultation, entrapment neuropathies account for a substantial proportion of the diagnoses rendered. Entrapment neuropathies were found in 4% of patients presenting to a British musicians clinic, 10% of instrumentalists presenting to an orthopedic hand surgeon, 11% of those attending a music medicine clinic in Boston, 18% of this author’s patients, 22.5% of musicians treated at the Mayo Clinic, and in 48% of patients presenting to a neurologist with a special interest in peripheral nerve disorders. Because the various entrapment neuropathies encountered in performing arts medicine clinics are well-known to EDX physicians, these are only briefly reviewed, emphasizing aspects that may be particularly characteristic for instrumentalists.

The most frequent entrapment neuropathy among the author’s musician-patients is ulnar neuropathy at the elbow (UNE). It is not clear why UNE appears to be so common among instrumentalists, whereas CTS is so much more frequently diagnosed in the general population. It could be that the symptoms of UNE are more readily associated with performance, whereas symptoms of CTS tend to be more intrusive during the night and the instrumentalists do not consider these night-time symptoms “playing-related.” This might lead to selection bias in referral to a performing arts clinic. It also may be that the act of playing an instrument does indeed predispose the development of UNE, particularly in bowed string players (see below).

The clinical picture consists of pain at the elbow and, not infrequently, along the ulnar aspect of the forearm to the hand. Paresthesias are generally restricted and sensory loss localized to the ulnar distribution on the hand and fingers. Painless weakness and atrophy of ulnar-innervated muscles may occasionally be the presenting picture but, in most cases, the weakness is subtle or even nonexistent. Provocation of symptoms by 1 minute of maximal flexion of the elbow and production of paresthesias by percussion of the ulnar nerve at the elbow are often seen but one must avoid overinterpreting these findings, as both phenomena can at times be demonstrated in otherwise asymptomatic individuals. Subluxation of the ulnar nerve with elbow flexion is quite common in the general population and also has little if any usefulness in confirming a diagnosis of UNE. There were 85 instrumentalists out of the 1872 patients with UNE, of whom 34 were bowed string players, 12 plucked string players, 24 keyboard instrumentalists, 11 wind players, 2 brass players, and 2 percussionists. There were 38 female and 47 male instrumentalists, with an average age of 39 years at evaluation. Of the 34 bowed string players, including 23 violinists or violists, the left arm was affected in all and only in 5 were the symptoms bilateral. Given that the left arm is held in prolonged flexion, combined with supination and
repetitive finger motion, whereas the right arm alternately flexes and extends at the elbow, with nearly full pronation of the forearm, this distribution would strongly suggest that the playing position is critical in provoking the UNE. Among keyboard instrumentalists, UNE was diagnosed on the left in 19 and on the right in 9; of the 11 woodwind players, 7 had symptoms on the right and 6 on the left. There were six instrumentalists in this series with ulnar neuropathy at sites other than the elbow, including two at the wrist, two in the forearm (related to trauma), and two non-localizable but clearly proximal to the elbow and predominantly motor. One of these has had virtually complete recovery and the other has stabilized with moderate residua. These may represent an unusual form of neuralgic amyotrophy.

In other clinics, the frequency of UNE has varied widely, being uncommon in Winspur’s\textsuperscript{43} and Dawson’s\textsuperscript{44} clinics, accounting for 4% of 1000 presenting problems in Hochberg’s series,\textsuperscript{45} and identified in 59 of 117 musicians with nerve entrapments seen by Charness.\textsuperscript{49}

The second most common peripheral nerve disorder in the 1872 patients, thoracic outlet syndrome (TOS), also happens to be the most controversial. The problems with this diagnosis and the areas of disagreement regarding its existence, frequency, methods of diagnosis, and treatment are well known.\textsuperscript{50-55}

The diagnosis of the common symptomatic (also known as nonspecific or disputed) form of TOS is made on the basis of criteria that have not been adequately defined or validated. The criteria utilized include the following: (1) pain most often localized to the forearm, ulnar more than radial, but on occasion reported both proximally in the upper arm and periscapular region and distally in the hand; (2) sensory symptoms, including numbness, tingling, burning, or “swelling,” generally again involving the ulnar aspect of the forearm and hand but occasionally the radial forearm or even upper arm; (3) symptoms associated with specific positions or activities, although in more advanced cases they may be constant; (4) symptoms provoked by specific maneuvers such as hyperabduction of the arm, abduction and extension of the arm, or downward traction on the arm with some internal rotation at the shoulder; and (5) a normal neurological examination with no recognizable muscle weakness, sensory loss, or reflex abnormality.

Approximately half of the 79 patients diagnosed with TOS had a droopy shoulder configuration;\textsuperscript{56} women outnumbered men almost 3 to 1 and the average age at the time of evaluation was 25 years. Those with TOS included 36 bowed string players, of whom 28 played violin or viola, 19 keyboard players, 13 woodwind players, including 9 flautists, and 11 from other instrument groups. All of these patients had the symptomatic form of TOS; none had the true neurogenic form with a cervical band and demonstrable sensory and motor deficits, consistent with a lower trunk brachial plexopathy. In general, the distribution of symptoms followed that of the musculoskeletal disorders, with the left arm of string players and the right arm of keyboard instrumentalists more commonly affected. Winspur reported 9 musicians with TOS out of 137 “specific ortho-paedic/rheumatological” diagnoses in 323 patients at a musician’s clinic.\textsuperscript{43} Hochberg diagnosed TOS in 7% of 1,000 musicians seen in his clinic.\textsuperscript{45} Charness identified TOS in 40 of 117 instrumentalists (34%) with nerve entrapment.\textsuperscript{49}

Next in frequency among instrumentalists is median neuropathy at or distal to the wrist with CTS. This is considered to be the most common entrapment neuropathy of the upper extremity in the general population. Pain in the affected extremity (both distal and sometimes proximal), paresthesias largely but not invariably restricted to median nerve distribution, and impairment of dexterity are the most common complaints. Paresthesias and pain at night are frequent. Examination reveals sensory loss in less than half and motor impairment in only a small minority. Tinel’s sign is positive, as is the Phalen maneuver, in the majority but these findings are neither specific nor invariably present.

Of the 1872 musicians reviewed, there were 69 patients with CTS, including 42 women and 27 men, ranging in age from 17-79 years with an average of 44 years. Keyboard instrumentalists comprised 42%; string players, 38%; woodwind and brass instrumentalists, 16%; and percussionists, 4%. As in most series of patients with CTS, symptoms in more than half were bilateral. Among
keyboard players with unilateral symptoms only, more than twice as many had the right hand affected (19 versus 8). Interestingly, among 16 bowed string players, all but 3 had involvement on the right, either exclusively or predominantly in 10. This obviously differs from the findings among the UNE patients as well as those with musculoskeletal disorders. This might suggest either that bowing is somehow more stressful to the median nerve at the wrist than repetitive finger movement or, perhaps more likely, that other activities of the dominant hand play a more important role in the development of CTS among string players and other instrumentalists than does the playing of the instrument itself. Winspur reported 4 musicians with CTS among 323 (1%) seen at his musician’s clinic, Charness found 24 cases among the 117 with nerve entrapment (20.5%), Dawson identified 68 patients with CTS among 1,000 (7%) instrumentalists with upper extremity problems, and there were 5 with CTS among 40 musicians assessed at a Mayo Clinic musician’s clinic.

Other median neuropathies were identified in 12 patients, including 8 from trauma. Four of the 12 patients had selective involvement of the anterior intersosseous nerve; 2 showed complete resolution and 2 had mild residua. One of the latter underwent negative exploration of the forearm. All were assumed to be a form of neuralgic amyotrophy. One additional instrumentalist developed a pronator syndrome after repeatedly tuning several harps during a series of concerts. She ultimately recovered completely with conservative management.

Cervical radiculopathy was identified in 46 instrumentalists, including 25 string players (13 violinists or violists) and 15 keyboard instrumentalists. Among these were 34 men and 12 women, ranging in age from 29 to 90 years with a mean of 51 years. The intuitive assumption that violinists or violists might be more susceptible to cervical spondylosis and radiculopathy because of their playing position does not appear to be borne out by these numbers, although conclusions about prevalence are treacherous from such limited data. Symptoms in this group are similar to those expected, with neck and arm pain following characteristic patterns and both sensory and motor impairment typical for the root involved. C6 was the most commonly affected (18 patients) followed by C7 (17 patients) and C8 (8 patients). The left arm was more commonly affected than the right in both the keyboard and string groups but numbers are simply too small to draw any conclusions. Four musicians in Charness’ series had cervical radiculopathy (all C6; three were string players and had left arm symptoms).

Eighteen patients were found to have digital neuropathies, only nine of which were playing-related. Five flautists had involvement of the left index finger, resulting from compression against the instrument, as has been previously described. Two guitarists and one violinist had involvement of the radial digital branch of the index finger, presumably related to excessive pressure on the neck of the instrument. One marimba player who was practicing extensively with a four-mallet technique developed symptoms in the distribution of a digital branch to the middle finger related to compression on the stick. He recovered fully when he discontinued this activity.

A small but interesting group of instrumentalists, including four men and three women, were found to have long thoracic neuropathy. These are unlikely to be playing related and five of these were presumed to represent focal forms of neuralgic amyotrophy.

Other upper-limb mononeuropathies, including entrapment of the radial nerve and of the posterior cutaneous nerve of the arm, have been described in the literature and this author’s clinic has seen occasional cases. Another compression neuropathy, which is uncommon but possibly underreported, is found in brass and woodwind players, involving branches supplying the lip. This author has seen seven such patients, each showing segmental sensory loss with or without some motor impairment in a portion of the upper or lower lip which appears to be related to external and/or internal pressure. All have improved with changes in technique and reduction in playing time. A similar case was described by Frucht.

FOCAL DYSTONIA IN INSTRUMENTALISTS
The last 30 years has witnessed a remarkable surge of interest in focal dystonia, both in instrumentalists (musician’s cramp) and in others (e.g., writer’s cramp). Among instrumentalists, the majority of these disorders involve the distal upper limb, although a substantial group of brass and wind players have dystonia affecting the muscles involved in embouchure, the relationship of jaw, lip, and tongue to the instrument mouthpiece.62, 64-66

A number of groups interested in performing arts medicine have published a substantial series of reports of patients with focal dystonia.49, 67-72 Conti and colleagues73 have undertaken the monumental task of reviewing the literature on focal hand dystonia, emphasizing both the common features among the nearly 1000 cases described up to that time and the diversity of clinical characteristics even among musicians playing the same instrument.

This author’s series of 201 instrumentalists with focal dystonia includes 40 bowed string players, 30 plucked string players, 29 keyboard instrumentalists, 48 woodwind players, 44 brass instrumentalists, and 10 percussionists. All of the brass players, with the exception of 1 trumpet player with torticollis and another with right-hand dystonia, and 8 of 31 woodwind instrumentalists had involvement of the muscles of embouchure. All of the string, keyboard, and percussion instrumentalists, with the exception of a single violinist with playing-related retrocollis, had focal limb dystonia. In general, the limb affected followed the characteristic distribution observed in other disorders. Table 4 outlines the distribution of focal dystonia among the various instrumental groups and Table 5 shows the localization of the dystonia within these groups. An unusual and consistent feature in this series, and in all others of focal dystonia among instrumentalists, has been the predominance of males as opposed to all of the other playing-related disorders, which are more common in females. Genetic factors may play a role in this phenomenon.74-76 The average age at time of evaluation was in the mid-30s and average duration of symptoms was approximately 5 years. At the time of evaluation, 76% were professional musicians, 15% were students (the youngest was a violinist with onset of dystonia at age 15 year), and 9% were amateurs.

Symptoms generally begin insidiously and are characterized by difficulty with control, speed, or dexterity. Some patients have described stiffness, cramping, tightness, or fatigue; pain is only occasionally a prominent symptom and often can be attributed to the effort in trying to overcome the dystonic movements. Dystonia of the muscles of embouchure is usually signaled by difficulty in tone production.62,64,66 The majority of dystonias in instrumentalists in this and other series have been task-specific, limited to the playing of the instrument and sometimes to playing of only one of the two or more instruments that the musician commonly plays. Rosset-Llobet and colleagues77 looked specifically at the frequency with which other motor activities are affected as focal dystonia progresses and found less than 50% would remain task-specific. Sensory (proprioceptive) “tricks,” so commonly seen in torticollis and even in writer’s cramp, were only occasionally seen in this group of instrumentalists. Perhaps an explanation for this relative infrequency may be the lack of options for such maneuvers, given the need for using both hands to play the instrument.

Investigations into the pathogenesis of focal dystonia have appeared with increasing frequency over the last 30 years and have provided insight into the mechanisms and localization within the nervous system.78-89 This has been enhanced by the development of sophisticated electrophysiological (especially somatosensory evoked potentials (SEPs),79,80 MEG,32 and transcranial magnetic stimulation81) and imaging techniques (positron emission tomography scanning and particularly functional magnetic resonance imaging82-89) and by production of dystonic hand function in a primate model.81,94 Although the current level of understanding is far from complete, a reasonable hypothesis is that there is excessive sensorimotor cortical excitability, resulting at least partly from impaired intracortical inhibition. This most likely reflects abnormal integration of sensory and motor functions, all within the basal ganglia-thalamo-cortical system.86-88,95-97 The etiology in musicians, as well as others with focal dystonias, almost certainly involves both environmental and genetic factors.74,75

**EDX EVALUATION IN PERFORMERS**
EDX techniques have been applied to the study of performing artists in a number of settings. Surface recording, and occasionally intramuscular wires, has been applied to the study of patterns of muscle activation in playing different instruments, primarily as a means of understanding which groups of muscles are most active during specific activities and hence may be at greatest risk for fatigue and pain. Such studies have generally focused on muscles of the upper trunk, upper limb, and lip.\textsuperscript{98,99} Difficulties in interpreting these results have limited the amount of useful information obtained, but EDX techniques, including routine needle electromyography (EMG),\textsuperscript{100} upper limb \textit{H}-reflex reciprocal inhibition,\textsuperscript{86,101} SEP brain mapping techniques,\textsuperscript{78,102} and transcranial magnetic stimulation\textsuperscript{78,102} have been used particularly in studying focal dystonia and cortical plasticity. EMG surface recording for biofeedback has been used as an adjunct in treatment of pain problems as well as dystonia. Intramuscular recording is usually considered an integral part of the muscle localization required for treatment of limb dystonia with botulinum toxin (see below).\textsuperscript{103-105}

The EDX techniques used by the vast majority of physicians examining performing artists will, of course, be those commonly utilized in most laboratories. Musicians may be reluctant to undergo EDX testing. They are frequently wary of any procedure that might involve electrical shocks to or placing needles in the part of the body upon which they rely for their livelihood. Providing an explanation of the procedure is important to place the musician at ease with the procedure. Because instrumentalists may seek evaluation at a time when symptoms are intermittent and relatively mild, EDX studies may be normal or equivocal. Careful clinical evaluation, serial examination, and conservative therapeutic interventions are generally appropriate in these circumstances.

EDX studies in the common regional muscle pain syndromes are generally normal. The decision to utilize these techniques obviously depends on the clinical situation, but it is useful to exclude nerve entrapment in patients with upper limb pain that has been resistant to the usual treatment measures. In most cases, however, the studies are, as expected, unrevealing and nerve entrapment can reasonably be excluded. Many of these cases would have been referred as possible examples of TOS or of “resistant tennis elbow,” looking for evidence of radial entrapment. The controversies regarding the EDX examination of TOS are widely recognized. In this author’s laboratory, nerve conduction studies (NCSs) and needle EMG are virtually always normal in these patients. The ulnar NCS reported as useful in TOS\textsuperscript{106} has been shown to be of no value\textsuperscript{107} as have other techniques designed to look at this segment of the peripheral nervous system.\textsuperscript{108} The symptomatic TOS remains a clinical diagnosis.

The EDX examination of suspected CTS is one of the most consistently useful and rewarding procedures in the EDX laboratory.\textsuperscript{109} In addition to the standard median sensory and motor NCSs, a variety of specific variations have been recommended for confirming the diagnosis of CTS.\textsuperscript{109,110} MacLean has summarized the EDX approach to CTS in the performing artist.\textsuperscript{111} Of the 69 instrumentalists with CTS in the present series, EDX studies were performed in 59, 56 of which (95%) were abnormal. Of these, 40 (71%) showed evidence of bilateral involvement electrically.

EDX evaluation of UNE is both more difficult and generally less consistently reliable than for CTS. The various factors contributing to this have been reviewed extensively.\textsuperscript{112,113} A number of special NCSs have been suggested to improve upon the sensitivity and specificity of the EDX evaluation, including intraoperative techniques,\textsuperscript{114} short-segment incremental studies,\textsuperscript{115} and near-nerve recording.\textsuperscript{116} Adding ultrasound to the EDX evaluation of UNE has been reported to increase the diagnostic sensitivity significantly.\textsuperscript{117} Using standard surface techniques with routine stimulation above and below the elbow and short-segment incremental stimulation when appropriate, this author has found EDX studies positive in about half the instrumentalists with clinically suspected UNE, whether at the level of the retrocondylar groove or more distally in the cubital tunnel. Charness has reported a large series of musicians with UNE, many studied by near-nerve techniques.\textsuperscript{49} Whether the apparent increased sensitivity of this technique justifies both the time necessary to perform it and the possible loss of specificity remains uncertain.

EDX evaluation of other nerve entrapments, including cervical radiculopathy, has been variably
useful, depending on duration and severity of the clinical symptoms and signs as well as the vigor with which abnormalities are sought. Sonography may on occasion add helpful diagnostic information in difficult cases. Sonography may on occasion add helpful diagnostic information in difficult cases.118 Because of technical difficulties, EDX evaluation of digital mononeuropathies and the neuropathies involving the lip generally has not been helpful.

The usefulness of EDX techniques in evaluating focal dystonia has been largely restricted to research, with the exception of searching for evidence of associated nerve entrapment, particularly UNE in those with the common clinical pattern of D4/5 flexion dystonia. Needle EMG is, of course, commonly utilized for muscle localization in treatment with botulinum toxin (see below). The ability to identify simultaneous co-contraction of agonists and antagonists or poorly modulated bursts of motor unit action potentials on attempted voluntary contraction has not added significantly to the clinical evaluation, and the technical difficulties involved in H-reflex excitability curves for demonstrating abnormal reciprocal inhibition has precluded their routine use.

TREATMENT OF NEUROMUSCULAR AND MUSCULOSKELETAL DISORDERS

Space constraints dictate that therapy for these various problems be discussed only briefly. Dealing with performing artists can be difficult. Their intense determination and desire to perform are often at least partially responsible for their disorder, yet they commonly express a need for quick if not immediate symptom relief. At the same time, many musicians are almost pathologically fearful of medical, to say nothing of surgical, interventions.

For the regional pain syndromes or overuse disorders, treatment largely has centered on initial rest or abstinence from the offending activity.120 For most patients, this can consist of a relative reduction in the amount and intensity of playing, generally in the range of 50-75%. Only occasionally is a more radical restriction necessary. The physical, technical, and psychological risks of total abstinence from playing must be weighed against the potential tendency for the instrumentalist to do more than recommended, a behavior pattern that may well have gotten them into trouble initially. Along with rest, anti-inflammatory medication or simple analgesics can be helpful, as well as thermal and other adjunctive modalities. For resistant cases, more invasive methods including local injections and surgery may be required. Once the pain has subsided, a rehabilitation phase would include physical and occupational therapy techniques designed to increase the capacity to withstand the static and dynamic stresses of playing the instrument.121 Utilization of various body awareness techniques often can be extremely helpful, not only for therapy following injury, but for prevention of musculoskeletal playing-related disorders.122 Instrument adaptations, such as extending keys on a wind instrument or providing a support post, or changes of the chin rest or shoulder rest on a violin or viola, can be helpful.123-126 Attention must be paid to psychological factors and emotional stress; this can be critical in reducing unwanted muscle tension and preventing recurrences. Enlisting the help of the teacher or coach in identifying technical flaws or faulty practice habits can be crucial.

In a followup study of 100 instrumentalists, 66 had been diagnosed as having a primary musculoskeletal disorder.127 After 5 to 7 years, 75% had either no symptoms or at least a 50% reduction in level of symptoms. Only four were unchanged but eight had new musculoskeletal symptoms at the time of followup. Fry, in a followup survey of 168 patients with overuse injury, reported that close to 90% were improved.120 However, he excluded those in the initial group who had declined to follow the prescribed treatment regimen or dropped out early on, reducing the actual number evaluated for outcome to 90. Bengtson and Schutt surveyed 73 musicians with upper extremity musculoskeletal problems for outcome, and approximately two-thirds were able to return to playing, although male instrumentalists had a somewhat better outcome than females.128

The general principles involved in treating nerve compression syndromes in musicians have been presented in a number of publications.43,47,127,129 These have emphasized the desirability of a conservative approach initially, reserving surgical therapy for those who do not respond to nonoperative measures. The reluctance of
instrumentalists to consider surgical therapy has been referred to earlier and has been emphasized by others as well. At the same time, however, the impact of what might in some patients be a relatively minor degree of neurological impairment may be disabling for the instrumentalist, and there are situations in which early surgery may be warranted.

Modification of hand or arm position and usage is an important part of initial treatment. Obviously, there are limitations to what can be changed in the playing of an instrument. Nonetheless, the degree of wrist flexion may be modified in a pianist or violinist and perhaps even more readily in a guitarist. The total amount of playing time usually can be reduced at least temporarily and playing sessions can be shortened with longer rest periods between them, during which stretching can occur. Adequate warm-up and cool-down can be emphasized. Wrist flexion in the patient with CTS certainly can be minimized at night using a wrist splint, and this is often effective in reducing not only the nocturnal paresthesias but daytime symptoms as well. The patient’s anatomy as well as the characteristics of the instrument often dictate the degree of elbow flexion required for playing, but playing time can be reduced and unnecessary elbow flexion during nonplaying time, including sleep, can be facilitated by patient awareness as well as by elbow splints or protectors. Similar alteration in position and posture can be relevant to the patient with TOS or cervical radiculopathy. Modification of the shoulder and neck position can be facilitated by instrument adaptations. The physical or occupational therapist can help by providing instruction in postural training and stretching as well as strengthening exercises for these disorders. A variety of modalities which help to relieve the symptoms associated with nerve compression can be utilized by these practitioners. Anti-inflammatory medications, which this author utilizes sparingly, can reduce perineural swelling and inflammation. In some cases, particularly CTS, local steroid injection can provide at least temporary relief.

In this author’s series, about 50% of patients with CTS have responded favorably to nonoperative management, as have about 60-70% with UNE (many of whom have relatively mild symptoms), 70-80% of those with TOS, and 80% of those with cervical radiculopathy. In Dawson’s series of 98 musicians with CTS, 27 of 59 with adequate followup had at least moderate improvement with nonsurgical management. However, an additional 27 were seen only once or lost to followup.

Surgical treatment of CTS has been extremely effective in musicians and in others. The decision to proceed with surgery generally is made after at least a trial of nonoperative treatment, although some of this author’s patients were first seen after unsuccessful trials of conservative management. As noted above, some musicians are willing to try almost anything to avoid surgery and others are quite anxious to proceed with the most definitive form of treatment as soon as possible, although generally after at least a brief trial of conservative therapy. The specific techniques for surgical management are beyond the scope of this review. Almost all of this author’s surgically treated patients have undergone open release of the carpal tunnel but in a few the endoscopic technique has been utilized with equally favorable results. In the followup series this author reported previously, 16 musicians underwent carpal tunnel release; all 16 had excellent outcome and were able to return to a full playing schedule. Dawson carried out carpal tunnel release in 38 musician patients, 8 of these after failing conservative treatment. Of the 38, 1 apparently suffered recurrent symptoms and 2 others had postoperative complications. Overall, Dawson reported a 93% cure rate or significant improvement among the patients treated.

Options for surgical treatment of UNE are more numerous and somewhat more controversial, ranging from simple decompression at the elbow to some form of nerve transposition. The advantages and risks of these approaches in musicians and others have been reviewed and the interested reader can consult these publications. Success in surgical management of UNE has generally been in the range of 50-80%. In a series of 85 patients by this author, followup information
is available in 61 (72%), ranging from 3 months to 18 years. Treatment was nonoperative in 47; 35 (74%) reported good to excellent results. Among the 14 who underwent surgical treatment, 11 had good/excellent outcome, 1 equivocal benefit, and 2 poor result, with no improvement in symptoms.

With the exception of cervical radiculopathy, for which surgery should be performed only for progressive neurological impairment or intractable radicular pain, the other nerve entrapment syndromes are almost always treated conservatively. Only 8 of this author’s 46 patients with cervical radiculopathy have required surgical intervention, and 1 has required intervention twice. Fortunately, all have had excellent results and have returned to full activity.

The treatment of focal dystonia continues to be disappointing although some recent innovations provide at least some promise for better results. Over the years, this author has utilized various modalities including medications (particularly anticholinergic drugs), relaxation techniques (including biofeedback and physical and occupational therapy), and psychotherapy. A variety of sensory stimuli (proprioceptive “tricks,” cooling, sustained muscle contraction with fatigue) may transiently ameliorate the dystonia. Technical retraining, a slow and tedious process best accomplished in conjunction with a skilled teacher or therapist, has been the most successful approach so far, but few patients have had the perseverance and the luxury of time to carry out such a program. Botulinum toxin has been utilized for focal limb dystonia with variable benefits in musicians. In the series from Hannover, Germany, reported by Schuele and colleagues, 88 musicians with focal limb dystonia were treated with botulinum toxin A using needle EMG guidance from 1995 to 2002. Of the 84 available for follow-up, 58 (69%) reported benefit from treatment, including 30 who noted a sustained improvement in performance. Of these, 13 apparently showed “substantial and sustained improvement of long-standing focal dystonia.” This author has been far less successful in identifying focal nerve entrapment among patients with dystonia and has not seen improvement in the focal dystonia following release of nerve entrapment in the few patients so treated.

Two relatively new treatment approaches have evolved over the past 10-15 years, both based upon the changes in somatosensory cortical representation of the dystonic hand. Candia and colleagues employed a modification of the constraint-induced movement therapy previously utilized in rehabilitation of the upper extremity of stroke patients. The authors described a total of 11 professional musicians in whom the nondystonic fingers were splinted, forcing the dystonic digits to
carry out repetitive exercises over a period of 8 days. The six pianists and two guitarists each were said to have experienced marked improvement in performance, sustained for up to 2 years. Three wind players, however, did not improve significantly. Priori and his colleagues\textsuperscript{145,146} have reported a technique of limb immobilization of the dystonic forearm and hand, lasting 4-6 weeks, followed by a period of rehabilitation. About one-third of the splinted instrumentalists had a marked improvement; another one-third experienced little or no benefit. Factors appearing to favor improvement included younger age, more acute and severe involvement, and an observed transient lessening of dystonia after a sustained voluntary contraction.\textsuperscript{133} Both of these techniques are based on the assumption that the disordered cortical sensorimotor representation in focal limb dystonia can be modified by changes in limb activity and improvement in the dystonia may be realized on the basis of this cortical plasticity.\textsuperscript{147}

Treatment outcome in focal dystonia, overall, remains unsatisfactory. Jabusch and colleagues reported that only 54\% of 144 instrumentalists with focal dystonia experienced some improvement with one or more treatment modalities.\textsuperscript{148} This author has looked at a group of bowed string players and woodwind instrumentalists with focal limb dystonia and assessed the long-term outcome after a variety of treatment modalities.\textsuperscript{149,150} Fewer than half the violinists and violists were able to maintain their careers; of those with bow arm dystonia, none could continue playing professionally.\textsuperscript{149} Of the wind players, about half were able to continue performing at a professional level, including three of six with embouchure dystonia.\textsuperscript{150} Further experience with a large number of brass instrumentalists with embouchure dystonia has been more discouraging.

**CONCLUSION**

Instrumentalists are subject to a number of disturbances in neuromuscular function. Based on survey methods, they appear to be particularly disposed to musculoskeletal disorders and may be more susceptible to both nerve entrapments and focal dystonia. The evaluation and treatment of these disorders is enhanced by a modicum of knowledge regarding the technical aspects of the particular art form and by a sympathetic and supportive approach to the performing artist’s problem. Instrumentalists tend to be introspective, self-analytical, and exceptionally single-minded and determined about their art. They have set high standards for themselves, which are sometimes unrealistic. Their expectation of others, including their healthcare providers, may be similarly high. By enlisting their unqualified support and collaboration, by including the teacher or coach in the process, and by outlining the therapeutic modalities and expectations clearly, successful treatment of these playing-related problems can be achieved in the large majority of musicians.
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Table 1. Diagnoses in instrumentalists.

<table>
<thead>
<tr>
<th>Diagnoses</th>
<th>Strings No. (%)</th>
<th>Keyboard No. (%)</th>
<th>Wind No. (%)</th>
<th>Percussion No. (%)</th>
<th>Total No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculoskeletal</td>
<td>730 (68)</td>
<td>369 (65)</td>
<td>219 (48)</td>
<td>51 (65)</td>
<td>1367 (63)</td>
</tr>
<tr>
<td>Peripheral nerve</td>
<td>183 (17)</td>
<td>121 (21)</td>
<td>78 (17)</td>
<td>11 (14)</td>
<td>393 (18)</td>
</tr>
<tr>
<td>Focal dystonia</td>
<td>70 (7)</td>
<td>29 (5)</td>
<td>92 (20)</td>
<td>10 (13)</td>
<td>201 (9)</td>
</tr>
<tr>
<td>Other</td>
<td>94 (9)</td>
<td>49 (9)</td>
<td>63 (14)</td>
<td>8 (10)</td>
<td>212 (10)</td>
</tr>
</tbody>
</table>

Table 2. Lateralization of upper extremity disorders in instrumentalists.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>No.</th>
<th>Right</th>
<th>Left</th>
<th>Bilateral</th>
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<tbody>
<tr>
<td>Strings</td>
<td>924</td>
<td>26</td>
<td>54</td>
<td>20</td>
</tr>
<tr>
<td>Bowed</td>
<td>743</td>
<td>26</td>
<td>56</td>
<td>18</td>
</tr>
<tr>
<td>Plucked</td>
<td>181</td>
<td>26</td>
<td>45</td>
<td>29</td>
</tr>
<tr>
<td>Keyboard</td>
<td>478</td>
<td>41</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>Woodwind</td>
<td>247</td>
<td>42</td>
<td>27</td>
<td>31</td>
</tr>
<tr>
<td>Instrument</td>
<td>Number</td>
<td>25</td>
<td>47</td>
<td>28</td>
</tr>
<tr>
<td>------------</td>
<td>--------</td>
<td>---</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Brass</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percussion</td>
<td>66</td>
<td>35</td>
<td>22</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 3. Instrumentalists with peripheral nerve disorders.

<table>
<thead>
<tr>
<th>Disorder</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar neuropathy (elbow)</td>
<td>85</td>
</tr>
<tr>
<td>Thoracic outlet syndromes</td>
<td>79</td>
</tr>
<tr>
<td>Carpal tunnel syndrome</td>
<td>69</td>
</tr>
<tr>
<td>Cervical radiculopathy</td>
<td>46</td>
</tr>
<tr>
<td>Cranial neuropathy</td>
<td>19</td>
</tr>
<tr>
<td>Digital neuropathy</td>
<td>18</td>
</tr>
<tr>
<td>Median neuropathy (other)</td>
<td>13</td>
</tr>
<tr>
<td>Radial neuropathy</td>
<td>13</td>
</tr>
<tr>
<td>Ulnar neuropathy (other)</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>393</td>
</tr>
</tbody>
</table>

Table 4. Focal dystonia in instrumentalists.
<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bowed strings</strong></td>
<td></td>
</tr>
<tr>
<td>Violin</td>
<td>31</td>
</tr>
<tr>
<td>Viola</td>
<td>8</td>
</tr>
<tr>
<td>Cello</td>
<td>1</td>
</tr>
<tr>
<td><strong>Plucked strings</strong></td>
<td></td>
</tr>
<tr>
<td>Guitar/banjo</td>
<td>27</td>
</tr>
<tr>
<td>Harp/zither</td>
<td>3</td>
</tr>
<tr>
<td><strong>Keyboard</strong></td>
<td></td>
</tr>
<tr>
<td>Piano</td>
<td>25</td>
</tr>
<tr>
<td>Organ/other</td>
<td>4</td>
</tr>
<tr>
<td><strong>Percussion</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Woodwinds</strong></td>
<td></td>
</tr>
<tr>
<td>Clarinet/saxophone</td>
<td>19</td>
</tr>
<tr>
<td>Flute</td>
<td>14</td>
</tr>
<tr>
<td>Bagpipes</td>
<td>8</td>
</tr>
<tr>
<td>Oboe/English horn</td>
<td>5</td>
</tr>
<tr>
<td>Instrument group</td>
<td>No.</td>
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<tr>
<td>--------------------------</td>
<td>-----</td>
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<tr>
<td>Bowed strings</td>
<td>40</td>
</tr>
<tr>
<td>Plucked strings</td>
<td>30</td>
</tr>
<tr>
<td>Keyboard</td>
<td>29</td>
</tr>
<tr>
<td>Woodwind</td>
<td>48</td>
</tr>
<tr>
<td>Brass</td>
<td>44</td>
</tr>
<tr>
<td>Percussion</td>
<td>10</td>
</tr>
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</table>