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Electromyography and Muscle Activities in Double Bass Playing

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Two electromyography (EMG) experiments related to double bass playing are described. By means of surface electrodes and synchronous recordings of finger movements on the string, it is shown in the first experiment that the production of vibrato is associated with pulsating contractions of two back muscles, the teres minor and the teres major. A failure in the coordination of the activity of these muscles was observed in a student having problems in producing a proper vibrato. The second experiment demonstrates clear effects of a small change in the holding of the instrument on muscular stress in the left and right trapezius muscles. These changes were revealed by the occurrence of different degrees of muscular force developed during playing. The pedagogical implications of these findings are discussed.

Introduction

Every music teacher trying to convey instrumental experience, knowledge, and skill to the student will refer to his or her own mental images in order to describe how the limbs and body work when interacting with the tone-producing musical instrument. Some of these images will be based on genuine knowledge of how the body acts; others will merely be a subjective description of how the movement "feels" and what the teacher believes to happen. Both categories may work, as means of communication, provided the student is able to recognize the images and the comparison makes sense. There is always the danger, however, that the student will try to get more out of the instruction than what was intended and that a partly figurative expression could be misleading if interpreted too literally.

Double bass students often have problems with developing an acceptable vibrato. The vibrato tends to sound cramped and uneven, not giving the appropriate "freedom to the sound." As a double bass teacher, I have noticed that my best students tend to play with a quite relaxed upper left

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arm, whereas students with vibrato problems tend to play with rather tight biceps and triceps brachii muscles. Often the student compensates for this by twisting and/or bending the wrist in order to create some movement in the stiff limb. The question naturally arises as to which muscles should initiate the movement and which should be more passive in this context. As described here, electromyography (EMG) is a useful tool for bringing more realism into the descriptions of "how to play the instrument" and removing some of the subjectiveness that may endanger this communication.

Method

EMG recordings were made with standard surface electrodes and associated electronics. In the first experiment, the electrodes were placed over the teres minor and teres major muscles of the left side of the back and the biceps brachii of the upper left arm. Representation of the position of the playing finger during vibrato performance was obtained by coupling the finger, by means of a rod, to a potentiometer. In this way, the electrical signals of the potentiometer reflect the movements of the finger. EMG is based on the fact that every muscle in the body is activated by a series of electrical discharges, causing the electrical potential to change rapidly between two chosen points on the skin surface and under it. Each of these discharges is fired by a nerve connected to a number of muscle fibers, constituting one "motor unit." During the electrical impulse these fibers contract, but afterward they quickly relax. A contraction of the whole muscle requires a number of motor units to fire at different times in quick succession; the overall contraction is the sum of all the small ones.

In the field of musical performance, EMG can be useful in at least three ways: (1) analysis of muscular coordination (qualitative), (2) measurement of muscular stress and tension (quantitative), and (3) biofeedback. The usefulness of biofeedback for modifying behavior is well known and will not be discussed here. In this article, I present some examples of the first two applications gained through my experience as a teacher of double bass playing.

Results

ANALYSIS OF MUSCULAR COORDINATION

Surprisingly, EMG measurements of a player with an acceptable vibrato revealed that the main effort has to be made by two small muscles in the back, situated on the lower half of the left shoulder blade: teres minor and teres major (Figure 1). If these muscles do not contract in a regular pattern, a natural swing of the arm will not occur.

Each of the two graphs in Figure 2 displays three traces. The upper trace shows the raw EMG of teres minor and major. The middle trace describes the position of the playing finger, that is, a representation of the vibrato. The lower trace gives the raw EMG of the biceps. The upper graph in Figure 2 shows the attack of a note (during 1 sec) when a "good

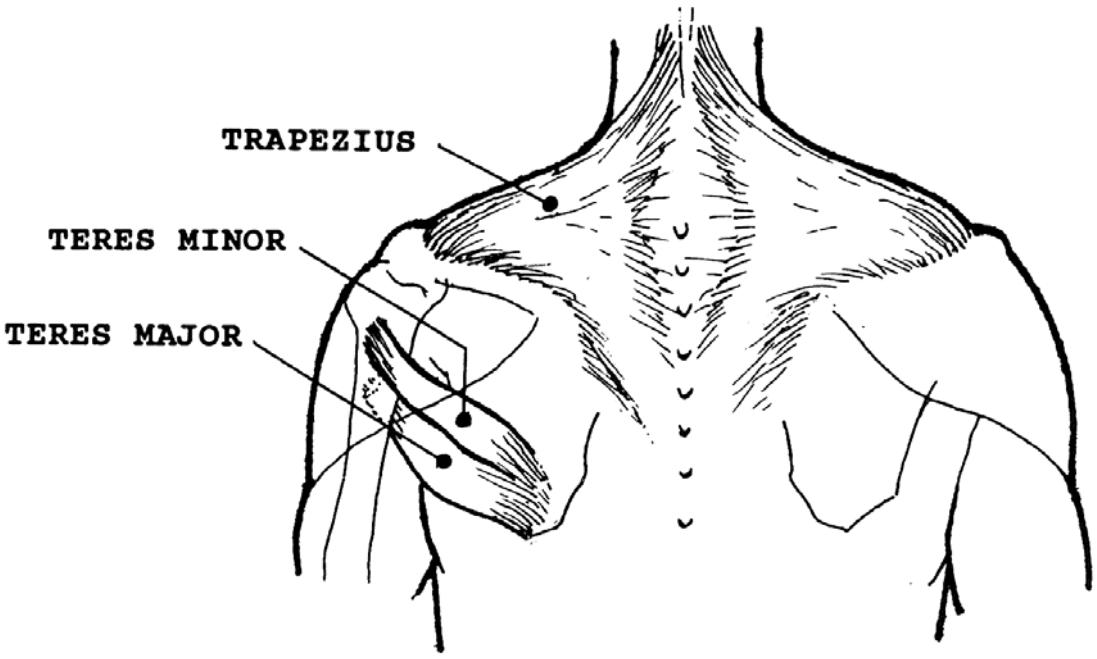

Fig. 1. Some muscles of particular importance in double bass playing.

student" is playing. The lower graph shows the corresponding data for the same task as performed by a student having a vibrato problem. The EMG activity shown in the upper graph is associated with a regularly pulsating, alternate activity in the biceps and the teres major and minor muscles triggered by vibrato playing. Only a slight activity could be noted in the biceps, but this EMG activity quickly drops close to zero when the impulse from the shoulder-blade muscles starts. Quick changes in the muscular activity generally are a healthy sign and show bodily freedom. For the student represented in the lower graph, the problems are obvious: there is no real impulse to start the movement and there is a constant and intense activity in the biceps. To improve the vibrato as well as playing of the instrument in general, this player would need some exercises for his shoulder-blade muscles, the teres minor and teres major. It is, however, difficult for a player to know whether these muscles are active, unless somebody is touching them, or through biofeedback. The activity of the biceps, on the other hand, is more visible and obvious, but it will require thorough practice to reduce its activity.

MEASUREMENT OF MUSCULAR STRESS AND TENSION

Most professional musicians occasionally suffer from sore muscles because of tendinitis or related injuries. The pain may become so intense that playing is impossible for some time. There are two main reasons why this kind of trouble may occur. One is that a muscle is being stressed beyond its working capacity. The second and more common reason is that a

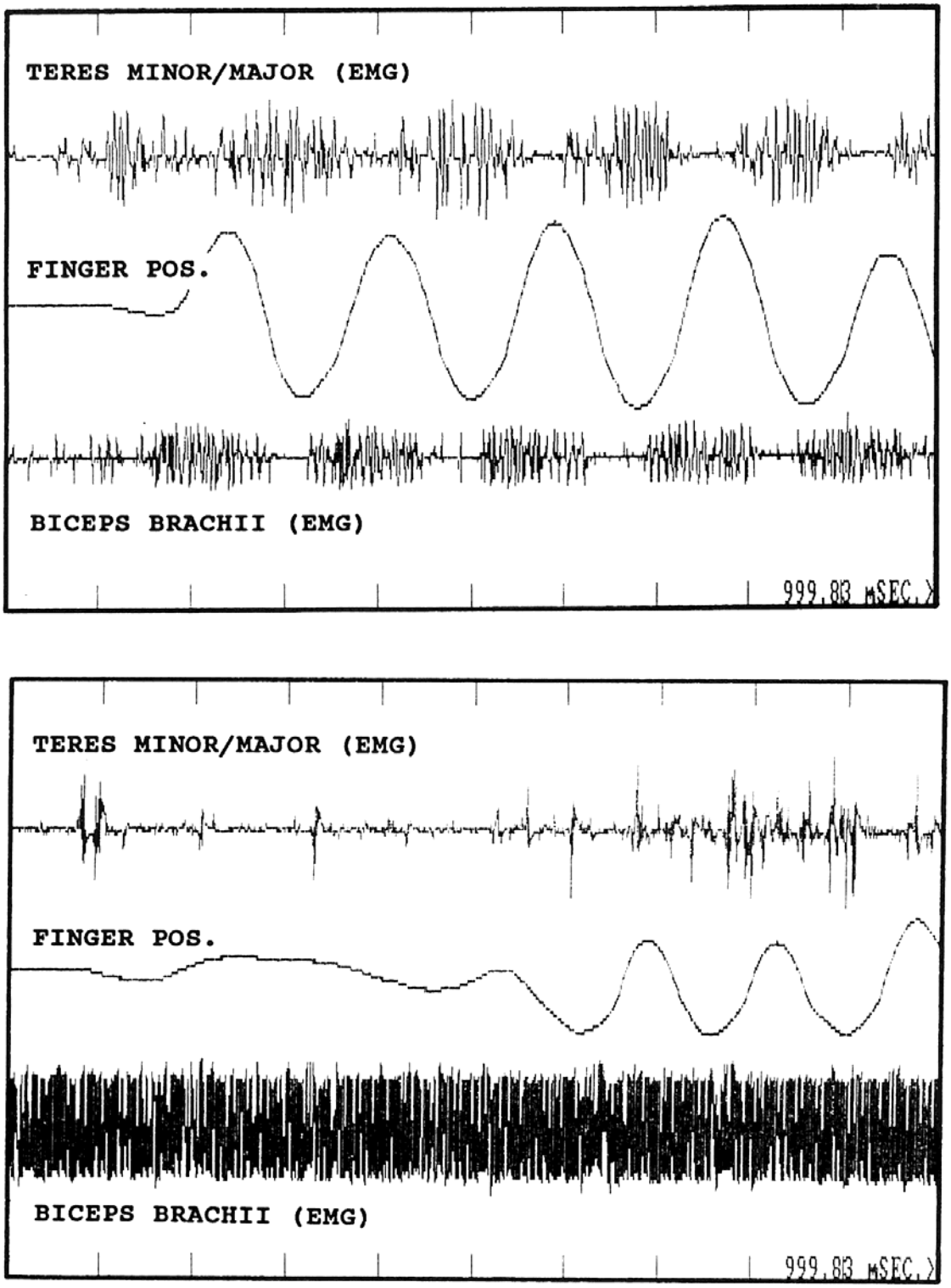

Fig. 2. Upper panel: Recordings made from a "good" student playing a vibrato. Lower panel: Recordings made from a student having problems playing a vibrato. In both panels, the upper trace is the electromyographic (EMG) recording of the teres minor and major muscles; the middle trace represents the position of the playing finger, measured by means of a potentiometer coupled to the finger; and the lower trace is the EMG recording of the biceps muscle.

muscle is constantly contracting, although perhaps only to a moderate degree. The problem is caused by a lack of oxygen in the tendons due to constriction of local blood vessels or capillaries, thus obstructing blood circulation. Tendinitis usually implies death of tendon cells due to the lack of oxygen. Unfortunately, although these cells usually regenerate, they will not regenerate to the same strength as that of their predecessors. The structure of the scar tissue is less well organized than the original cell structure, where the cells are in parallel. Furthermore, the regenerated cells can be damaged more easily by strain.

If the cause of the injury lies in the playing technique or in the posture, only two solutions are possible: changing the way of playing and, in some cases, strengthening weak muscles through regular exercises.

EMG can be a very useful tool for diagnosing and evaluating the consequences of a change in playing technique. Sometimes even a very small change in the holding of the instrument may lead to a great reduction in the activity level of several muscles. This effect was strikingly demonstrated by an experiment. The author played the first movement of Koussevitzky's Double Bass Concerto while the EMG levels of the left and right upper trapezius muscles were recorded. In a subsequent session, the EMG signals were carefully calibrated by measuring the signal levels observed while the subject lifted a yoke loaded with known masses. The piece was played twice, both times while sitting on a bass stool. The first time the instrument was held like a cello, with the top belly of the instrument facing more or less straight forward. The second time the instrument was rotated on its end pin some 20 degrees to the right.

The results of the playing tests are illustrated in Figure 3. The frequent measurements have been sorted with respect to muscular force, with increasing values of force plotted on the ordinate. The unit used for force is pounds (1 lb = 0.45 kg). The duration of the piece of music has been normalized and is represented on the abscissa as proportion of the playing time. This enables us to observe the proportion of total playing time the piece was played at any particular level of muscular force. In the figure, the values 0.1, 0.5, and 0.9 of the playing time have been marked with a vertical line, representing the most relaxed 10% of the time, the median value at 50% of the total duration, and the most stressing 10% of the playing time, respectively.

The load on the left trapezius muscle is illustrated in the left panel of Figure 3. It can be seen that the change of instrument position affected neither the most relaxed 10% nor the median value appreciably. However, there is a significant difference in force in the upper 25% of the playing time; at the value of 0.9 this difference amounts to no less than 15 lbs. (7 kg). The highest values are found when the instrument was turned somewhat to the right. This is not surprising because under these con-

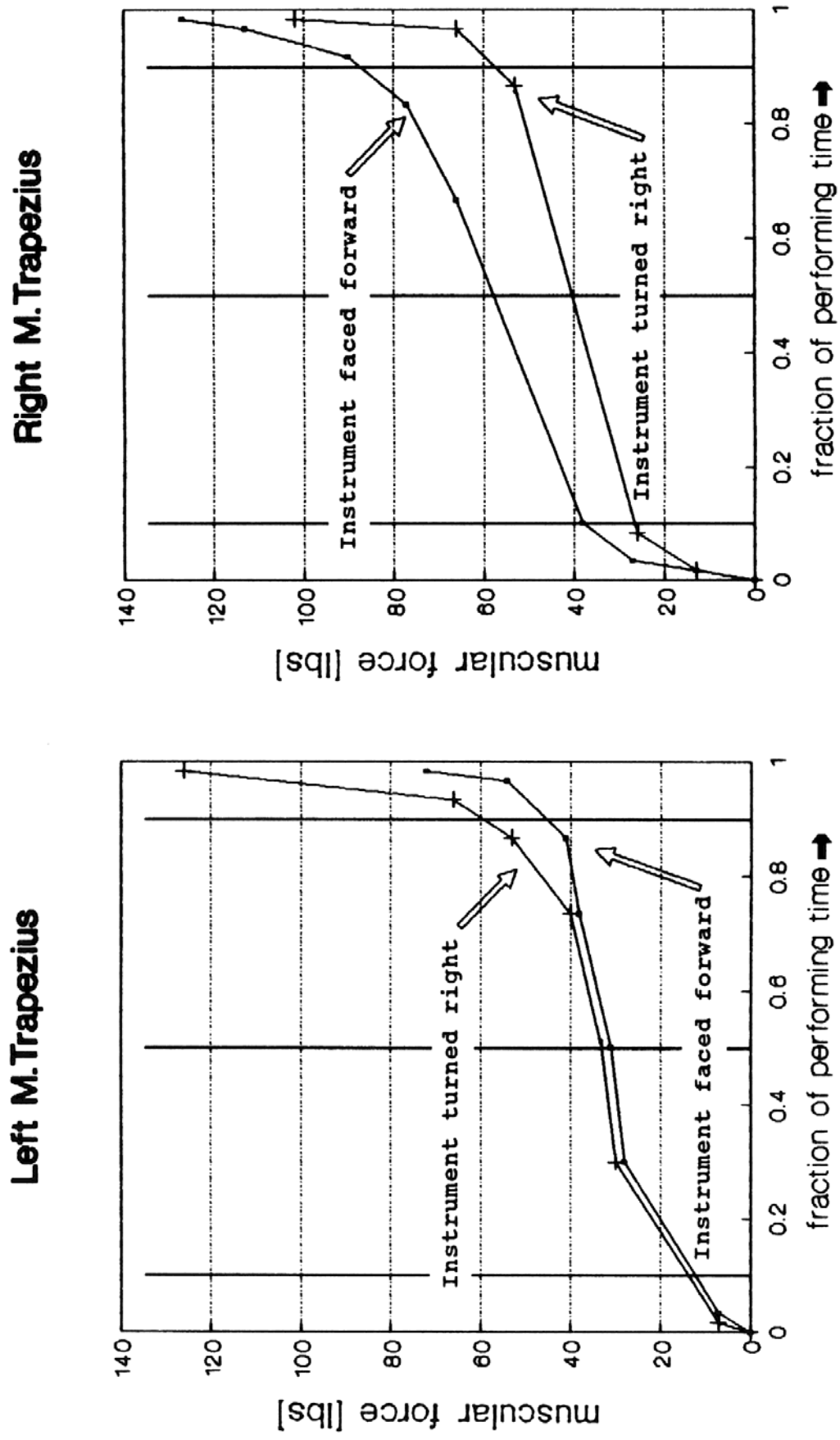

Fig. 3. Muscle force exerted by the left and right trapezius muscles as a function of proportion of time during the playing of the first movement of Koussevitzky's Double Bass Concerto. Recordings of electromyographic signal amplitudes have been converted to force in pounds. The force unit 1 lb. (0.45 kg) is equivalent to 4.4 N.

ditions the player has to lift the left elbow higher to reach the high positions on the fingerboard.

In the right panel of Figure 3, which refers to the right shoulder, the reverse effects can be observed. Turning the instrument slightly to the right reduced the forces considerably in all time ranges. The median difference is 18 lbs (8 kg). The differences at performing times of 0.1 and 0.9 amount to 11 lbs (5 kg) and 29 lbs (13 kg), respectively. It can also be observed that holding the bass like a cello, that is, with the instrument facing straight forward, produces more stress on the right shoulder than on the left, whereas the muscles on both sides are more equally stressed when the instrument is turned slightly to the right.

Choosing the appropriate playing position of the bass requires that a number of other factors be taken into consideration, such as the activities of other muscles. If only one shoulder is causing problems, a slight rotation of the instrument is likely to have a good effect. If both of the player's shoulders are hurting and the EMG level at rest is low, other solutions should be tried, such as lowering the end pin. EMG data can provide valuable information for localizing the problem and selecting the appropriate solution.

Conclusion

EMG measurements can be used in different ways for various purposes within instrumental playing practices. As yet, it has been used mostly in connection with excess muscle tension, but it certainly also carries the potential for analyzing and guiding interactively the process of obtaining the best possible technique for playing the instrument.