Musculoskeletal pain & dysfunction in musicians
Woldendorp, Kees Hein

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Chapter 2

Muscle activation pattern & musculoskeletal complaints

Published as:
Kees H. Woldendorp, Pieter van de Werk, Anne M. Boonstra,
Roy E. Stewart, Egbert Otten.
Relationship between muscle activation pattern and pain;
an explorative study in a bassists-population.
Relation between muscle activation pattern and pain: An explorative study in a bassists population.

Abstract
Objective: To explore the muscle activation patterns in relation to pain complaints in bassists studied during a musical task. This study was based on the assumption that pain complaints are caused by increased muscle activation during playing or relaxation and/or faster onset of fatigue of muscles.
Design: Cross-sectional study.
Setting: Nonclinical.
Participants: Student bass guitarists (N=36) from conservatories in the Netherlands.
Interventions: Not applicable.
Main Outcome Measures: Bassists played a standard music piece for 30 minutes. Muscle activation levels and pain were recorded. Pain was registered with a Numeric Rating Scale (NRS 0-10). The muscle activation level of both the trapezius muscles and flexor carpi radialis was measured with sEMG: sEMG as the percentage of the maximal voluntary isometric contraction (%MVC) and the slope of the sEMG (slope of % MVC) were calculated. The %MVC as a function of time and the slope of %MVC were calculated during playing and for rest periods before and after playing. For statistic analysis, the Mann-Whitney U test and a multilevel multi-regression analysis were used for comparing the sEMG data of bassists with and without pain.
Results: No significant differences in %MVC or the slope of %MVC were between the bassists with and without pain complaints.
Conclusions: The results surprisingly indicate that pain complaints of bassists may not be associated with another muscle activation pattern. It is, therefore, not likely that pain is caused by increased muscle activation during playing and/or relaxation, nor by faster onset of fatigue.

Introduction

Musculoskeletal problems are frequent among professional instrumental musicians as well as music students. A high prevalence of musculoskeletal pain is reported in the literature, with 40% to 60% of musicians in general,1-3 and up to nearly 100% of flamenco guitarists and bassists who are men.4 The impact of pain on playing is great and frequently leads to the end of the musician's career.3,5 A complex of various intrinsic and extrinsic causes contribute to this very high prevalence of chronic pain.1,3,6
Musicians are engaged in difficult, repetitive, long-lasting physical work. In this they resemble workers in other repetitive work situations.7 Therefore, it is likely that the mechanisms of pain causation are identical to that of other workers with pain complaints. The underlying physiological mechanisms of pain in musicians and other low-intensity, high-frequency work-related pain complaints (eg. computer staff or cashiers) are still debated. In the chronification process of pain there is evidence indicating a change in motor control and muscle activation strategies during activity and relaxation.8-12 Three studies have been made concerning this mechanism in musicians.7,13,14 However, they showed conflicting results, ranging from higher13,14 to lower7 muscle activation levels in the musicians with pain compared with the non-
pain group. Our strong clinical impression was that musicians with (chronic) pain have an enhanced level of muscle activation in the muscles of the neck and arms, both in rest and during playing, compared with musicians without any pain. Based on the previously described ambiguities and our clinical experience, the aim of this study was to explore the muscle activation patterns of musicians during a musical task in relation to pain complaints. The study is based on the assumption that pain complaints are caused by increased muscle activation during playing, relaxation, and/or faster onset of fatigue of muscles. In order to be able to play the same musical piece, we restricted the study to players of 1 type of musical instrument, that is, the electrical bass guitar. We formulated and tested the following hypotheses: (1) bassists with pain have higher muscle activation levels during 30 minutes of playing and/or in the rest period before and after playing compared with bassists without pain; and (2) bassists with pain show an increased progression in muscle activation levels during 30 minutes of playing compared with bassists without pain.

Methods

Participants
Participants included 36 student bass guitarists from 3 different conservatories in the Netherlands, recruited from October 2010 to February 2011. They were informed and recruited through their teachers and were given further information by the researcher (P.vd.W.). Bassists who suffered from severe health problems not associated with playing the bass, or who were not able to fill out the questionnaire (because of a native language other than English or Dutch), were excluded. All subjects gave explicit consent. Because of the type of study, using healthy volunteers and a task compared with their daily activities, the medical ethics committee decided that no approval was obligatory.

Measures

Questionnaires
We used 3 types of questionnaires. A description of the subject was made by assessing the bassists’ characteristics with the first questionnaire, the questionnaire general (appendix 1), which included questions about age, sex, pain medication, hours playing per week, and pain. A drawing of the upper part of the body was included; here the bassists could mark the location of their pain (maximum of 6 locations). No authorized pain questionnaire was available in the literature for this specific situation with bassists. Therefore, we formulated the questions concerning pain with regard to the location and duration of pain complaints, based on other questionnaires found in the literature. A Numeric Rating Scale ([NRS] 11-point) was used to measure the intensity of the (average) experienced pain of the 4 most prominent pain locations. The questionnaire general was digitally completed, by the bassist at home, approximately 1 week before the test procedure. The second and third questionnaires, respectively, the questionnaire before and the questionnaire after playing the musical piece, were short versions of the questionnaire general. They assessed the intensity, location, and duration of pain if pain was present at that moment. An English and Dutch version was available, depending on the preference of the bassist.
List of abbreviations:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>bpm</td>
<td>beats per minute</td>
</tr>
<tr>
<td>MVC</td>
<td>maximal voluntary isometric contraction</td>
</tr>
<tr>
<td>%MVC</td>
<td>percentage maximal voluntary isometric contraction</td>
</tr>
<tr>
<td>NRS</td>
<td>Numeric Rating Scale</td>
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<tr>
<td>sEMG</td>
<td>surface electromyography</td>
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</table>

Surface electromyography measurement

The registration was done with a bipolar surface electromyography tool. The muscle activity in the trapezius muscles (pars descendens) and the wrist flexors (above the flexor carpi radialis muscles) on both sides was recorded. The activity of the trapezius muscles was measured because of their stabilization (postural and supporting) function, and the wrist flexors were measured because of their dynamic function during playing. Moreover, their superficial locations make these muscles highly suitable for surface electromyography (sEMG) recording.

All 4 muscles were recorded simultaneously. The electrodes were placed on the skin above the previously mentioned muscles, conforming to European guidelines. Two adhesive electrodes were placed at each location, with an inter electrode distance of 3cm, to create bipolar sEMG recordings, which are much more reliable than unipolar recordings. The electrodes on the trapezius muscles were placed halfway on the line between the processus spinosus C7 and the lateral end of the acromion parallel to the direction of the muscle fibers. In the region of the wrist flexors, the electrodes were placed halfway on the line, ranging from the lateral aspect of the biceps tendon insertion in the elbow near to the os pisiforme. This location is anatomically above the m. flexor carpi radialis; because of the phenomena of crosstalk of the adjacent muscles, we interpreted the sEMG recordings in terms of wrist flexors. The reference electrode was placed on the distal end of the ulnae. The sEMG module sent the 4 signals to a receiver, which was coupled with a laptop. The sEMG signal was recorded using the software program Biofeedback 2000 X-pert. No specifications were available from the manufacturer of the sEMG device on bandwidth. It could be established from the waveforms that there was a strong low pass filter applied with a low pass frequency of about 10Hz, which makes a low sample frequency of 40Hz feasible.

The action potentials were amplified, rectified, and meaned by integration with a time constant of 250ms. The reported parameter therefore corresponds to the rectified mean of the reading. After-ward the sEMG was checked, and peaks of more than 1000mV were removed, because these peaks are caused by interference of the signal. To exclude confounding variables in the sEMG registration, such as variable conduction of the electrode or level of subcutaneous fat, the maximal voluntary isometric contraction (MVC) was determined for the trapezius muscles and wrist flexors. There are no international guidelines to measure the MVC for specific muscles. The MVC of the trapezius muscles was obtained by recording the sEMG signal of these muscles when the bassist was standing on a platform with 2 iron chains on both sides. The participant had to pull the chains symmetrically, vertically...
using the trapezius muscles, maximally while keeping the elbows stretched along the body. The MVC of the wrist flexors was recorded while the bassist (keeping the elbow flexed at 90 degrees, the underarm horizontal and the wrist in neutral position) was maximally trying to flex the wrist against resistance. This resistance was provided by the observer (P.vd.W.), who stood in such a position to give enough resistance to prevent the bassist from flexing his/her wrist. Both MVC measurements were recorded twice for 10 seconds, and the average of the peak values was calculated.

**Video recordings**
Video recordings, by a simple digital video camera on a tripod, were made in order to enable us to later visually control the procedure.

**Procedure for the playing task**
The bassists were asked to stand or sit as relaxed as possible in their normative playing posture with their own instruments (the weight of the instruments differed only slightly). The standing bassists used a strap around the neck to fix their instrument. Visual control was done by the observer (P.vd.W.) to see if the strap influenced the sEMG recording in any way. This was not ever the case. A metronome was run at 80 beats per minute (bpm) to ensure the same performance for all bassists. One scale (C-major) had to be played up and down in this tempo. From a previous (Tijssma et al, 2009, unpublished data) study, we knew that playing 1 scale before the real task avoids unwanted movements the bassists unintentionally make before playing a few notes because of changing their (bass guitar) position to a more comfortable one. We observed that these movements interfered seriously with the sEMG recordings, making a good interpretation impossible. The sEMG recordings of the rest before the scale and the playing of the scale weren't planned to be used in the study analysis. It was only used (together with the video streams) to control the rest period before the real task for confounding influences.

After completing the scale, the bassist returned to the resting position on verbal demand of the researcher (P.vd.W.). This is defined as the start of the rest period before the task. The observer recorded digitally, in the sEMG signal, the moment of starting and playing of the scale. Approximately 15 seconds after the verbal command for rest, a half hour of playing followed. The recording of rest sEMG can reliably be done over a short period of 15 seconds, because the main frequency account of sEMG is around 25Hz (in this study 40Hz), and even 1 second is indicative of the muscle activation level. The metronome level was increased to 100bpm to play a Blues in F more comfortably (first chorus 2-beat, second and third chorus in an individually preferred groove and a normative way of playing (to enhance the ecologic validity of the task as much as possible), fourth solo and fifth chorus again 2-beat in the last bar modulated a half tone up). The same procedure was repeated in all keys until the key of F was reached again. This took 28 minutes and 54 seconds to play at 100bpm. The observer then gave a verbal command to stop playing; a rest registration for approximately 15 seconds was noted (the subsequent rest period).

**Data analysis**
Bassists can play their instrument either right- or left-handed. The movement patterns of the accompaniment playing hand (above the resonance box) are different from the
hand (at the neck of the bass) playing the melody. For this reason, the terms left and right were substituted by neck side and box side.

The answers to the pain location-related questions were clustered into 4 anatomical regions to simplify the registration: (1) forearm and elbow at the box side (forearm box side); (2) forearm and elbow at the neck side (forearm neck side); (3) upper arm, shoulder up to the distal from the elbow, and the ipsilateral half of neck at the box side (upper arm/shoulder box side); and (4) the upper arm, shoulder up to the distal from elbow, and the ipsilateral half of the neck at the neck side (upper arm/shoulder neck side).

Consequently, an NRS for pain from the 4 areas was obtained. The bassists could indicate maximally 6 pain locations in the drawing of the upper body (the same drawing as previously mentioned, the 4 anatomic regions mentioned before were not indicated in this drawing). If they noted more pain locations within a region, the pain location with the highest pain score was used for that region. The percentage MVC (%MVC) and the slope in the %MVC (the rate of rise or decline of the relative muscle contraction) were calculated. This calculation (E.O.) took place without knowledge about presence of pain or no pain. The %MVC was the mean sEMG level during a defined period as a percentage of the MVC; a high percentage means a high muscle activation level. The slope in the %MVC was the coefficient of the linear regression of the relation between the %MVC and the time during the defined period. A positive slope means an increase of muscle activation during playing. The defined periods in the tests were determined by the observer when giving the verbal instructions matching each particular task, and it was simultaneously marked digitally in the registration file. The time frames for the calculation of the slope in the %MVC of the previously mentioned periods were also marked by the observer at the moment that the musician actually executed the given verbal instructions (sometimes there was a delay of 1 or 2 seconds in execution, and this would bias the calculation). The sEMG locations were each named as pain regions to avoid the problem with left and right, that is, neck side and box side.

**Statistical analysis**

For the statistical analysis, MATLAB, SPSS version 18, and SAS version 9.2 were used. We first intended to divide the bassists into 3 groups: without pain, with subacute pain, and with chronic pain, as indicated in the questionnaire general. Pain was defined as a score of 1 or higher on the NRS. However, before linking the sEMG data to the groups pain/no pain, we noticed that some bassists who indicated not having any pain at all on the questionnaire general did indicate pain on the questionnaire before or questionnaire after; some bassists who indicated (subacute or chronic) pain on the questionnaire general did not indicate pain on the questionnaire before or questionnaire after. Based on our assumption that pain is caused by increased muscular activity, we decided to base the main analysis on the pain scores before and after playing. We had expected that pain before the task would remain on the same level or would increase during playing. However, it became clear during the data analysis that a few bassists experienced less pain after than before playing. Based on our assumption that pain is caused by increased muscular activity, it is likely that
bassists, with decreasing pain during playing, showed an activation pattern (more) similar to bassists without pain than those with pain. Therefore, we classified the bassists with a decrease of more than 1 point on the NRS, in the group of bassists with no pain at the particular location. Because we defined 4 anatomic regions (forearm box side, forearm neck side, upper arm/ shoulder box side, and upper arm/ shoulder neck side) and 3 periods (before, during, and after playing), 12 analyses were carried out. Bassists could indicate pain in 1 region and not in another region. As a consequence, the distribution of bassists, in the groups with and without pain, was not the same in the different analyses.

We did two sub analyses. Because the previously mentioned assumption may be incorrect, that bassists with decreasing pain during playing showed an activation pattern (more) similar to bassists without pain than those with pain, a sub analysis was done excluding the bassists with decreasing pain during playing. The association between pain and the muscle activation pattern in persons with subacute pain and chronic pain may be different10; therefore, we did a second sub analysis in which we excluded the bassists with subacute pain and those who failed to fill out the questionnaire general.

Because of the non normative distribution of the %MVC and the slope of the %MVC scores per muscle, the Mann Whitney U test was used in the analysis comparing the data of bassists with and without pain. The 2-tailed significance level was set at P 0.05. Because in the analyses for each period (before, during, and after playing) 4 comparisons were made, the Bonferroni correction was used resulting in a significance level of P < 0.013.

Several sets of data were available from each person. Therefore, a multilevel, multi-regression analysis was done. Two analyses were made, the first with the %MVC as the dependent variable and the second with the slope in the %MVC as the dependent variable. Because of the skewed distribution of the %MVC, the Poisson type of multilevel analysis was used in the first analysis.

Three levels were found in the analysis. The highest level was from the person who had NRS pain scores before and after playing. The middle level was from the 4 muscles from which the sEMG was taken. The lowest level was from the 3 periods: before, during, and after playing. The model with the 3 levels, without including independent variables, was first taken in order to answer whether variance was present. Thereafter, the independent variables were included: the NRS pain scores before and after playing, the 4 muscles, and the 3 periods as categorical variables (before, during, and after playing on the lowest level). The significance level, in the multilevel analysis, was set at P 0.05.
Results

Thirty-six bassists were enrolled in the study. To our knowledge, no bassists refused to participate. The questionnaire general was completed by 33 bassists; 3 subjects didn’t send the questionnaire general back, for unknown reasons, although it was repeatedly requested. All of the 36 bassists completed the questionnaire before and questionnaire after. Population characteristics are summarized in table 1.

Most bassists were men, which is in line with the expectation, because few women play this instrument. One dominantly left-handed bassist played with his left hand on the box side. Twenty bassists indicated no pain complaints on the questionnaire general, 2 bassists indicated having pain complaints for less than 3 months, and 11 bassists experienced continuous or recurrent pain for longer than 3 months. Only 7 bassists experienced no pain at all before or after the playing task (on the questionnaire before and/or questionnaire after). Another 7 bassists experienced less pain before, of more than 1 point on the NRS, than after playing: 3 in the forearm box side, 2 bassists in the upper arm/shoulder box side, 1 in the upper arm/shoulder neck side, and 1 in both the forearm neck side and upper arm/shoulder neck side. There was no clear pattern in decrease or increase of pain per bassist; some bassists experienced more pain on 1 side than the other (table 2, an overview of all NRS pain scores are available on request).
The video recording showed that it seemed difficult for a lot of bassists to relax during the rest period, because they had to continue holding their bass guitars. Some bassists moved their arms during the resting periods for a short time.

Table 2: Mean and standard deviation (M,SD) of %MVC and slope of the EMG of the m.flexor carpi radialis and m.trapezius of neckside and boxside before, during and after playing; total group and divided for the bassists with and without appearance, persistent or worsening of pain in underarm respectively shoulder/upperarm.

<table>
<thead>
<tr>
<th></th>
<th>total group</th>
<th>with pain</th>
<th>without pain</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%MVC M (SD)</td>
<td>Slope M (SD)</td>
<td>n</td>
<td>%MVC M (SD)</td>
</tr>
<tr>
<td>m.flexor carpi rad. neckside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rest before playing</td>
<td>0.80 (3.17)</td>
<td>-0.28 (1.70)</td>
<td>4</td>
<td>0.05 (0.66)</td>
</tr>
<tr>
<td>playing</td>
<td>3.34 (3.31)</td>
<td>-0.56 (1.27)</td>
<td>4</td>
<td>2.93 (1.57)</td>
</tr>
<tr>
<td>rest after playing</td>
<td>0.36 (0.66)</td>
<td>-0.20 (1.08)</td>
<td>4</td>
<td>0.03 (0.04)</td>
</tr>
<tr>
<td>m.flexor carpi rad. boxside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rest before playing</td>
<td>0.18 (0.61)</td>
<td>0.02 (0.55)</td>
<td>10</td>
<td>0.02 (0.04)</td>
</tr>
<tr>
<td>playing</td>
<td>3.91 (2.51)</td>
<td>-0.47 (1.91)</td>
<td>10</td>
<td>5.20 (2.56)</td>
</tr>
<tr>
<td>rest after playing</td>
<td>0.21 (0.43)</td>
<td>0.22 (1.52)</td>
<td>10</td>
<td>0.02 (0.03)</td>
</tr>
<tr>
<td>m.trapezius neckside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rest before playing</td>
<td>1.15 (2.35)</td>
<td>-0.06 (0.42)</td>
<td>14</td>
<td>0.65 (1.19)</td>
</tr>
<tr>
<td>playing</td>
<td>2.08 (2.41)</td>
<td>-0.04 (2.11)</td>
<td>14</td>
<td>2.12 (2.47)</td>
</tr>
<tr>
<td>rest after playing</td>
<td>2.41 (4.08)</td>
<td>-0.37 (2.46)</td>
<td>13</td>
<td>0.65 (0.91)</td>
</tr>
<tr>
<td>m.trapezius boxside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rest before playing</td>
<td>1.18 (1.54)</td>
<td>-0.29 (0.90)</td>
<td>12</td>
<td>0.74 (1.22)</td>
</tr>
<tr>
<td>playing</td>
<td>1.80 (2.43)</td>
<td>0.98 (2.87)</td>
<td>12</td>
<td>1.63 (2.15)</td>
</tr>
<tr>
<td>rest after playing</td>
<td>2.42 (2.58)</td>
<td>-0.32 (4.77)</td>
<td>12</td>
<td>2.28 (2.01)</td>
</tr>
</tbody>
</table>
A sEMG recording of 1 bassist failed during the rest period after playing. The mean and SD of the %MVC and the slope of the %MVC of the 4 muscles are shown in table 3. The muscle activation patterns of the wrist flexors were quite similar for all bassists, as expected: the highest occurred during playing and the lowest occurred before and after playing. However, the patterns in muscle activation in the trapezius muscles were far more diverse. The mean %MVC was found to be the highest in the rest period after playing, but individually, the highest %MVC could be found in every phase (before, during, as well as after playing). Examples of patterns of the %MVC during the 3 periods are given in figure 1.

Figure 1: Examples of individual bassists with patterns of muscle activation. The y axis is % MVC, and the x axis is the period (rest before, during playing, and rest after).
No significant differences were found between the bassists with and without pain complaints. The 2 sub analyses, that is, the first one excluding, as a comparison, the bassists with decreasing pain score and the second one excluding the bassists with subacute pain, or those who did not send back the questionnaire general, gave comparable results.

The multilevel multivariate analysis (Poisson type) showed that the %MVC was influenced by all 3 levels (person, muscle, and period) with a variance above zero for all 3 levels. In the model without the independent variables, the variance on the first level was .55, on the second level was .12, and on the third level was 3.19. The slope in %MVC was only influenced by level 3 (the period) (variance of this level above zero) but not by level 1 (person) or level 2 (muscle): variance on levels 1 and 2 was zero and on the third level was 4.53. A significant relation between %MVC, or the slope in the %MVC with pain, was not found (table 4). In the periods “during playing” and “rest after playing,” the muscle activation level was higher than in the period “rest before playing,” as shown by the rates of the %MVC of 3.39 and 1.65, respectively.

| Table 4: Three level Poisson (%MVC) and linear regression (Slope of %MVC) models |
|------------------------------------------|------------------|------------------|
| Factor | %MVC (Poisson regression) | Slope of %MVC (linear regression) |
|        | estimate | SE    | Rate (95% confidence limits) | estimate | SE    |
| Intercept | -0.10    | 0.26  | -0.020 | 0.21   |
| **Person level** |          |       |        |        |
| **Pain** |          |       |        |        |
| Box side |          |       |        |        |
| - before playing lower arm | -0.17    | 0.12  | 0.84 (0.67-1.07) | -0.02    | 0.08  |
| - before playing upper arm / neck | 0.01     | 0.12  | 1.01 (0.80-1.28) | -0.06    | 0.09  |
| - after playing lower arm / neck | 0.09     | 0.11  | 1.09 (0.88-1.36) | -0.05    | 0.09  |
| - after playing upper arm / neck | 0.01     | 0.13  | 1.01 (0.78-1.18) | 0.02     | 0.10  |
| **Neck side** |          |       |        |        |
| - before playing lower arm | -0.05    | 0.11  | 0.95 (0.78-1.18) | 0.02     | 0.09  |
| - before playing upper arm / neck | -0.16    | 0.16  | 0.85 (0.61-1.16) | -0.01    | 0.11  |
| - after playing lower arm / neck | -0.20    | 0.21  | 0.82 (0.54-1.25) | -0.14    | 0.15  |
| - after playing upper arm / neck | 0.02     | 0.11  | 1.02 (0.82-1.27) | -0.07    | 0.08  |
| **Period level** |          |       |        |        |
| - during playing | 1.22     | 0.18  | 3.39 (2.39-4.81) | 0.13     | 0.25  |
| - after playing | 0.50     | 0.20  | 1.65 (1.12-2.44) | -0.02    | 0.25  |
| **Variance** |          |       |        |        |
| Level 1: person | 0.40     |       | 0.00   |        |
| Level 2: muscle | 0.13     |       | 0.00   |        |
| Level 3: period | 3.00     |       | 4.50   |        |

* reference value is rest period before playing
Discussion

The aim of this study was to explore the muscle activation patterns of musicians during a musical task in relation to pain complaints. We could not confirm our hypotheses: we did not find a difference in muscle activation levels in the muscles during 30 minutes playing or in the rest period before and after playing, between bassists with pain and without pain. We also did not find an increased progression in muscle activation levels during 30 minutes of playing in bassists with pain, compared with bassists without pain. These results indicate that pain complaints in bassists were not associated with other muscle activation patterns. It is, therefore, not likely that pain is caused by increased muscle activation during playing and/or relaxation. This is an unexpected result, not in line with our clinical expectations, and it is interesting because of the extensive debate in the literature with conflicting outcomes in this field.\textsuperscript{7,9-14,23-25,31,32} No difference in muscle activation patterns in persons with musculoskeletal pain as compared with persons without pain is scarcely reported in the literature\textsuperscript{26,27}; most studies found an increased\textsuperscript{8-13,23,31,32} or decreased\textsuperscript{7,25,32} muscle activity. This may be because of publication bias, that is, studies with a positive result are more likely to be accepted for publication than studies with a negative result. Another explanation may be that we did not find a difference because of a type II error, also known as a false negative result.

The distribution of the scores is very large, according to the high SD. Although the test seemed ecologically valid, it may have been given possible individual interpretations by the bassists. Also, according to the high activation of the trapezius muscles before and after playing, it seemed difficult for both bassists with and without pain to relax. A possible source of bias could be the relatively free way in which the bassists could play their own instrument. Visual control of the sEMG in regards to the influence of the strap around the neck didn’t show relevant bias in the recordings, as was also the case with a standing or sitting position. Musicians are very sensitive to changes in the way they have to play, and therefore they may develop an adapted muscle activation pattern if they play on another instrument (for a left-handed bassist it is even impossible). Therefore, although a bias may have been introduced, this bias would be relatively small compared with a bias introduced if the musicians had to play with the same instrument or with strict orders on how to perform.

There are indications that persons with chronic pain have a different muscle activation pattern than persons with acute or subacute pain.\textsuperscript{10} Furthermore, Berque and Gray\textsuperscript{7} suggested that musicians with severe complaints are possibly more prone to an increased activity than musicians with mild complaints. In our study, a few bassists reported pain with duration of less than 3 months; about one third of the bassists indicated chronic pain. The severity of complaints differed between individuals. Also, the pain scores were not always consistent per bassist; some bassists reported no pain beforehand on the questionnaire general, but reported pain just before and/or after the task. Other bassists reported less pain after the task than before the task. Maybe this mixed pattern wrongly influenced the true relation. The sub-analyses, however, did not show other results. Excluding bassists with inconsistent scores before, during, and after the task was not a possibility to prove a relation between muscle activation...
pattern and pain. We did not do a power analysis beforehand, in order to find the minimum number of bassists, to minimize the type II error because of not having appropriate data from other research. As we study our data, we realize that we would need a huge number of bassists, if we repeated the same study, in order to minimize the chance of a type II error because of large SDs of the data. Therefore, we intend to plan a study in the future with quite a different design. It seems better to devise a task more like a laboratory task, although it may be difficult to design such a task with sufficient ecologic validity.

Another option for future research could be the detection of differences in co-contraction patterns between bassists with and without pain. A changed ratio between agonists and antagonist is mentioned in the literature, as a result of fatigue, although there is no direct relation affirmed in the literature between fatigue and pain. Signs of fatigue could be best detected through registration with many intramuscular electromyography needles per muscle in order to detect intramuscular reorganization to maintain a certain level of muscle force. However, the feasibility of a study of such a painful procedure is questionable.

Because of the rather specific subject population (musicians), interpretation, and extrapolation of results to other populations requires caution. It may be the case that in other work-related musculoskeletal pain, the association with muscle activation patterns is more prominent.

As previously stated, an increased muscular activation pattern is mentioned in the literature as one of the possible causes of (chronic) pain. Additional causes are also highlighted. Calder, Madeleine, Kleine, Yoon, and colleagues focused on the role of muscular fatigue. Although we did not find a positive slope of muscular activity, which may be an indication of fatigue, this way of measuring fatigue is not very precise. The equipment we used was not able to provide raw data with sufficiently high-frequency content to measure fatigue in terms of a drop in motor unit firing rate and/or motor unit synchronization. Change in the frequency of the sEMG would have been a better measure. Other factors associated with chronic pain complaints are increasingly mentioned in the literature, such as an aberration of the autonomic nervous system, conditioning, psychological factors, and central pain mechanisms, such as sensitization.

With our study we focused on the role of 1 muscular aspect, which we expected to be important in the onset and “chronification” of musculoskeletal pain. In literature, there is a growing tendency to focus on other nonphysical aspects in relation to pain like brain plasticity or manifesting in sensitization, interesting processes in subjects with (chronic) pain. The relation between peripheral physical aspects and central brain mechanisms are mainly unknown, and research focused on this topic is recommended.

**Study limitations**
A very large distribution of the scores with a high SD was found in both bassists with and without pain. The bassist played, for the ecological validity of the study, in a free way during the standardized task. This could have introduced some bias in one way
or another in muscle activation patterns. Several scores of pain per individual were not consistent. As a result, a true relation between muscle activation patterns and pain could be wrongly influenced. The sEMG equipment used was not able to provide raw data with a sufficient sample frequency to measure muscle fatigue compensation mechanisms in the muscle.

**Conclusions**

Our findings do not support the assumption that in bassists, increased or decreased muscle activation, during playing or relaxation, is associated with pain complaints. Pain complaints may be caused by other mechanisms than a pathologic muscle activation pattern.

**Suppliers**

a. SCHUHFRIED GmbH, Hyrtlstraße 45, 2340 Mödling, Austria.
b. 3M Corporate Headquarters, 3M Center, St. Paul, MN 55144-1000.
c. MathWorks, 3 Apple Hill Dr, Natick, MA 01760-2098.
d. SPSS Inc, 233 S Wacker Dr, #1100, Chicago, IL 60606-6412.
e. SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513-2414.
Appendix 1: Questionnaire about bass guitar players with chronic pain.

Questionnaire about bass guitar players with chronic pain.

This questionnaire is for research into the relationship between chronic pain and muscle activation patterns. Questions 1-8 consist of general questions. Questions 9-21 are detailed questions about your pain. Questions 22-23 are about any additional health problems. Questions 24-27 are about how you experience playing music.

General information:
Name: __________________________________________
Age: __________________________________________
Gender: ________________________________________

1) How many hours do you spend on playing bass guitar?
   - less than 7 hours/week  (1 hour/day)
   - 7-14 hours/week       (1-2 hours/day)
   - 14-21 hours/week      (2-3 hours/day)
   - 21-28 hours/week      (3-4 hours/day)
   - more than 28 hours/week (>= 4 hours/day)

2) On which age did you start playing the bass guitar?
   Age: ___ year

3) What is your dominant hand?
   - Right
   - Left

4) Do you have other activities, besides your work as bass guitar player or your study to become professional bass guitar player?
   - No
   - Yes
     If yes, which: _______________________________________________________

5) Are there other activities, during activities other than your work as bass guitar player or your study to become professional bass guitar player (hobbies, computing), whereby you execute a lot of repetitive movements?
   - No
   - Yes, namely __________________________________________________________

6) What is your height?
   Height: _____ m

7) What is your weight?
   Weight: _____ kg
8) Are you using medication?

- No
- Yes, which:
  - Paracetamol
  - Aspirin
  - Ibuprofen
  - Baclofen
  - Other: 

9) Draw at the pictures below the places where your pain is located (maximum are 4 pain locations) Give the pain location a number from 1 t/m 4, where number 1 is the location with the most pain and number 4 with the least pain.

Front

Back

In case you did not mark any pain location at the pictures belonging to question 9, you can continue with question 22.

With questions 10-17, you are able to specify your pain in more detail. You can give more than one answer at each question. Behind the answers, you can mark the pain location(s) on which your answer does apply.

10) How long does your pain(s) exist?

- shorter than 1 month
- 1 to 3 month(s)
- 3 to 6 months
- 6 to 12 months
- 1 to 2 year(s)
- 2 to 5 years
- longer than 5 years

Pain location: 1 2 3 4
11) Are there 2 or more location painful at the same time? Pain location: 1 2 3 4
   □ No
   □ Yes, namely

12) Pain pattern (multiple answers possible)
   □ The pain is permanent and equally constant present
   □ The pain is permanent present with changing level of pain
   □ Attack-wise pain with between times mild pain
   □ Attack-wise pain with between times no pain
   □ Continues present of pain which worsen during activity
   □ The pain worsen at rest

13) Pain progress (multiple answers possible)
   Pain location: 1 2 3 4
   □ The pain is intermitterend present or absent
   □ The pain increased during the last months
   □ The pain decreased during the last months
   □ The pain increased during the last days
   □ The pain decreased during the last months

Causes of pain
14) What is according to you the cause of your pain(s)?
   Cause pain location 1:
   Cause pain location 2:
   Cause pain location 3:
   Cause pain location 4:

15) Is the pain provoked by playing music?
   Pain location: 1 2 3 4
   □ No
   □ Yes

16) Is the pain provoked by other factors?
   Pain location: 1 2 3 4
   □ No
   □ Yes,
      If yes, which
      Factor pain location 1:
      Factor pain location 2:
      Factor pain location 3:
      Factor pain location 4:

Severity of pain
17) How severe was your pain the past week?
   Pain location 1:
   □ No pain
   □ 0 1 2 3 4 5 6 7 8 9 10 Worst pain thinkable
Painlocation 2:

<table>
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<tr>
<th>No pain</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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Worst pain thinkable

Painlocation 3:

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<th>3</th>
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Worst pain thinkable

Painlocation 4:

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Worst pain thinkable

The questions 18-21 are about the consequences of your pain complaints for your daily activities. Please mark the number that best describes your physical ability in the past week.

18) Did you have any difficulty with using your usual technique for playing your electric bass guitar?
   No difficulty | Mild difficulty | Moderate difficulty | Severe more difficulty | Not capable of playing at all
   1  2  3  4  5

19) Did you have any difficulty playing your electric bass guitar?
   No difficulty | Mild difficulty | Moderate difficulty | Severe more difficulty | Not capable of playing at all
   1  2  3  4  5

20) Did you have any difficulty playing your electric bass guitar as well as you would like?
   No difficulty | Mild difficulty | Moderate difficulty | Severe more difficulty | Not capable of playing at all
   1  2  3  4  5

21) Did you play less on your electric bass guitar because of the consequences of your pain complaints?
   Not less | Slightly less | Moderately less | Very less | Quit playing
   1  2  3  4  5

Questions 22-23 are about additional health problems which could have an effect on your pain complains.

22) Are there at the moment any additional health problems which could have any effect on your pain complaints?
   No
   Yes
   If yes, which: ____________________________

23) Where there at the past any additional health problems which could have any effect on your pain complaints?
   No
   Yes
   If yes, which: ____________________________