

Original Article

## Electrophysiological assessment of piano players' back extensor muscles on a regular piano bench and chair with back rest

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**Abstract.** [Purpose] Sitting position is the dominant position for a professional pianist. There are many static and dynamic forces which affect musculoskeletal system during sitting. In prolonged sitting, these forces are harmful. The aim of this study was to compare pianists' back extensor muscles activity during playing piano while sitting on a regular piano bench and a chair with back rest. [Subjects and Methods] Ten professional piano players (mean age  $25.4 \pm 5.28$ , 60% male, 40% female) performed similar tasks for 5 hours in two sessions: one session sitting on a regular piano bench and the other sitting on a chair with back rest. In each session, muscular activity was assessed in 3 ways: 1) recording surface electromyography of the back-extensor muscles at the beginning and end of each session, 2) isometric back extension test, and 3) musculoskeletal discomfort questionnaire. [Results] There were significantly lesser muscular activity, more ability to perform isometric back extension and better personal comfort while sitting on a chair with back rest. [Conclusion] Decreased muscular activity and perhaps fatigue during prolonged piano playing on a chair with back rest may reduce acquired musculoskeletal disorders amongst professional pianists.

**Key words:** Acquired musculoskeletal disorders, Piano player, Surface electromyography

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### INTRODUCTION

Sitting position is usually considered as a rest position, but there are many harmful static and dynamic forces affecting musculoskeletal system in prolonged sitting<sup>1)</sup>. Sitting position is the dominant position in many jobs<sup>2)</sup>. Frequently, changing position, increasing muscular endurance and using a proper chair for sitting are effective solutions for decreasing damaging forces<sup>3)</sup>. Fixed prolonged position and repetitive movements are well known causes for work related musculoskeletal disorders (WRMDs)<sup>4)</sup>. Ergonomically, it is proposed to change work stations to more safe places in order to decrease WRMDs<sup>5)</sup>. Professional piano players sit every day in front of a piano and rehearsal for a long time<sup>6)</sup>. A regular piano bench is a simple bench with no back rest and no ability to fix height and seat rest tilt<sup>7)</sup>. Only in some special piano benches, there are a limited ability for height adjustment and a fixed anterior tilt for seat rest. Absence of back rest in a piano bench makes a suspended position for back and shoulder of piano player.

Suspended position and repetitive movements are known as primary causes for acquired musculoskeletal disorders (AMDs)<sup>8)</sup> which are more common among piano players comparing to other instrumentalists<sup>9)</sup>. Approximately 45% of all

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**Table 1.** Anthropometric characteristics

	Number of volunteer	Age (years)	Weight (kg)	Height (meter)	Body mass Index (kg/m <sup>2</sup> )	Piano playing experience (year)	Gender	Missing participants
1		23	72/3	1/96	18/82	7	Male	No
2		23	42	1/64	15/62	8	Female	No
3		22	80	1/81	24/42	8	Male	No
4		29	80	1/83	23/89	18	Male	No
5		19	51/6	1/62	19/66	8	Female	No
6		20	91	1/76	29/38	8	Male	No
7		23	52/7	1/57	21/38	12	Female	No
8		26	94	1/79	29/34	15	Male	No
9		35	68	1/69	23/81	19	Female	No
10		34	62	1/7	21/45	15	Male	No
Average		25/4	69/36	1/737	22/78	11/80		
Standard deviation		5/28	16/46	0/11	4/15	4/38		

musicians with AMDs are pianists<sup>9</sup>) and more than 50% of them have the back or shoulder pain<sup>8</sup>). After the wrist, back and shoulder have the highest rate of AMDs among professional pianists<sup>9, 10</sup>. AMDs are painful and disabling disorders and affect individual lives physically, emotionally, professionally, and socially<sup>11</sup>). AMDs treatment procedures are costly and sometimes defects are permanent<sup>12</sup>).

Professional piano players have normally long time rehearsals every day which usually impose on them physical and emotional stresses<sup>8</sup>). It appears that during rehearsal, the focus on the music sonority and accordingly acquired body fatigue make musicians to neglect of the body posture and adopt bad positions<sup>13</sup>). Common malpostures for pianists are included: forward head posture, hyper kyphosis, hypo lordosis, and round shoulders<sup>12</sup>). Sustaining these faulty positions and repetitive long time movements may finally lead to WRMDs<sup>11</sup>).

Although piano is a popular instrument and keyboard instruments have over 500 years of history, investigation on pianists with AMDs is very limited. To our knowledge, the first study on acquired disorders in classical music players was published by Zaza in 1989<sup>11</sup>). He then published the concept of playing related musculoskeletal disorders (PRMD)<sup>14</sup>). Some data suggest that the senior players have higher prevalence rate of PRMSD's which confirms the importance of prevention<sup>8, 15, 16</sup>). It seems that introducing and exercising an effective strategy for sitting and playing piano with benefit of producing less amount of force to the musculoskeletal system leads to decreasing PRMDs in piano players. The purpose of this study was to compare pianists' back extensor muscles activity during playing piano while sitting on a regular piano bench and a chair with back rest. We hypothesized that sitting on a chair with back rest and playing piano decreases back extensor muscles activity compared to sitting on a regular piano bench.

## SUBJECTS AND METHODS

The subjects were 10 professional healthy and normal piano players, 6 male and 4 female form Tehran Art University (Table 1). Their (mean  $\pm$  SD) age was 25.4  $\pm$  5.2 years, their height was 173.7  $\pm$  11.6 cm and their weight was 69.4  $\pm$  17.3 kg. Their piano playing experience was 11.8  $\pm$  4.6 years. They were recruited with non-probability sampling method under the supervision of the music adviser of the study. The participants had an experience of at least 7 years of piano playing professionally. The qualifying participants were first informed of the study purpose and the study protocol. Written informed consent was then obtained from all of the participants, and the protocol was approved by Tabriz University of Medical Sciences' Ethics Committee with a code of 1394.843.

The participants were assessed in two sessions, one session sitting on a regular piano bench (hereafter called A) and the other session sitting on a chair with back rest (hereafter called B) with the interval of one week between the sessions. In sessions B, a chair with back rest (model 5504, Arvand, Iran) with the ability to adjust the seat rest height, seat rest size, back rest position and back rest spring force. This chair had wheel base, no arm rest and vertical pivot rotation ability. In order to have a comfortable chair adjustment, the seat rest height was adjusted to mid patella of the participants in standing position to keep the knee and hip in a horizontal balance during sitting with a free space beneath the knee and the seat rest<sup>17</sup>). Back rest was adjusted vertically with hard spring force. Both session A and B were performed in the same places including home, studio, or office.

In each session, muscular activity was assessed in 3 ways: 1) recording surface electromyography (sEMG) of the back-extensor muscles including the Longissimus and Iliocostalis muscles as the main back extensors<sup>18</sup>). 2) Isometric back extension test, and 3) discomfort musculoskeletal questionnaire. Priority of the sessions (A or B) were determined by simple coin randomization<sup>19</sup>).

At the beginning of each session, participants were visited by a physician to evaluate his or her general health status by the 12-Item General Health Questionnaire (GHQ-12)<sup>20</sup>). The items were as follows: front head temperature, heart rate, blood

pressure, blood sugar (BS), consciousness, duration of the previous night sleep and mood state. The results recorded in a sample general health condition form and signed by the physician. This assessment was applied to prevent any confounding factors from data collection.

Surface EMG is a developed and reliable method to assess muscular activity and induced fatigue<sup>21</sup>). Joint Analysis of Spectra and Amplitude (JASA) proposed by Luttmann is a method to assess muscular activity<sup>22, 23</sup>). EMG amplitude and spectrum were recorded throughout the task without interrupting. Electrical Activity (EA) in micro Volts ( $\mu\text{V}$ ) which describes the EMG Amplitude and Median Frequency (MDF) in hertz (Hz) which describes muscular activity spectrum, are variables considered for analyzing muscular activity and fatigue stage. For electrode placement, according to SENIAM guide line<sup>24</sup>), the participant positioned prone with slight forward flexion. A pair of surface electrodes ( $10 \text{ mm}^2$  Ag/AgCl skintact, Austria) were placed over the back extensors on the Longissimus (2 finger lateral to L1 spinous process) and Iliocostalis muscles (one finger medial to the line which connects the lowest part of the last rib to posterior spina Illiaca at the level of L2) for each side. The reference electrode was placed on the C7 spinous process. Muscular activity was recorded by EMG device (Nexus 10 Mark II, Holland) through channel C (left side of trunk) and channel D (right side of trunk). Biotrace + software (version 2015B, Mind Media) analyzed sEMG data with 256 Samples Per Second (SPS) resolution<sup>25</sup>). Raw EMG signals in the range of 20 to 500 Hz were calculated and the presence of noisy electrical environments less than  $\pm 50 \mu\text{V}$  was considered an appropriate condition for collecting EMG signals<sup>25</sup>).

There were two sEMG recording in each session. For the first recording (here after called T1), the participant played a song for 10 minutes and sEMG was recorded during the 10 minutes. Placing electrodes for T1, the surrounded skin was marked with an anti-allergic eye pencil, to re-place electrodes at the second recording (here after called T2) on the same places, precisely. After T1, electrodes removed and the participant started to perform the rehearsal for 5 hours with a free repertoire. Following every 50 minutes of playing, the participant had 10 minutes' rest. After 5 hours, T2 recording was started while the participant was playing the identical song as he (or she) played during T1 recording.

In order to assess the isometric back extension, ITO test described by Ito et al.<sup>26</sup>) was performed. Following the T2, the participant laid on a mat placed on the floor in prone position with a cushion below the belly. With a voice command, the participant lifted the head, cervical and pectoral parts of the trunk from the mat. Recording time continued as long as the participant was able to keep the position. To prevent too much force to the body, if a participant could keep the position for 5 minutes, he (or she) was allowed a 10 second rest and then isometric back extension was continued and the time was recorded. The result was reported in minute and second units in session A (A ITO) and session B (B ITO).

The last part in each assessment session was filling a Cornell Muscular Discomfort Questionnaire (CMDQ) which is a visual self-administered questionnaire<sup>27</sup>). In this study, we used the valid and reliable Persian translation of the CMDQ with 63 boxes each can be scored 0 to 10<sup>28</sup>). The participant scored feeling pain, tiredness and movement disability in the questionnaire by means of Visual Analogue Scale (VAS) for each part of the body. Full comfort is defined by 0 and maximum discomfort is defined by 10. The final score of the CMDQ is the sum of boxes score ranging from 0 to 630 and reported as the questionnaire score (QS).

As sEMG was recorded bilaterally, channel C was assigned to the left and channel D was assigned to the right side of the trunk. The following equations were used to calculate EA and MDF for T1, for session A:

$$AT1 EA = \frac{AT1 C EA + AT1 D EA}{2}$$

$$AT1 MDF = \frac{AT1 C MDF + AT1 D MDF}{2}$$

In the same way, AT2 EA and AT2 MDF were calculated for T2 recording in session A and BT1 EA, BT1 MDF, BT2 EA, and BT2 MDF were calculated for session B.

By calculating  $nT2 EA - nT1 EA = nEA$  index, the EA changes can be studied in a session. By calculating  $nT2 MDF - nT1 MDF = nMDF$  index, the MDF changes can be studied in a session.

There are four possible results with nEA index and nMDF index as follows<sup>22</sup>):

1. If nEA index  $>0$  and nMDF index  $>0$  then the muscle force has increased.
2. If nEA index  $>0$  and nMDF index  $<0$  then fatigue has happened in the muscle.
3. If nEA index  $<0$  and nMDF index  $>0$  then the muscle has adaptation.
4. If nEA index  $<0$  and nMDF index  $<0$  then the muscle force has declined.

In ITO test, all the results converted to second unit and by decreasing B ITO from A ITO, the ITO index calculated as follows.

$$B ITO - A ITO = ITO \text{ index}$$

There are three possibilities for the ITO index as follows<sup>29)</sup>:

1. If ITO index =0 then there are no difference for isometric contraction.
2. If ITO index >0 then the ability for isometric contraction has improved.
3. If ITO index <0 then the ability for isometric contraction has decreased.

The CMDQ with the final score ranging between 0 and 630 was used to study questionnaire score (QS) as a possible discomfort feeling of the participants as follows:

$$0 \leq QS \leq 630$$

The closer QS is to 0, the more feeling of comfort for participant, and the more QS is inclined to 630, the more feeling of discomfort for the participant. Discomfort and pain cognition is an individual concept and are related to personal experiences, sprit, mentality, and atmosphere<sup>30, 31)</sup>. By calculating QS in session A and session B, the questionnaire index (Q index) was obtained as follows:

$$A \text{ QS} - B \text{ QS} = \text{Q index}$$

Following are three possibilities for Q index:

1. If Q index =0 then the feeling of comfort has been the same in session A and B.
2. If Q index >0 then the feeling of comfort has been greater in session B than session A.
3. If Q index <0 then the feeling of comfort has been greater in session A than session B.

In order to compare nQ index of participants, we normalized (N) AQS and BQS for all of 10 participants as follows<sup>32)</sup>:

$$\frac{QS - \mu}{\sigma} = \text{nNQS index}$$

As QS stands for questionnaire score of the participant,  $\mu$ =average for QS for all participants,  $\sigma$ =standard deviation for all QS results, and n=name of the session, A or B.

By calculating BNQS index – ANQS index, the amount of NQS index is obtained that is comparable among all of the study participants.

By now, 4 indexes were extracted from the study data: EA index (electrical activity), MDF index (median frequency), ITO index (isometric contraction), and NQ index (musculoskeletal discomfort questionnaire). These indexes were analyzed and compared for two sessions: playing piano on a regular piano bench and on a chair with back rest.

Data analysis was performed off-line using IBM SPSS version 22 for Windows. Data tested  $v$  for Skewness and kurtosis to confirm normal distribution for data. Then the data were analyzed using Paired t-test to compare data changes within sessions. Significance was considered for values of  $p < 0.05$ .

## RESULTS

Assessment sessions in 70% of cases started with session A. In all participants, EA significantly increased in T2 compared with that in T1 in both sessions A and B. The mean EA changes in session A and B were 6.31  $\mu\text{V}$  and 3.02  $\mu\text{V}$ , respectively. The mean of EA changes in session B was 47.86% of session A (Table 2). In other words, EA changes were 52.14% smaller when participants played piano sitting on a chair with back rest, compared to sitting on a regular piano chair.

In sessions A, MDF significantly decreased in 90% of the participants at T2, compared to T1 and for only one participant, increasing of MDF was reported. On the other hand, in session B, MDF increased in 40% of the participants in T2, and in 100% of cases, the changes of MDF in session B were smaller than those in session A. The mean MDF changes in session B and A were -2.225 Hz and -11.41 Hz, respectively. In other words, the mean MDF changes in session B was 82.03% smaller of changes in session A.

Isometric contraction power in the back-extensor muscles increased for all participants in session B, with an increased mean (SD) ITO index of 69.9 (5.49). In other words ITO increased 61.48% in session B.

After normalization of data from CMDQ, there was a decrease in 90% of B NQS with a mean (SD) change of -0.81 (0.87) compared with that in A NQS. BNQS was 43.92% of ANQS.

The results of paired t test indicated that there was a significant difference of EA and MDF between sessions (EA:  $t=4.00$ ,  $p < 0.05$ , MDF:  $t=-4.00$ ,  $p < 0.05$ ). For EA and MDF, Sigma reported was less than 0.05%.

## DISCUSSION

The aim of this study was to compare pianists' back extensor muscles activity during playing piano while sitting on a regular piano bench and a chair with back rest. The sEMG assessments of the current study revealed that following 5 hours

**Table 2.** Changes of Electrical Activity (EA) and Median Frequency (MDF) in session A and session B

AT2 EA- AT1 EA	BT2 EA-BT1 EA	AT2 MDF-AT1 MDF	BT2 MDF-BT1 MDF
7/19	3/31	-10/86	-5/27
2/45	1/13	-15/25	-10/46
6/10	4/76	-9/69	4/35
8/67	3/47	-24/86	-1/74
10/17	2/30	-5/06	2/90
8/22	5/61	0/94	0/90
6/02	2/53	-8/56	0/15
7/04	5/06	-19/52	-6/67
5/65	1/17	-5/69	-2/08
1/55	0/82	-15/52	-2/62

A: assessment on a regular piano bench; B: assessment on a chair with back rest; EA: Electrical Activity; MDF: Median Frequency; T1: Time 1 sEMG recording; T2: Time 2 sEMG recording.

playing piano sitting on a regular piano chair or a chair with back rest, back extensor muscles fatigue occurred which is indicated by a significant increase in EA and decrease in MDF<sup>22</sup>). However, less changes in EA and MDF when they were playing piano using a chair with back rest than when using a regular piano chair can be ascribed to more comfort for the player on a chair with back rest with a consequent reduction in muscular activity. In one participant, EA and MDF increased in both sessions, which may be explained by the ability of the participant's back extensor muscles for better responses to the applied forces. Even in this participant, the quantity of EA and MDF changes was lesser in session B than that of session A, suggesting that this participant has been able to keep vertical trunk position with lesser amount of muscular activities using a chair with back rest.

Overall, an increase in MDF as well as EA was observed in 40% of participants in session B and this is 4 times more than what happened for MDF in session B, which may be associated with the higher ability of the participants for prolonged sitting on a chair with a back rest. Taking these into account, it appears that playing piano for a long time using a chair with back rest is superior to a regular piano chair in terms of back extensor muscular activities, which may in turn lead to less fatigue rate and there are connections between muscular activity and playing Piano on a chair with back rest.

Isometric back extension power which was assessed by the ITO test in this study, indicated that the power of the back-extensor muscles was greater in all participants when they played piano on a chair with back rest compared with when they played piano on a regular piano chair. Furthermore, Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) results indicated that 90% of the participants had more satisfaction at the end of session B. Only one participant (number 4) had a higher score or less satisfaction in session B. It is worth mentioning that this participant had a small degree of fluctuations in EA and MDF and 41 second (16.80%) improvement in ITO test in session B. Decreasing in EA and MDF changes and improvement in ITO test together with less satisfaction in this participant may be ascribed to pain cognition and perception in CMDQ<sup>30</sup>). Nevertheless, decreasing muscular activity and increasing isometric back extension power at the end of session B, as seen in the majority of the participants in this study, may be a good indication of less acquired fatigue in the back-extensor muscles which keep the trunk upward while playing piano for a long time. Thus, according to high rate of PRMDs in professional pianists, prevention could play an important role to overcome PRMDs<sup>33</sup>) and choosing an appropriate chair may help a pianist to postpone fatigue and play piano more effectively.

Some studies have shown that senior pianists have higher rates of PRMDs<sup>9</sup>), whereas other studies added the results that increasing in EA and decreasing in MDF will produce fatigue and this may lead to higher rates of PRMDs<sup>34</sup>). A study on musician students has indicated that approximately 91% of students had complained about minor PRMDs and 9% had major complaint about PRMDs<sup>7</sup>). The major complain of PRMDs has been reported to be 68% in senior professional pianists<sup>8</sup>) emphasizing more on the importance of prevention<sup>12, 33</sup>). Playing piano and evaluating induced fatigue while sitting on a regular piano chair has been a general topic in some studies<sup>6, 12, 34, 35</sup>). To our knowledge, there was no study similar to our methodology to evaluate the painists' back muscles on different kinds of chairs with various approaches.

This study describes the effects of using a proper chair for piano playing. In the past, piano players were always asked to adapt themselves to piano bench and try to keep proper trunk position<sup>6</sup>). However, piano players spend many hours rehearsing sitting on an improper chair. Thus, designing a specified ergonomic chair would be effective in reducing muscular activity in the back extensors muscles with a consequent reduction in fatigue rate.

Thus, we conclude from the results of this study that sitting on a chair with back rest is effective in decreasing muscular activity and perhaps fatigue during prolonged piano playing may reduce acquired musculoskeletal disorders among professional pianists.

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