

24 **Abstract**

25 Activation of back musculature during work tasks leads to fatigue and potential
26 injury. This is especially prevalent in dentists who perform much of their work from a
27 seated position. We examined the use of an ergonomic dental stool with mid-sternum chest
28 support for reducing lower back muscle activation. Electromyography (EMG) of lower
29 back extensors was assessed from 30 dental students for 20 seconds during three conditions
30 in random order: 1) sitting up-right at 90° of hip flexion in a standard stool, 2) leaning
31 forward at 80° of hip flexion on the standard stool, and 3) leaning forward at 80° of hip
32 flexion while sitting on the ergonomic stool. Muscular activity of the back extensors was
33 reduced when using the ergonomic stool compared to the standard stool, by 33 -50%
34 ($p<0.01$). This suggests a potential musculoskeletal benefit with use of a dental stool with
35 mid-sternum chest support.

36

37 **Keywords:** spine, posture, fatigue, injury

38 **1. Introduction**

39 The profession of general dentistry is at a high risk for development of
40 musculoskeletal disorders because dentists require optimal visualization of a relatively
41 small operative field resulting in prolonged and static maintenance of posture [1-3]. This
42 type of strain places the dental practitioner at an increased risk of developing lower back
43 pain. The prevalence of back pain among dentists ranges from 36 to 72% [1,2,4,5].

44 A variety of ergonomically designed dental stools have been proposed for
45 alleviating musculoskeletal disorders [6,7]. Hardage et al. [6] showed that low back muscle
46 activity could be reduced with a back support; however, this may be impractical during
47 practice when a dentist must lean forward to work on a patient. Parsell et al. [7] showed
48 that neither rigid arm support nor chest support with mobile arm support on a dental stool
49 was effective for reducing lower back muscle activity. They suggested that the dentists'
50 unfamiliarity with the mobile arm support may have increased low back activation,
51 cancelling any benefit from chest support. The objective of the present investigation was to
52 compare the degree of back musculature activation in dental students while leaning forward
53 on a regular dental stool and on an ergonomically-altered dental stool with mid-sternum
54 chest support. We hypothesized that the ergonomic stool would result in significantly less
55 lower-back muscle activation.

56

57 **2. Material and Methods**

58 **2.1. Participants**

59 A total of 30 (16 male and 14 female) participants were tested in this study. The
60 participants ranged from second to fifth year dental students from the College of Dentistry

61 at the University of Saskatchewan. Participants were 21 to 30 years of age with an average
62 of 24 (SD 3) years. All participants were considered healthy with no previous history of
63 back injury or complaint and absence of any known systemic musculoskeletal disorders.
64 All participants signed an informed consent form and the study was approved by our
65 university's human ethics review board.

66

67 ***2.2. Muscles investigated***

68 Dorsal muscle activity was recorded using electromyography (EMG) from two back
69 muscles, the longissimus thoracis and iliocostalis lumborum. The iliocostalis lumborum is
70 a global stabilizer while the longissimus thoracis is considered a global mobilizer [8].

71 These two muscles, along with the spinalis thoracis, form the erector spinae muscle group,
72 which is involved in vertebral extension, and lay within a fascial compartment between the
73 posterior and anterior layers of the thoracolumbar fascia and traverses the length of the
74 back. These two posterior extensor muscles were chosen due to their superficial nature
75 allowing for relative ease of landmark placement for EMG surface electrodes.

76

77 ***2.3. Experimental method***

78 A two lead analog surface EMG (Bagnoli-2, Delsys Inc., Boston, Mass.) along with the
79 EMGworks computer software program was used to measure muscle activation. Two
80 electrodes, 10 mm apart, were attached at each the level of L2 and L3 of the right
81 iliocostalis lumborum and longissimus thoracis muscles respectively. A reference electrode
82 (ground) was attached to the kneecap. The EMG main amplifier unit included single
83 differential electrodes with a bandwidth of 20 (5) Hz to 450 (50) Hz, a 12 dB/ octave cut-

84 off slope, and a maximum output voltage frequency range ± 5 V. The overall amplification
85 or gain per channel was 10,000. The system noise was $<1.2 \mu\text{V}$ (rms) for the specified
86 bandwidth. The electrodes were two silver bars (10 mm \cdot 1 mm diameter) spaced 10 mm
87 apart, with a common mode rejection ratio of 92 dB. The EMG was recorded as raw EMG
88 (V) and stored in the computer for analysis. The sampling rate was set at 1,024 Hz which is
89 more than double the highest frequency cut-off value of the bandwidth (450 Hz) as required
90 by the Nyquist criterion. The raw EMG data were then used to calculate root mean square
91 (RMS) using the EMGworks software.

92 Participants' muscle activity was tested using two dental stool designs. The first
93 standard dental stool was a model "G" serial #1119 (Ritter, Canada). The second stool had
94 a similar seat but was modified to include a chest support, located at mid-sternum, aimed at
95 minimizing lower back strain. The function of this anterior chest support is to allow the
96 operator to transfer their weight onto the chest pad in turn reducing the strain placed on the
97 lower back.

98 Muscle activity was assessed during three conditions (Figure 1), in a randomized,
99 counter-balanced order. In the first condition participants were measured sitting at 90° of
100 hip flexion and knee flexion on a standard stool (Condition 1; Figure 1a) with their hands
101 out in front of them as though they were working on a patient (i.e. elbows flexed at 90° ,
102 with forearms unsupported, hands in a neutral position). A consistent 90° posture was
103 verified using a goniometer. This 90° posture was used as a baseline to simulate what
104 would be considered perfect posture; a posture that places minimal strain on the lower
105 back. In the second condition participants leaned forward to 80° of hip flexion on the
106 standard dental stool and placed their hands out in front of them, again with elbows flexed

107 at 90° with forearms unsupported, and hands in a neutral position (Figure 1b). The final
108 test condition had the participants seated on the modified dental stool (Condition 3) with
109 80° of hip flexion, the same as the second condition, but this time supported in the position
110 by a chest pad (Figure 1c). EMG was collected during muscle contractions for all three
111 isometric conditions and was measured for a period of 20 seconds.

112

113 **2.4. Statistics**

114 A repeated measures ANOVA was used to determine differences in EMG values
115 between conditions for each muscle group. The alpha level was set at 0.025 to adjust for
116 the number of statistical tests (i.e. 0.05/2) to reduce chance of type I error. When warranted,
117 post-hoc analysis was performed using Tukey's HSD test to determine the differences
118 between the three conditions. All analyses were done using (Statistica version 7, StatSoft
119 Inc., Tulsa, Oklahoma). All data are reported as mean (SD).

120

121 **3. Results**

122 A main effect of condition was observed for both muscle groups ($p < 0.01$). For each
123 muscle group, the Tukey's post-hoc test indicated muscle activity was highest in condition
124 2 (i.e. standard dental stool, hips at 80° flexion) when compared with conditions 1 (i.e.
125 standard dental stool, hips at 90° flexion) and 3 (dental stool with chest support, hips at 80°
126 flexion) ($p < 0.01$; Figure 2). Iliocostalis lumborum and longissimus thoracis muscle activity
127 was reduced by approximately 33% and 50% respectively when comparing condition 2 to
128 condition 3.

129

130 **4. Discussion**

131 The current study has demonstrated that the use of a chest support on a dental stool
132 results in a significant decrease in EMG activity of both the longissimus thoracis and
133 iliocostalis lumborum during a simulated operating position when compared with a
134 standard dental stool. This suggests that using a chest support may reduce erector spinae
135 fatigue in dental practitioners. This has important implications because dental professionals
136 frequently have low back pain associated with the postures maintained during work [1,2,9].
137 This study is novel in that it is the first to show that use of a sternum support extending
138 from a dental stool can reduce muscle activation in the lower back and potentially reduce
139 lower back strain.

140 Only two previous studies have assessed ergonomic design of dental stools using
141 EMG. Hardage et al. [6] compared stools with and without lower back support and
142 determined that EMG activity of the lower back was reduced by about 49% with the lower
143 back support. Participants were evaluated in an upright position (i.e. with hips at a 90°
144 angle) and hands resting on the knees. One could argue that this might not be the best
145 simulation of a dentist's position while working on a patient. A proper simulation would
146 require a forward lean with arms extended. Parsell et al. [7] found that stools with rigid arm
147 supports and with chest support combined with mobile arm support had no effect on
148 activation of lower back musculature. They suggested that the lack of familiarity with the
149 mobile arm support may have increased lower back muscle activation in their participants,
150 cancelling out any benefit of the chest support. They only studied 13 participants and
151 therefore, their study may have been underpowered to detect statistical differences between

152 their chairs. Our study indicates that chest support on a dental stool is effective for reducing
153 muscle activity of the lower back.

154 A limitation of our study was that muscle EMG activity was only recorded for a 20
155 second interval. The short time interval was utilized in order to obtain pilot data that would
156 be able to determine the practical nature of adding a chest support to a standard dental
157 stool. The reality of dental work suggests dental practitioners will sustain strained static
158 positions for a much longer time than measured.

159 Our results imply that chest support on a dental stool may result in reduced lower
160 back strain which could lead to reduced lower back pain if used in a clinical setting. This
161 inference is suggested but it is acknowledged that our study did not test this hypothesis
162 directly. Further, certain positions of the dentist during dental procedures may require
163 more hip flexion or more exaggerated trunk flexion or rotation to gain direct vision or
164 proper instrument orientation. Thus, the chest support may interfere with some of these
165 movements which may limit its application in a clinical setting.

166 A more extensive clinical trial would be needed to verify that a measureable
167 reduction in back muscle strain can be demonstrated in practitioners using the chest support
168 while performing dental procedures; however, there does remain potential for a health
169 benefit with the use of an ergonomically designed operator stool for dental professionals.
170 When abnormal postures are not necessary, the chest support stool could permit dental
171 practitioners to operate in a more comfortable and relaxed manner which may lead to a
172 reduction in lower back pain in this population.

173

174 **5. Conclusion**

175 Our results suggest that the use of a chest support during hip flexion reduces the
176 activity of two major erector spinae muscles. This may be one method of modifying the
177 environment of dental professionals to reduce the risk of lower back injury in this highly
178 susceptible group. Further clinical trials evaluating both environmental (modification of
179 dental stools) and personal (improved fitness levels and core musculature strength) factors
180 will help determine which interventions are effective for reducing the risk of lower back
181 pain in dental practitioners.

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213 **Figure Captions**

214

215 Figure 1. The three different testing conditions: **a)** Condition 1: hips, knees, and elbows at
216 90° flexion **b)** Condition 2: hips at 80° flexion, and knees and elbows at 90° flexion **c)**
217 Condition 3: Identical to position 2, except with mid-sternum chest support.

218

219 Figure 2. Average root mean square EMG activity of **a)** longissimus thoracis; and **b)**
220 iliocostalis lumborum over 20 seconds in three conditions. *Significantly greater muscle
221 activity in condition 2 (80° hip flexion, no support) when compared to condition 1 (90° hip
222 flexion, no support) and condition 3 (80° hip flexion, chest support) ($p < 0.01$). Data are
223 presented as mean \pm SD.

224

225

Figure 1 a.

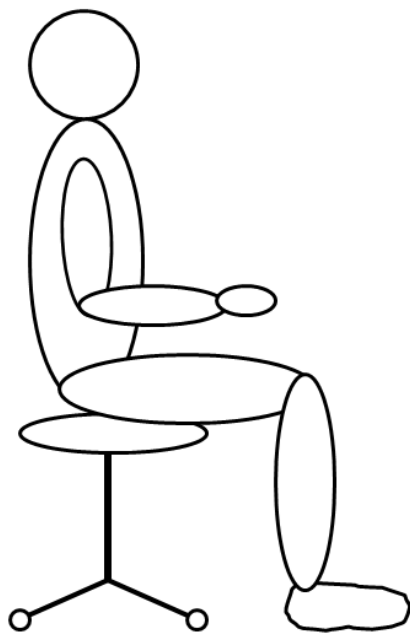


Figure 1 b.

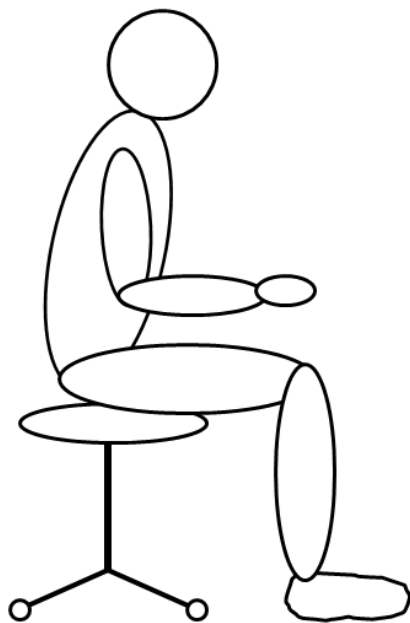
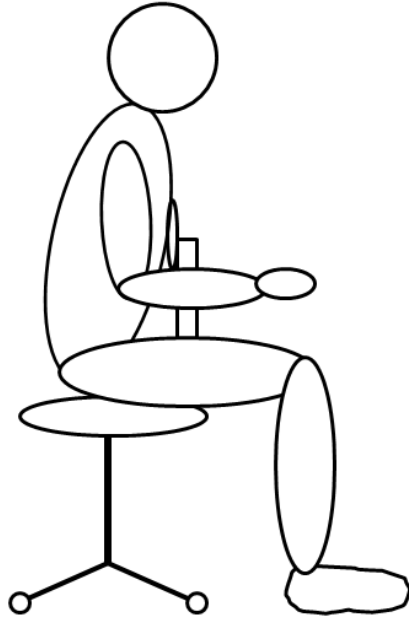
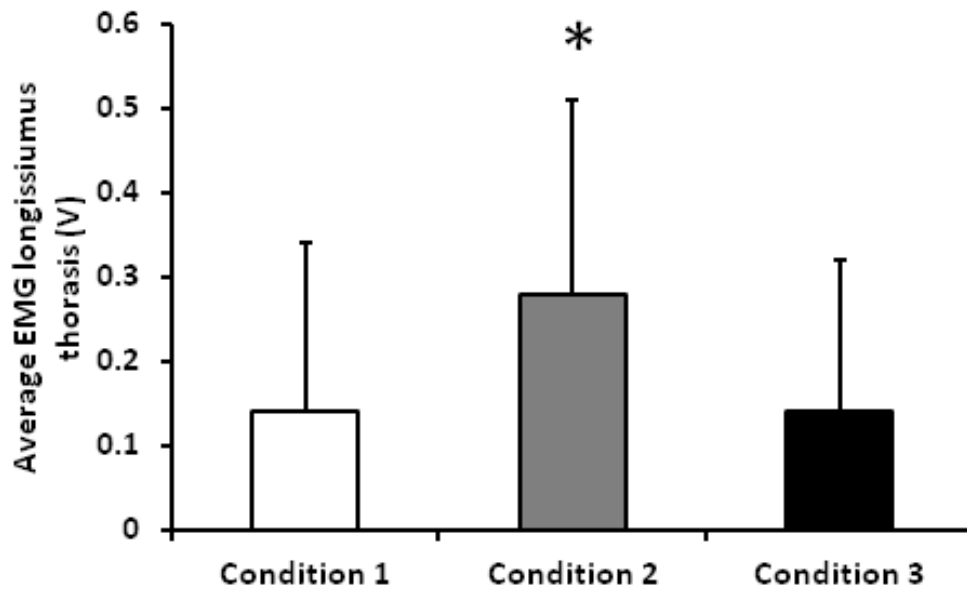


Figure 1 c.

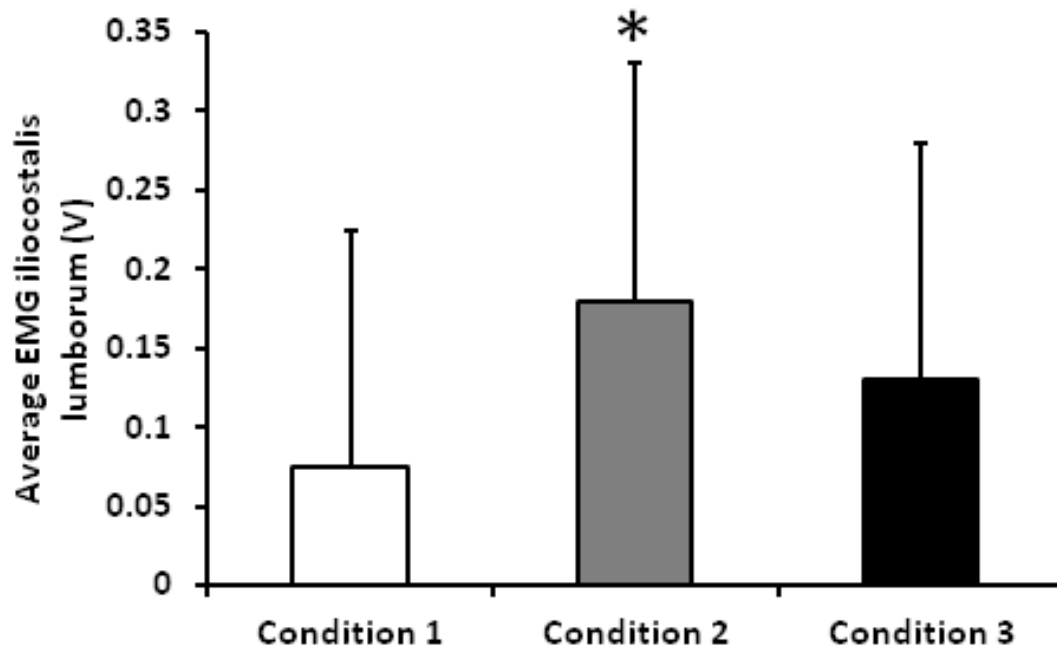


229 Figure 2a



230

231 Figure 2b



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