COMPARISON OF EMG AND TORQUES ON VARIOUS SHAPES OF KNOBS

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Abstract: This study was a laboratory experimental one designed to investigate the EMG activities and torques on four hand muscles while gripping and torqueing on handles of different shapes, as in opening a jar. The shapes were triangle, square, pentagon, hexagon, heptagon, and octagon. The muscles were Extensor Digitorum (ED), Extensor Digiti Minimi (EDM), Palmaris Longus (PL), and Opponens Pollicis (OP). Analysis of the data showed that the triangular and quadrilateral handles produce greater torques than the other shapes. The EMG amplitude analysis showed that only the Extensor Digitorum (ED) muscle showed differences across the handles of different shapes. For this muscle, the triangle and quadrilateral has the smallest amplitude, and the hexagon the greatest. The mean amplitudes showed no difference among the shapes, for all muscles.

1. INTRODUCTION

Hand torque exertions are essential for many daily activities. Common activities such as joining or removing threaded or non-threaded parts, using hand tools or controls, and turning doorknobs may be physically challenging if the handle is improperly designed. The packaging of consumer products, such as jar and bottle closures, is often designed to protect and preserve the contents. Much consideration has been paid to the closure aspect of the packaging for hygiene, safety, and other purposes. Tightly closed jars are necessary, but may lead to musculoskeletal strains in trying to open them, especially among the elderly. Research has shown that torque required to open some bottles and jars may be above people’s maximal torquing capabilities (Berns, 1981; Department of Trade and Industry [DTI], 1997; Imrhan & Loo, 1988; Rohles, Moldrup, & Laviana, 1983). Discomfort, cumulative strains or injuries to the hand and arm are likely to occur in such cases. Prevention of these problems requires that we understand the biomechanics and physiology involved in hand torqueing. In gripping and twisting (torqueing) an object, there is a complex interplay between the intrinsic muscles and extrinsic muscles of the hand. The former contracts isometrically to steady the hand while, at the same time, the latter produces forces that are translated into torques at the hand-handle contact. An understanding of the EMG activities of some of these muscles can help us to understand the process better. Imrhan (2011) investigated MVC static peak torques on the handles of different shapes that are used in the present study, but did not investigate the muscle EMG activities involved. The objective of the present study is to evaluate the electromyograms (EMGs) of four selected hand muscles while exerting MVC static torques on handles of different shapes.

2. METHODS

Subjects in this study were eight healthy college age student volunteers (5 males, 3 females; 1 left-handed). They were required to exert MVC torques in the opening direction, with the right hand, on handles of different shapes - triangle, square, pentagon, hexagon, heptagon, and octagon. All handles were designed to have the same thickness (height) and about the same overall size, and fitted comfortably in the hand of an average size American male. Subjects stood comfortably and gripped the knob (handle) at about waist height with the right hand and exerted the torque. The handle was mounted on a torque transducer (Figure 1). The left hand rested on the stand on which the torque transducer was mounted. While torqueing on each handle, the torque and EMG activities of the following muscles were recorded: Extensor Digitorum (ED), Extensor Digiti Minimi (EDM), Palmaris Longus (PL), and Opponens Pollicis (OP).
The MVC maximum torque was recorded using Mecmesin AFTI Advanced Force & Torque Indicator, measurements made in Newton-meter, with a sampling rate of 5000 Hz. The electrical activity, EMG amplitude and EMG mean frequency, of the Extensor Digitorum (ED), Extensor Digitii Minimi (EDM), Palmaris Longus (PL), and Opponens Pollicis (OP) muscles were recorded using a 16 channel Bagnoli desktop EMG system. Prior to electrode placement, the skin was lightly abraded and cleaned with rubbing alcohol to reduce signal impedance. Pre-amplified bipolar surface electrodes composed of two silver bars and fixed inter-electrode distance of 10 mm were placed over the middle of the muscle surface located between the motor point (muscle mid-point) and the tendon–muscle interface. A large 2-inch self-adhering Dermatrode electrode. ground electrode was positioned on the medial surface of the anterior tibia. The EMG signals were amplified 1000 × and band-passed filtered using a Bagnoli biological amplifier. The EMG data were sampled at 1000 Hz using a National Instruments PCI-6229, 16-bit analog-to-digital converter with a voltage range of ±5 V.

### 3. Results and Discussion

Table 1 shows the MVC torque, and the EMG Amplitudes of the six muscles -- Extensor Digitorum (ED), Extensor Digitii Minimi (EDM), Palmaris Longus (PL), and Opponens Pollicis (OP). ANOVA indicated that the torques were not of the same magnitudes across shapes (p<0.05). Tukey’s multiple comparison test confirmed that the triangle and quadrilateral generated greater torques than the other shapes (p<0.05), which were not different from one another (p>0.05).

<table>
<thead>
<tr>
<th>Handle Shape</th>
<th>Ave. MVC Torque (Nm)</th>
<th>ED EMG Amplitude (mV)</th>
<th>EDM EMG Amplitude (mV)</th>
<th>PL EMG Amplitude (mV)</th>
<th>OP EMG Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangle</td>
<td>4.46±1.25</td>
<td>67.7±15.5</td>
<td>69.6±42.4</td>
<td>91.9±59.4</td>
<td>222.7±105.5</td>
</tr>
<tr>
<td>Quadrilateral</td>
<td>4.63±1.40</td>
<td>49.3±22.3</td>
<td>73.4±43.1</td>
<td>66.9±28.2</td>
<td>135.2±63.7</td>
</tr>
<tr>
<td>Pentagon</td>
<td>3.81±1.11</td>
<td>112.9±20.3</td>
<td>94.3±43.2</td>
<td>76.4±36.0</td>
<td>186.1±88.5</td>
</tr>
<tr>
<td>Hexagon</td>
<td>4.01±0.67</td>
<td>153.5±25.3</td>
<td>101.9±46.7</td>
<td>87.3±49.8</td>
<td>232.1±108.1</td>
</tr>
<tr>
<td>Heptagon</td>
<td>3.92±0.79</td>
<td>109.9±31.1</td>
<td>101.5±42.9</td>
<td>79.0±35.5</td>
<td>237.1±113.2</td>
</tr>
<tr>
<td>Octagon</td>
<td>3.87±0.95</td>
<td>97.5±30.9</td>
<td>67.2±21.1</td>
<td>63.6±30.1</td>
<td>192.0±66.5</td>
</tr>
</tbody>
</table>

Box plots of average MVC torques, showing the quartiles are shown in Figures 2 and 3. The average MVC torque for the triangle and quadrilateral handles was 20% greater than the average for the others shapes combined (p<0.05) (Figure 3).
Analysis of the EMG data (ANOVA) across shapes indicated that the EMG amplitude was not different across the different shapes for muscles EDM, PL, and OP (p>0.05) but was different for muscle ED (Figure 4). Tukey’s multiple comparison test for the ED data confirmed that the amplitudes fell into 3 groups (Figure 5) – the lowest for the 3 and 4 sided handles (triangle and quadrilateral), followed by the 5, 7, and 8 sided handles (pentagon, heptagon and octagon), then by the 6 sided handle (hexagon). It is important to note that the shapes that gave the greatest torques were the ones that gave the smallest EMG amplitudes. This seems to be the result of the type of grip used. It was possible to buttress the thenar eminence of the thumb against one side of the triangle or square comfortably (which was not possible for handles of greater number of sides), thus allowing greater torques for lesser muscle activation. The average ED EMG amplitude was 50% greater for pentagon and hexagon handles, combined, than for triangle and quadrilateral handles, combined; and the hexagon average was 25% greater than for the average for pentagon, heptagon, and octagon, combined (p<0.05).

4. CONCLUSIONS

In general, triangular and quadrilateral knobs allow for the generation of as much or more torque than any of the other shapes. Triangle and quadrilateral shapes shown significantly difference from pentagon, hexagon, heptagon, and octagon shapes which were generated almost the same level of maximum torque. Designing tool with heptagon, and octagon shape reduces required muscle force for a given torque and could reduce the risks of fatigue or musculoskeletal disorders.
5. REFERENCES