Maximal Torque and Muscle Strength is Affected by Seat Distance from the Steering Wheel when Driving

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Abstract. [Purpose] This research analyzed how seat distance and gender affect maximal torque and muscle strength when driving to present base data for the optimal driving posture. [Subjects and Methods] The subjects were 27 college students in their 20’s, 15 males and 12 females. After had been measured, the subjects sat in front of a steering wheel with the distance between the steering wheel and the seat set in turns. at 50, 70, and 90% their arm length, and the maximal torque and muscle strength were measured. [Results] Both the maximal torque and muscle strength were found to be greater in male subjects than female subjects whether they turned the steering wheel clockwise or counterclockwise. The difference was big enough to be statistically significant. Maximal torque was greatest when the seat distance was 50% of arm length, whether turning the steering wheel clockwise or counterclockwise. There were statistically significant differences in maximal torque between seat distances of 50 and 70% and 90% of the arm length. Muscle strength, in contrast, was found to be the greatest at a seat distance of 70% of arm length. [Conclusion] We conclude that greater torque can be obtained when the steering wheel is nearer the seat while greater muscle strength can be obtained when the seat distance from the steering wheel is 70% of the arm length.

Key words: Maximal torque, Muscle strength, Arm length

INTRODUCTION

When driving, “slumping” often happens; drivers move their hips forward when they feel uncomfortable mainly because of the inadequate design of car seats. Their intention is to shift to a more comfortable position when the level of seat is too low, the cushion of the seat is too firm, or the back of a seat is not properly reclined¹). This phenomenon occurs when drivers adopt a comfortable posture instead of a correct one, and it often results in a bent backbone and, consequently, low back pain²).

Musculoskeletal disorders such as low back pain and shoulder discomfort often arise from doing simple repetitive jobs and appear in the low back, neck, shoulders, arms, and legs³). Long hours of driving may yield fatigue in the neck, shoulders, or low back. Pain might be the result of sitting posture, vibration during driving, tension, or fatigue⁴). Gyi and Porter⁵), in their study of musculoskeletal disorders of policemen, reported that shoulder discomfort was a significant problem for driving policemen. Porter and Gyi⁶) also found that drivers are more likely to have low back pain than people working either while sitting or standing. Kim et al.⁷) reported that workers in the transport industry had a 2.14 subjective degree of fatigue on a 5-point scale, and the main locations of pain were the shoulders (56.59%), neck (50.24%), and knees (43.90%).

Judic et al.⁸) examined some previous studies proposing an optimal driving posture based on comfortable posture, and measured mean values of angles for each joint. They made an alternative proposal of an optimal posture that takes into consideration all the aspects of driving posture. Lee⁹), in his study of uncomfortableness of elbow motion, applied a magnitude estimation method to kinematic parameters of the elbow joint and made a quantitative estimation of the degree of uncomfortableness of the steering motion. His analysis of uncomfortableness was based on the measurement of the radius and angle of the steering wheel, and the distance between a driver’s shoulders and the steering wheel. Andreoni et al.¹⁰) performed a 3D analysis of the pressure between a driver’s joint angle and the seat in a sitting position. Kyung and Nussbaum¹¹) offered three kinds of subjective evaluation (overall evaluation, discomfort, and comfort) in assessing the design and layout of seats based on body pressure distribution. Hostens and Ramon¹²) investigated the activation of the muscles during driving, and active and passive motion using surface electromyography of the deltoid muscle of both the shoulders and the trapezius muscle.

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Most analyses of driving postures have been conducted from the perspective of mechanical engineering, technology, industry, and ergonomics. However, little research has been reported in the literature that focuses on maximal torque and muscle strength according to arm length and gender. The goal of this study was to propose an optimal driving posture based on the key factors of maximal torque and muscle strength.

SUBJECTS AND METHODS

Twenty-seven college students in their 20’s who were attending a University located in Chonan, Korea, participated in the present research. They all voluntarily agreed to participate in the experiment after an orientation session about the research. The subjects were healthy adults who had no congenital deformity in the upper body or neurologic disorder. Table 1 shows the physical characteristics of the subjects participating in the present research. The Ethics Committee of Namseoul University in Korea approved the study.

The orientation session conducted with the subjects offered the subjects a detailed explanation of the contents of the research. All the subjects signed a consent form before the experiment began. A body composition analyzer (InBody 720, Biospace, Korea) was used to measure their basic physical characteristics.

We measured the arm lengths of the subjects in a standing position with their shoulder joints in 90° flexion. A tape measure (Fitting, Apsun, Korea) was used to measure the arm length from the acromion to the styloid process of the radius. The arm lengths were used as the basis for the three different driving seat positions.

For the purpose of measuring maximal torque and muscle strength, we used a Primus RS (Baltimore Therapeutic Equipment, USA). Subjects sat on the equipment and belts were fastened around the trunk and thigh in order to prevent compensation movements that might occur during driving. The arm length from the acromion to the styloid process of the radius was then measured. The center of the subject’s body and that of the steering wheel were aligned, and the distance between the steering wheel and the seat was adjusted to create the three different driving seat positions as illustrated in Fig. 1, 2, and 3. In each position (distance from the driving wheel of 50%, 70%, and 90% of subject arm length) subjects’ maximal torque and muscle strength were measured. A slightly revised version of the definition of Yoo et al. of 50%, 70%, and 90% of arm length was used in this study.

Maximal torque was measured in each of the three driving seat positions in three alternate sessions of clockwise and counterclockwise turning. We calculated the mean values of these test-retest processes to enhance the reliability of our research. In cases where the COV (coefficient of variation) was found to be greater than 15%, the experiment was repeated. In order to eliminate the possibility of higher momentary pressures, the subjects maintained maximal pressure for five seconds. They were also asked to sit straight up and use only their arms and shoulders to turn the steering wheel, so that we could reduce the error attributable to weight variations from hanging on the steering wheel. A rest of 30 seconds was given after each session of 5 seconds. After 3 rounds of clockwise and counterclockwise sessions, another 30 seconds of rest was given before we measured muscle strength. Values of 50% of the measured maximal torque were used as the 100% resistance level for muscle strength.

For fatigue recovery, the experiments were conducted at 24-hour intervals. After the experiment was performed at a

| Table 1. Subject characteristics |
|---------------------------------|
|                                | Means ± SD |
| Height (cm)                    | 168.70 ± 8.40 |
| Weight (kg)                    | 63.20 ± 10.99 |
| Age (years)                    | 21.56 ± 1.78  |
| arm length (cm)                | 56.74 ± 3.63  |
| skeletal muscle (%)            | 26.42 ± 6.91  |
| body fat (%)                   | 16.10 ± 7.71  |
| BMI                            | 22.17 ± 2.76  |

BMI: Body Mass Index
seat distance of 50% arm length, the experiment was performed at a seat distance of 70% arm length after 24 hours, and at 90% arm length after a further 24 hours (15). The same procedure was followed for both male and female subjects.

SPSS Version 18.0 was utilized for the analysis of the results, and the data were confirmed to have a normal distribution by the Kolmogorov-Smirnov Test. A descriptive statistical survey to identify the general characteristics of the subjects participating in the research was performed as well. MANOVA (Multivariate Analysis of Variance) was employed to compare the measured results of maximal torque and muscle strength between gender and among seat distances. In cases where significant differences were found with MANOVA, the Scheffe test was conducted as a post hoc test. The level of significance used was α=0.05.

**RESULTS**

Table 2 shows that there were significant differences (p<0.05) between males and females in both maximal torque and muscle strength, whether they were turning the steering wheel clockwise or counterclockwise. Further, male subjects showed greater values than female subjects for both parameters.

|                | Male (n=15) | Female (n=12) |
|----------------|-------------|---------------|
| clockwise maximal torque* | 350.600±77.432 | 180.389±41.106 |
| counterclockwise maximal torque* | 359.444±81.410 | 183.778±40.450 |
| maximal strength* | 4,424.933±1,378.589 | 2,038.917±554.625 |

Values are expressed as mean ± SD.
* Significant difference p<0.05

Table 3. MANOVA analysis of maximal torque and muscle strength

|                | Type III sum of squares | Degree of freedom | Mean square    |
|----------------|-------------------------|-------------------|----------------|
| Gender         |                         |                   |                |
| clockwise maximal torque* | 579,436.447 | 1 | 579,436.447 |
| counterclockwise maximal torque* | 617,175.556 | 1 | 617,175.556 |
| muscle strength* | 1.139E8 | 1 | 1.139E8 |
| Arm length     |                         |                   |                |
| clockwise maximal torque* | 47,330.927 | 2 | 23,665.464 |
| counterclockwise maximal torque* | 44,663.709 | 2 | 22,331.854 |
| muscle strength* | 1.751E7 | 2 | 8,754,797.024 |
| Gender × Arm length |                   |                   |                |
| clockwise maximal torque | 6,630.927 | 2 | 3,315.464 |
| counterclockwise maximal torque | 7,402.770 | 2 | 3,701.385 |
| muscle strength | 5,026,005.900 | 2 | 2,518,002.950 |

* Significant difference p<0.05

SPSS Version 18.0 was utilized for the analysis of the results, and the data were confirmed to have a normal distribution by the Kolmogorov-Smirnov Test. A descriptive statistical survey to identify the general characteristics of the subjects participating in the research was performed as well. MANOVA (Multivariate Analysis of Variance) was employed to compare the measured results of maximal torque and muscle strength between gender and among seat distances. In cases where significant differences were found with MANOVA, the Scheffe test was conducted as a post hoc test. The level of significance used was α=0.05.

The current research compared maximal torque and muscle strength between gender and among seat distances relative to arm length when turning a steering wheel clockwise and counterclockwise. Our goal was to identify the optimal driving position.

Muscle strength and muscle endurance are not indices that directly evaluate health. However, the greater the muscle strength or endurance is, the lesser the physical burden a subject experiences when participating in physical activities (14). Thus, it might be safe to assume that greater maximal torque and muscle strength reduce the physical stress of drivers, leading to a more desirable driving posture.

We found no interaction between gender and seat distance relative to arm length with maximal torque, either in clockwise or counterclockwise turning, and with muscle strength (p>0.05). Thus, we can conclude that neither gender nor seat distance has an independent effect on maximal torque or muscle strength. Park (16) conducted a survey of body size, muscle strength, nutrition intake, and nutritive conditions among a group of 245 students attending a
college in Taegu, Korea. She found significant differences in both back muscle strength and grip strength, with male students showing higher values than female students. The results of our present study are similar in that muscular strength and endurance showed differences that were statistically significant.

Askew et al. also found that males possess greater flexion and extension strength of the elbow joint, and maximal torque of forearm pronation and supination. These differences in muscular strength between males and females arise from the actions of sex hormones. During the period of adolescence, a female’s secondary sexual characteristics lead to an accumulation of internal body fat leading to less accumulation of muscle than in males. Their study conducted a descriptive statistical analysis of the subjects’ physical characteristics in order to examine the differences in the amount of muscle and body fat. The data for males and females were as follows: 31.820 ± 3.264 vs 19.667 ± 3.120 for skeletal muscle, and 12.973 ± 6.460 vs 20.008 ± 7.583 for body fat, respectively. These figures support the widely accepted conclusion of past research that females’ weaker muscle strength results from less skeletal muscle due to greater volume of body fat.

An et al. report in their study of the biceps brachii, brachialis, brachioradialis, and torque, that the greatest torque was generated at elbow angles between 75–100°. Neumann found that the supination torque when the elbow joint is flexed at 90° is twice as much as when it is flexed at was 30°, since the biceps brachii plays an important role as a supination muscle. We found that maximal torque was greater when the steering wheel was nearer the body. Maximal torque was greater when the seat distance was 50% and 70% of arm length than when it was 90%. We conclude that maximal torque is greatest when the seat distance is between 50% and 70% arm length.

In conclusion, male subjects exhibited greater maximal torque and muscle strength turning a steering wheel both clockwise and counterclockwise. A shorter distance between the steering wheel and the driving seat leads to greater maximal torque. Muscle strength, in contrast, is greatest when the seat distance from the steering wheel is 70% arm length. We conclude that a proper driving posture exerts a positive influence on muscle strength and, as a consequence, helps drivers feel less tired.

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### Table 4. Multiple comparison of maximal torque and muscle strength according to seat distance relative to arm length

|       |       | mean difference(I–J) | standard error |
|-------|-------|----------------------|----------------|
| **clockwise maximal torque** |       |                      |                |
| A     | B     | 3.000                | 16.160         |
| A     | C*    | 55.148               | 16.160         |
| B     | A     | −3.000               | 16.160         |
| B     | C*    | 52.148               | 16.160         |
| C     | A*    | −55.148              | 16.160         |
| C     | B*    | −52.259              | 16.160         |
| **counterclockwise maximal torque** |       |                      |                |
| A     | B     | 0.185                | 16.996         |
| A     | C*    | 52.260               | 16.996         |
| B     | A     | −0.185               | 16.996         |
| B     | C*    | 52.074               | 16.996         |
| C     | A*    | −52.260              | 16.996         |
| C     | B*    | −52.074              | 16.996         |
| **muscle strength** |       |                      |                |
| A     | B*    | −1,088.667           | 261.900        |
| A     | C     | −78.667              | 261.900        |
| B     | A*    | 1,088.667            | 261.900        |
| B     | C*    | 1,010.000            | 261.900        |
| C     | A     | 78.667               | 261.900        |
| C     | B*    | −1,010.000           | 261.900        |

A: 50% of arm length B: 70% of arm length C: 90% of arm length

* Significant difference p<0.05
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