朝陽科技大學

人因工程實驗室

清瀚企業有限公司委託

【螺絲起子作業之前臂肌群施力量測】

實驗報告書

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Contents

Ⅰ.Purpose of the experiment……1

Ⅱ.Experimental equipment……1

2.1 Screwdriver……1

2.2 Torque sensor……2

2.3 Myoelectric signals measurement recording system……3

Ⅲ.Results of the experiment……6

3.1 Screwdriver maximum torque……6

3.2 Forearm muscle group force for screwdriver operation……7

3.3 Screwdriver use satisfaction……11

Ⅳ. Conclusion……12

Appendix Ⅰ ……13

Ⅰ.Purpose of the experiment

The purpose of this experiment is to measure and compare the maximum torque of the three screwdrivers and the application of force (%maximum voluntary contractions proportion, %MVC) of the forearm muscle group with constant value of the tightening torque. To prove that in normal use, the screwdriver with a special soft structure inside the handle can effectively reduce the force load of the hand and forearm site, and then reduce the damage of muscle soreness caused by using screwdrivers.

Ⅱ.Experimental equipment

2.1 Screwdriver

The three screwdrivers (non-powered) measured and evaluated in this experiment as shown in Figure1. On the left side of Figure1 is the screwdriver with a special soft structure inside the handle (The Republic of China Invention Patent I609747)(hereinafter Referred to SD-1), and the middle and right side are common on the market without special soft structure screwdrivers (hereinafter SD-2 and SD-3). All three are short-handled Phillips screwdrivers for narrow/limited operating spaces.

Figure1. Three screwdriver side view (left) and upper view (right), and the numbers from left to right are SD-1, SD-2, and SD-3

2.2 Torque sensor

This experiment uses the Futek T5162 torque sensor to measure the maximum torque of the three screwdrivers and the fixed torque when tightening. Figure 2 is an experimental diagram of the subject performing a constant value of the tightening torque on the torque sensor, and the torque sensor signal is collected by the laboratory-made amplification and synchronization receiver (synchronized with the muscle force EMG signal) and displayed on a computer screen for the subject to perform a constant value of the tightening torque.

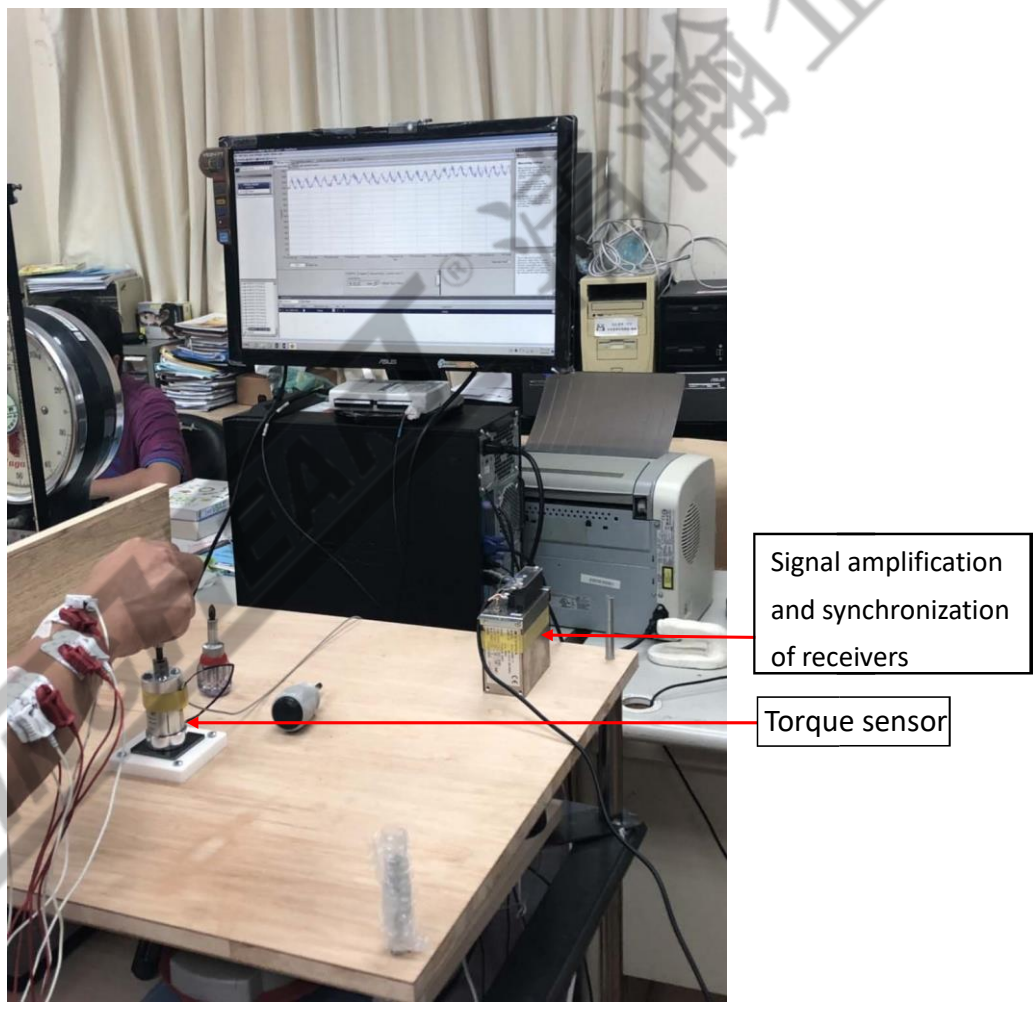

Figure 2 is an experimental diagram of the subject performing a constant value of the tightening torque on the torque sensor

The torque sensors use weights to regulate.The length of moment arm is 0.14 m (14 cm) and a correction torque value are 0, 0.686 N-m, 1.372 N-m, 2.058 N-m, 2.744 N-m, 3.430 N-m, and 4.116 N-m. The correction regression line as shown in Figure 3. The torque prediction equation is Y (N-m)= - 0.65078 + 7.72304X (mV). The coefficient of determination is R2 = 0.998218 (F=3362.35, p < 0.00001).The linear regression mode can be evaluated 99.82 percent value of the torque sensor.

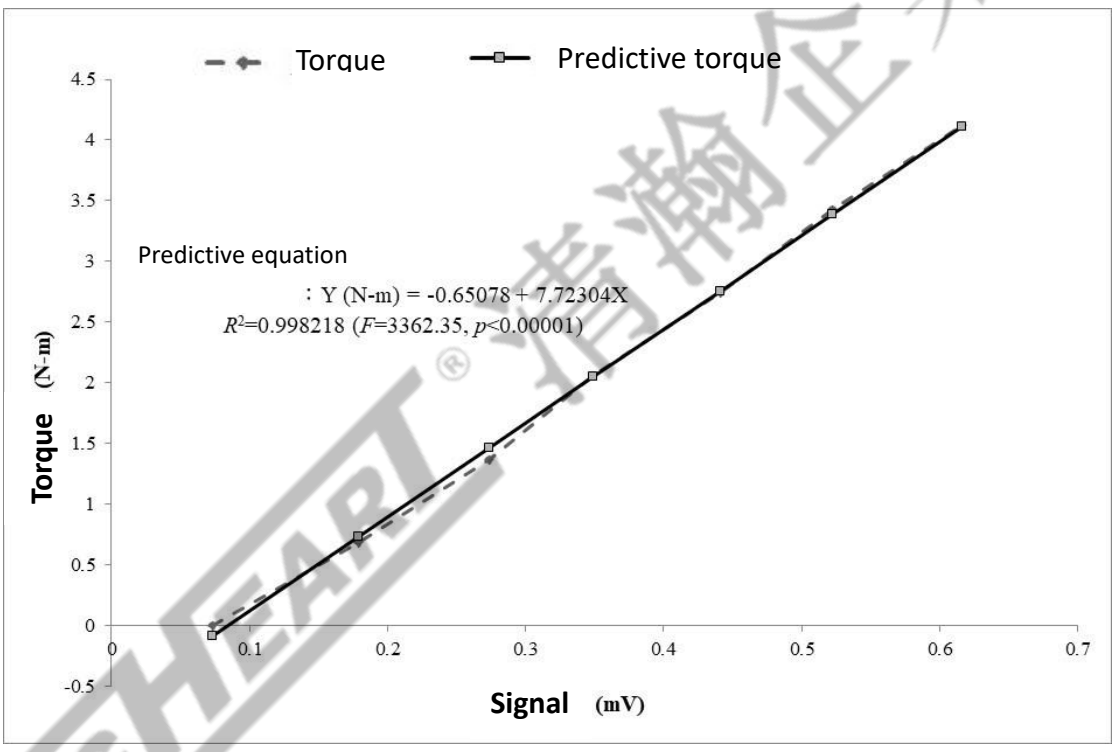

Figure 3. The correction regression line of the torque sensor

2.3 Myoelectric signals measurement recording system

This study used Biopac System, Inc., MP150 system (Figure 4) and data acquisition software (Acq Knowledge 3.7.2) installed in laptops to collect myoelectric signals. The original myoelectric signals collected by the surface electrodes are first amplified by the preamplifier (gain is 5000Hz)

and filtered with a 500 Hz low pass filter, and then collected at a sampling frequency of 1000 Hz via an analog-digital converter. When measuring, after wiping the recording site with alcohol, attach the surface electrode patch (Figure 5) to the four muscle groups (appendix 1), the abductor pollicis longus, APL, the flexor digitorum superficialis muscle, FDS muscle, the flexor carpi radialis muscle, FCR muscle, and the extensor carpi radialis longus muscle, ECR muscle, and the ground electrode is placed at the collarbone of the subject. The collected myoelectric signal data is converted to the Root Mean Square(RMS) using formula 1 to regularize the myoelectric signals. In order to measure the exertion of each muscle of the experiment, the rest state myoelectric signals before the test subject's experiment is first collected, and the data after the regularization of the rest state myoelectric signals is defined as RMSrest. Then measured the digital of the Maximum Voluntary Contraction(MVC) myoelectric signals of each muscle, and the data after the regularization for myoelectric signals of the digital of the maximum voluntary contraction is defined as RMS_{MVC}. Finally, carrying on each screwdriver locking operation combination to obtain the muscle parts of the myoelectric signals, each muscle part of the myoelectric signals after regularize data defined as RMStask. Finally, RMSrest, RMSMVC and RMStask were introduced into Formula 2 to calculate the digital of the maximum voluntary contraction proportion (%MVC) of each muscles.

Figure 4. Biopac MP150 myoelectric signals measurement recording system

Figure 5. the surface electrode patch

$$RMS = \sqrt{\frac{\sum_{i=1}^{n} Xi^2}{n}},\ i = 1,2,3...n \qquad \text{(Formula 1)}$$

n : total number of myoelectric signals

Xi : i th data value in the myoelestric signals

$$\%\ \mathrm{MVC} = \frac{\mathrm{RMS}_{\mathrm{task}} - \mathrm{RMS}_{\mathrm{rest}}}{\mathrm{RMS}_{\mathrm{MVC}} - \mathrm{RMS}_{\mathrm{rest}}} \times 100\% \qquad \text{(Formula 2)}$$

RMS_{task}：RMS value during the locked operation

RMS_{rest}：RMS value of the basic resting state

RMS_{MVC}：RMS average value of two maximum voluntary forces.

Ⅲ.Results of the experiment

3.1 Screwdriver maximum torque

This experiment measured the maximum torque that 12 male subjects could apply force with using screwdrivers when it performs locking operation on the horizontal (H) and the vertical (V). The results of the measurements are shown in Figure 6. The maximum torque that can be applied for horizontal operation are 3.63 N-m (SD-1), 1.31 N-m (SD-2), and 2.25 Nm (SD-3). The SD-1 screwdriver with special soft structure inside the handle can apply is 2.77 times higher than SD-2 and 1.61 times higher than SD-3 respectively. The maximum torque that can be applied for vertical operation are 3.21 N-m (SD-1), 1.33 N-m (SD-2), and 2.21 Nm (SD-3). The SD-1 screwdriver with special soft structure inside the handle can apply is 2.41 times higher than SD-2 and 1.45 times higher than SD-3 respectively. When using three screwdrivers for locking operations at maximum torque, the load on the hands and wrists should be similar. Therefore, when locking operation with a fixed-value torque less than the maximum torque, the SD-1 screwdriver with special soft structure inside the handle can reduce the load on the hand and wrist parts compared to the other two screwdrivers.

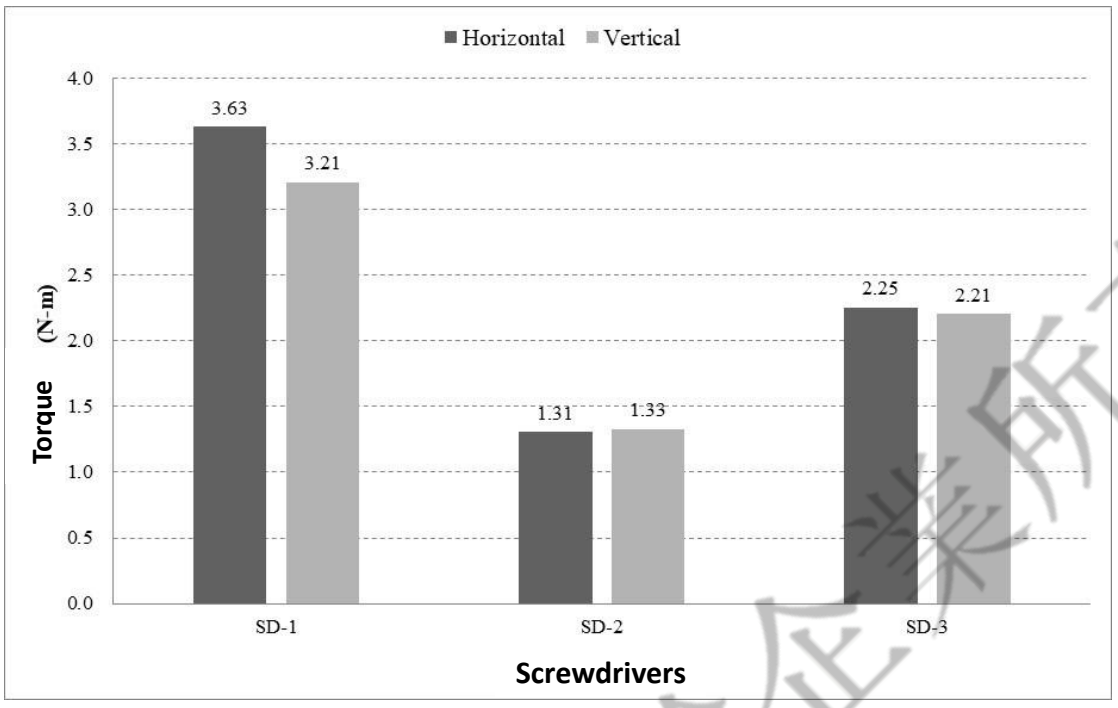

Figure 6. The maximum torque chart for the measurement of three screwdrivers

3.2 Forearm muscle group force for screwdriver operation

In this experiment, 12 male subjects used screwdrivers to apply locking operations on horizontal (H) and vertical (V) at a fixed value torque, while measuring the force of the forearm four muscle groups with surface electrode patches. The fixed value torque operation is 50% and 75% of the maximum torque of the SD-2 screwdriver. The horizontal torques are 0.65 N-m and 0.95 N-m, and the vertical torques are 0.67 N-m and 1.00 N-m, respectively.

Measured the proportion of the four muscle groups applied force (%MVC) as shown in Figure7 to Figure10. When the SD-1 screwdriver is operated for locking operation, the flexor carpi radialis muscle, FCR muscle is the main force muscle group, and the proportion of force applied for horizontal is higher than the vertical (Figure 9). When the SD-2 screwdriver is operated for locking operation, the flexor digitorum superficialis muscle, FDS muscle and the flexor carpi radialis muscle, FCR

muscle are the main muscle groups, and the proportion of force applied for horizontal is also higher than the vertical (Figures 8 and 9). When the SD-3 screwdriver is operated for locking operation, the abductor pollicis longus muscle, APL muscle and the flexor carpi radialis muscle, FCR muscle are the main muscle groups, and the proportion of force applied for horizontal is also higher than the vertical (Figures 7 and 9).

Comparing the proportion of the force (%MVC) with the same and the main muscle group (flexor carpi radialis muscle, FCR). Figure 9 shows that when locking the force at 50% torque, the SD-1 and SD-3 work at a horizontal are similar in the force proportion (10.99% and 11.23% MVC), and these two screwdrivers is approximately 16% less force than the SD-2 force (27.00% MVC). The SD-1 force proportion (5.76% MVC) when operating on the vertical surface is 12.93% and 7.42% lower than SD-2 (18.69% MVC) and SD-3 (13.18% MVC), respectively. When locking the applied force at 75% torque, the SD-1 force proportion (18.23% MVC) is 32.36 % lower than SD-2 (50.59% MVC) and SD-3 (22.55% MVC) and 4.31% lower than the applied force in horizontal surface operation. The SD-1 force proportion (8.51% MVC) when working on the vertical surface is 25.54% and 10.21% lower than SD-2 (34.05% MVC) and SD3 (18.73% MVC), respectively.

When locking operations are performed at each fixed torque, the proportion of the muscle group applied force (%MVC) with SD-1 screwdriver's four muscle groups is lower than the other two screwdrivers, showing that compared to the other two screwdrivers, the screwdriver (SD-1) inside the handle has a special soft structure can effectively reduce

the strength of the forearm muscle group in the horizontal and vertical surface operation.

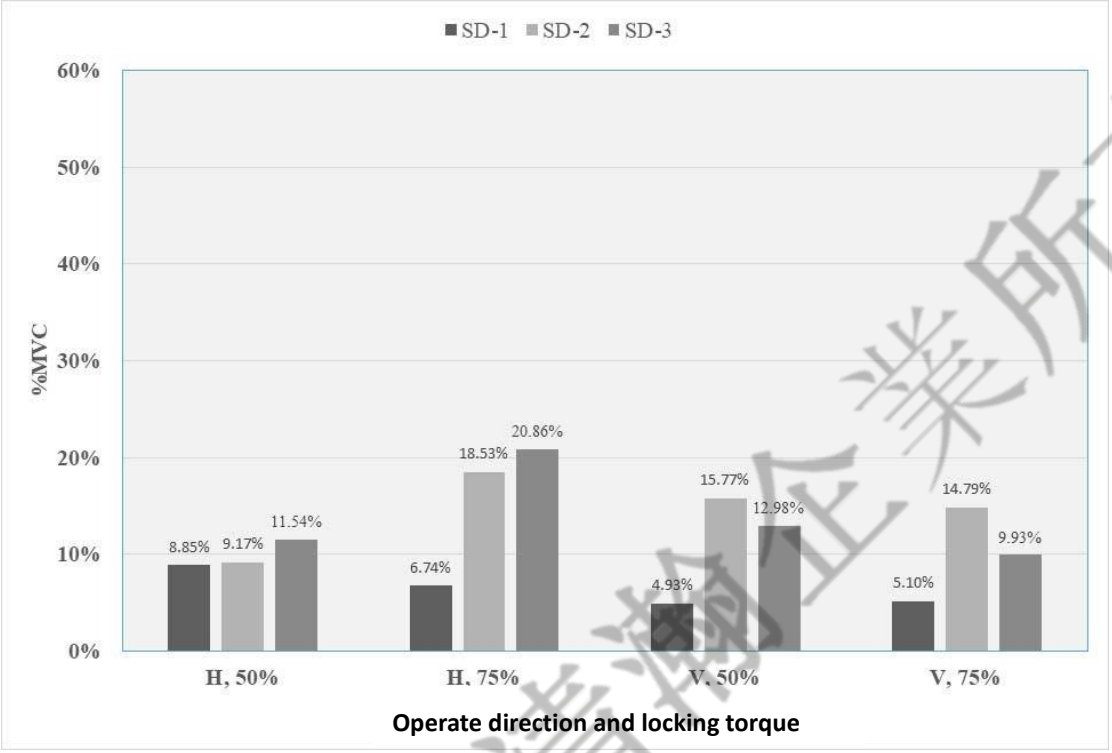

Figure 7. Abductor pollicis longus, APL muscle group force proportion(%MVC)

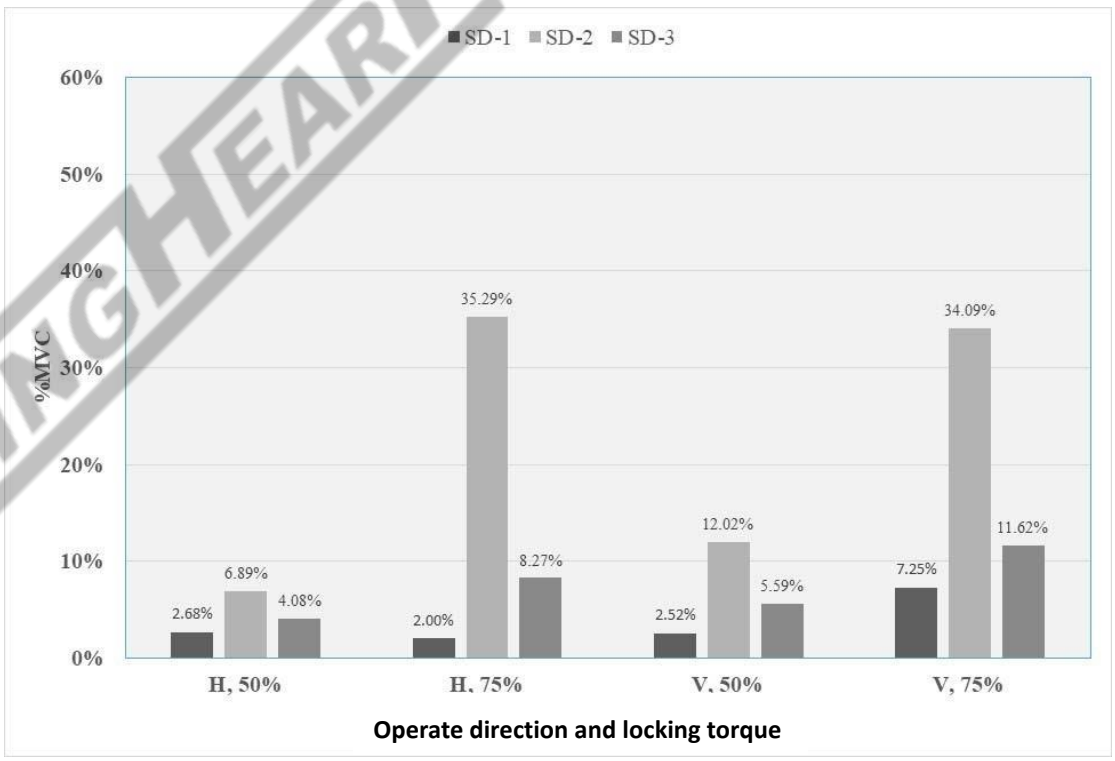

Figure 8. Flexor digitorum superficialis, FDS muscle group force proportion(%MVC)

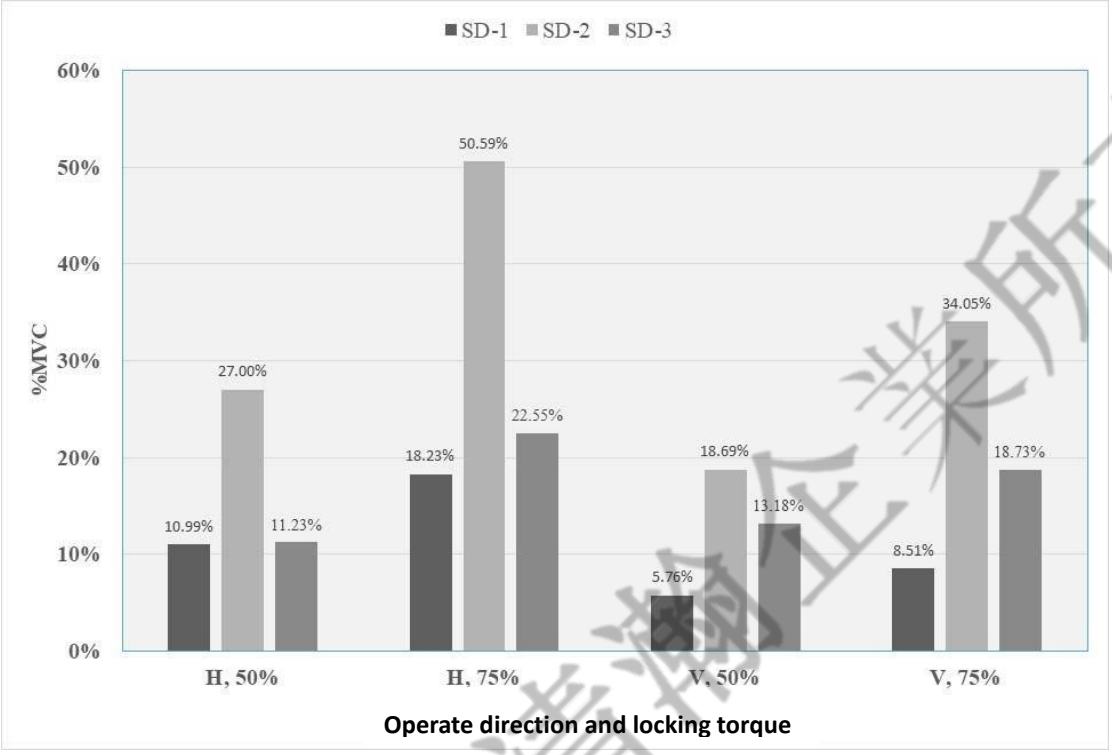

Figure 9. Flexor carpi radialis, FCR muscle group force proportion(%MVC)

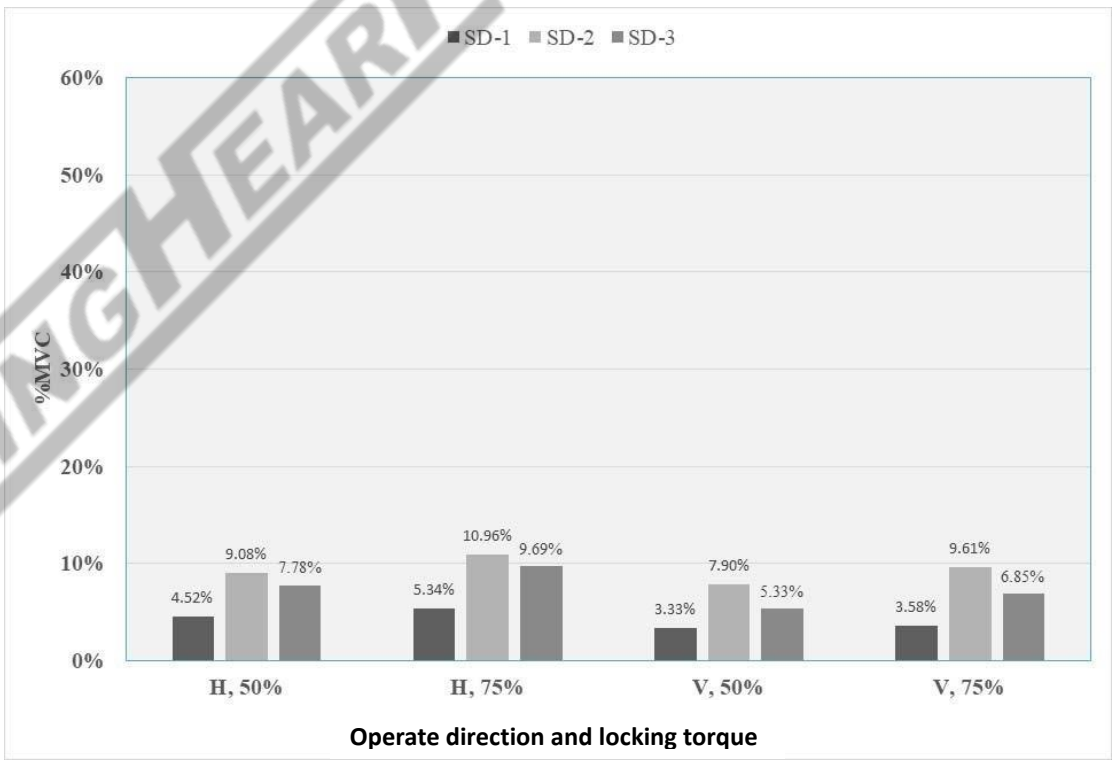

Figure 10. Extensor carpi radialis longus, ECR muscle group force proportion(%MVC)

3.3 Screwdriver use satisfaction

This experiment used the Likert scale to assess the satisfaction of 12 male subjects using three screwdrivers to 50% and 75% locking torque horizontally and vertically, the result as shown in Figure 11. The subjects had a satisfaction rate of 5 points (very satisfied) with SD-1 screwdrivers. Satisfaction with SD-2 screwdrivers ranges from 2.42 points (horizontal work, 75% torque) to 3.58 points (vertical work, 50% torque). The satisfaction of using the SD-3 screwdriver ranges from 2.50 points (horizontal operation, 75% torque) to 4.25 points (horizontal operation, 50% torque). The satisfaction of the subjects with SD-1 screwdrivers was higher than with SD-2 and SD-3 highs of 1.42 - 2.58 and 0.75 - 2.50. Indicating that the respondents were more satisfied with using the screwdrivers with special soft structure inside the handle to work on both horizontal and vertical surfaces than the other two screwdrivers.

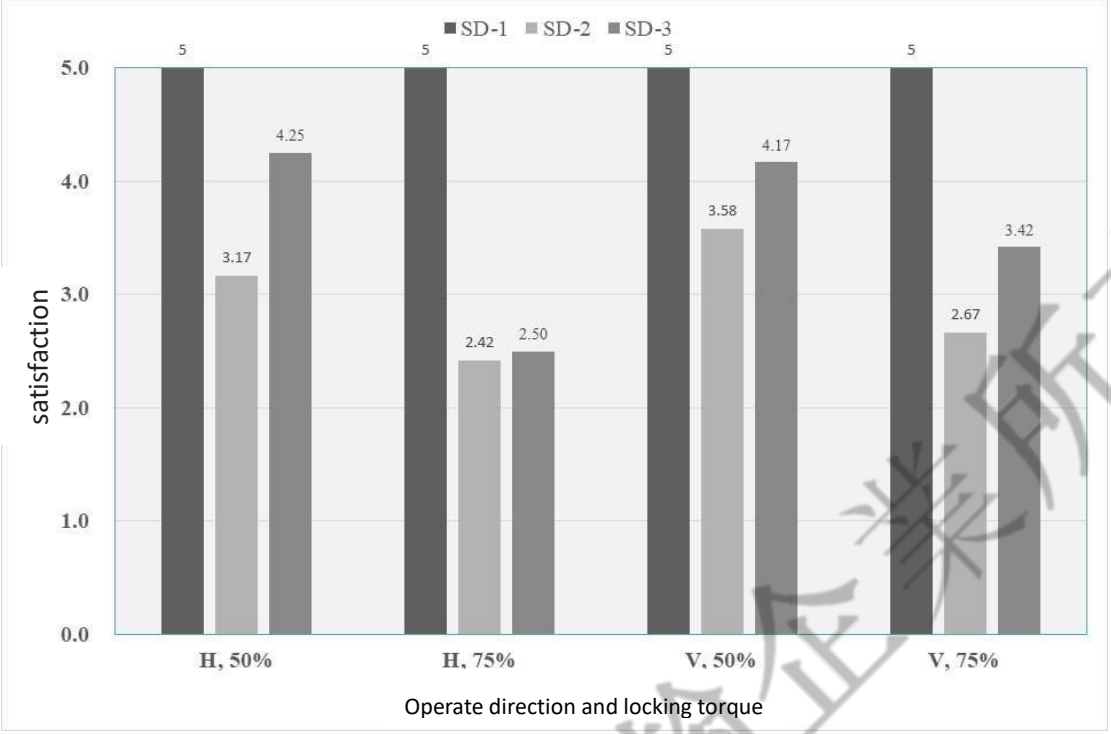

Figure 11. Subjective satisfaction with the use of screwdrivers

Ⅳ. Conclusion

In terms of maximum torque measurement, the SD-1 screwdriver with a special soft structure inside the handle can perform the maximum force torque on the horizontal surface are 2.77 times higher (SD-2) and 1.61 times (SD-3) than the other; the maximum torque that can be performed on the vertical surface are 2.41 times higher (SD-2) and 1.45 times (SD-3) than the other two screwdrivers.

In terms of muscle force measurement, when locking operations are performed at each fixed torque, the proportion of the SD-1 screwdriver four muscle group muscle applied force (%MVC) is lower than the other two screwdrivers, showing that compared to the other two screwdrivers, the screwdriver (SD-1) inside the handle has a special soft structure can effectively reduce the strength of the forearm muscle group in the horizontal and vertical surface operation.

When locking work with any screwdriver at maximum torque, the load on the hand and wrist part should be similar. Therefore, the comprehensive maximum torque and muscle force test results, to fixed torque for locking work, the screwdriver with a special soft structure inside the handle can effectively reduce the force load of the hand and forearm site, and then reduce the damage of muscle soreness caused by using screwdrivers.

Appendix Ⅰ. Forearm four muscle groups icon (Derived from Wikipedia)

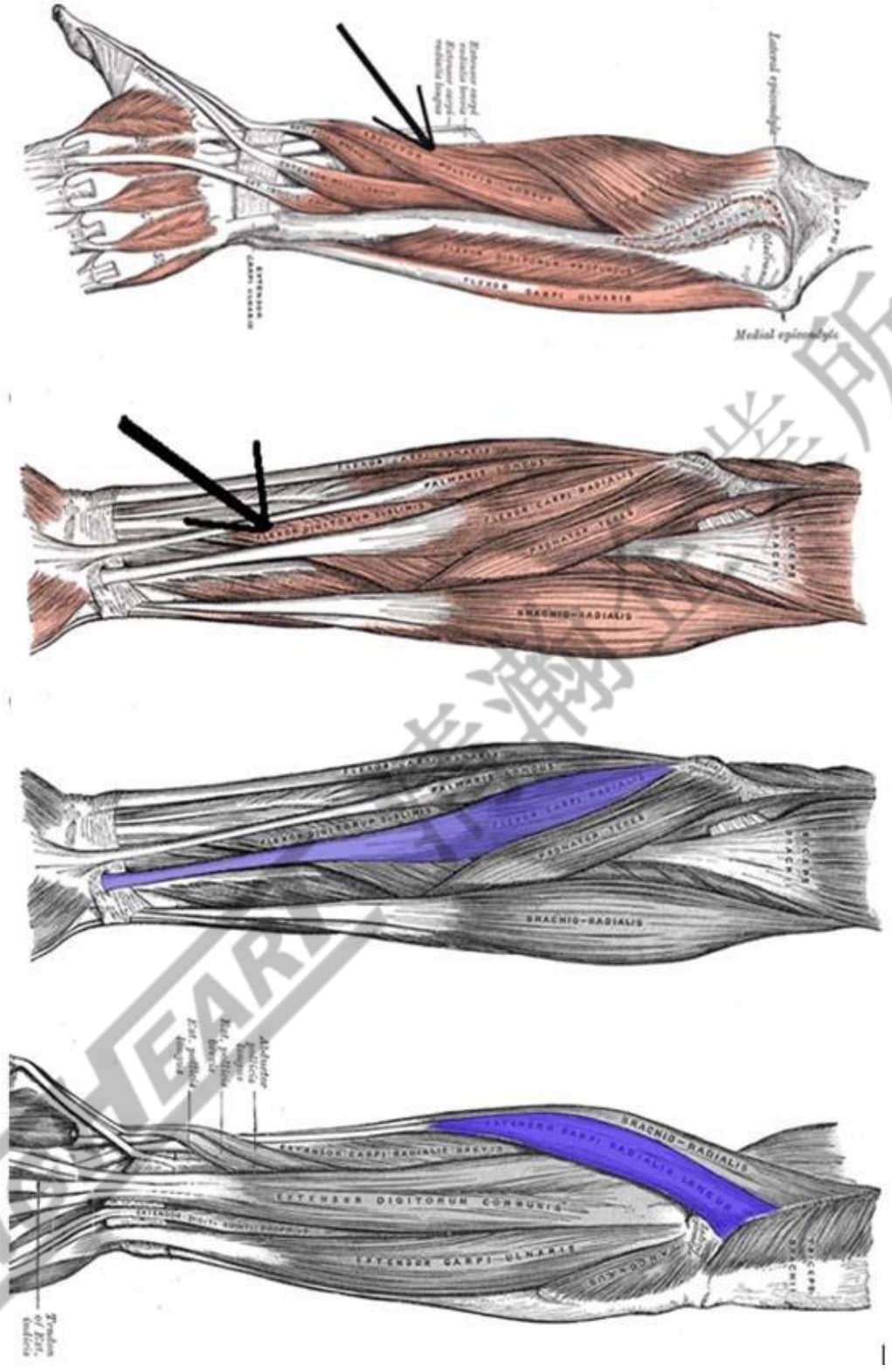

Figure 12. The muscle from top to bottom are abductor pollicis longus, flexor digitorum superficialis, flexor carpi radialis, and extensor carpi radialis longus