Estimation of maximum output force direction considering function of bi-articular muscles by joint torque

H. Takahama[1], M. Yoshimura[2], M. Manno[3], T. Koide[4], T. Fujikawa[1]
[1]Osaka Electoro-Communication University Graduate School, Osaka, Japan
[2]SHOWA University Fujigaoka Hospital, Kanagawa, Japan
[3]Ritsumeikan University, Kyoto, Japan
[4]Osaka Electro-Communication University, Osaka, Japan
Email: dl21b001@oecu.jp

Summary

The joint torque commonly used for muscle strength evaluation does not take into account the function of bi-articular muscles that act on two joints simultaneously. Therefore, this study attempts to estimate the output force characteristics of the wrist joint while considering the function of bi-articular muscles using joint torque values.

Introduction

Joint torque is commonly used for evaluating limb muscle strength. However, joint torque does not account for the function of bi-articular muscles, which act on two joints simultaneously. This has been demonstrated by the difference between the parallelogram-shaped output force distribution calculated based on joint torque and the hexagonal output force distribution that considers the function of bi-articular muscles [1]. Therefore, this study attempts to estimate the characteristics of the output force exerted at the distal end of an upper limb while considering the function of bi-articular muscles using joint torque values.

Methods

The subjects were seven healthy male university students. The hexagonal output force distribution at the wrist joint was calculated using the maximum output forces P_i (i=1−6), measured with a load cell at the wrist joint while the body was fixed in a seating frame, as shown in Figure 1. During the measurement, the straight line connecting the wrist and shoulder joints was kept perpendicular to the frontal plane, and the elbow joint angle was set at 90°. The movement plane was adjusted to ensure that the shoulder, elbow, and wrist joints were aligned horizontally. The parallelogram-shaped output force distribution at the wrist joint was determined using the shoulder joint torque, measured with a load cell placed on the upper arm, and the elbow joint torque, measured with a load cell placed on the forearm, while the body was fixed in the frame. The joint angles were also maintained at 90° during the joint torque measurements.

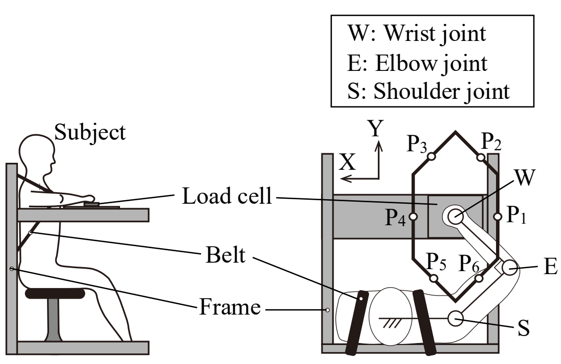


Figure 1. Measurement position and output force direction for hexagonal output distribution

Results and Discussion

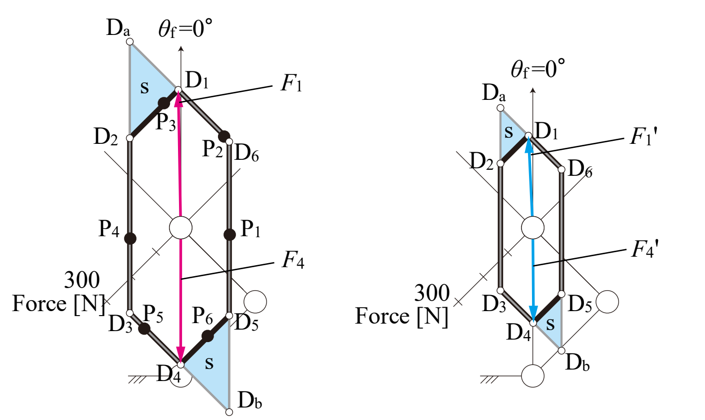
Figure 2 shows the results for one subject. The black line in Figure 2(a) represents the hexagonal output force distribution D_i (i=1−6) obtained from the measured maximum output forces P_i (i=1−6). The gray line represents the parallelogram-shaped output force distribution D_i (i=a,3,b,6) estimated from the hexagonal output force distribution. From these results, the ratio of the sum of the areas of shaded triangles D_a−D_1−D_2 and D_b−D_4−D_5 to the total area is calculated to be 2s=30.7%, with each shaded triangle having an area ratio of s=15.4%. The gray line in Figure 2(b) represents the parallelogram-shaped output force distribution D_i' (i=a,3,b,6) obtained from the joint torques. Using the value s=15.4% obtained from Figure 2(a) as a reference, the hexagonal output force distribution was estimated, resulting in the black outlined hexagonal output force distribution D_i' (i=1−6) in Figure 2(b). The angles for the maximum output force directions in the hexagonal distribution in Figure 2(b) are θ_{F1}'=3.6° and θ_{F4}'=180.8°, which are close to the values θ_{F1}=0.4° and θ_{F4}=180.7° in Figure 2(a). These results suggest that muscle strength evaluation using joint torque can also take the function of bi-articular muscles into consideration.

Conclusions

Using numerical values of joint torque in the upper limb, we estimated the output characteristics considering the function of bi-articular muscles. As a result, we were able to predict the maximum output force direction at the wrist joint based on the shoulder and elbow joint torques.

References

[1] T. Oshima et al. (2012). *Journal of the Japan Society for Precision Engineering*, **Vol. 78**, **No. 1**: 62-66.



(a) Output force distribution from output forces Pi (i=1−6)

(b) Output force distribution from joint torques

Figure 2. Output force distribution for one subject