POWER GRIP FORCE IS MODULATED IN DYNAMIC ARM MOVEMENT

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INTRODUCTION

During hand precision grip both grip force (normal to the contact surface) and load force (tangential to the contact surface) are needed and a strong coupling between these two forces has been well documented under various conditions ranging from lifting an object to performing rapid arm movement (Gao et al. 2005). Though precision grip is very useful in our daily lives, power grip is often used in work settings. Power grip force could be evaluated using hand dynamometer and this has been standardized in ergonomics and hand rehabilitation. Though most of job activities, such as food processing, construction, need power gripping coupled with dynamic arm movement only few studies have been done to evaluate the power grip force in dynamic condition. The objective of this study is to examine the modulation of power grip force under dynamic arm movement and its relationship to muscle activities and potential risk related to musculoskeletal injury. We hypothesize that the power grip force will be modulated with the dynamics of arm movement. Specifically, with the increase in speed of arm movement the physical demanding will be increased as indicated by an increase of EMG activities. The increase in muscle activities may be related to a higher risk of musculoskeletal injury incurred in the working sites.

METHODS

Six subjects voluntarily participated in the pilot study. Subject was standing erect and instructed to hold a digital dynamometer with three different levels of grip forces (low, medium and strong, corresponding to 20%, 40% and 60% of the maximum grip force respectively) and perform cyclic arm movement in the sagittal plane at three different speeds (slow, self-paced, fast) with upper arm held by side. BIOPACK MP150 system (Aero Camino, Goleta, CA 93117, USA) with accelerometer (±5 g), EMG and hand dynamometer (.315 kg, Isometric range: 0-100 Kg) modules were used for hand acceleration, muscle activity and grip force recording. Hand acceleration, muscle activity (sEMG) and grip force were recorded using AcqKnowledge software at a rate of 1,000 Hz. Before each task the subject was asked to practice and be familiar with the speed and force level prescribed. The data collection was started as soon as the subject was ready to keep the grip force and arm movement. The subject was instructed to keep the grip force and arm movement rate for about 30 s. Initially, the elbow was flexed at 90 degrees with forearm pronated. In total, subject performed 9 tasks. Each task lasted ~30 second and a one min break was provided to avoid fatigue. For each task, surface Electromyography on major elbow flexors (Biceps Brachii), elbow extensors (Triceps Brachii) and finger flexor muscles were recorded (Figure 1).
Raw sEMG signals were processed with bias removal, full-wave rectification and low pass filtering (5 Hz cut-off frequency) and then normalized with respect to the largest value of activation obtained in each muscle group. Muscle co-contraction was quantified using the method proposed by Frost et al. (1997). However, in this study a 5 second window was used in stead (Figure 2). Averaged normalized EMG signals within 5 seconds were used to quantify the muscle activities. Grip force was high pass filtered to remove the baseline drift and standard deviation was calculated to quantify the modulation of grip force with respect to arm movement. Statistics including t-test and one-way ANOVA were conducted using SPSS (SPSS Inc., Chicago, IL, USA).

RESULTS and DISCUSSION

In general, the cyclic movement frequencies were consistent across subjects, ranging from 1.6±.15 to 4.27±.15 Hz with self-paced frequency at 2.27±.46 Hz. With the increase of cyclic movement speed (P<0.05) and grip force level (P<0.05) the deviation of normalized grip force increased. In addition, the corresponding grip index, characterized as the normalized EMG activity, increased with the increase of both grip force levels (P<0.05) and cyclic movement speed (P<0.05). The index of co-contraction of elbow muscles also increased as either grip force level (P<0.05) or cyclic movement speed increased (P<0.05). Using a simple model based on harmonic motion the elbow joint stiffness was found to be proportional to the square of cyclic movement frequency and the moment inertia of the forearm and hand-held object.

CONCLUSION

In summary, the increase of co-contraction of elbow muscles with the increase of arm movement frequencies (dynamics) could be attributed to the increase of elbow joint stiffness and hence will facilitate the fast arm movement. The increased physical demand will result in higher muscle activities and potential risk of repetitive musculoskeletal injuries. The results of this study could provide recommendation for workers who will experience both power grip and dynamic arm movement. Based on the pilot study we recommend that power grip force coupled with fast arm movement should be avoided or reduced in the working sites and if needed arm movement should be performed at a self-paced or even lower rate.

REFERENCES