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Evaluation of Hand Grip Strength and EMG Signal on Visual Reaction

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***Abstract*—**Hand grip strength has been utilized as an indicator to evaluate the motor ability of hands, responsible for performing multiple body functions. It is, however, difficult to evaluate other factors (other than hand muscular strength) utilizing the hand grip strength only. In this study, we analyzed the motor ability of hands using EMG and the hand grip strength, simultaneously in order to evaluate concentration, muscular strength reaction time, instantaneous muscular strength change, and agility in response to visual reaction. In results, the average time (and their standard deviations) of muscular strength reaction EMG signal and hand grip strength was found to be 209.6 ± 56.2 ms and 354.3 ± 54.6 ms, respectively. In addition, the onset time which represents acceleration time to reach 90% of maximum hand grip strength, was 382.9 ± 129.9 ms.

***Keywords*—**Hand grip strength, EMG, visual reaction, endurance.

I. Introduction

HANDS are one of the body parts responsible for free movements and multiple body functions. As expected, the motor ability of hands is critical in various aspects such as a routine living activities, occupational environments, and exercise. Mostly, the motor ability of hands is often evaluated using the assessment of hand grip strength and it (i.e., the hand grip strength) is known to indicate how long do hands sustain muscular strength over certain period of time; it has been also utilized as an indicator to predict ADL (activities of daily living), physical capacity evaluation, as well as a physical disability [1]. As a human body ages, there are decreases in nimbleness, muscular strength, and endurance due to the loss of muscle mass. Because of this, not only many operations dependent on hand grip strength cannot be performed efficiently but also the risks of accidents or injuries are increased [1]-[5]. Trainings in muscular strength may recover lowered hand grip strength in consequence of either aging or diseases (disorders). It is however difficult evaluate muscular strength of hands via the assessment of hand grip strength warranting relevant additional indicators for endurance and nimbleness of hands [6]. Of those, endurance particularly represents the muscular strength for sustaining and maintaining force and thus is suitable to evaluate in relation to hand grip strength [7]. There are multiple investigations have been performed in regards to sEMG (surface electromyography) as it quantitatively analyzes muscle exercise unit for overall activity and easily extract signal thereby assessing muscular strength and endurance for various motor abilities of hands; further, a number of quantification studies have dealt with hands' functions and performance of rehabilitation due to brain diseases via evaluation of changes in hand grip strength [5], [7], [8]. In this study, it was analyzed for real time analysis of changes of hand grip strength and EMG signal in response to visual reaction via a digital hand grip and EMG in order to assess motor ability of hands such as reaction time and endurance.

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II. Method and Materials

A. Subject

In this study, we recruited seven healthy adult men subjects (21-28 olds, 177 ± 5cm height, and 74.6 ± 11 kg body weight) who did not have any previous musculoskeletal-related medical history such as shoulder, and arms.

B. Experimental Posture

Subjects were educated about the objectives of the experiment and its methods in detail prior to participate. Depending upon the angle of shoulder and elbow, the hand grip strength could be changed since it is consisted of multiple joints such as flexion/extension and pronation/supination of shoulder, elbow as well as wrist. Therefore, in the study, we attached EMG electrodes and then asked subjects to hold the standard posture recommended by the American Society of Hand Therapists (ASHT) which is a sitting position with 0° of shoulder and 90° of arm angle in advance to the evaluation.

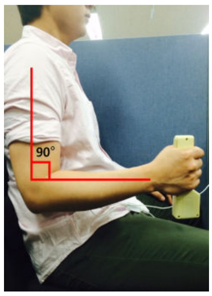

Fig. 1 Measurement of hand grip strength in a sitting posture

C. Placement of EMG Electrodes

As shown in Fig. 2, the EMG electrodes were attached on the Flexor Digitorium Superficialis (FDS) which is anatomically responsible for flexion of wrist and fingers. We utilized active EMG AM 530 sensors (Laxtha Co. Daejeon, Korea) with excellent sensitive Ag/AgCl (bipolar) electrodes, widely used for EMG signal measurement. The effective signal range of

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EMG was 10~500Hz and the sensor data was A/D converted with 1 kHz sampling speed using the ATmega 16. Once converted, data was acquired via PC and serial communication and then analyzed [9].

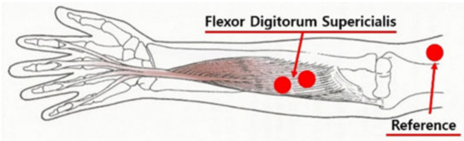

Fig. 2 Attachment location of EMG electrodes

Acquired raw data of EMG signal was rectified with full-wave and then converted to average EMG signal by applying moving average with window sized 50 in order to simplify computational complexity and to monitor changes in muscle usage over time[10]. Raw, full-wave rectified and average EMG signal data are shown in Fig. 3.

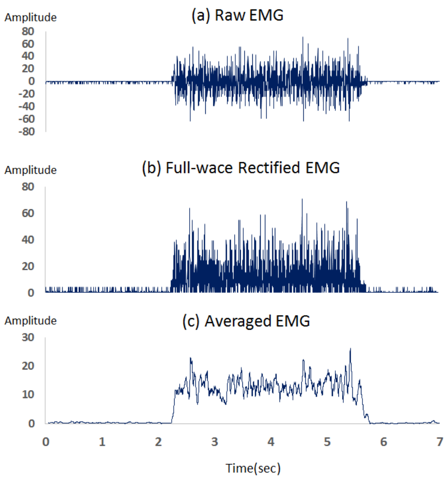

Fig. 3 Representative EMG signal results

D.Digital Hand Grip

As shown in Fig. 4, a digital had grip and a wireless receiver were self-manufactured for the study. This digital hand grip was mounting with load cells that can measure up to 60 kg with the error rate ± 0.1 kg. Data was acquired with the 100 Hz sampling frequency and transferred to PC using the Zig-bee.

Fig. 4 Digital hand grip and a receiver

E. Experimental Design

The experiment was performed in three phases. Firstly, reaction time of EMG and hand grip strength in response to visual reaction was compared. Secondly, the onset and offset time were assessed; the onset time was defined as the time needed to reach 90% of maximum hand grip strength whereas the offset time was for realizing force applied on the grip. Lastly, the endurance test was performed which measured the time maintaining 90% of maximum hand grip strength. Prior to the main experiments, subjects' average of hand grip strength was obtained through its measurement for five times. Fig. 5 shows the software developed for the evaluation of hand grip strength and muscular reaction in response to visual reaction. The experiment was began when traffic signal changes from green to red light and then hand grip strength as well as EMG signal were analyzed simultaneously. The reaction time (on) was compared in between time required for changes in hand grip strength and muscle after the visual reaction was given. For study participants, the guideline was provided for their 90% hand grip strength on the screen and the onset time, requiring time to reach 90% of hand grip strength from their 10%, was assessed. In addition, the endurance of hand grip strength and muscle were measured while participants were maintaining 90% of their maximum hand grip strength; once endurance was measured, changes in muscle as well as hand grip strength of reaction time (off) in between the time points when the signal was changing to green and applied force was completely released. Lastly, the offset time was assessed; the offset time was defined as time takes from the last moment for endurance test (i.e., 90% of hand grip strength) to 0 kg.

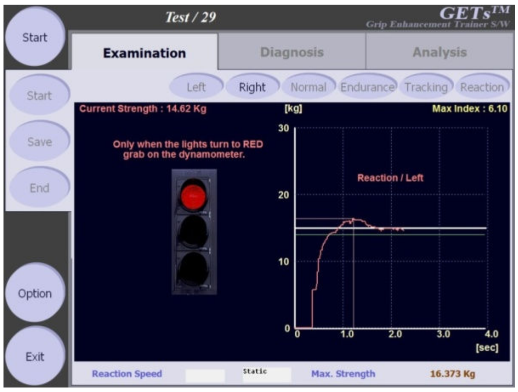

Fig. 5 The software for hand grip strength measurement in response to visual reaction

III. Results

Fig. 6 depicts the average of changes in EMG signal and hand grip strength measured via stepwise experiments.

A. Occurrence Time of EMG Signal and Hand Grip Strength in Response to Visual Reaction

The occurrence time of EMG signal and hand grip strength for reflexes in concentration and agility of muscular strength provided in response to visual reaction were measured and summarized in the Table I. Upon the visual reaction was provided, EMG signal was occurring as shown in the Fig. 6 (1) whereas hand grip strength was shown in the Fig. 6 (2). In that, occurrence time for EMG signal and hand grip strength were 209.6 ± 56.2 ms and 354.3 ± 54.6 ms, respectively. The results indicated that EMG signal is observed earlier than that of hand grip strength occurrence in most participants (144.7 ± 31.9 ms) which could be due to the electromechanical delay, time needed for actual muscular strength upon the activation of EMG [11].

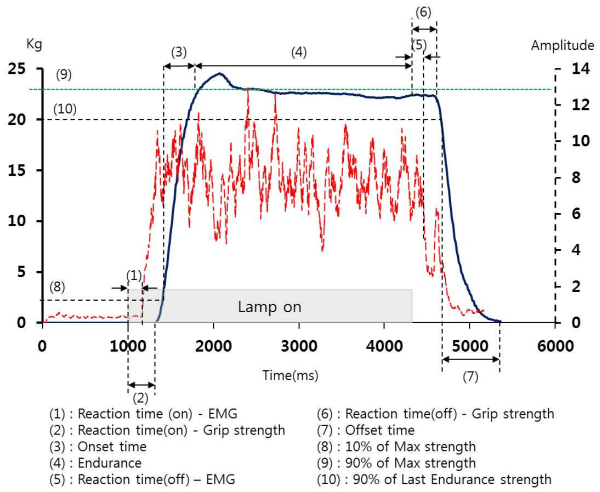

Fig. 6 Changes in EMG signal and hand grip strength

TABLE I
OCCURRENCE TIME AND EMG SIGNAL OF HAND GRIP STRENGTH IN RESPONSE TO VISUAL REACTION

Subject	Visual Reaction (on)		Visual Reaction (off)	
	EMG (ms)	Grip strength (ms)	EMG (ms)	Grip strength (ms)
A	156	334	117	330
B	169	291	138	238
C	291	443	247	484
D	229	320	115	287
E	289	431	162	243
F	183	317	128	248
G	150	344	144	293
Mean	209.6	354.3	144.7	301.9
SD	56.2	54.6	31.9	80.3

B. Onset Time and Offset Time

The onset time was defined as the time required for each subject to reach 90% of maximum hand grip strength from their 10%; in the study it was only analyzed for the onset time of hand grip strength since it is not possible to assess and analyze the EMG signal onset time. As shown in the Fig. 6 ((3) and (7)), the onset and offset time of hand grip strength were measured and summarized in the Table II in order to evaluate subjects' instantaneous hand grip strength and closed kinetic chain exercise.

The onset time and off set time were 382 ± 129.9 ms and 557.1 ± 72.8 ms, respectively which shows that the offset time is longer than onset time. This indicates that there are partial reactions in muscle to maintain muscular strength even though subjects released applied force [12].

TABLE II
ONSET AND OFFSET TIME OF HAND GRIP STRENGTH

Subject	Onset time (ms)	Offset time (ms)
A	300	510
B	570	480
C	540	600
D	180	450
E	440	590
F	310	670
G	340	600
Mean	382.9	557.1
SD	129.9	72.8

C. Endurance

In order to measure the endurance, the change in hand grip strength was monitored while subjects were maintaining their 90% of maximum hand grip strength. The results of endurance are shown in Fig. 6 (4). In general, endurance has been utilized to evaluate performance in isometric exercise, static exercise applying force into fixed objects, for rehabilitation. The average for 90% of maximum hand grip strength was found to be 22.9 kg while the average of changes (and standard deviations) in hand grip strength was 22.8 ± 1.1 kg. Endurance results from all participants are summarized in Table III and small changes in hand grip strength found in the study might be because they were young with similar ages. Further investigations with different age groups, sex, and occupations are warranted.

TABLE III
ENDURANCE FOR HAND GRIP STRENGTH

Subject	90% of Max grip strength (kg)	Averaged Endurance (kg)	Endurance SD
A	23	23.16	0.88
B	18	17.73	0.7
C	15	14.50	0.89
D	17	17.70	1.95
E	31	30.26	1.24
F	26	26.16	0.71
G	30	29.83	1.39
Mean	22.9	22.8	1.1
SD	5.9	5.8	0.4

IV. DISCUSSION

In the present study, we investigated and compared changes in EMG signal and hand grip strength in response to EMG signal. The reaction time of EMG signal in response to visual reaction was faster than that of hand grip strength (144.7±31.9 and 53.6±15.7ms for visual reaction (on) and (off), respectively). Results in visual reaction (on) indicate the differences in muscular strength agility and concentration of participants in regards to visual reaction. Furthermore, the onset time and offset time for hand grip strength were shown to be 382±129.9 ms and 557.1±72.8 ms, respectively. The onset time represents the instantaneous acceleration of hand grip strength whereas the offset time shows the existence of partial muscular reactions even after releasing the force applied on the

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grip upon the visual reaction. Since subjects were young adults with similar ages, the endurance test exhibited small changes in hand grip strength mostly. Hence, additional investigations with different age groups, sex, and occupations are warranted. Lastly, the magnitude of overshoot and time required for reaching 90% maximum hand grip strength may provide the quantitative results of hand grip strength control as well as subjects' concentration which might be utilized to assess the improved performance in concentration and controllability of hand grip strength followed by repetitive trainings.

For future studies, various experimental groups will be recruited in order to analyze the correlation between EMG signal and hand grip strength which is closely related to other muscular strength as well. To be specific, experimental groups can be stratified by sex and age in order to find the effects of aging on muscular strength decrease and poor nimbleness while groups stratified by occupations would show the correlation for muscular strength usage. Through these comparisons, more systematic indicators for hand motor ability might be proposed thereby utilizing for Activities of Daily Living (ADL) evaluation scales as well as health assessment.

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