

Research Article

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## Study on an Electrode Attachment Method Suitable for Underwater Electromyography Measurements

Seul-ki Han, PT, PhD · Jung-seo Park, PT, PhD<sup>1†</sup> · Taek-gil Nam, PT, PhD<sup>2</sup>

Daejeon Rehabilitation Center, Aaqua-Physical Therapy Team

<sup>1</sup>Department of Physical Therapy, Youngdong University

<sup>2</sup>Department of Physical Therapy, Daejeon Health Sciences College

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### | Abstract |

**PURPOSE:** This study was conducted to devise a method of preventing water infiltration into the surface electrodes during EMG measurements underwater and on the ground and to check the reliability of Electromyography (EMG) measurements when underwater.

**METHODS:** Six healthy adults were selected as subjects in this study. The measurements in this study were conducted in pool dedicated to underwater exercise and physical therapy room in the hospital building. An MP150 (Biopac Systems, US, 2010) and a BioNomadix 2-channel wireless EMG transmitter (Biopac Systems, US, 2012) was used to examine the muscle activity of rectus femoris, biceps femoris, tibialis anterior, gastrocnemius of dominant side. The subjects repeated circulation tasks on the ground for more than 10 min for enough surface electrode attachment movement. After a 15-min break, subjects performed the circulation task underwater (water depth 1.1m, water temperature 33.5°C, air temperature 27°C), as on the ground, for more than 10 min,

and the MVIC of each muscle was measured again. SPSS v20.0 was used for all statistical computations.

**RESULTS:** The maximum voluntary isometric contraction (MVIC) values between the underwater and on the ground measurements showed no significant differences in all four muscles and showed a high intraclass correlation coefficient (ICC) of >0.80.

**CONCLUSION:** We determined that EMG measurements obtained underwater could be used with high reliability, comparable to ground measurements.

**Key Words:** Underwater, Electromyography, MVIC

### I. INTRODUCTION

Interest in aquatic exercise has increased, and there are many ongoing studies to evaluate human body movements in water (Jung et al, 2010; Kim et al, 2000; Masumoto et al, 2008; Barela et al, 2006; Silvers et al, 2011; Masumoto et al, 2007). Through this study, we propose that electromyography (EMG) can be actively utilized to study movement underwater and on the ground by preventing water infiltration into the surface electrodes during EMG measurement. Water infiltration through the wires during

†Corresponding Author : emotion526@nate.com

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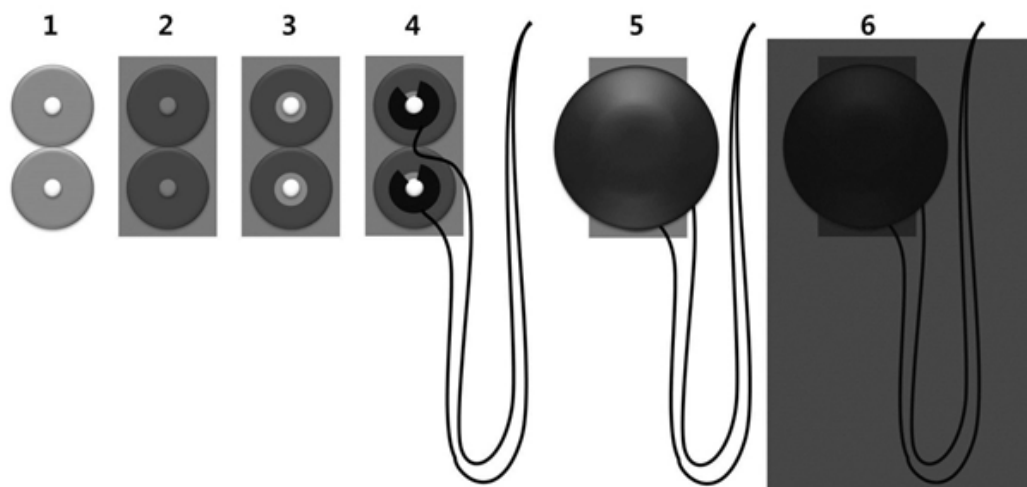


Fig. 1. Waterproof of surface electrode

movement could not be prevented when methods suggested in previous studies were used. Thus, in this study, we devised a method for resisting water infiltration through the wires using air pressure inside silicone pads. This study was conducted to devise a method of preventing water infiltration into the surface electrodes during EMG measurements underwater and on the ground and to check the reliability of EMG measurements when underwater.

## II. METHODS

The subjects of this study consisted of six males, and their age was 23~24 years. Their mean height was  $173.33 \pm 4.55$  cm and their mean weight was  $73.50 \pm 6.36$  kg.

The electrodes were attached to the subjects as follows. 1) An electrode was attached onto each of the four muscles (tibialis anterior, gastrocnemius, rectus femoris, biceps femoris). 2) A sheet of waterproof tape (AIDerm roll 10cm, Everaid, Korea) was attached to the surface electrode and to the skin around the surface electrode. 3) A hole was made in the waterproof tape to connect the catheter to

the surface electrode. The catheter was connected to the surface electrode. 4) The wire was fixed using downward-facing waterproof tape and then flipped upright, so that the wire faced towards the repeater on the surface of the water. 5) A silicone pad was attached to cover the whole catheter, and one large sheet of waterproof tape was attached to the skin, covering the whole silicone pad and part of the wire (fig 1).

The subjects repeated circulation tasks on the ground for more than 10 min for enough surface electrode attachment movement. The specifics of the circulation task were as follows. 1) walking on stable surface 10m. 2) Subjects walked on the foam surface of connected underwater sand bags(Aqua weight 7.5lbs, Sprint's, USA) for 10 m. 3) obstacles crossing (height 10cm, Isopa, Hwaseong, South Korea, 2010) 4) Obstacle climbing & downing (60cm\*40cm\*15cm, Aqua step, Sprint's, USA). And the maximum voluntary isometric contraction (MVIC) of each muscle was measured after the circulation task. After a 15-min break, subjects performed the circulation task underwater(water depth 1.1m, water temperature 33.5°C, air temperature 27°C), as on the ground, for more than 10 min, and the MVIC of each muscle was measured again.

Table 1. Comparison of muscle activity during maximum isometric contraction on the ground and unwater.

	Mean±SD(μV)		t-test <sup>1)</sup>	Correlation <sup>2)</sup>	ICC <sup>3)</sup>
	Ground	Underwater	z	r	
TA <sup>4)</sup>	2.59±0.46	2.70±0.57	-0.52	0.89*	0.89
GA	0.08±0.02	0.08±0.02	-1.57	0.83*	0.85
RF	0.12±0.05	0.12±0.04	-0.11	0.94*	0.96
BF	0.21±0.06	0.21±0.06	-0.31	1.00**	0.98

<sup>1)</sup>Wilcoxon signed rank test, <sup>2)</sup>Spearman rank correlation analysis, <sup>3)</sup>Intra-class correlation coefficient

<sup>4)</sup>TA: tibialis anterior, GA: gastrocnemius, RF: rectus femoris, BF: biceps femoris, \*p<.05, \*\*p<.01

SPSS v20.0 was used for all statistical computations. Descriptive statistics (mean and standard deviation) were calculated for MVIC scores for all muscles and testing conditions for each muscle, a Wilcoxon signed rank test with repeated measures was used to compare the MVIC scores between testing conditions. For each muscle, the intra-class correlation coefficient (ICC) was calculated to evaluate the reproducibility of MVIC scores between testing conditions.

### III. RESULTS

The MVIC values between the underwater and on the ground measurements showed no significant differences in all four muscles and showed a high intraclass correlation coefficient (ICC) of >0.80 (table 1).

### IV. DISCUSSION

Reports by Masumoto and Mercer (2008) have indicated the difficulty of quantifying movements in water, as water interference must be differentiated from collected data, and water damage to electronic devices must be prevented. Nevertheless, as quantifying movement is crucial to prove the efficacy of aquatic exercise, overcoming these challenges is important. Clarys (1985) reported that muscle activities in water tend to be lower than on land, which is different

from the present study. Also Pöyhönen et al. (1999) reported the similar present study. And Carvalho et al. (2010) reported that EMG amplitude with extra protection tend to be lower than without extra protection, which is different from the present study. Consistent with the present study, Silvers et al. (2001) reported no differences in measured muscle activities on land or in water. Rainoldi et al. (2004) suggested that lower muscle activity measurements were lower in water as electrodes were inadequately waterproofed and wires were improperly organized. Carvalho et al. (2010) stated that proper waterproofing should result in no difference between muscle activity measurements on land and in water. Therefore, improved technologies for measuring muscle activities in water are needed. Waterproofing methods suggested in previous studies allowed water infiltration through the wires when measurement was done over a long period of time or when specific movements were performed underwater. Water infiltration resistance was explored in this study using a small amount of air pressure around the electrode attachment area. Although water infiltration was observed through the wires using the above-mentioned method, the water was not able to reach the surface electrode. Using this technique, we determined that EMG measurements obtained underwater could be used with high reliability, comparable to ground measurements.

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