Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

SEMG MEASUREMENTS ON LAND AND IN WATER PRIOR TO AND AFTER 60-90 MINUTES OF SUBMERSION (SWIMMING) ARE HIGHLY RELIABLE

Bjørn Harald Olstad[1], Jan Cabri[1], Christoph Zinner[2], Neuza Nunes[3] and Per-Ludvik Kjendlie[1,4]

Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway[1]
Institute of Training Science and Sport Informatics, German Sport University Cologne, Cologne, Germany[2]
Faculty of Science and Technology, New University of Lisbon, Lisbon, Portugal[3]
Vestfold University College, Tønsberg, Norway[4]

The purpose of this study was to investigate the reliability of surface electromyography (sEMG) measurements after being submerged (swimming) for 60-90 minutes. Isometric maximal voluntary contractions (MVC) on land and in water were collected of eight muscles in three males and three females (mean age 22.5±4.5 years). A paired samples t-test showed no significant differences in the mean MVC signal between pre and post test after prolonged water submersion ($p<0.954$ for average of the two highest MVC scores and $p<0.946$ for the highest MVC score pre and post submerging respectively). Intraclass Correlation (ICC)(1,1) were 0.977 and 0.972, the Chronbach's alpha was 0.976 and 0.972. The mean coefficient of variation for all muscles was 11%. Testing sEMG in water exercises, before or after a prolonged submersion seems to be highly reliable.

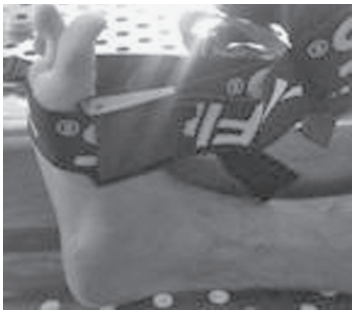
KEY WORDS: reliability, electromyography, methods, MVC, land, water.

INTRODUCTION: The use of surface electromyography (sEMG) in swimming and water exercises has become increasingly popular to monitor and objectivize muscle activity. However, the use of sEMG in water is slightly different from dry land conditions, and some challenges with respect to waterproofing the equipment and gluing the electrodes to the skin for a prolonged period of time are prevalent. Several previous studies have measured sEMG during aquatic exercises and the reliability of sEMG measurements comparing land and water situations. Many of these studies have found good reliability between land and water measurements. Silvers et al. (2011) and Pinto et al. (2010) found that during MVC, the sEMG values appear to be reproducible across the land and water testing conditions. Veneziano et al. (2006) also reported no changes during MVCs taken in air or underwater. Abbiss et al. (2006) showed that sEMG signal amplitude during isometric MVC can be accurately determined following water immersion. From these studies high reliability between sEMG obtained on land and in water can be expected. However, no previous studies have investigated the reliability of sEMG after a prolonged submersion. Therefore, the aim of this study was to investigate the reliability of sEMG measurements after prolonged submersion in water (60-90 minutes) and simultaneously to investigate eight muscles, four of the upper and four of the lower extremity.

METHODS: Six healthy sports students from the Norwegian School of Sport Sciences (three females and three males), age 20.5±2.5 years volunteered to participate in this study. All subjects provided written informed consent, and the study was approved by the local ethics committee of the university. All participants completed a familiarization session approximately 5±2 days prior to testing. The familiarization session included MVC testing on land and in water.
Eight muscles on the right side of the body were selected for this study; biceps brachii, triceps brachii, trapezius (pars descendens), pectoralis major (pars clavicularis), rectus femoris, biceps femoris, tibialis anterior (Figure 1A) and gastronemius (Figure 1B). To minimize skin resistance, electrode sites were shaved and cleaned with a solution of 70 %

alcohol. Disposable waterproof triodes (Plux Ltda, Lisbon, Portugal) were positioned in line with the direction of the muscle fibers. Anatomical references for the electrode placement were determined by the recommendations of the SENIAM project (Hermes et al., 1999). A ground electrode was placed in the middle of the forehead. The electrodes were covered with insulating tape around the outside perimeter. The waterproof electrodes were connected to waterproof EMG active sensors for sEMG (Plux Ltda, Lisbon, Portugal) with a band pass filter of 25-500Hz (-6dB) and with a gain of 1.000. The sensors were connected to the bioPlux Research (Plux Ltda, Lisbon, Portugal) inside a waterproof pouch with 8 analogue channels (12 bit) and sampled at a rate of 1000Hz. The signals were sampled into a laptop with the MonitorPlux software (Plux Ltda, Lisbon, Portugal) through a Bluetooth high range adapter.

Isometric MVC testing was used to verify the reliability of sEMG signal on land and underwater before and after 60-90 minutes of submerging and relaxed swimming (25m intervals). For each muscle MVC testing consisted of three trials lasting five seconds separated by 60 seconds of recovery in standardized exercises. Verbal encouragement was given to facilitate participants' maximal effort. For all subjects the MVCs were performed in the following order: (1) on land – (2) in water – (3) in water after 60-90 minutes submersion and swimming and (4) on land. The order of muscle testing was identical for each set of MVC tests on land and in water. During the MVC testing in water, water depth for each exercise was set so that all electrodes were fully submerged.


A

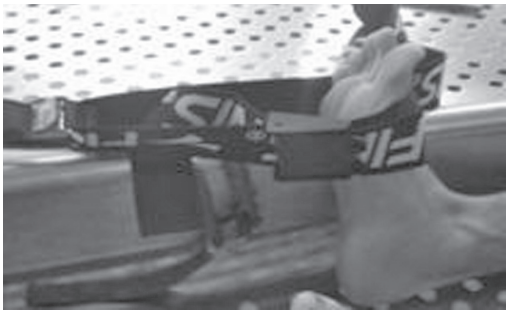

B

Figure 1: Standard position for the measurement of Tibialis anterior (A) and Gastronemius (B).

Raw sEMG signals were full-wave rectified and RMS windows of 200ms were centred on the highest peak for all trials. SPSS v18.0 (SPSS Inc, Chicago, III.) and Microsoft Excel (Microsoft Corp., USA) were used for all statistical computations between pre and post land measurements. A paired sampled t-test, ICC and Chronbach's alpha were carried out on the mean and average MVC signal between pre and post extended water submerging on land. Descriptive statistics (mean and standard deviations) were calculated for MVC scores for all muscles and testing conditions (pre land, pre water, post water and post land). For each muscle typical errors represented by the coefficient of variation (CV%) were calculated to provide an indication of the intra-class variability between pre and post water submersion.

RESULTS: The testing procedure of submersion in water for 60-90 minutes appeared to successfully maintain the reliability and integrity of the sEMG recordings. Average CV% was 11% and ranged between 4-17% between all muscles prior to and after water submersion, see (Table 1). Paired samples correlations for the average of the two highest MVCs and max peak MVC between pre and post water submersion showed r values of .954 and .946 ($p<0.05$). Chronbach's alpha was .976 for the average MVCs and .972 for max peak MVC. ICC(1,1) between pre and post water submersion were .977 for the average of the two highest MVCs and .972 for max peak MVC.

Table 1
Mean, Standard deviation (SD) and Coefficient of Variation (CV) for pre land and post water submersion

	Max peak RMS during MVC (μV)			Average RMS of 2 highest MVCs (μV)		
	Mean	SD	CV%	Mean	SD	CV%
Triceps b.	194.51	20.82	12%	179.21	20.28	12%
Biceps b.	251.22	27.19	11%	235.68	21.12	10%
Trapezius	386.63	15.44	4%	359.14	15.71	4%
Pectoralis	169.90	16.25	7%	158.40	13.73	9%
Gastronemius	100.53	19.43	21%	88.38	14.14	17%
Tibialis	165.16	15.32	11%	157.69	17.65	13%
Biceps fem.	140.59	13.76	10%	131.37	10.01	8%
Rectus fem.	174.84	23.79	14%	166.10	19.14	11%
Average:	201.22	18.32	11%	184.50	16.47	11%

DISCUSSION: The results of the present study showed that the sEMG recordings were not significantly different prior to and after 60-90 minutes of water submersion, indicating good to high reliability without additional waterproofing of the electrodes. The standardized exercises were designed so that they could easily be performed in a field setting on the pool deck and in the swimming pool with no stationary machines. The high coefficient of variation between land pre and land post for the average MVCs in gastronemius (17%) and tibialis anterior (13%), can possibly be influenced by this set-up. After inspecting the video recordings from the experiment we could see that the aimed joint angle of 90 degrees of the art. talo-cruralis did not stay constant through all trials. The strap did sometimes give the subjects a little range of motion through this testing procedure (see figure 1 and 2). Therefore, a follow up study on these two muscles with a different exercise set-up is needed in order to identify whether these two muscles can be reliably recorded after prolonged water submersion.

CONCLUSION: This study identified that sEMG measurements are highly reliable after 60-90 minutes of water submersion whether expressed as the maximal peak of three MVCs or as the average of the two peak values. The gastronemius muscle showed a CV of 21% for max peak and 17% for the average of the two highest. The tibialis anterior showed an average CV of 13%. Thus, both muscles showed variability in activation, which was higher than any of the other muscles measured.

REFERENCES:

Abbiss C.R., Peiffer, J.J, Netto, K.J. & Laursen, P.B. (2006). Reliability of surface EMG measurements of the quadriceps during maximal isometric contractions following water immersion. *Journal of Musculoskeletal Research*, 10(4), 197-203.

Hermes, H.J., Freriks, B., Merletti, R., Stegeman, D., Blok, J. Rau, G. et al. (1999). European recommendations for surface electromyography: results of the SENIAM project. 2nd ed. Roessingh Research and Development.

Pinto, S.S., Alberton, C.L., Cadore, E.L., Liedtke, G.V., da Silva, E.M. & Kruel, L.F.M. (2010). Electromyograpic signal and force comparisons during maximal voluntary isometric contraction in water and on dry land. *Eur J Appl Physiol,* 110, 1075-1082.

Silvers Moore, C. & Info, E.Z. (2011). Comparison and reproducibility of sEMG during manual muscle testing on land and in water. *Journal of Electromyography and Kinesiology*, 21, 95-101.

Veneziano, W.H., da Rocha, A.F., Gonçalves, C.A., Pena, A.G., Carmo, J.C., Nascimento, F.A.O. & Rainoldi, A. (2006). Confounding factors in water EMG recording: an approach to a definitive standard. *Med Biol Eng Comput,* 44, 348-351.