23

Water Surface Electromyography

David Pánek, Dagmar Pavlů and Jitka Čemusová
Department of Physiotherapy, Faculty of Physical Education and Sport,
Charles University
Czech Republic

1. Introduction

Registration of electrical muscle activity with the use of surface electromyography (SEMG) is today already a routine neuro-physiological method. Over the course of a few decades it has moved from the field of the purely experimental to the area of rehabilitation medicine, kinesiology, and sports issues. Together with this trend, interest has begun to deepen in the study of all types of movement patterns stereotypes conducted in a water environment and in a dry environment. This has also opened a new area of electromyographic diagnostics that represents a modification of the basic methodology of surface EMG in a water environment, so-called Water Surface Electromyography -WaS-EMG (Pánek et al., 2010).

Although current modern technology allows a huge number of computer post-processing of an acquired native recording, a key phase of the actual recording of electrical activity remains in the hands of the experimenter. For these reasons significant attention is paid to the methodology and issue of correct placement and fixing of electrodes in all neuro-physiological methods. In general approach, recording an EMG signal in a water environment is no different from the common methodology of surface EMG, but there are certain specifics in that case. Currently, great attention is paid in the literature to the issue of the different effect of water and dry environments on the nature of the EMG recording itself (Kelly et al., 2000; Masumoto et al., 2004, 2008; Rainoldi et al., 2004; Veneziano et al., 2006), and thus on the course of a defined movement stereotype (Kelly et al., 2000; Masumoto et al., 2004, 2005, 2008; Pavlů & Panek, 2008; Holländerova, 2011; Sladká, 2011).

In this work we take up the issue of Water Surface Electromyography (WaS-EMG), both in terms of research and the practical, including a summary of the results of several of our experiments.

2. WaS-EMG methodology

In our workplace we use a telemetric EMG instrument, the TelemyoMini 16, which is made by the Neurodata company. We evaluate and process the acquired data with the help of MyoResearch XP Master Edition software for concurrent video monitoring. However, the following items are also needed to complement the equipment for recording an EMG signal in a water environment (Fig. 1):

1. Water-resistant sac for the EMG amplifier and transmitter.
2. Special bipolar electrodes with a set of two-sided adhesive patches that are necessary for solidly affixing the electrodes to the skin.

3. Covering, waterproof patches for the electrodes, which prevent moistening and the subsequent release of electrodes into the water.
4. An abrasive and conductive paste.
5. Alcohol benzine.
6. Electrode conductive cream (from GE Medical System).
7. Universal Silicone.

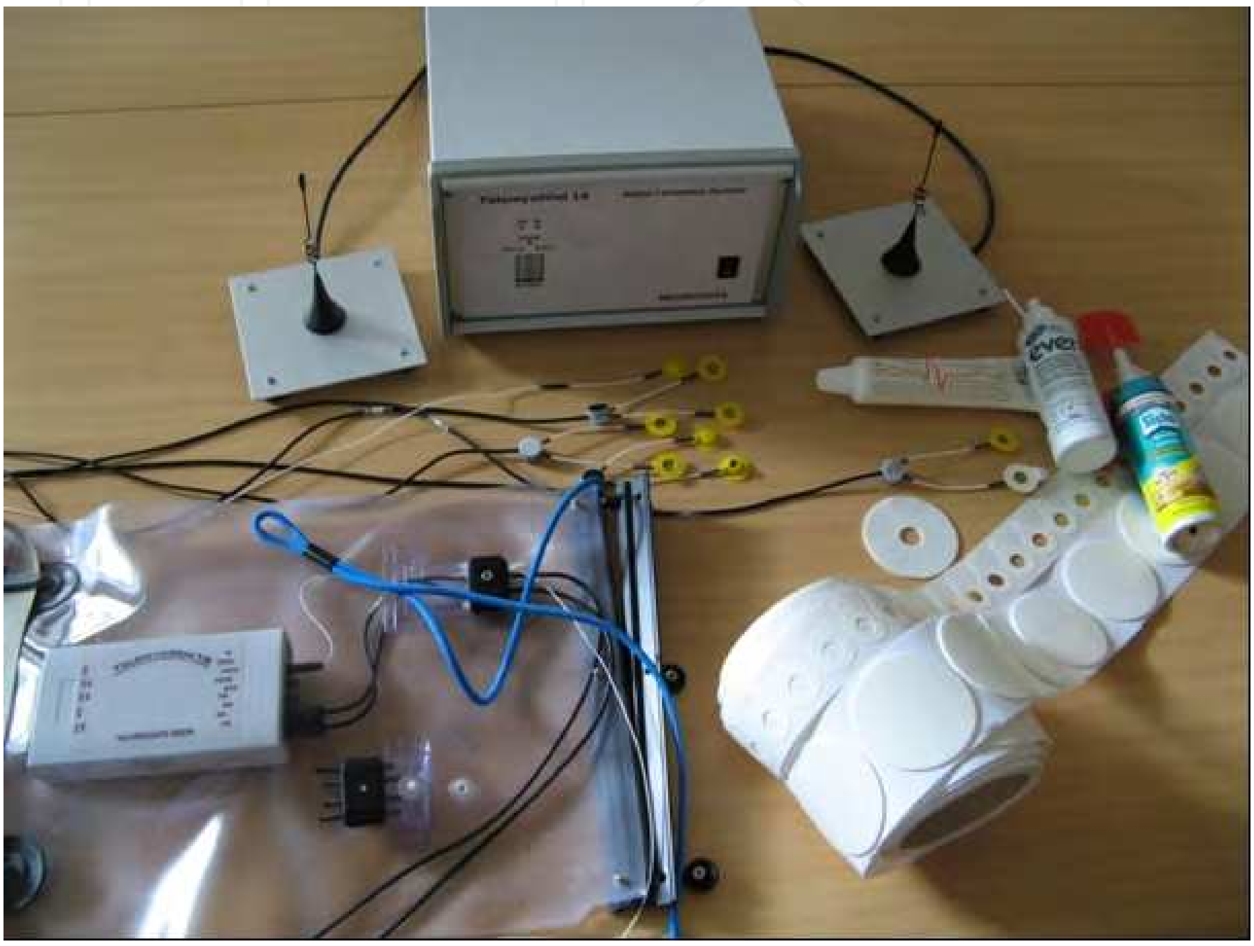


Fig. 1. The equipment for recording EMG singnal in a water environment (Pánek et al., 2010).

2.1 Preparatory phase of measurement

Significant attention must be paid to placing the EMG transmitter in the water-resistant sac. Unless we ensure proper sealing of the sac, the damage will reach large financial sums. Closing the main opening of the sac poses no problems, but sealing the openings for the bipolar electrode cables is more complicated. Because this involves relatively complex and precise work, we recommend immediately preparing all the cables that we have at our disposal. If we do not use all the cables in the measurement, we can secure the remaining cables with water-resistant adhesive tape right to the sac. We place the cables in grooves already prepared in the sealing rubber, which is divided into two halves and secured with a screw. Nevertheless, it is still necessary to assure that it is water-resistant by sealing the cables in the grooves with common Universal Silicone. This method makes it possible to later free up the cables and clean the grooves in the sealing rubber without problems. Before closing the main opening of the sac it is good to place the transmitter on a polystyrene board, which will allow the transmitter to float. In this way we can avoid loss of the EMG signal at the moment when the proband is moving actively in the water, which can lead to the EMG transmitter being submerged below water level (Pánek et al., 2010).

2.2 Application of electrodes on the skin

For recording an EMG signal in a water environment we use special bipolar electrodes (Fig.2). This involves Ag/AgCl disk electrodes that are 5 mm in diameter, which are embedded in plastic periphery so that only the central part, which is placed against the skin, remains free.

Fig. 2. WaS- EMG electrodes intended for water environments with accessories (Pánek et al., 2010).

Here, too, the basic rule applies that the electrodes are affixed to thoroughly cleaned and degreased skin. In our case, we used an abrasive tape and alcohol benzine. We stick two-sided adhesive tape, which copies the round shape of the electrode and is supplied together with the electrodes, to the plastic disk of the electrode, which is placed against the skin. Only then do we apply the conductive gel to the electrode. In our experience this phase is very important, because too much gel markedly increases the risk of the electrode coming loose during the course of the experiment. Of course a small amount does not ensure proper adherence of the electrode to the skin, it increases the impedance between the electrodes and the skin, and there is a weakening and disruption of the electrical signal. Each subsequent correction of the attachment to the skin is, due to the wet environment, significantly complicated. After sticking the electrode to the skin, we cover it with a special round sealing patch with a central opening, which we place precisely over the electrode. We also paste over the electrode cable; passing the cable through the central opening has not worked, as in water the electrode itself always came unstuck. Maintaining the recommended distance between electrodes at 1cm (DeLuca, 2002) is impossible for use of this methodology, as any decrease in the diameter of the covering patch leads to the electrode becoming unstuck. However, it follows from our experience that covering the individual patches by about 1/3 of their diameter is stable, and the electrodes do not fall off in water.

2.3 Affixing the water-resistent sac to the body, and entering the pool

After applying all the electrodes on the skin we can proceed to affixing the water-resistant sac to the body. It seemed to us that the best option is to pull the sac's blue hanger (Fig. 3) over the head and loosen it sufficiently so that during movement in water it will slip into the C-Th area and not cause an unpleasant feeling of pulling in the area of the neck. We adjust the sac's strap in the area of the torso in such a way that during movements the sac can be above water surface level.

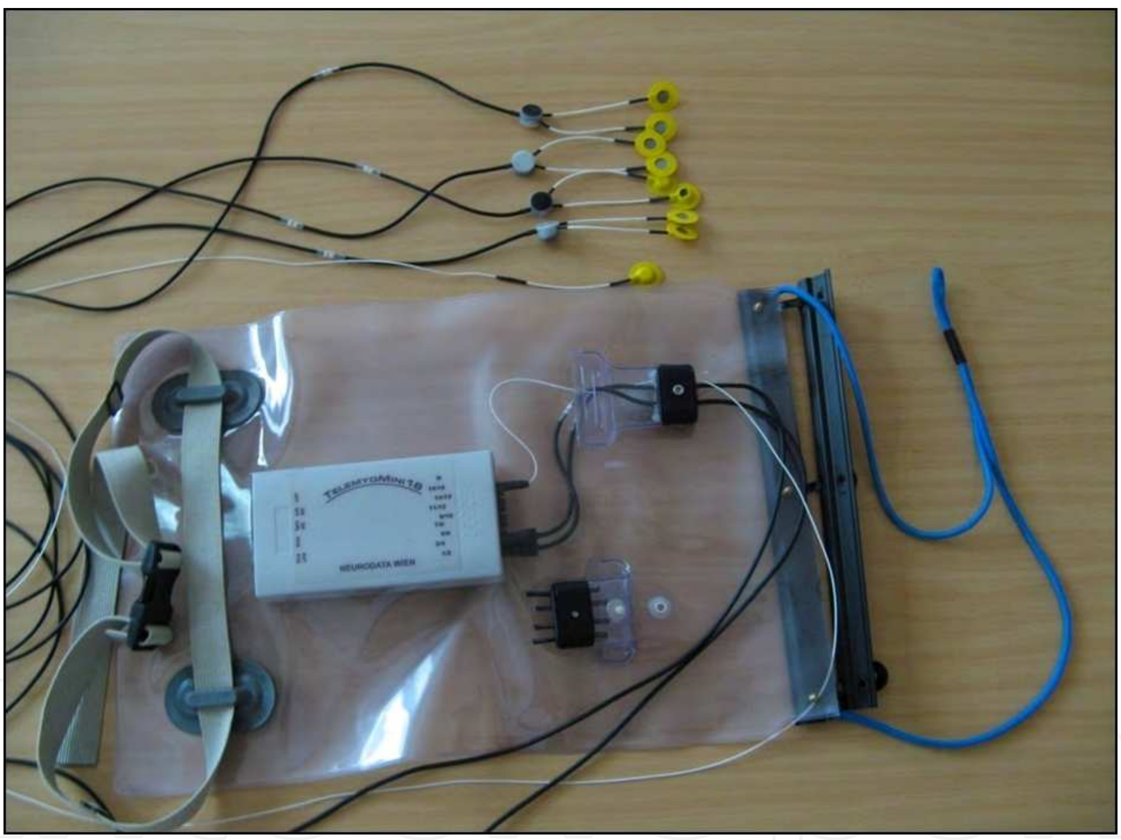


Fig. 3. Water-resistant sac with EMG transmitter and electrodes (Pánek et al., 2010).

It is necessary to affix the loose cables from the bipolar electrodes placed on the skin to the proband's body, because they can both obstruct movement and lead to detachment of the electrode from the preamplifier placed for the electrode itself, and their free movement can also affect the EMG signal (Rainoldi et al., 2004). It is possible to use water-resistant straps that are used in various water sports for affixing loose cables, but there is the possible risk of allergic contact reactions. One variant appears to be to cut patches for the electrodes that do not come unstuck in water or cause allergic reactions.

Because we are working in a wet environment, we must protect the EMG instrument itself and the notebook against damage. We select a place that is relatively well protected against

direct contact with water. For this reason, most of the affixing of electrodes and the overall preparation of the proband proceed further from optimal entry into the water.
In Figure 4 we see how the proband climbs over the side area of the pool only with the help of an assistant who holds the sac and the loose cables. We consider this method of entering the pool to be simply unsuitable, because its result can be only yanking or unsticking an electrode.

Fig. 4. Unsuitable entry into swimming pool

Fig. 5. Recommended entry into pool.

For this reason we recommend that the proband enter the pool in a freely accessible place, in our case by the steps, and on the side of the pool, where it is possible to comfortably stand on the bottom (Fig. 5). In this way the proband can´t demage the loose cables and the water-resistant sac, which remains on the water surface behind the proband. When using the telemetric EMG instrument it is necessary to ensure that the water-resistant sac remains above the water level during the course of the experiment. We achieved this by placing lightening floats right in the sac (Fig. 6), or we used an assistant who always kept the sac above water level, thereby limiting increased movement of loose cables during the course of the probands’ motor activity (Sladká, 2011).

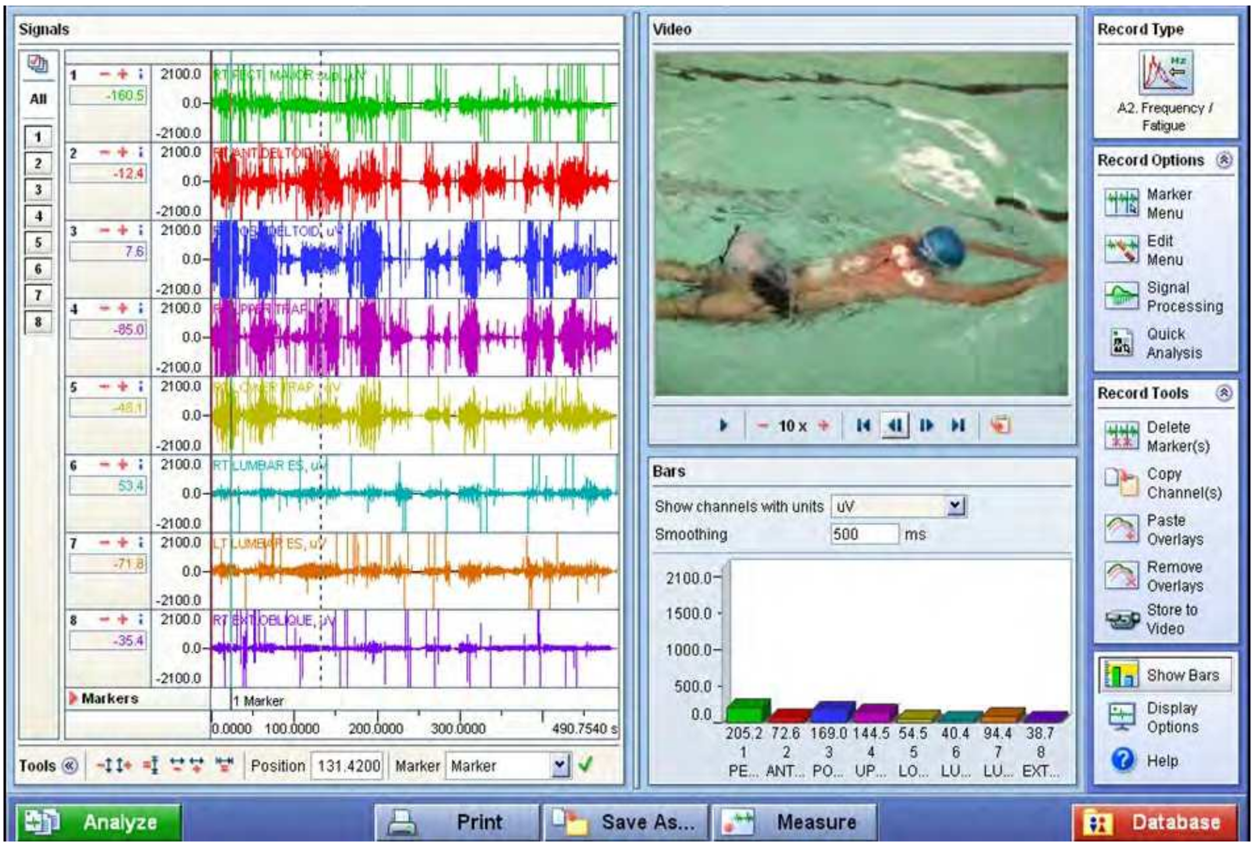


Fig. 6. WaS-EMG: Recording of swimming (Pánek et al, 2010).

The issue of the difference between telemetric measurement and direct connection of the EMG instrument and the electrodes by cables has already been dealt with in the study by Clarys et al. (Clarys et al., 1985). When using both methods for registering an EMG signal no difference was found. And for this reason, due to the more advantageous manipulation with the telemetric system, this method is primarily recommended for recording electrical activity of muscles.

Other technical parameters of registration are also taken up by Masumoto and Mercer (Masumoto & Mercer, 2008), who evaluated whether it is better to use a water-resistant suit or to affix each electrode covered by water-resistant tape with a foam cushion. Although a water-resistant suit appears to be better, there are also many disadvantages. The suit must both fit every individual, thereby increasing the price of the measurement, and the cables must leave through holes in the suit, resulting in potential places for leaks. And, last but not least, it is not entirely clear whether the suit limits the proband's dynamic movement. For these reasons, according to Masumoto and Mercer it is better to apply each electrode separately, with covers of waterproof tape.

3. Effect of water environment on the amplitude and spectral characteristics of an EMG signal

During electromyographic studies in a water environment, and especially when comparing the motor behaviour of an individual in water and on a dry land, the relevant question arises as to how the water environment affects the native EMG signal, and what the specific changes are in muscle activity caused by the change in gravitation and by the resistance of the water environment.

The original studies by Clarys et al. (Clarys et al., 1985) and Pöyhönem et al. (Pöyhömen et al. 1999) pointed to decreased amplitude of the EMG signal in the course of maximal voluntary contraction (MVC) in water compared to EMG activity on a dry land. But it was not clear whether this result was affected by methodological limitations or physiological changes caused by the water environment. That is to say, in both cases the authors did not use waterproof attachment of electrodes or attachment of electrode by means of adhesive tape (Sulkova, 2011).

A significant contribution to the solution of this problem is the study by Rainoldi et al. (Rainoldi et al., 2004). The authors monitored the EMG activity of the brachial biceps muscle during maximal voluntary contraction on a dry land, in standing water, and in a flowing water at 25° C. In all cases they compared the individual parameters of the EMG signal (average rectified value, root mean square, mean frequency, median frequency) during isometric contraction with and without attachment of electrodes by means of water-resistant adhesive tape and with attachment of free electrode cables. The results of the study indicated that without the covering tape over the electrodes, the amplitude of the signal is recorded in standing and flowing water as lower (by 6.7%) than during contractions on a dry land. A dramatic change appeared during isometric contractions in flowing water without the covering tape, when there was a significant increase of the frequency component in the low frequency band of 0-20Hz, which affected all of the monitored parameters. The incidence of this artefact was caused by the movement of free cables, and after they were affixed and the electrodes were glued on it disappeared. The conclusion of this study was to recommend the use, when registering EMG activity in water, water-resistant adhesive tape, whereby we can rule out the occurrence of marked artefacts and ensure constant conditions during the course of the entire experiment.

Da Silva Carvalhoa et al. (Da Silva Carvalhoa et al., 2010) present many studies that stress the importance of water-resistant tape when measuring EMG in a water environment, but also several practices that cast this fact in doubt. They conducted an experiment that should have clarified the inconsistency. We can see the following from the results: during isometric contractions in water without taping, there was a EMG amplitude decreased in to 50%. When comparing isometric contractions in a water environment with the use of covering tape, the results were in accord with those that were measured on a dry land with and without tape. So according to them, the covering tape used on a dry surface does not affect the EMG amplitude, yet it had a marked effect on the EMG recording in a water environment.

Similarly, Veneziana et al. (Veneziano et al., 2006) also recommend the use of covering tape in a water environment and on dry land, because among other things, the covering tape also develops a certain mechanical pressure on the skin and the muscle tissue under the electrode.

Many authors thus agree on the necessity of attaching the electrodes with water-resistant tape, which eliminates the artificially lowered amplitude of the EMG recording and the spectral changes in water. We thus ensure that the EMG signals acquired on a dry land and in water can be correctly reproduced and compared. When adhering to the correct methodology for attaching the electrodes the water environment does not affect the registered electrical activity of the muscle or the maximum muscle contraction.

Another discussed question is whether we should normalise the EMG data to the maximal voluntary contraction (MVC) in water or on a dry land. Masumoto and Mercer (Masumoto

& Mercer, 2008) recommend that it all be normalised to MVC on a dry land, because most prior studies were conducted in precisely by this way. Silvers and Dolny (Silvers & Dolny, 2001) tested maximal voluntary contraction on a dry land and in water on 12 probands. From the results they conclude that no marked difference was found between individual MVC values on a dry land and under water. So they also recommend normalisation to MVC values registered on a dry surface.

4. Effect of water temperature on the native EMG signal

The heat conductivity of water is 23 times higher than the conductivity of air. Dewhurst et al. (Dewhurst et al., 2005) documents that the temperature of a muscle is, under ordinary conditions, always higher than the temperature on the surface of the body. In a water environment there is a faster exchange of heat between the water and tissues, and therefore the organism cools earlier than on the air.

Proximal muscles are warmer at rest, by an average of 4.1° C, than distal muscles. Muscle temperature changes the most in the first 5 minutes after being submerged in water, and in 15 minutes their temperature equals the temperature of ambient water (Petrofsky J, 2005).

Petrofsky and Laymon (Petrofsky & Laymon, 2005) tracked the effect on an EMG signal in connection with water temperature on 7 probands. They registered EMG activity from the upper and lower extremities (m. biceps brachii, m. brachioradialis, m. quadriceps femoris, m. gastrocnemius) after 20 minutes of submersion in water at temperatures of 24°, 27°, 34° a 37° C. For all four examined muscles there was no statistically significant difference between the MVC values and the median frequency among the three highest water temperature. Nevertheless, after submersion in the coolest water (24° C), all of the monitored muscles showed a significant MVC decrease (by up to 44.8%), a shift of the median frequency by 32 Hz in the direction of lower values, and a slower speed of action potential conduction in the muscle fibre by 2m/s in comparison with the value achieved in the warmest water.

A similar issue was taken up in the diploma thesis by Stejskalová (Stejskalová, 2011), where she evaluated the amplitude changes in isometric contraction after 5 minutes in water at temperatures of 15° C, 24° C, 35° C for 30%, 50%, and 70% of the maximum output muscle strength measured by pressing a hand dynamometer. She registered EMG activity from finger flexors and the wrist of the right upper extremity, which was submerged in a water bath at the level of half the forearm. The results of the study, as opposed to the work of Petrofsky and Laymon (Petrofsky & Laymon, 2005), did not show any effect of water temperature on the EMG recording. This finding explains the shorter period of the extremity's submersion in water, when for the first time after 15 minutes the temperature between the ambient water and the muscle stabilize which subsequently appears in cool water as changes of electromyographic activity.

The water temperature and duration of submersion are significant factors that affect the EMG record. For these reasons, the stimulation of the water temperature must be stated and considered. According to Jandová (Jandová, 2009), after an isothermic bath the water bath temperature was designated as 34-35˚ C. But this involved baths in their entirety for which no physical activity was assumed. At a temperature of 25-32˚ C, the bath was cooling, hypothermal. At a temperature of 25˚ C there was already a decline in body temperature of 1˚ C after 7 minutes (Jandová, 2009). Most electromyographic studies in a water environment work at temperatures between 27 and 34° C (Miyoshi et al., 2004; Masumoto et al., 2004, 2009; Veneziano et al., 2006; Shono et al., 2007; Kaneda et al., 2008; Pavlů & Pánek, 2008).

5. Comparison of movement in a water environment and on a dry land

The growing popularity of all sorts of rehabilitation and fitness procedures in water has led to many studies that deal with dynamic regimens of muscle activity and their comparison when done on dry land or in water. The specificity of the water environment leads, in comparison with dry surfaces, to different muscle timing through a change in the proportional representation of activity agonistic-antagonistic muscles, and through a different compensation mechanism that follows from a certain postural “instability” in movements in water. Most published works deal with the issue of normal or modified gait or the monitoring of activity of muscles of the lower extremities in variously defined movements. Less attention is paid to the activity of muscles of the upper extremities, mostly with a focus on the shoulder girdle.

5.1 WaS-EMG analysis of walking in water

Movements in a water environment are affected by the viscosity of the water, which is eight hundred times as great as that of air. Bodies submerged in water are lighter than in air thanks to the buoying force. This buoying force of water decreases the vertical burden in a water environment against to walking on a dry land. This result was objectivised on the basis of treading on a Kistler pressure-sensitive surface in a water environment (Miyoshi et al., 2004).
Masumoto et al. (Masumoto et al., 2004) monitored muscle activity during walking on a treadmill in a water environment with the use of an water counterflow and without, and they compared it with walking on a dry land. They monitored muscles in the lower extremities (m.gluteus medius, m.rectus femoris, m.vastus medialis, m.biceps femoris, m.gastrocnemius lateralis, m.tibialis anterior) and bilaterally on the trunk (mm.paravertebrales in the area of the fourth lumbar vertebra and the m.rectus abdominis). The gait speed in a water environment (30 m/min, 40 m/min, 50 m/min) was half that of the gait speed on a dry surface. The depth of the water in the pool reached the level of the processus xiphoideus. Significantly lower electrical activity values were found in the monitored muscles when walking in a water environment with a counterflow and without a counterflow in comparison with identical movement on a dry land, the difference amounting to 10-20%. These results corresponded to previous studies, which also describe decreased EMG activity in a water environment compared with identical movement on a dry land (Clarys et.al., 1985; Fujisawa et al., 1998; Pöyhömen et al., 1999; Kelly et al., 2000). The following year Masumoto et al. (Masumoto et al., 2005) published a further study. In which, while keeping the previous conditions, they again monitored the activity of muscles of the lower extremity and trunk musculature while walking on a treadmill backwards on a dry land and in a water environment (with and without a water counterflow). They arrived at similar reasults. The sole exception was heightened activity of paravertebral muscles in the area of the fourth lumbar vertebra. They explained the increase in their activity in water by citing the greater resistance of the water environment, greater demands on balance, and backwards walking.
In the work of Shono et al. (Shono et al., 2007), electrodes were placed on muscles of the right lower extremity: m.tibialis anterior, m.gastrocnemius medialis, m.vastus medialis, m.rectus femoris, m.biceps femoris. Gait was measured among sixty years old women at speeds of 20 m/min., 30 m/min, and 40 m/min in a water environment, and then at twice these speeds on a dry land. The gait cadence was lower (by nearly one-half) and the stride length was longer in a water environment, if the same gait speeds in both environments were compared. However, when comparing the same intensity of movement, i.e.,

approximately 30 m/min in a water environment against 60 m/min on a dry land, the stride length was not significantly different. At a corresponding intensity of movement, nearly identical activity for the m. tibialis anterior, m. vastus medialis, and m. biceps femoris was recorded, but the m. gastrocnemius medialis and m. rectus femoris showed lower activity in a water environment. When comparing the results of the same speeds, activity of the tibialis anterior, vastus medialis, and biceps femoris was higher in a water environment, while activity of the gastrocnemius medialis and the rectus femoris was the same.
Pöyhönen (Pöyhönen T, 2001) evaluated the muscle activity of the m. quadriceps femoris and the m. biceps femoris during flexing and extension of the knee on a dry land and in a water environment. In the water environment the test was run with and without the use of a "Hydro Boot." Eighteen persons without any physical problems took part in the study. The underwater EMG results showed a decline in time in the concentric activity of the agonist muscles with concurrent activity of the antagonist muscles without the "Hydro Boot." When measuring activity in a water environment with and without the resistance boot the probands were seated on a chair so that they are submerged up to the mid-sternum level. In the results, the EMG amplitudes were similar in both cases. The authors are of the opinion that with and without the use of the boot the size of the EMG amplitude was similar, especially thanks to the "power-speed" relationship of the muscle contraction. But it was pointed out that if a muscle acts as an agonist it is active in roughly the first 50-60% of the extent of the movement. If it is acting as an antagonist it is active in roughly the last 50-60% of the extent of the movement, while on a dry surface an agonist is active throughout the entire period of movement and an antagonist shows only a little activity.

5.2 WaS-EMG analysis of muscle timing during cycling on dry land and in a water environment

In the work of Sladká (Sladká, 2011), with the help of surface EMG, was compared the timing of muscles of four probands aged 23-24, while riding a bicycle on a dry land and in a water environment. In the experiment she used two identical Sapilo water bicycles (Fig. 7). She placed WaS-EMG electrodes on the right and left paravertebrales muscles and the m. biceps femoris, m. gastrocnemius lateralis, m. vastus medialis, and m. tibialis anterior of the left, non-dominant extremity.

Fig. 7. Sapilo water bicycle.

The temperature of the water in the pool was 32˚ C (±0.5˚ C), and the temperature of the air was 28˚ C (±0.5˚ C). The depth of the water was up to 125 cm. The measurement itself of the EMG recording was made while riding on the water bicycle, first on a dry surface and then in the water. The pedalling speed was 60 revolutions per minute. The pedalling time on the dry land and in the water was one minute.

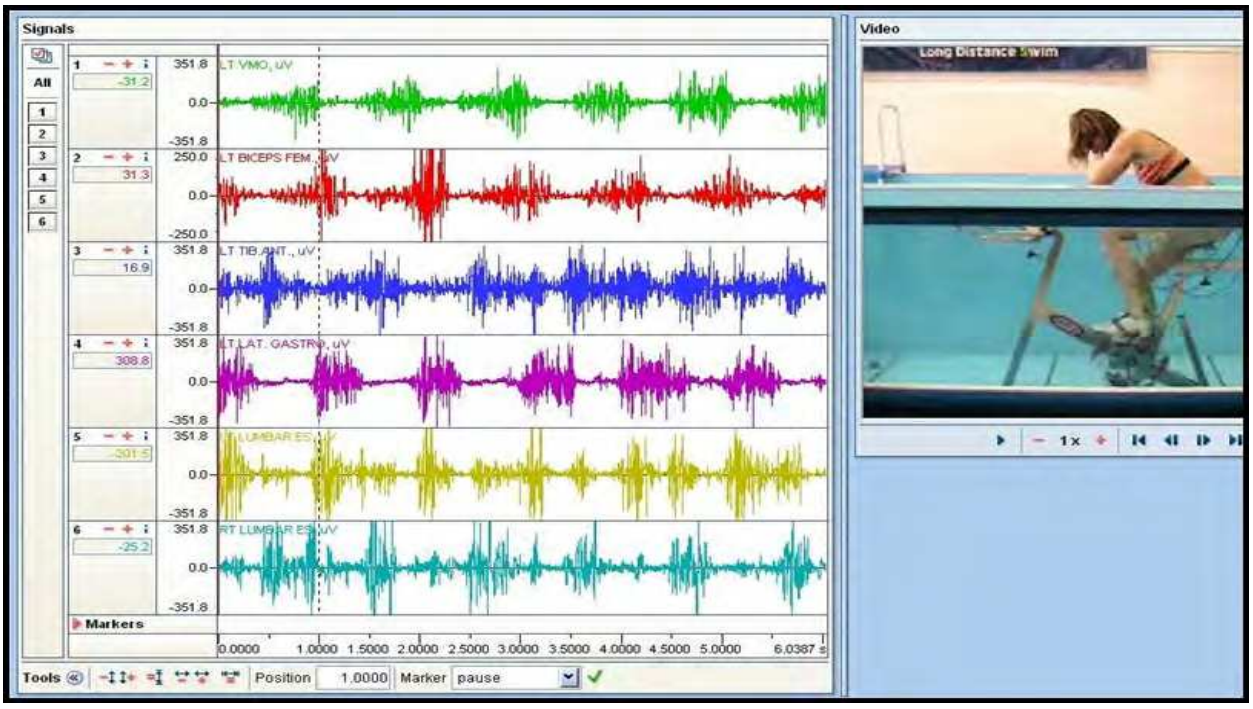


Fig. 8. EMG recording with a synchronized video recording. The interrupted vertical line captures the left lower extremity at the beginning of the pedal revolution (Sladká, 2011).

The results of the study did not show changes in the timing of the monitored muscles of the lower extremity when riding a bicycle on dry land and in a water environment. Due to greater demands related to stabilizing the pelvis in the water environment, there was co-contraction of both paravertebral muscles. On dry land this tendency was not recorded. At the same time, it was found that in the water environment pedalling was more regular than pedalling on dry land.

5.3 Analysis of muscles of the pectoral girdle with the help of WaS-EMG

The already outlined general trend towards decreasing electromyographical activity for identical movements in water versus dry land has also been described by many authors studying muscle activity in the area of the pectoral girdle (Rouard & Clarys, 1995; Fujisawa et al., 1998; Pavlů & Pánek, 2008).

Kelly et al. (Kelly et al., 2000) broadened their question to include the issue of the speed of abduction in the shoulder joint with a concurrent comparison of the activity of muscles of the rotator cuff and the synergies of the shoulder during exercise on dry land and in water. Six probands took part in the research. In the water environment, the probands were submerged up to neck level. In both environments they caused abduction in their shoulder joints at speeds of 30°/s, 45°/s, and 90°/s. The results showed that when the selected speed corresponded to 30°/s and 45°/s, the activity of the muscles (supraspinatus,

infraspinatus, subscapularis, and the front, middle and back parts of the deltoideus) was smaller than on dry land. At 90°/s, the muscle activity especially of the m. subscapularis, increased markedly.
Holländerová (Holländerová, 2011), during the course of her study, which was conducted in our workplace, evaluated the timing and size of activation of muscles during abduction in the shoulder joint as opposed to the resistance of a flexible pull on dry land and in water. The flexible resistance was provided with the help of Thera-Band yellow dye. Four probands took part in the study. EMG activity was registered from the m. trapezius pars superior et inferior and the m. deltoideus pars medialis muscles (Fig. 9).

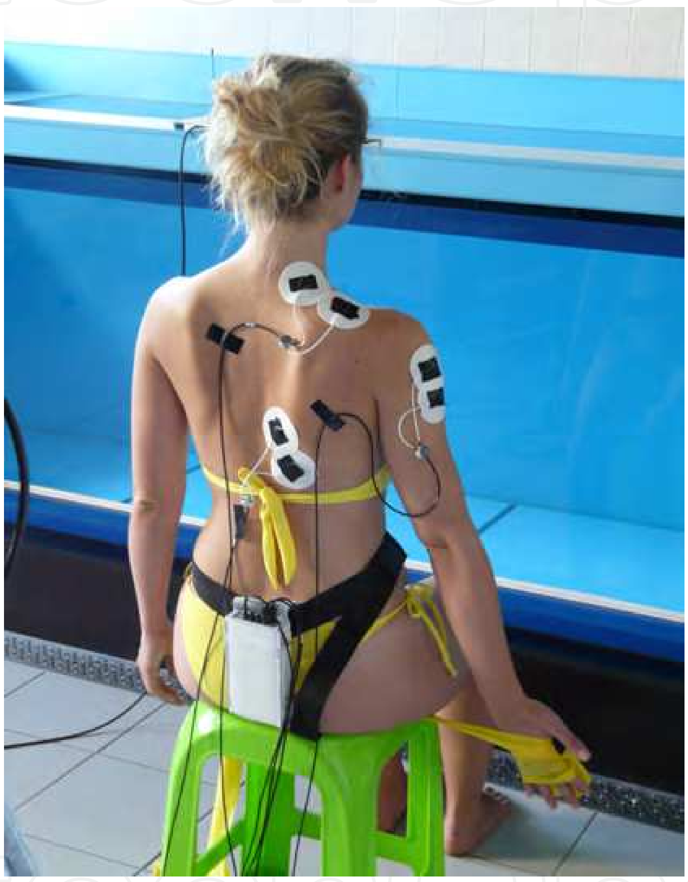


Fig. 9. Localization of WaS-EMG electrodes during study of muscle activity against flexible resistance with the help of Thera-Band yellow dye (Holländerová, 2011).

The water temperature was 32° C. The probands caused abduction in the shoulder joint at a speed of 30°/s to the horizontal position of the brachium, first on a dry surface and then in water, which reached the level of the procesus spinosus vertebra C5. They continually repeated abduction of the brachium 10 times, and 7 stable cycles were evaluated (Fig. 10). The results of the study indicated a decrease in monitored muscle activity in the water environment; the most marked change was captured in the m. trapezius pars superior muscle - 47-57% - in the other two muscles the change ranged between 19 and 29%. She also found different muscle timing, coinciding with an earlier study (Pavlů & Pánek, 2008), between movement in water and on dry land, but this was individual and there was no common trend.

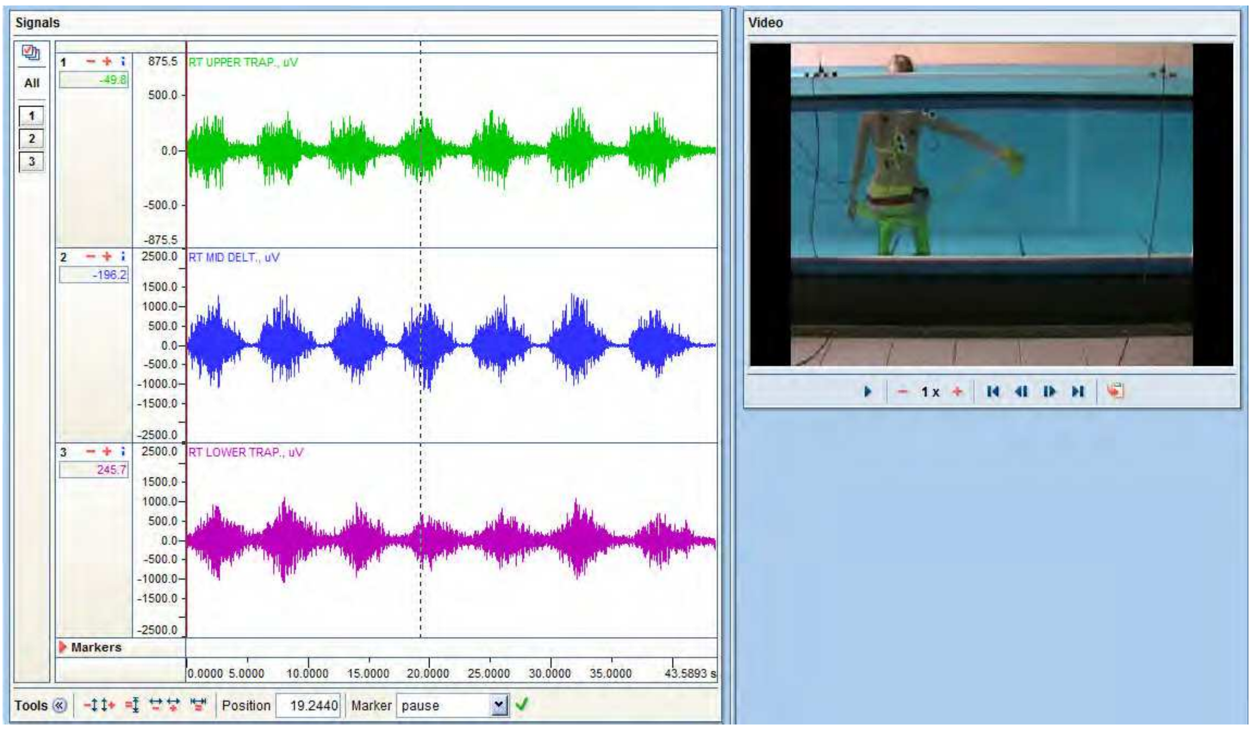


Fig. 10. EMG activity in the course of 7 cycles of brachial abduction in a water environment (Holländerová, 2011).

6. Conclusion

WaS-EMG is a relatively modern method for studying electrical muscle activity in an environment that was formerly rather inaccessible for neuro-physiological methods. Nevertheless, there are many studies that make it possible to follow up on acquired knowledge relating primarily to methodological measurement and the effect of a captured biological signal. In summary, here are the most basic of them:

1. For registering electrical activity it is best to use separate electrodes. Water resistant suits and garments are mainly more expensive, they place greater limitation on the probands' activity, and they are more likely to leak water onto the electrodes.
2. Electrodes should be attached with water-resistant tape, which should also affix loose cables. This limits the occurrence of artefacts from cable movements that appear in the 0-20 Hz frequency band.
3. Pasted on electrodes should be used for measurements on dry land as well, because this does not change the character of the EMG signal between the water environment and on a dry land.
4. For measurement of the maximal voluntary contraction (MVC) should be used movements on a dry land. This is a simple method, and furthermore, is also in standard use in prior publications.
5. In dynamic modes it is good to engage in a defined movement activity in water at half the speed of that on dry land. The greater viscosity of water as against air can lead, especially during faster movements, to the change in the native EMG recording.
6. The optimal water temperature is between 27 and 34° C. Cooler water leads to lower electrical muscle activity. Higher temperatures are uncomfortable for the performance

of movement activities. Stable temperatures of muscles and the ambient water are reached in approximately 15 minutes.

7. When making an identical movement in water and in a dry environment, in the water environment there is decreased muscle activity versus the identical movement on a dry land.
8. The change on the size of muscle activity in a water environment depends on the speed of the movement on a dry land, and primarily for fast movements, when greater effect of water's viscosity is emphasized.
9. If we study movements that are more demanding on posture, the activity of trunk muscles, which must adjust to this burden, is increased.

7. Acknowledgment

This work was elaborated with the help of the research plan of the Ministry of Education of the Czech Republic **VZ MŠMT ČR MSM 0021620864.**
We would like to thank the Department of Swimming of the FTVS UK, and namely Mgr. Daniel Jurák for his assistance and making possible measurement in the Aquatic Sports Research Laboratory.

8. References

Clarys, J.; Robeaux, R.& Delbeke, G. (1985). Telemetrical versus conventional EMG in air and water. *Biomachnics IX: Human Kinetics,* pp.286-294, ISBN:0-931250-52-8, Champaign, France, 1985

Da Silva Carvalhoa, R.; Amorimb, C.&Perácioa L.&Coelhoa H.&Vieiraa, A.& Menzelc, H.& Szmuchrowski, A. (2010). Analysis of various conditions in order to measure electromyography of isometric contractions in water and on air. *Journal of Electromyography and Kinesiology.* Vol. 20, No. 5, (2010), pp.988-993, ISSN 1050-6411

DeLuca, C. (2002). Surface Electromyography: Detection and Recording. In: Delsys, 2.3.2006, Available from http://delsys.com/KnowledgeCenter/Tutorials.html.

Dewhurst, S.; Riches, P. & Nimmo, M. & De Vito, G. (2005). Temperature dependence of soleus H-reflex and M-wave in young and older women. *European Journal of Applied Physiology.* Vol. 94, No. 5-6, (2005), pp. 491-499, ISSN 8750-7587

Fujisawa, H,; Seunaga, N.& Minami, A. (1998). Electromyographic study during isometric exercise of the shoulder in head-out water immersion. *Journal of Shoulder and Elbow Surgery.* Vol. 7, No.5, (1998), pp. 491-494, ISSN 1058-2746

Holländerova, D. (2011). *Evaluation of EMG Activity of the Shoulder Girdle Muscles during Exercises with Thera-Band in the Aquatic Environment and on the Land.* Diploma thesis, Departmen of Physiotherapy. Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic, 2011 (in Czech)

Jandová, D. (2009). *Balneologie.* Grada Publishing a.s., ISBN 978-80-247-2820-9, Prague, Czech Republic (in Czech)

Kaneda, K.; Wakabayashi, H.& Sato, D.& Uekusa, T.& Nomura, T. (2008). Lower extremity muscle activity during deep-water running on self-determined pace. *Journal of Electromyography and Kinesiology.* Vol.18, No. 6, (2008), pp. 965-972, ISSN 1050-6411

Kelly, B.; Roskin, D.& Kirkendall, D.& Speer, K. (2000). Shoulder muscle activation during aquatic and dry land exercises in nonimpaired subjects. *Journal of Orthopaedic & Sports Physical Therapy.* Vol.30. No.4, (2000), pp. 204-210, ISSN 0190-6011

Masumoto, K.; Takasugi, S. & Hotta, N. & Fujishima, K. & Iwamoto, Y. (2004). Electromyographic Analysis of Walking in Water in Healthy Humans. *Journal of Psychiological Anthropology and Applied Human Science.* Vol. 23, No. 4, (2004), pp. 119-127, ISSN 1345-3475

Masumoto, K.; Takasugi, S. & Hotta, N. & Fujishima, K. & Iwamoto, Y. (2005). Muscle activity and heart rate response during backward walking in water. *European Journal of Applied Physiology and Occupation Physiology.* Vol. 94, No. 1-2, (2005), pp. 54-61, ISSN 0301-5548

Masumoto, K. & Mercer, J. (2008). Biomechanics of Human Locomotion in Water: An Electromyographic Analysis: Methodological Considerations for Quantifying Muscle Activity During Water Locomotion. *Exercise and Sport Sciences Reviews.*, Vol. 36, No.3, (2008), pp.160-169, ISSN 0091-6331

Masumoto, K.; Delion, D. & Mercer, J. (2009). Insight into Muscle Activity during Deep Water Running. *Medicine & Science in Sports & Exercice.* Vol. 41, (2009), pp. 1958-1964, ISSN 0195-9131

Miyoshi, T.; Shirota, T. & Yamamoto, S. & Nakazawa, K. & Akai, M. (2004). Effect of the walking speed to the lower limb joint angular displasments, joint movements and ground reaction force during walking in water. *Disability & Rehabilitation.* Vol. 26, No. 12, (2004), pp. 724-732, ISSN 0963-8288

Pánek, D.; Jurák, D. & Pavlů, D. & Krajča, V. & Čemusová, J. (2010). Water Surface Electromyography –WaS-EMG. *Rehabilitation and Physical Medicine.*Vol. 17, No. 1, (2010), pp.21-25, ISSN 1211-2658 (in Czech)

Pavlů, D. & Pánek, D. (2008). EMG - Analysis of Selected Muscles of Upper Extremity Moving in Water Environment and Motion against Elastic Rezistance. *Rehabilitation and Physical Medicine.* Vol. 15, No. 4, (2008), pp. 167-173, ISSN 1211-2658 (in Czech]

Petrofsky, J. & Laymon, M. (2005). Muscle Temperature and EMG Amplitude and Frequency During Isometric Exercise. *Aviation, Space and Environment Medicine.* Vol. 76, No.11., (2005), pp. 1024- 1030, ISSN 0095-6562

Pöyhömen, T.; Kyrolainen, H. & Keskinen, K. & Hautala, A. & Savolainen, J. & Mälkiä, E. (1999). Isometric force production and electromyogram activity of knee extensor muscles in water and on dry land. *European Journal of Applied Physiology and Occupation Physiology.* Vol. 80, No. 1, (1999), pp. 52-56, 1999, ISSN 1432-1025

Pöyhönen, T.; Keskinen, K. & Kyröläinen, H. & Hautala, A. & Savolainen, J. & Mälkiä, E. (2001). Neuromuscular function during therapeutic knee exercise under water and on dry land. *Archives of Physical Medicine and Rehabilitation.* Vol. 82, No. 10, (2001), pp. 1446-1442, ISSN 0003-9993

Rainoldi, A.; Cescon, C. &, Bottin, A. & Casale, R. & Caruso, I. (2004). Surface EMG alteration induced by undewater recording. *Journal of Electromyography and Kinesiology.* Vol. 14, No.3, (2004), pp. 325-331, ISSN 1050-6411

Rouard, A. & Clarys, J. (1995). Cocontraction in the Elbow and Shoulder Muscles During Rapid Cyclic Movements in an Aquatic Environment. *Journal of Electromyography and Kinesiology. Vol.* 5, No. 3, (1995), pp. 177-183, ISSN 1050-6411

Shono, T.; Masumoto, K. & Fujishima, K. & Hotta, N. & Ogaki, T. & Adachi, T. (2007). Gait Patterns and Muscle Activity of the Lower Extremities of Elderly Women during Underwater Treadmill Walking againts Water Flow. *Journal of Physiological Anthropology.* Vol. 26, No. 6, (2007), pp. 579-586, ISSN 1880-6791

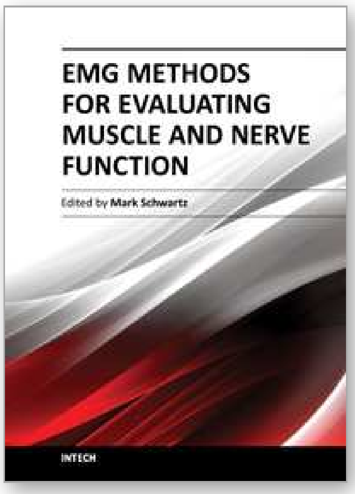
Silvers, W. & Dolny, D. (2001). Comparison and reproducibility of sEMG during manual muscle testing on land and in water. *Journal of Electromyography and Kinesiology.* Vol. 21, No.1, (2001), pp. 95-101, ISSN 1050-6411.

Sladká, H. 2011. *Compare of muscle timing during cycling on land and in water.* Diploma thesis. Departmen of Physiotherapy. Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic, 2011 (in Czech)

Stejskalova, P. (2011). *Effect of water temperature on muscle contraction.* Diploma thesis. Departmen of Physiotherapy. Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic, 2011 (in Czech)

Sulková, I. (2011). *Possibility of using Aquatherapy for shoulder stabilization.* Diploma thesis. Department of Physiotherapy, Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic, 2011 (in Czech)

Veneziano, W.; da Rocha, A. & Goncalves, C. & Pena, A. & Carmo J. & Nascimento, F. & Rainoldi, A. (2006). Confounding factors in water EMG recordings: an approach to a definitive standard. *Medical & Biological Engineering & Computing.* Vol. 44, No. 4, (2006), pp. 348-351, ISSN 0140-0118



EMG Methods for Evaluating Muscle and Nerve Function

Edited by Mr. Mark Schwartz

ISBN 978-953-307-793-2
Hard cover, 532 pages
Publisher InTech
Published online 11, January, 2012
Published in print edition January, 2012