Muscle tone (?), -relaxation (?) and -activity in an aquatic environment.

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A methodological introduction.

The electromyography of complex movements (swimming) and simple positions (active and passive floating) in water can be measured with a telemetric registration system and/or with an on-line system with or without portable amplifier and/or with a remote (but not telemetric) system. Independent of the water element and of the registration system used, the electrical potentials of a muscle can be captured with different types of electrodes, such as passive or active surface electrodes, intra muscular (concentric or bipolar or monopolar) needle electrodes, single fiber electrodes, multi-electrodes or intra muscular wire electrodes. However, it is not the registration system, but the water element that puts a restriction on the electrode possibilities and that is recognized as being a major technical abstacle in recording human electrical signals. Therefore the types of electrodes to be used in water are (i) the passive or classical surface electrode (Ikai et al 1964, Lewillie 1967, 1973, Clarys 1983); (ii) the active (preamplified) electrode (Okamoto-Wolf 1975). Since this last type of electrode is used in water at one occasion only and since Jonsson and Komi (1973) found better test-retest and day to day reliability for the (passive) surface electrode (table 1), it is obvious that our choice is amongst the other two types of surface electrodes .....

<u>Table 1</u>: The reliability of surface & wire electrodes.

Level of tension $\frac{P}{Po} \times 100$	Test-retest reliability		Day to day reliability	
	surface electrodes	wire electrodes	surface electrodes	wire electrodes
20	0.81	0.91	0.62	0.12
40	0.87	0.39	0.79	0.05
60	0.95	0.67	0.57	0.23
80	0.92	0.75	0.78	0.27
100	0.84	0.36	0.69	0.55
Average	0.88	0.62	0.69	0.22

From Jonsson and Komi (1973).

Originaly we used passive rasptype surface electrodes but these gave often "hum" or "artefact" registrations (Clarys, 1986); reason for which we developed an active surface electrode recently (Clarys-Publie, 1985).
"In most existing instrumentation an input impedance of 10 Megohms or even 1 Megohm is common, thus the skin has to be prepared until the resistance is down to less than 100 K. or even 10 K. respectively. Of course, then the impedance between the electrodes should be measured over the whole frequency band. However, the use of a high performance amplifier eliminates the preparation of the skin and the need of checking the resistance, thus simplifying the measuring procedure" (cited from Winter et al, 1980).
Consequently to capture a noise free EMG signal, we used preamplifiers in the electrodes themselves of more than 1 gigohm. These operational amplifiers (OpAmp) are coupled as voltage follower adjacent to both of the signals. A third OpAmp (as differential amplifier) provides an asymmetrical signal with respect to the reference. A fourth non inverting coupled OpAmp provides an amplification to 10dB and a low ohm output for branching off the electrode signal. Until recently the Brussels EMG project used metal rasp of silver, but "passive" type of electrodes; combined with a series of operational amplifiers we obtain "active" electrodes.
A finished active electrode thus contains within a plexi moulded frame, four operational amplifiers, housed in a 14 pins dual in line (type TL084 JFET) and six metalfilm resistances. The 2 mm deep inlay of the Ag plates in the frame allows electrolyte and avoids skin artefacts.
These active electrodes and its plexi moulded frame is coupled with a special triple conductor, containing the signal transporting conductor, two conductors for symmetrical power supply (+ and - 3,5 V) and shielding.
The advantage of the active electrode to the classic passive electrode is a decrease of erroneous registrations. This has become an important feature since we have found that despite thorough precautions (different tapings and plastic varnish on the electrodeprotection) the water does decrease the detectable electricital output of human muscle; in other words an imaginary identical muscle contraction, with identical intensity will produce more electricity in the air, than in the water (figure 1 - Clarys, Robeaux & Delbeke 1984).

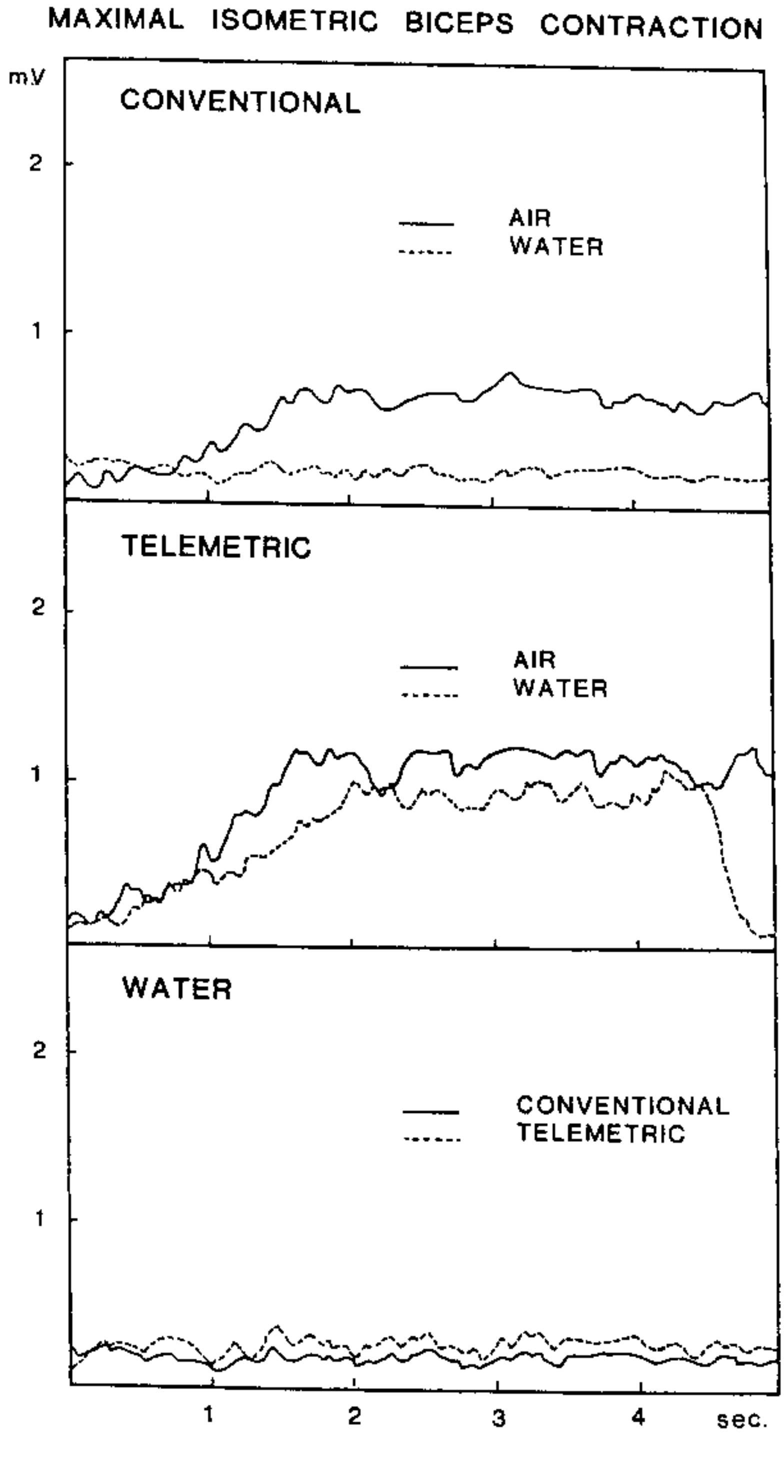

Figure 1.
Identical muscle activity in air and in water (Clarys et al 1984).

These findings - resulting from a comparative study between telemetric and conventional on-line EMG in air and water measured simultaneously with one single pair of passive electrodes (figure 2) - have very important consequences with regard to the interpretations of "whatever" muscular activity in an aquatic environment.

Stejskal (1972) stated: "Clinical experience suggests that postural reflex activity of the spastic muscle is less marked if the body is lying in water".

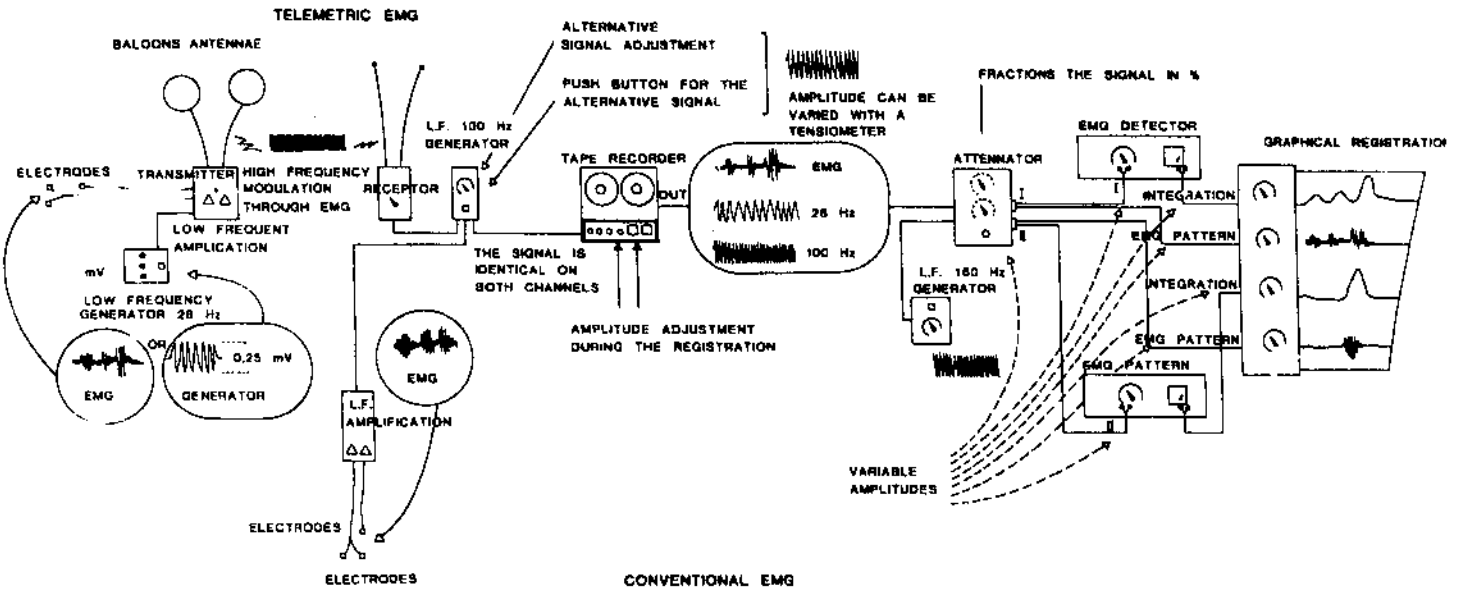

Figure 2.
Telemetric & Conventional EMG Regristration set-up starting from one pair of electrodes
(Clarys et al 1984).

In our EMG in air and water study we attributed the decrease of electrical output of a muscle in water partially to the telemetric registration system, partially to the loss of signals due the physical presence of the water .... But what if it were the muscle itself emitting less electrical activity because of the water? In that case it does explain Stejskal's statement and it would mean that the state of contraction of muscles maintaining a certain posture, is different in air than in water .... in a therapeutical sence to the advantage of water (?)
This idea might be sustained by Banzett, Lansing and Reid (1985) who found that similar adjustments occur during voluntary respiratory maneuvres. Their naive subjects where seated in a tank with water of hip level. Surface EMG of diaphragm (?) and intercostal muscle was registered with the water at the hip and then again after raising the water level to the xiphoid. In 30 of 42 trials there was a substantial fall in EMG peak activity.
Combining both, our findings (Clarys et al 1984) and those of Banzett et al (1985), it may create a better understanding of McMillan's (1986) "difficult concept of the body reactions to

water, being different to those when on land" and it certainly does confirm his assumption that "the apparent weightless condition contributes to a loss of muscle tone compromising proprioceptive feedback with a consequental loss of spatial relationships (sic). But what is meant by muscle tone? Is it dynamic activity? Or hypertonia? Or hypotonia? Muscle activity at rest, in posture, in relaxation ...?
Muscle "tone or tonus" is a term used in clinical neurology meaning resistance to stretch. Clinicians recognise hypertonia and hypotonia; between these two pathological states is normal tone. Hypertonia is due to lowering of threshold and increase in the response in tonic stretch reflexes together with certain visco-elastic properties of the muscles; normal tone is due to the visco-elastic properties, often with the addition of normal stretch reflexes, and hypotonia is due only to the visco-elastic properties of the muscles (Nathan 1973).
In their latest edition of muscles alive, Basmajian and De Luca (1985) precise that:
"Most neurophysiologists now agree that electromyography shows conclusively the complete relaxation of normal human striated muscle at rest (Clemmesen, 1951; Basmajian, 1952; Ralston and Libet, 1953). In other words, by relaxing a muscle, a normal human being can abolish neuromuscular activity in it. This does not mean that there is no "tone" (or "tonus") in skeletal muscle, as some enthusiasts have claimed. It does mean, however, that the definition of "tone" should include both the passive stiffness of muscular (and fibrous) tissues and the active (although not continous) contraction of muscle in response to the reaction of the nervous system to stimuli. Thus, at complete rest, a muscle has not lost its tone, even though there is no neuromuscular activity in it (Basmajian, 1957)".

With all this and previous knowledge we can agree with McMillan if his idea of tone is our idea of activity ... than it indeed decreases in water. However if muscle tone is according to Nathan (1973), Basmajian & De Luca (1985) and most neurophysiologists, we have difficulty to understand "a loss of something that is already non existand" ... In other words the statement would not be measurable.
We know that the speed with which voluntary relaxation can occur is quite impressive. Miyashita et al (1972) found the mean values for relaxation time in the biceps of normal healthy adults to be the same as those for contraction reaction time.
However, no EMG record can be found which could confirm these situations in water ... although we assume relaxation periods in between EMG peaks during frontcrawl swimming since we have noticed a return to the base line at several occasions (figure 3. - Clarys et al 1983, 1984, Clarys 1985) and under different research circumstances and using passive rasp electrodes.

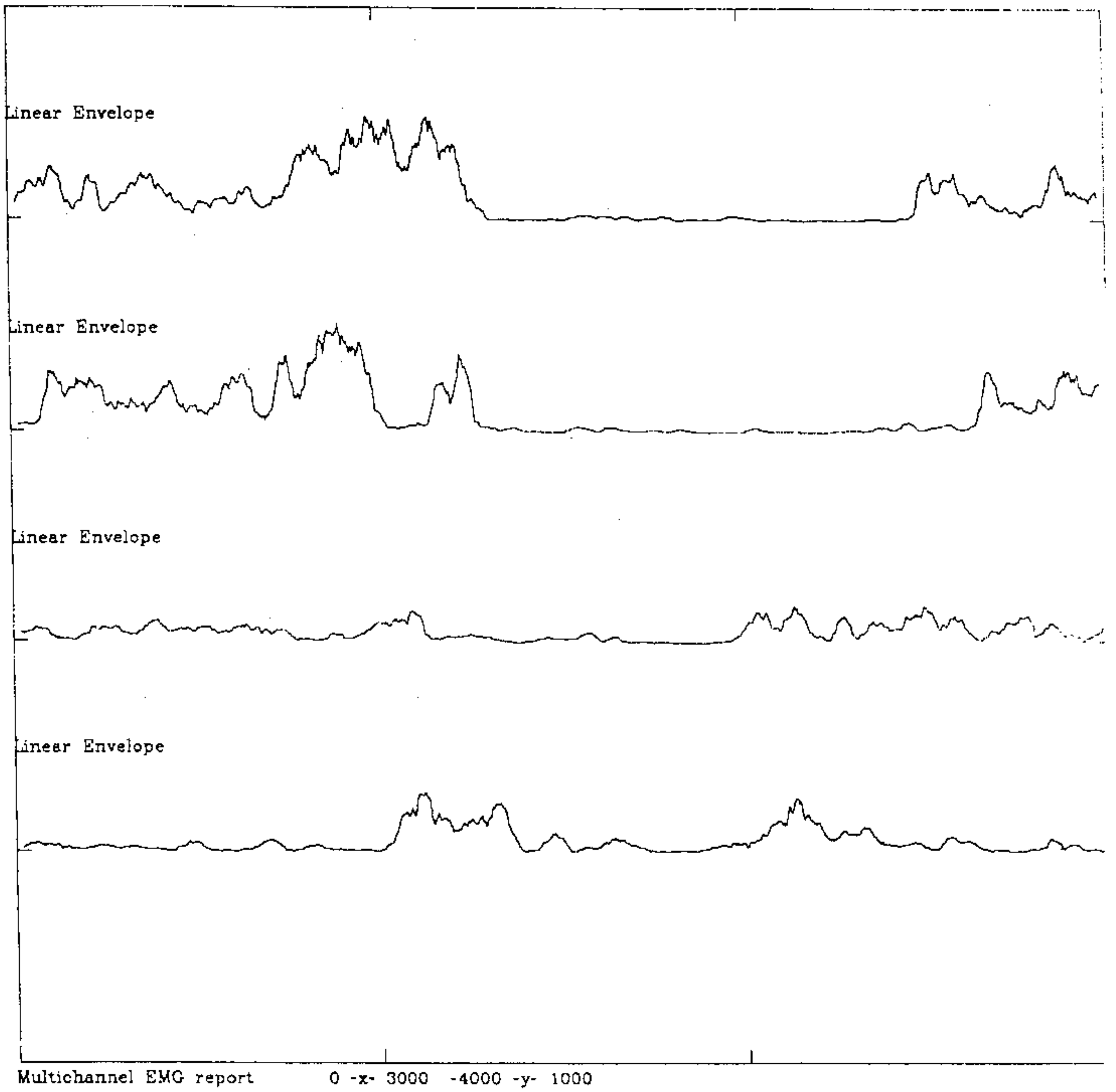

Figure 3.
Swimming activity and relaxation periods (Clarys 1985).

Since there is a need for more qualification, we have investigated the M. pectoralis major, the M. biceps brachii, the M. extensor digitorum, the M. triceps, the M. flexor digitorum and the M. latissimus dorsi in 15 healthy subjects during the "arrow prone position" in its propulsive trajectory and during a "fully relaxed prone - medusa position" using active electrodes ... In other words: EMG of a turbulent gliding (Nicol et al 1979) and a gravity - buoyancy situation.

Procedures for measuring active and passive floating.

In order to measure muscle activity of complex isotonic movements and isometric positions under field (e.g. aquatic) circumstances different features are taken into consideration:

- the EMG data aquisition system with its electrodes should allows total kinesiological freedom to the subject; or a movement without additional resistance;
- the set-up should allow adaptation to the characteristics of the field and movement circumstances, expecially the synchronisation system applicable not only to swimming but to other sports and various movements also;
- the influences of the complex skin resistance phenomena on the signal must be ommited by means of ultra high impedance amplifiers as suggested by the ad-hoc Committee of the International Society of Electrophysiological Kinesiology (Winter et al 1980), especially if an attempt to measure "tone" is made;
- 6 or 7 muscles should be monitored simultaneously;
- the combined registration and data aquisition set-up should be users friendly.

Separately, all these features are not inovative because they are actually applied in existing commercial systems. However, combined within one set-up they are uniqu in kinesiological (e.g. swimming) EMG.
To allow such a combination, we integrated a multichannel FM recorder, "active" electrodes, a regulation - amplification unit and different synchronisation modes into one system with different possibilities (figure 4 -Clarys - Publie 1985).

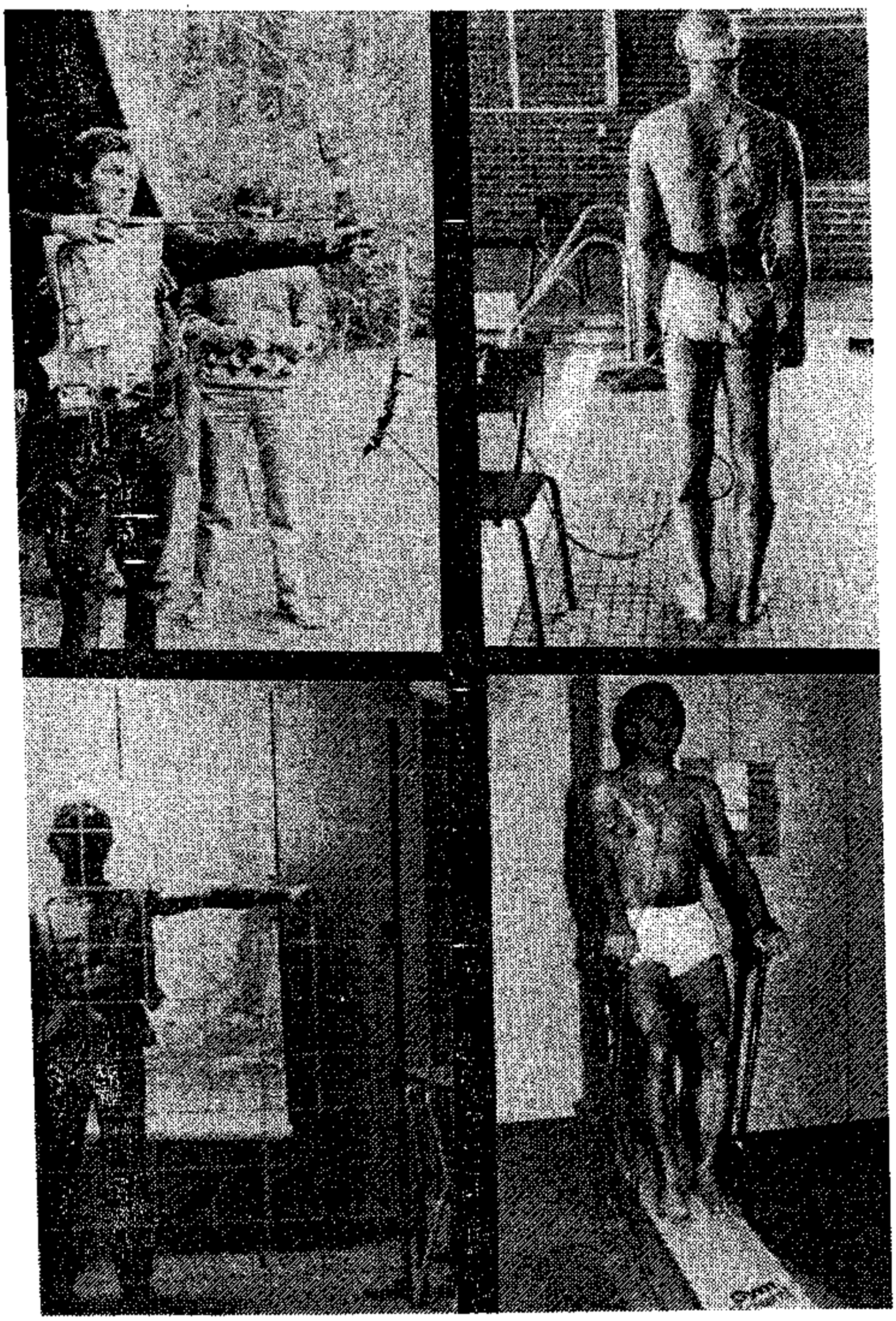

Figure 4.
A multichannel FM recorder active electrodes and a regulation - and amplification Unit
(Clarys - Publie 1985).

The active floating - or - the medusa position - or - relased buoyancy.

The subjects propulses himself from the swimming pool wall and raw EMG and linear envelope are registered from the moment, the fully errected prone position is reached until "floating

stand still".
For all muscles, and for all subjects investigated an activity with variable intensities was measured over the full distance of the active floating (figure 5.). The intensity of the EMG showed no constancy, nor in amplitude, nor in time (distance) and there was no relation between the EMG activity and the decreasing velocity after the push-off.

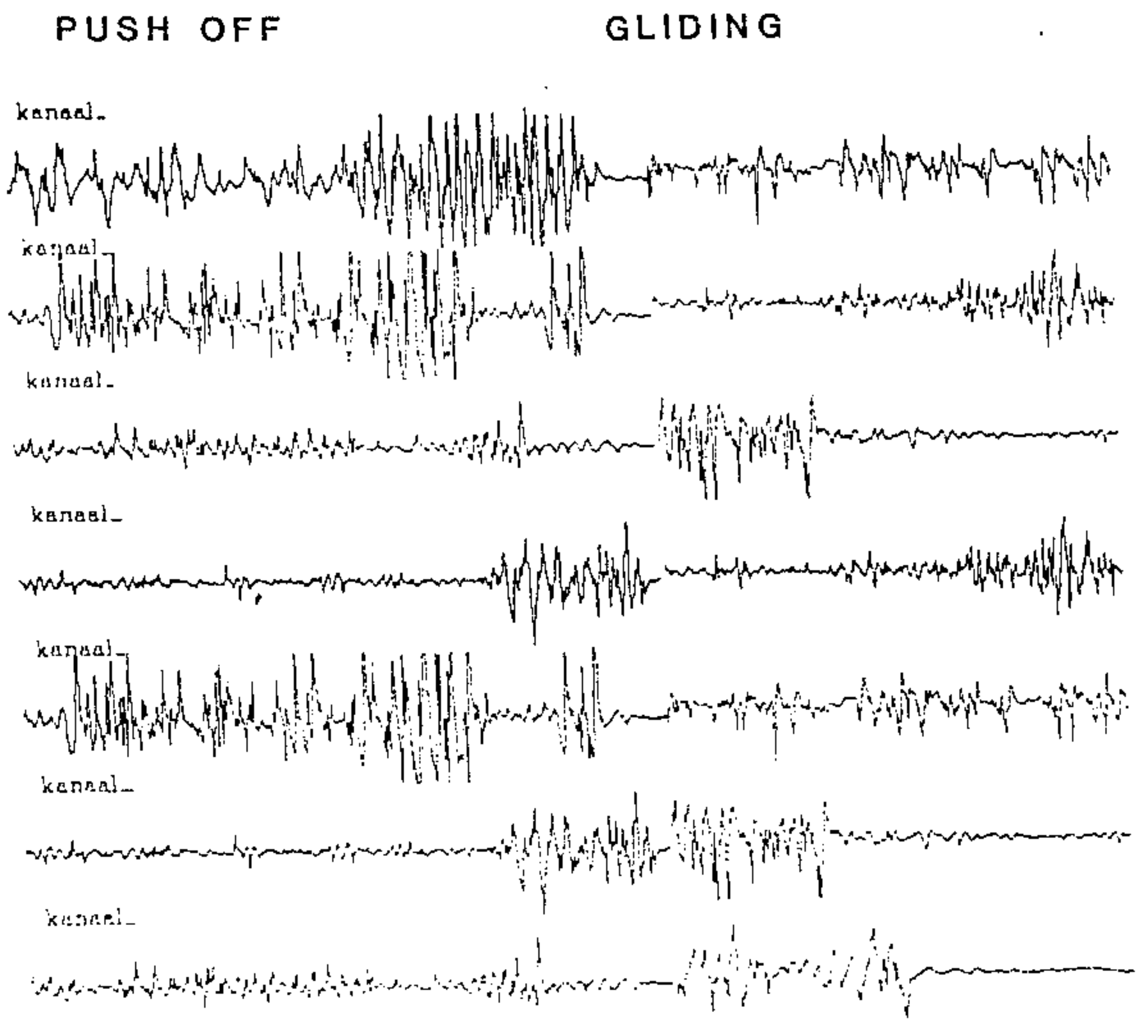

Figure 5.
Raw EMG of 7 muscles during Push-off and turbulent gliding through the water.

Obviously the muscular activity found is an intermediate state between restand activity, combining relaxation and the maintenance of posture or attitude (stretch).

The passive floating - or - the medusa position - or - relaxed buoyancy.

At the end of the turbulent gliding, the subjects are asked to float "at the spot" with arms and legs spread, but fully re-

laxed (apart from holding the respiration) during the registration.
"In thousands of electromyograms on normal muscles there has been complete and almost instantaneous relaxation when the subject has been ordered to relax. However, a small number of normal subjects do have great difficulty in relaxing quickly (Basmajian & De Luca 1985).
"Complete rest" requires some qualification. A normal person does not completely relax all his muscles at once, but realising the loss of muscular electricity in the water and realising the absence of EMG potentials at rest, it is not surprising that we have found no EMG at all; in other words: a complete silence for all muscles and all subjects, herewith confirming the findings of Leavitt and Beasley (1964) and Bierman and Ralston (1965)".
Repeated EMG studies of recumbent posture in air have demonstrated beyond the shadow of a doubt that resting muscles exibit no neuromuscular activity and there is no random activity of motor units in a resting muscle to provide what is often hazely called muscular tone (Basmajian 1955). In the water, were the electrical signal decreases (Clarys et al, 1984) it is however difficult to separate relaxation and unvoluntary contractions, because some muscles will respond immediately to any change endangering the loss of balance or buoyancy.
Muscular "tone" is a useful concept only if we keep in mind that at rest a muscle relaxes rapidly and completely. This has now been common knowledge among neurophysiologists for more than a decade. If one keeps one's hand off a resting normal muscle, it shows no more neuromuscular activity than one with its nerve cut. In fact, it shows less because the fibers of denervated muscle engage in many fine random contractions invisible through the skin but detected by electromyography as "fibrillation potentials". The muscles in lower motor neuron denervation actually exhibit very fine invisible contractions while normal resting muscles exhibit complete neuromuscular silence (These fibrillations are not to be confused with fasciculation, the coarse contractions of motor units visible through the skin and also often called fibrillations by older neurologists) (Basmajian & de Luca 1985).

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