The ABC of EMG

A Practical Introduction
to Kinesiological Electromyography

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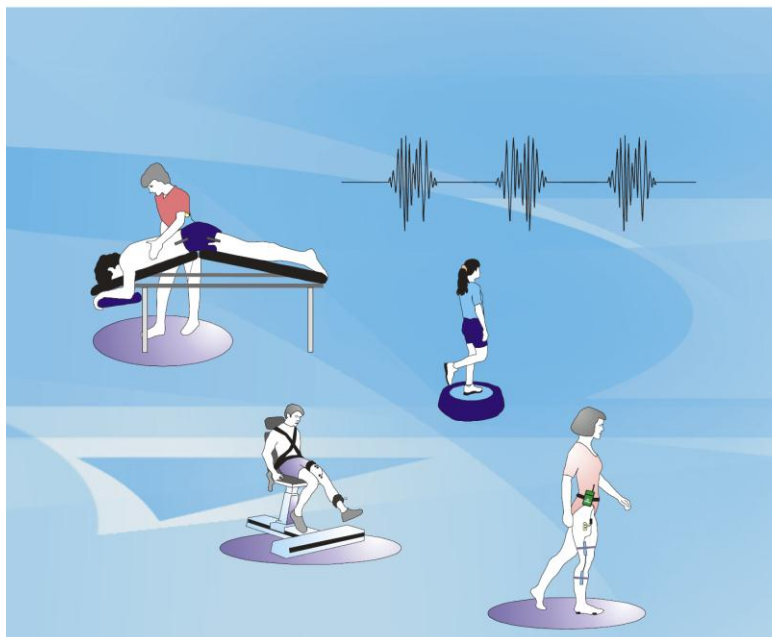
Version 1.4 March 2006



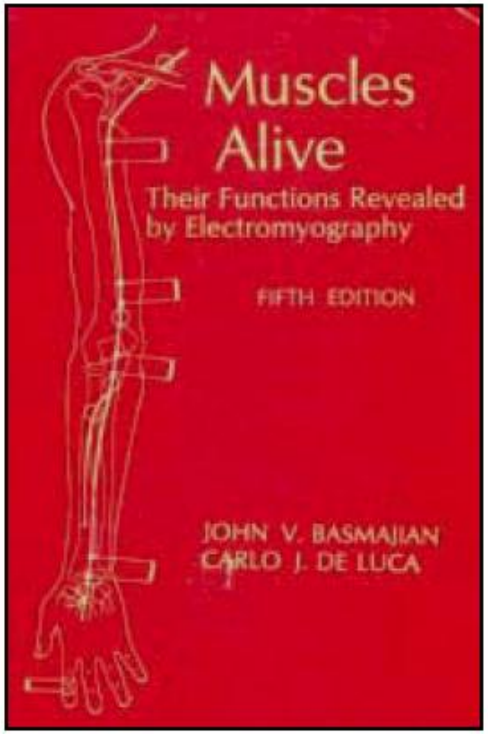
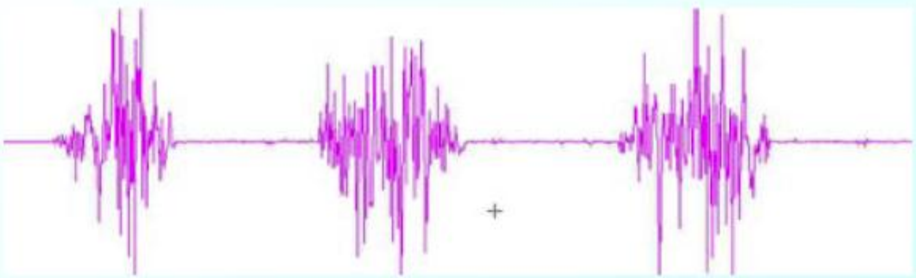


Fig.1: A fundamental EMG text book. Basmajian&DeLuca: ***Muscles Alive*** *(2)*

Electromyography…



"..is the study of muscle function through the inquiry of the electrical signal the muscles emanate."

Fig. 2: Basmajian & DeLuca: Definition Muscles Alive (2 - p. 1)

Medical Research

- Orthopedic
- Surgery
- Functional Neurology
- Gait & Posture Analysis

Rehabilitation

- Post surgery/accident
- Neurological Rehabilitation
- Physical Therapy
- Active Training Therapy

Ergonomics

- Analysis of demand
- Risk Prevention
- Ergonomics Design
- Product Certification

Sports Science

- Biomechanics
- Movement Analysis
- Athletes Strength Training
- Sports Rehabilitation

Fig 3: Application areas of kinesiological EMG

Fig. 4: Direct look into the body / muscle function: EMG synchronized with video and other movement sensors. Software screenshot of MyoResearch XP™ - NORAXON INC. USA

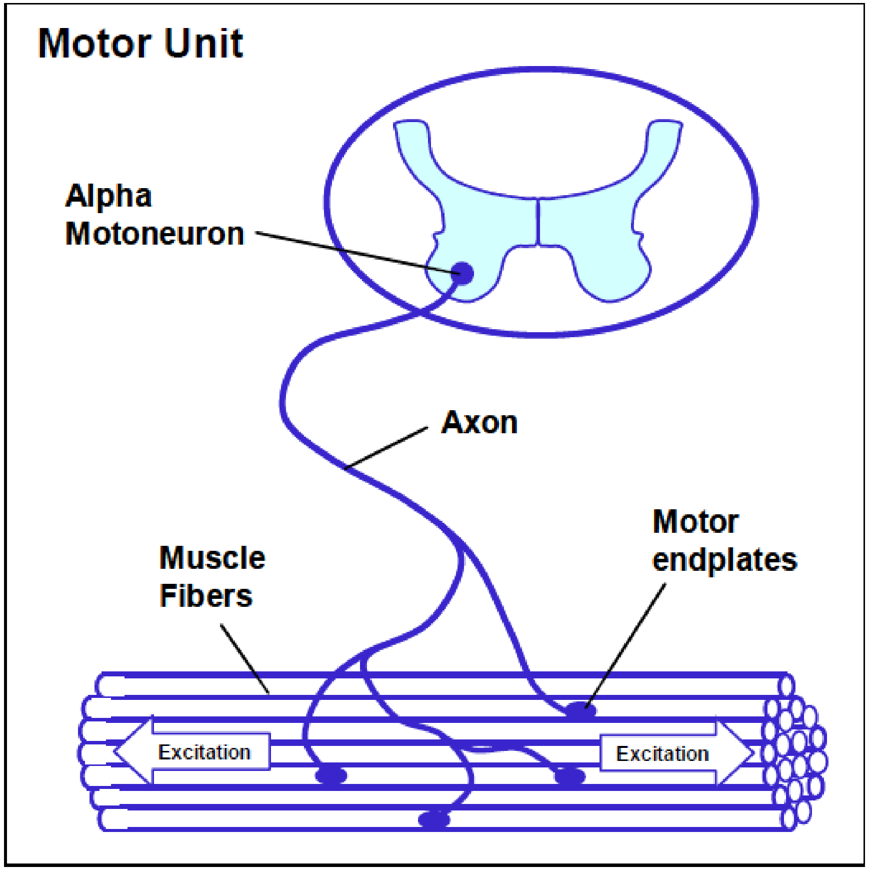


Fig.5: Motor unit. Adopted & modified from **2,7**

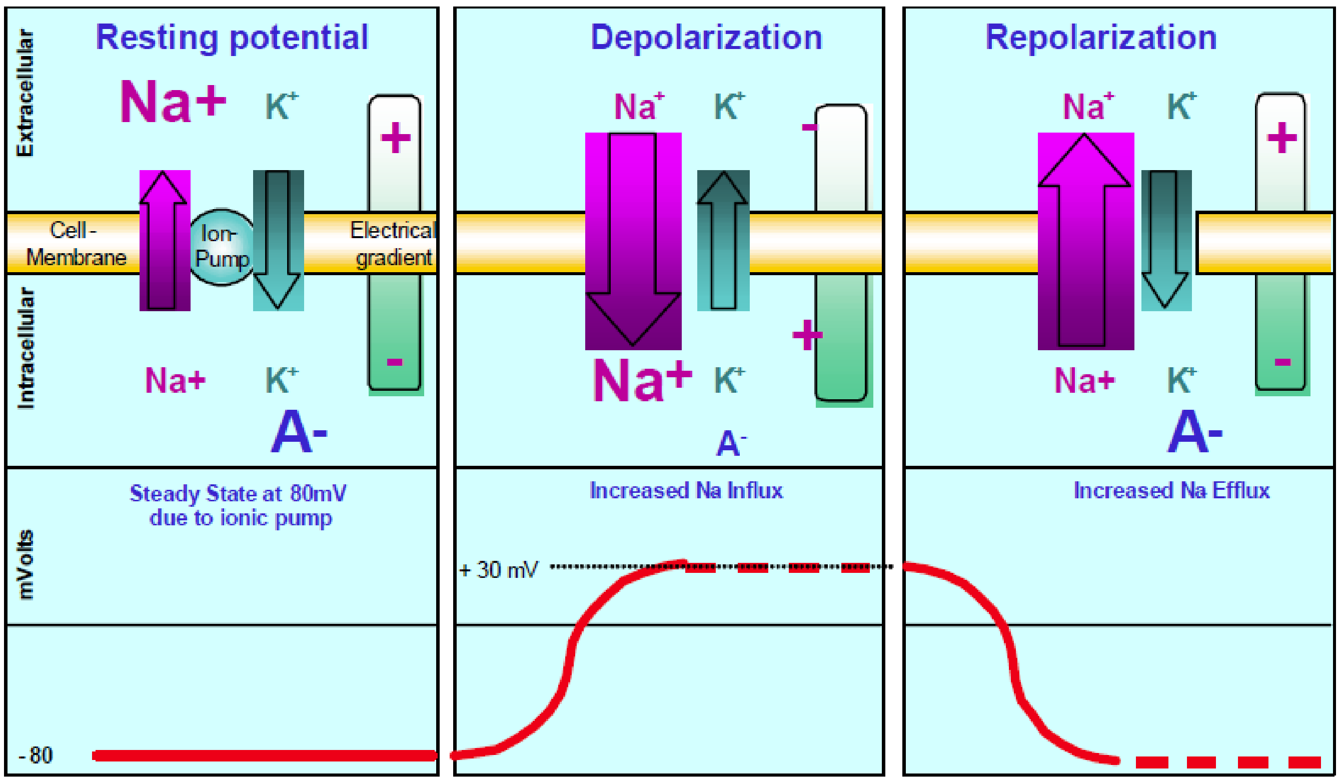


Fig.6: Schematic illustration of depolarization / repolarization cycle within excitable membranes

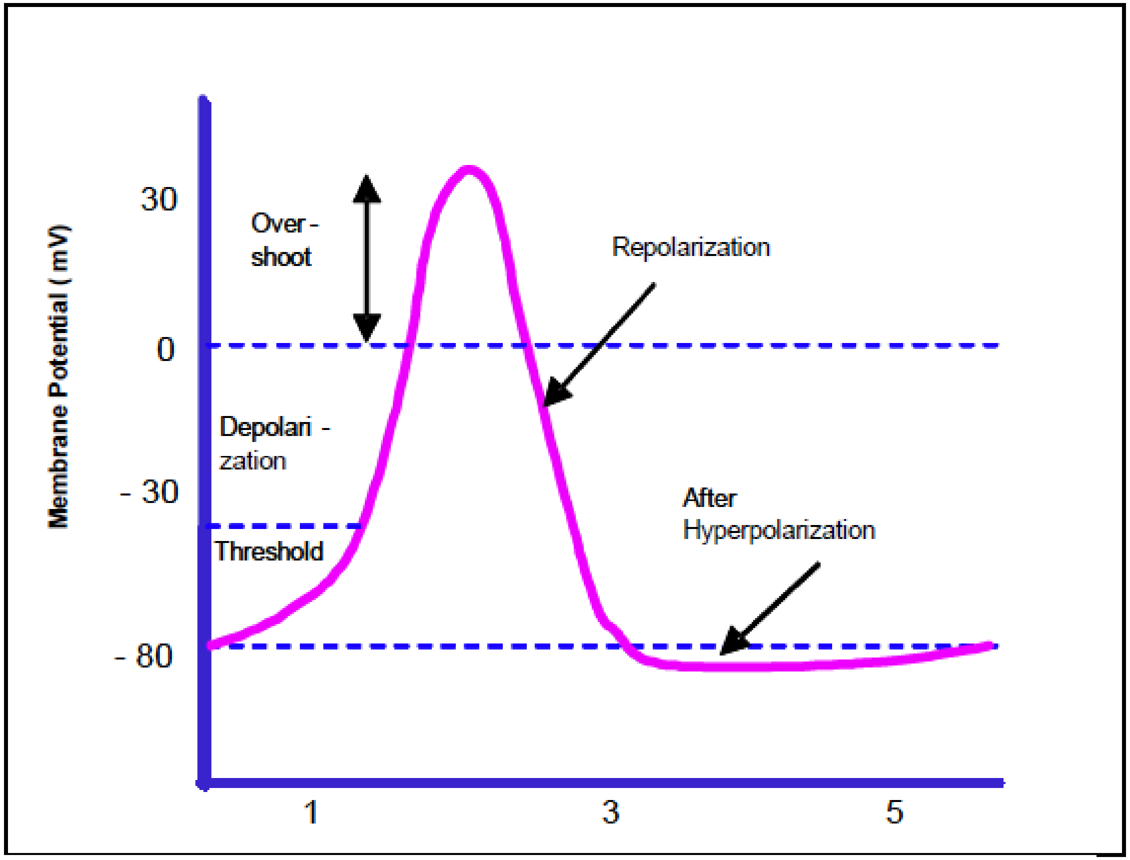


*Fig.7: The Action Potential. Adopted & redrawn from **5**, p. 164*

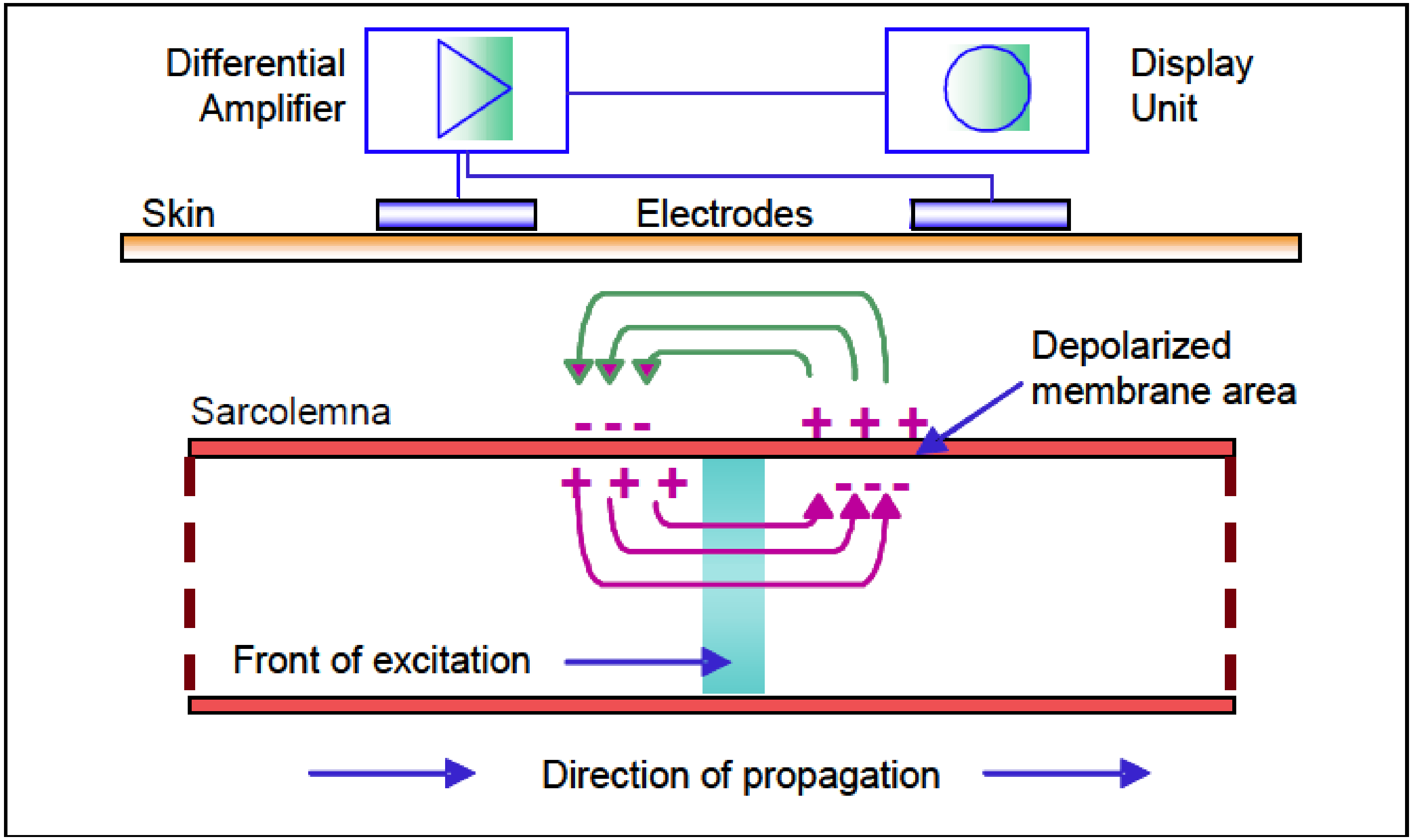


Fig.8: The depolarization zone on muscle fiber membranes. Adopted & modified from Z, p. 73)

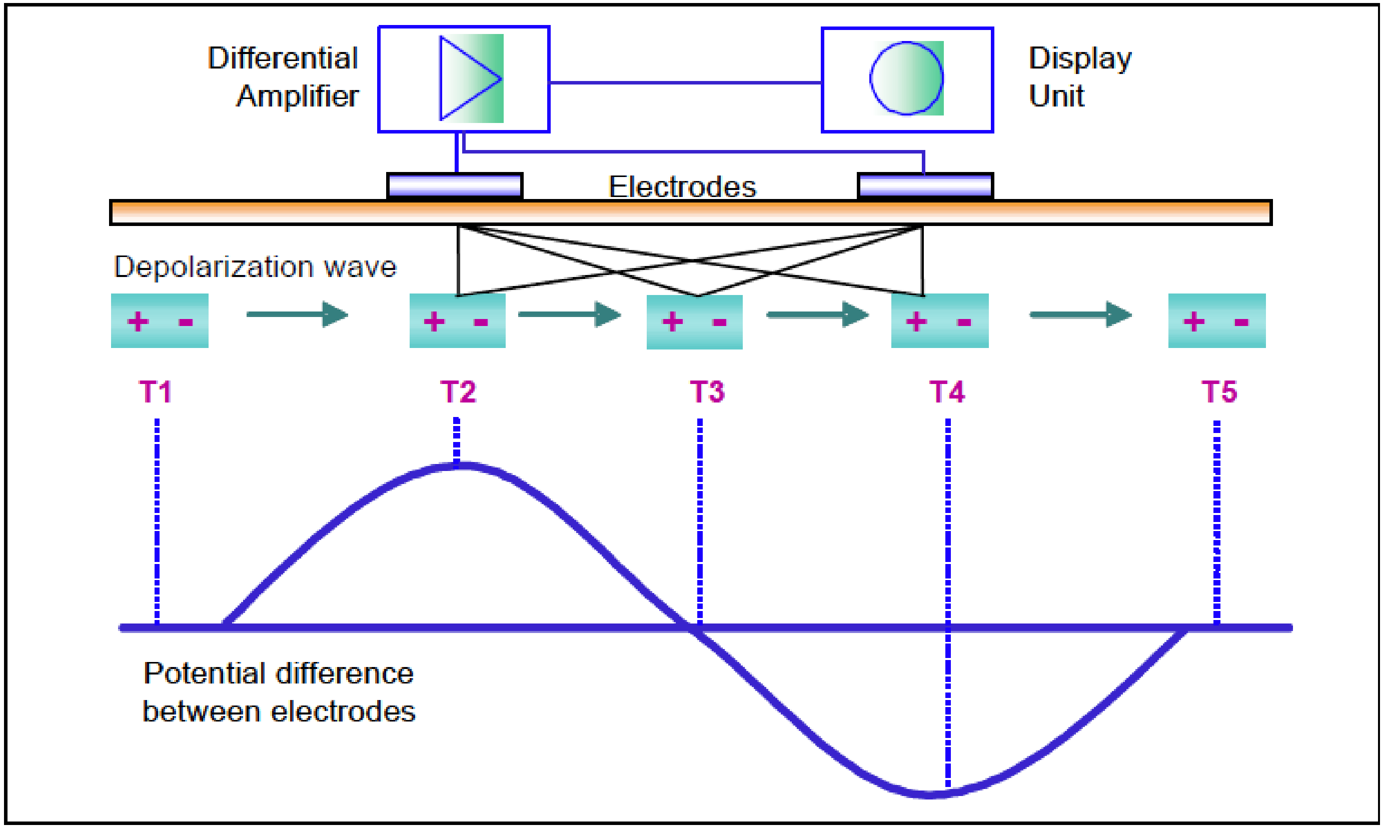


*Fig.9: The model of a wandering electrical dipole on muscle fiber membranes. Adopted & modified from **7**, p. 73*

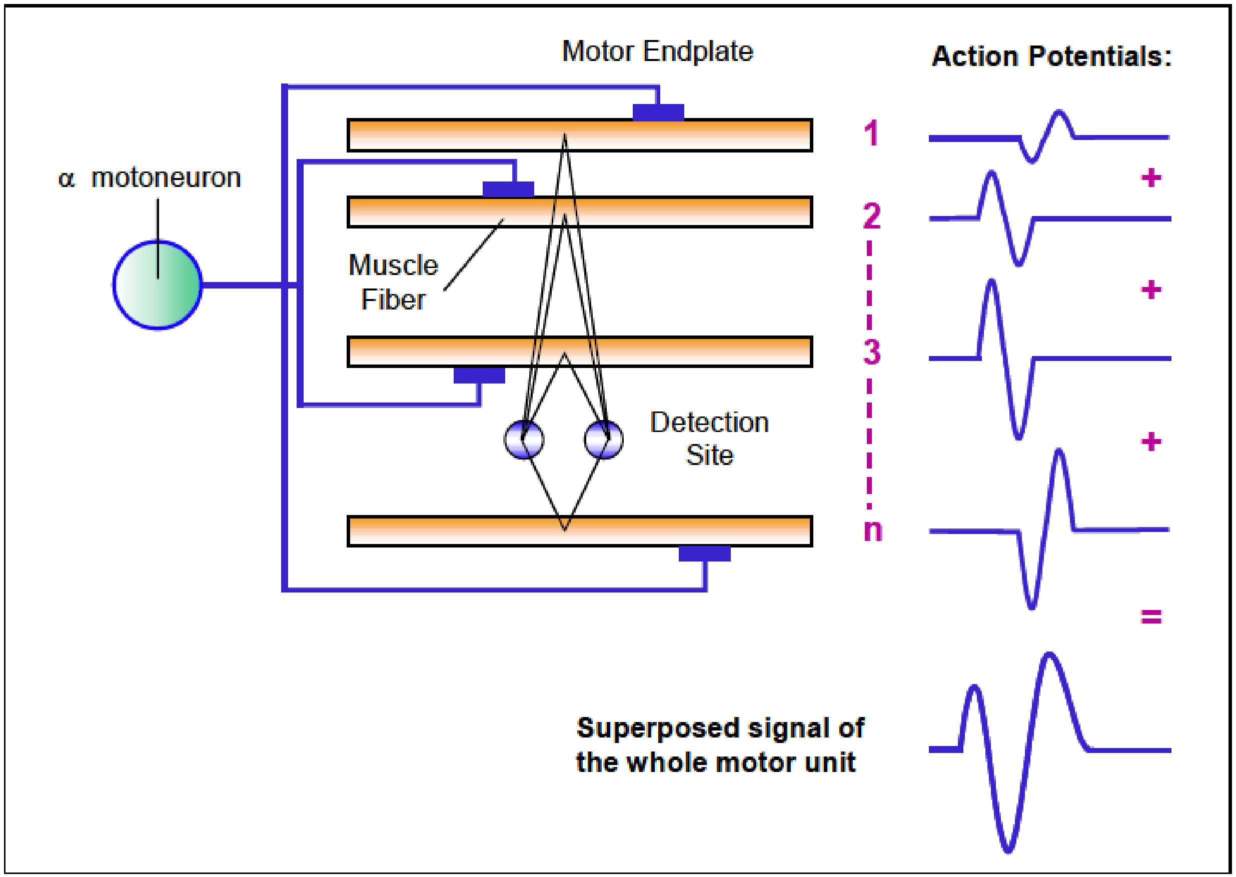


Fig.10: Generation of the triphasic motor unit action potential. Adopted & modified from 2, p. 68

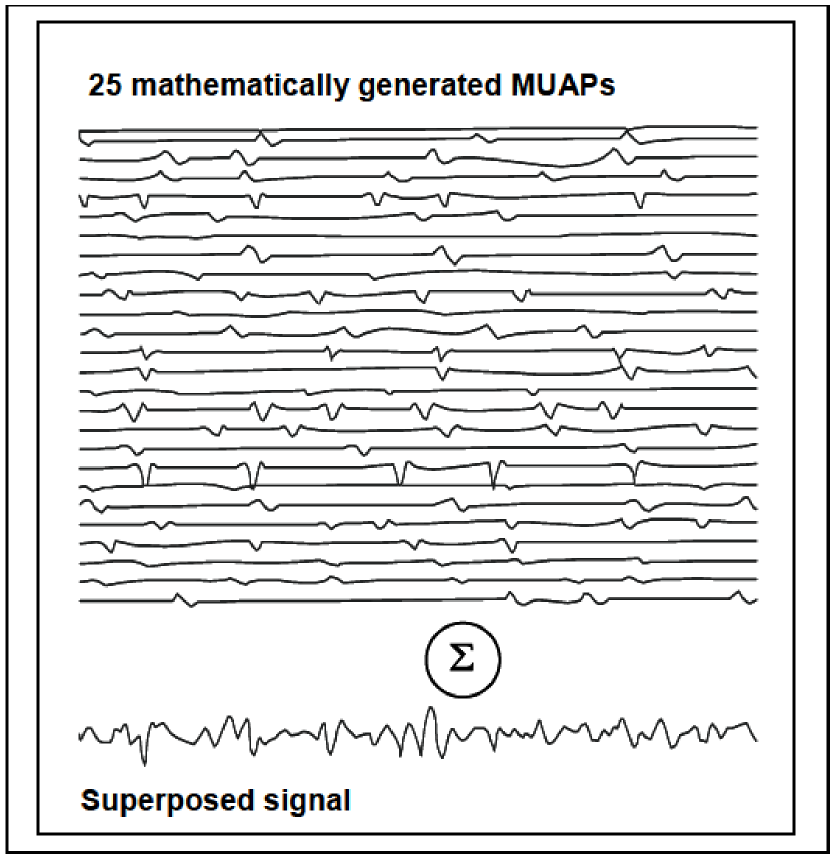


Fig.11: Superposition of MUAPs to a resulting electromyogram. Adopted & modified from 2, p. 81

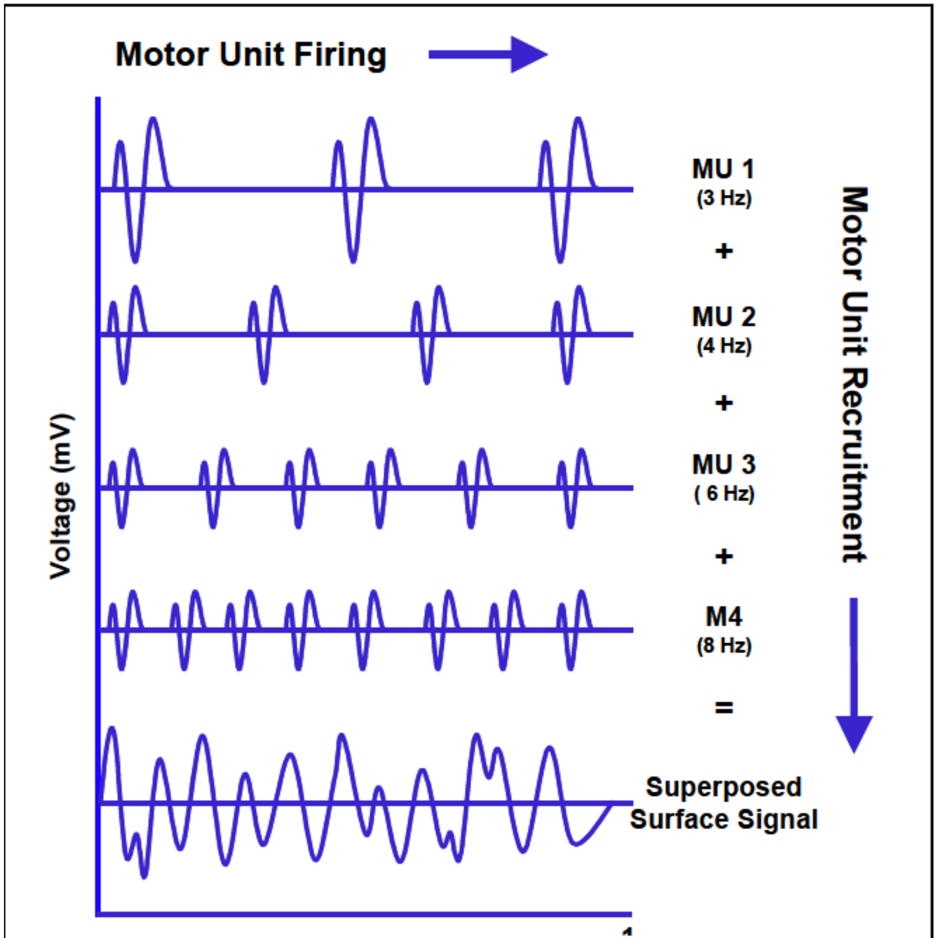


Fig.12: Recruitment and firing frequency of motor units modulates force output and is reflected in the superposed EMG signal. Adopted & modified from 7, p. 75

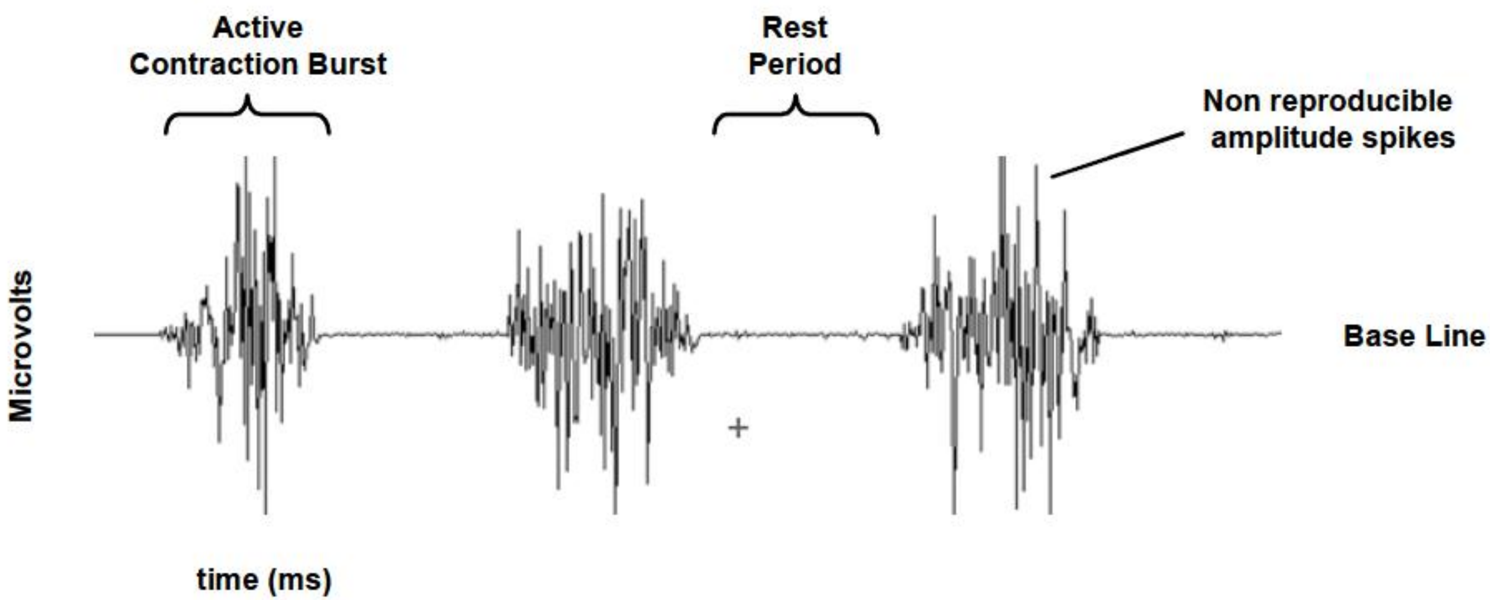


Fig.13: The raw EMG recording of 3 contractions bursts of the M. biceps br.

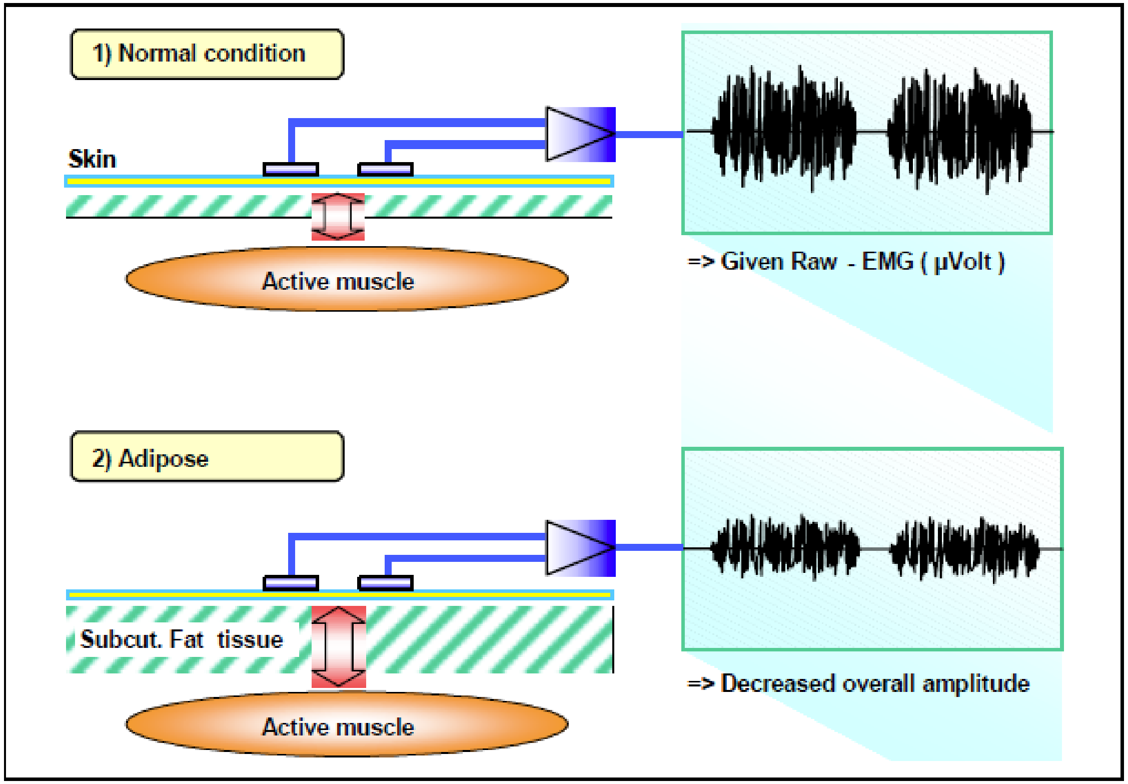


Fig.14: The influence of varying thickness of tissue layers below the electrodes: Given the same amount of muscle electricity, condition 1 produces more EMG magnitude due to smaller distance between muscle and electrodes

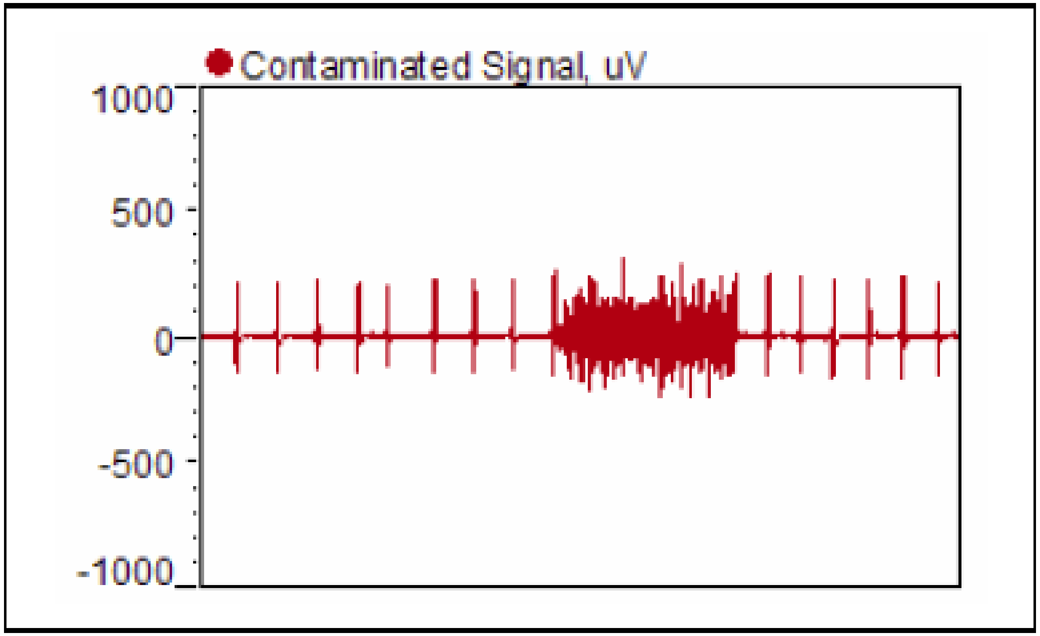


Fig.15: Raw EMG recording with heavy ECG interference

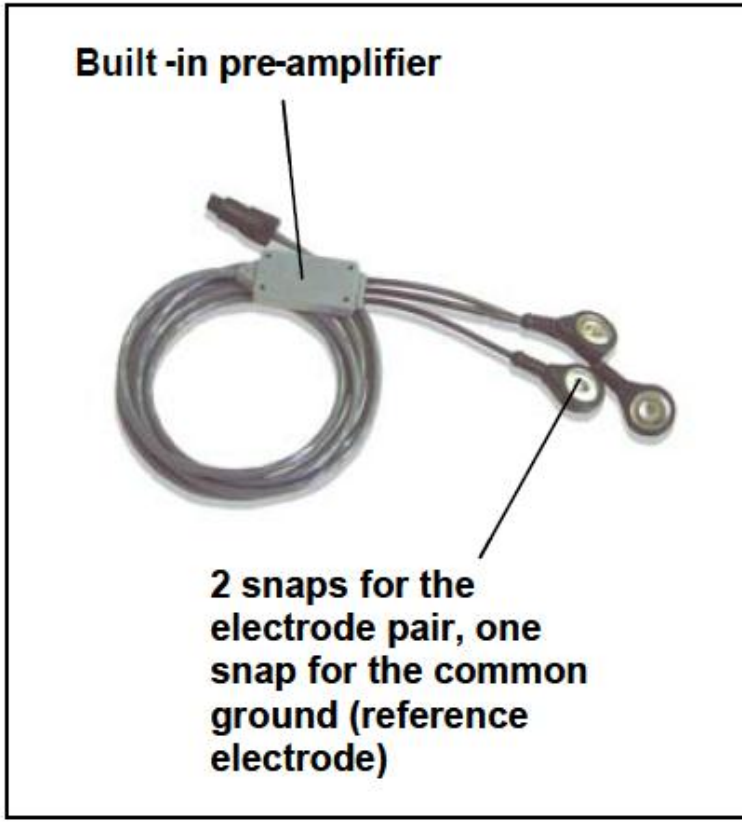


Fig.16: Electrode leads with cable built-in pre-amplifiers System NORAXON INC USA

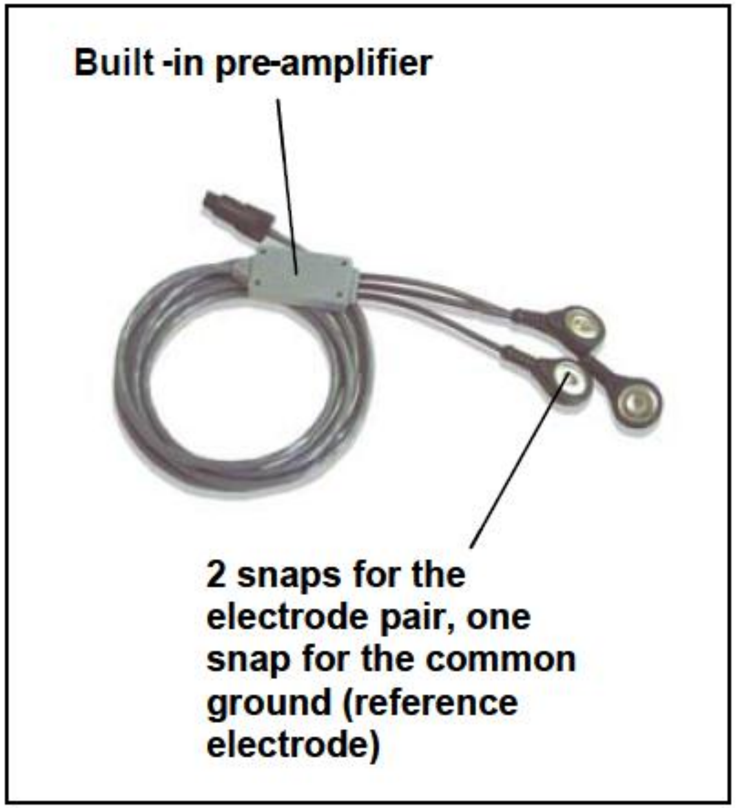


Fig. 16: Electrode leads with cable built-in pre-amplifiers System NORAXON INC USA

Fig.17: Variety of EMG amplifiers ranging from 1 or 2 channel Biofeedback units to tethered and telemetric systems. Systems by NORAXON INC. USA

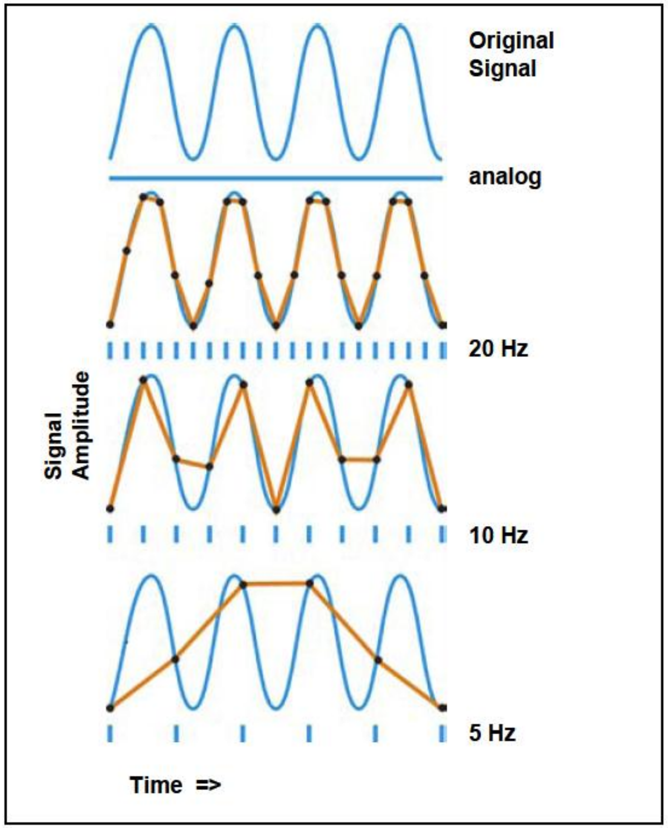


Fig.18: The effect of A/D sampling frequency on a digitized signal. Too low frequencies (lower traces) result in significant loss of signal information

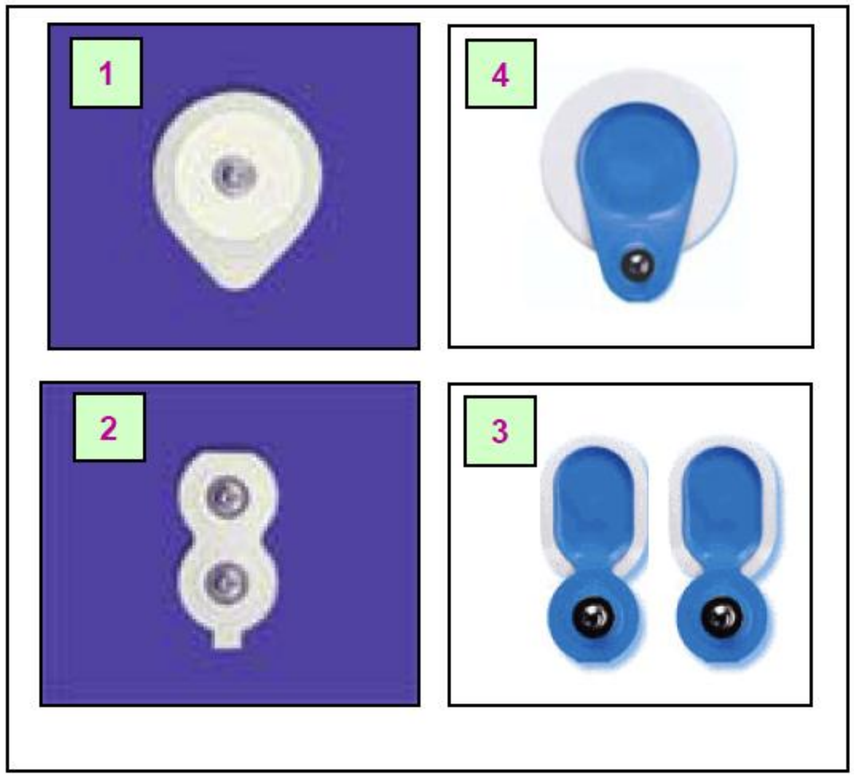


Fig.19: Selection of special EMG electrodes (1,2 NORAXON INC. USA) and regular ECG electrodes (3,4 AMBU-Blue Sensor)

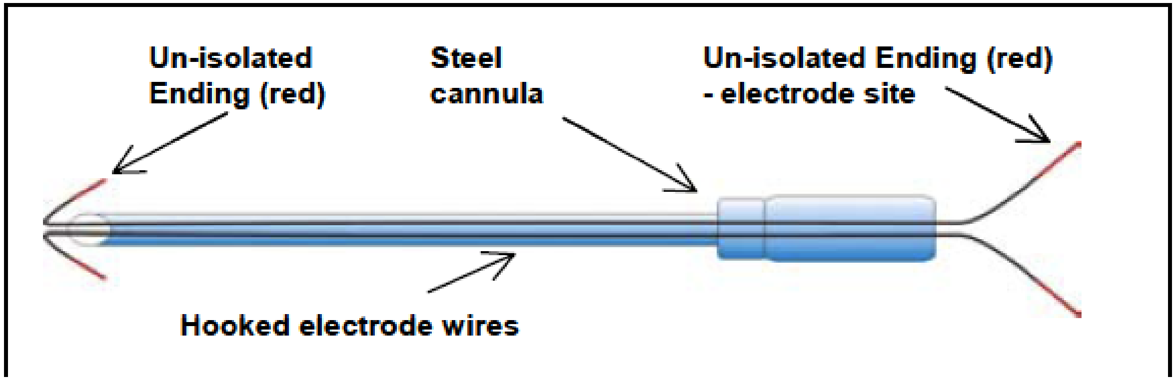


Fig.21: Schematics of a fine wire electrode: two fine wires with un-isolated endings are located with a steel cannula. System MEDELEC.

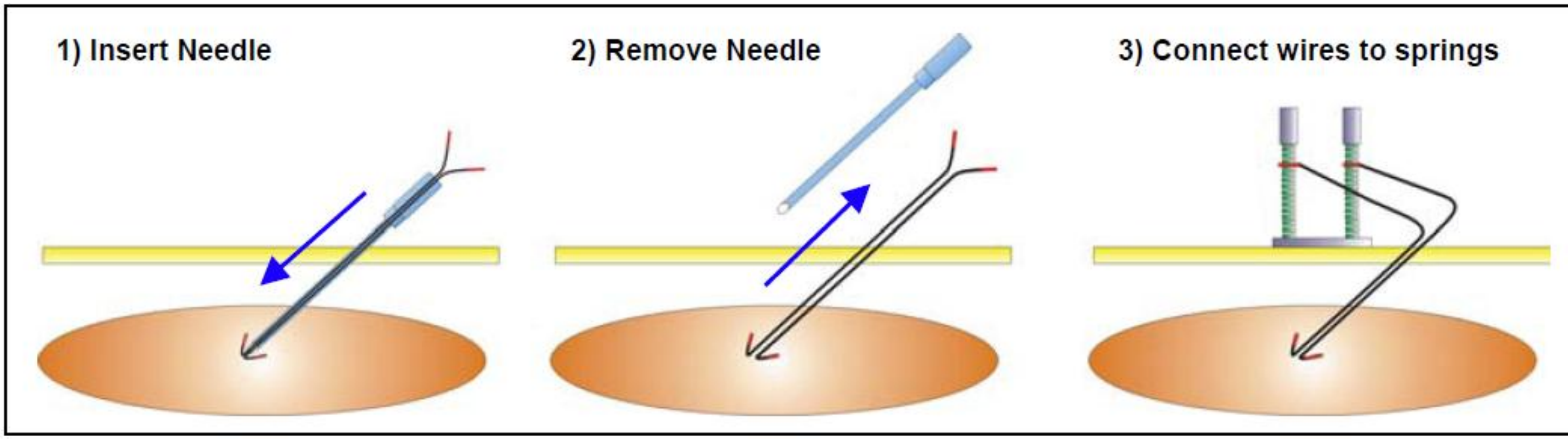
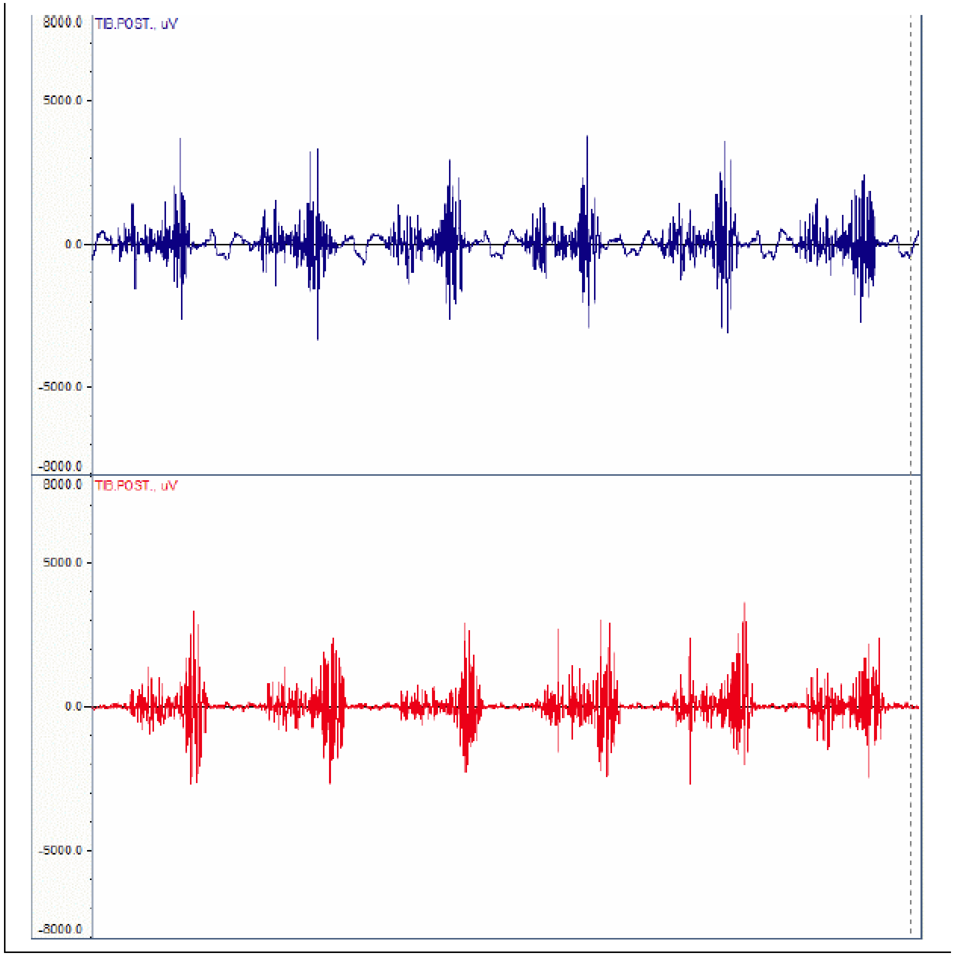


Fig.22: Procedure to insert the fine wires into the muscle tissue. After removing the needle, the distal endings of the wires are connected to steel spring adapters, which again are connected to the regular EMG pre-amplifier lead

sue.

Fig.22: Raw fine wire EMG recording of the M. tibialis posterior (upper blue trace) in treadmill walking. Baseline shifts indicate motion artifacts. The baseline can be stabilized by applying a 20 Hz highpass filter (lower red curve) – Institut fuer Biomechanik & Orthopaedie, D. Sporthochschule Köln-Germany)


8000.0
TIB.POST., uV
5000.0
0.0
-5000.0
-8000.0
8000.0
TIB.POST., uV
5000.0
0.0
-5000.0
-8000.0

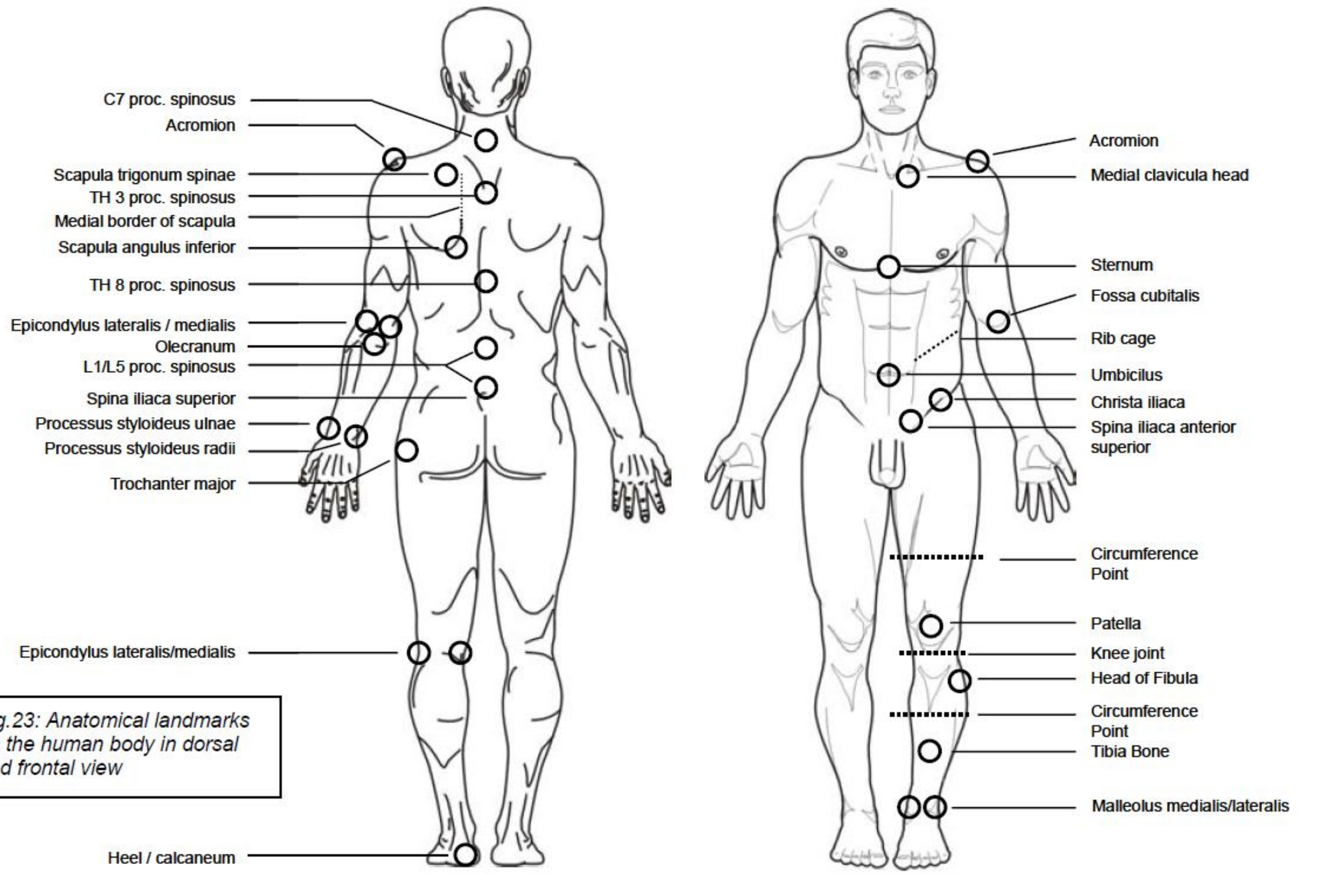


Fig.23: Anatomical landmarks on the human body in dorsal and frontal view

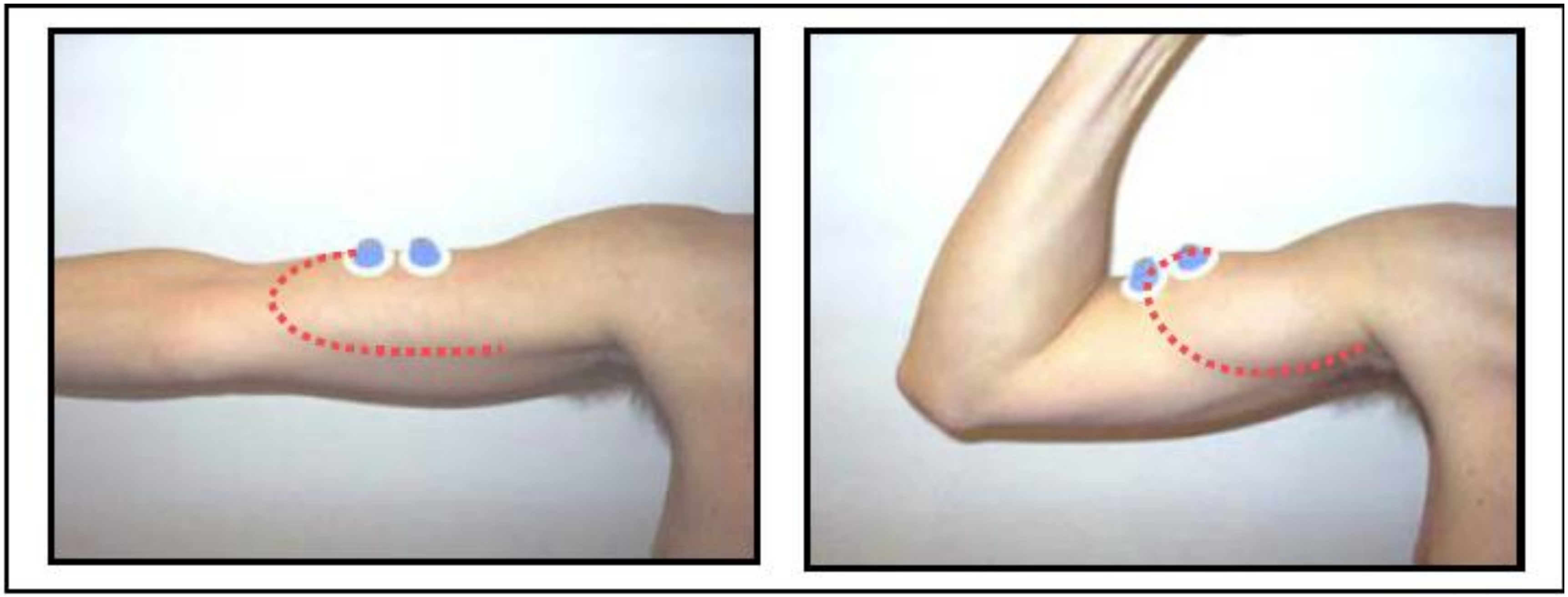
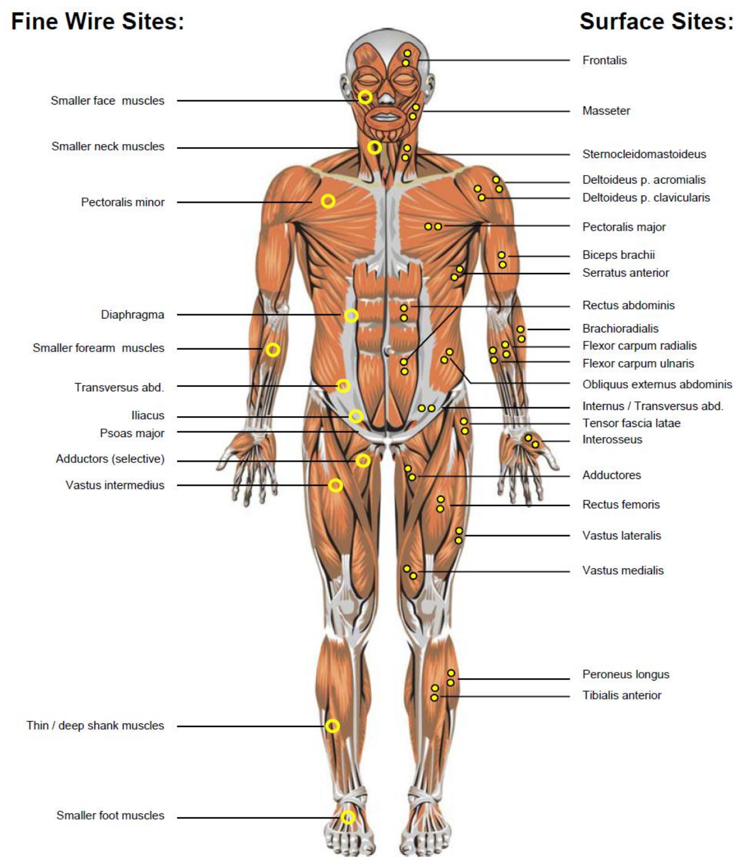


Fig.24: Migration of the muscle belly below the electrode pair attached at the biceps brachii. Note the in the extended position (right picture) the distal electrode has left the active muscle area. It is needed to attach electrodes at center position in the most flexed position.

Fig.25: Cable secured with elastic straps and tape

Frontal View



Dorsal View

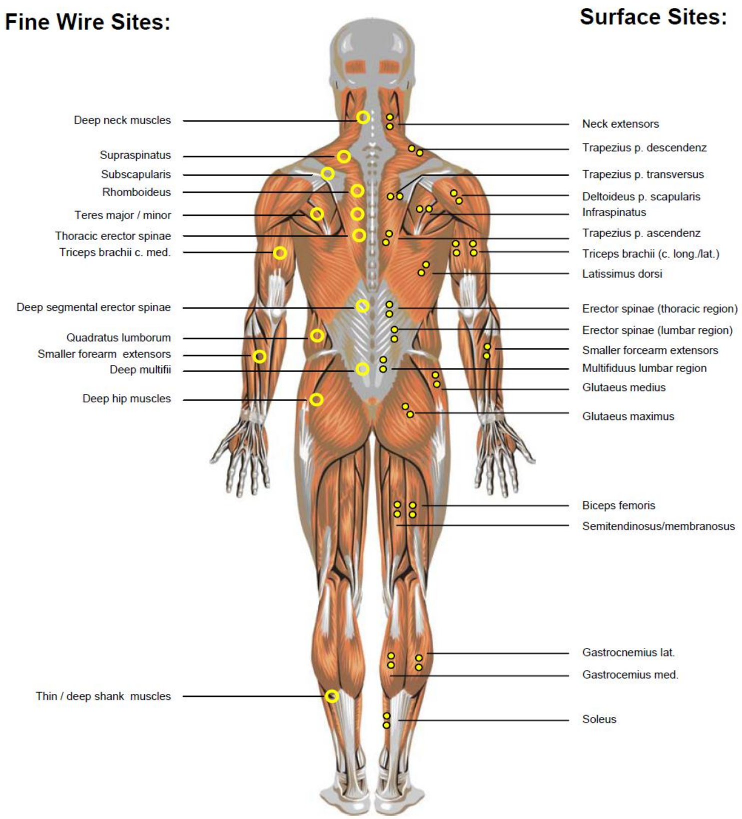
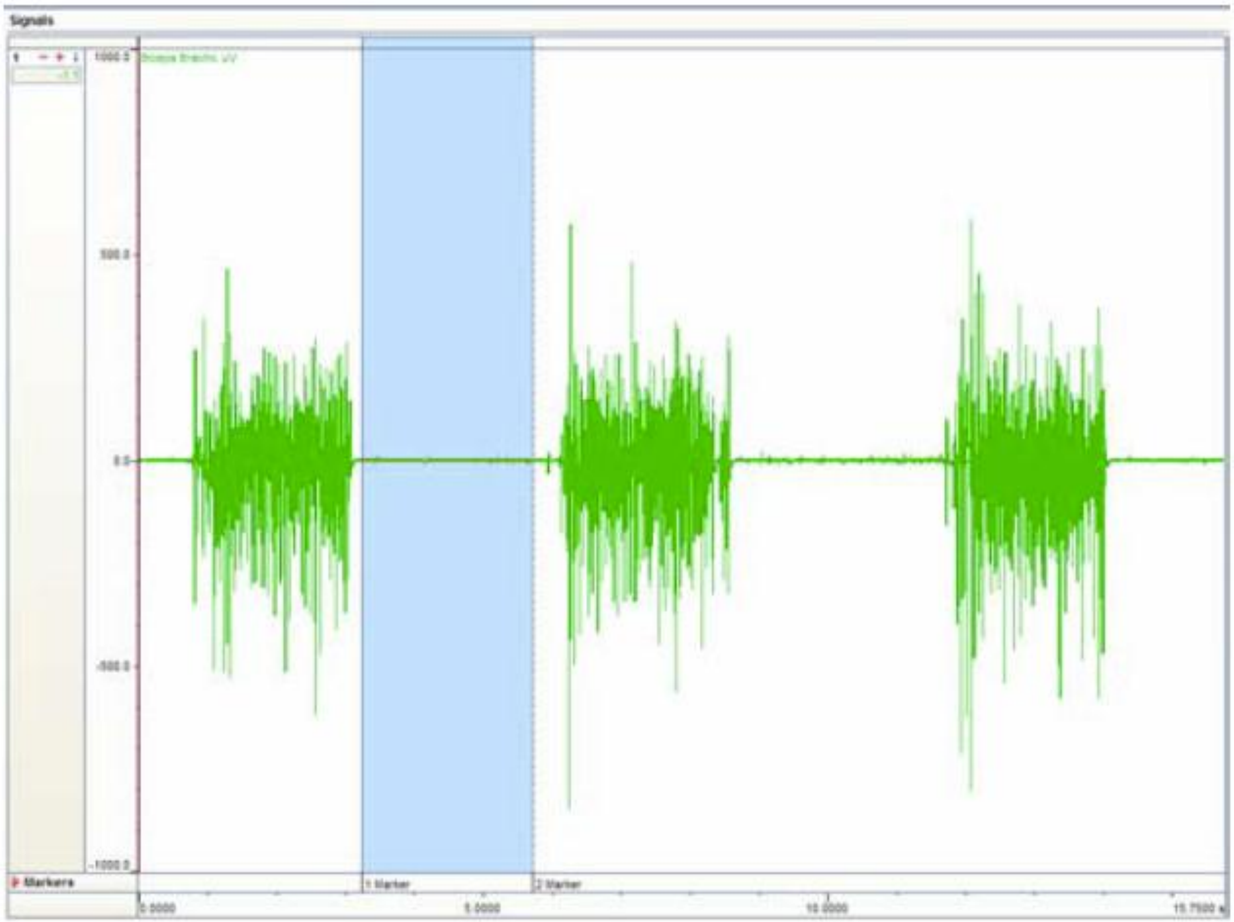


*Fig. 26b: Anatomical positions of selected electrode sites, dorsal view. The left side indicates **deep** muscles and positions for fine wire elec while the right side is for **surface** muscles and electrodes*

Fig. 27: EMG electrode impedance tester – model NORAXON INC. USA

Impedance range (KOhm)	**Recommendation**
1 - 5	-very good condition
5 - 10	- good and recommended if feasible
10 - 30	- acceptable for easy conditions
30 - 50	- less good, attention is needed (see next chapter)
> 50	- should be avoided or requires a second cleaning run

Fig. 28: Recommendations for electrode/skin impedance ranges


Signals
1000.0
500.0
0.0
-500.0
-1000.0
Markers
1 Marker
2 Marker
0.0000
5.0000
10.0000
15.7500 s

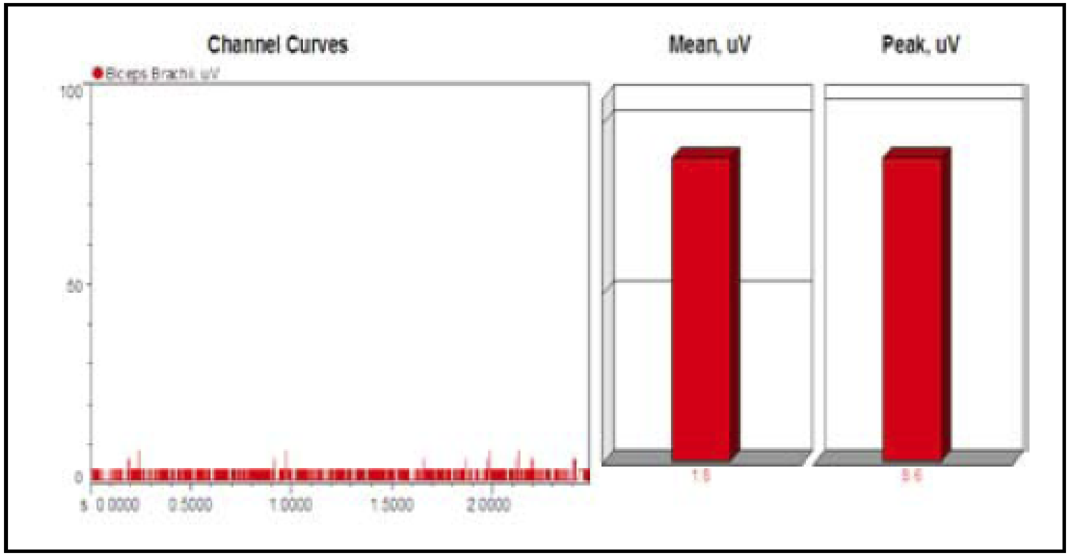


Fig. 29: Visual (left) and numerical (right) evaluation of the EMG baseline quality. The left raw EMG trace shows an example for a nearly perfect EMG recording with stable flat EMG baseline between active contractions. A quick analysis of a baseline section (blue area) indicates a mean noise level of 1.8 microvolts. System NORAXON INC. USA.

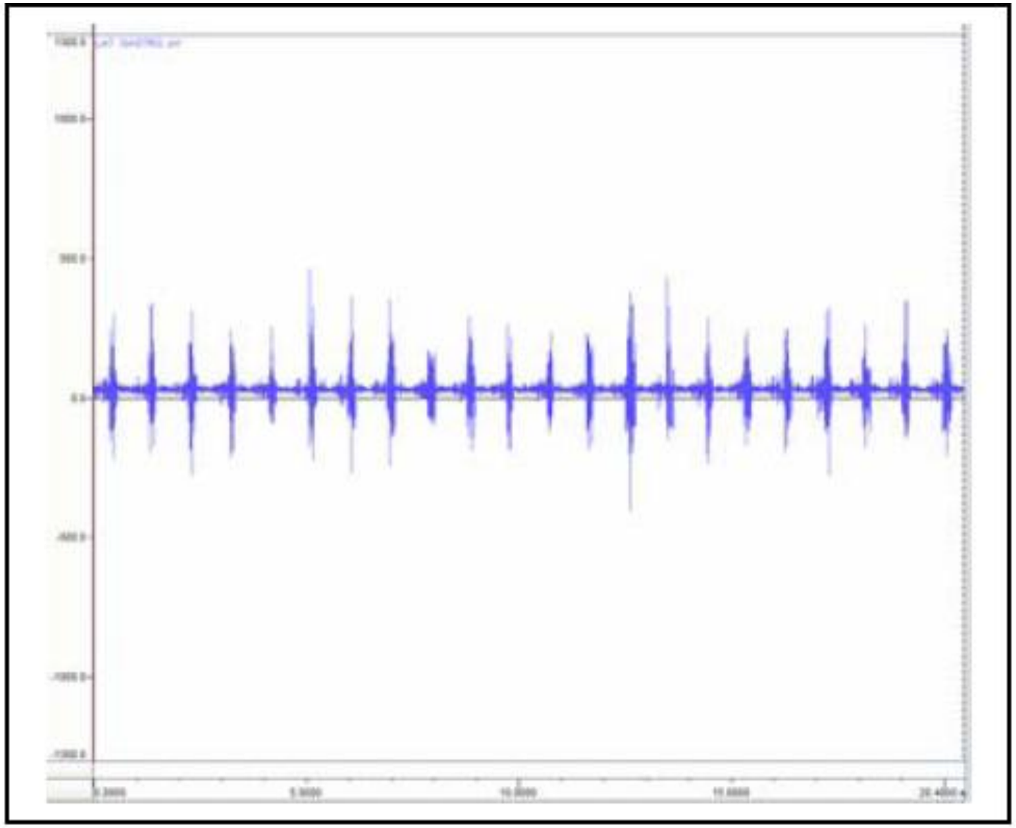


Fig. 30: Example for an offset shifted baseline. Special post recording edit functions should be applied to correct the shift

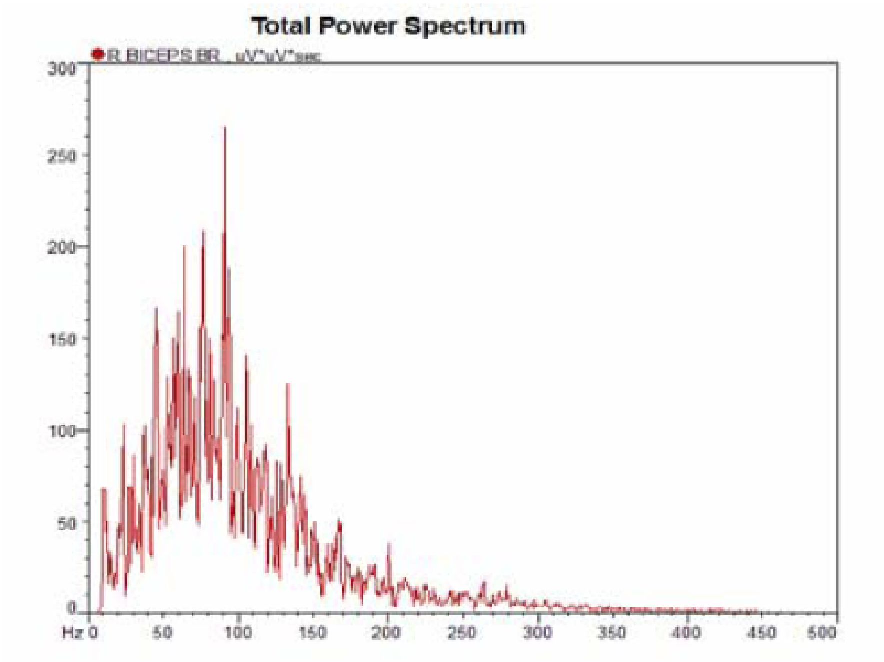
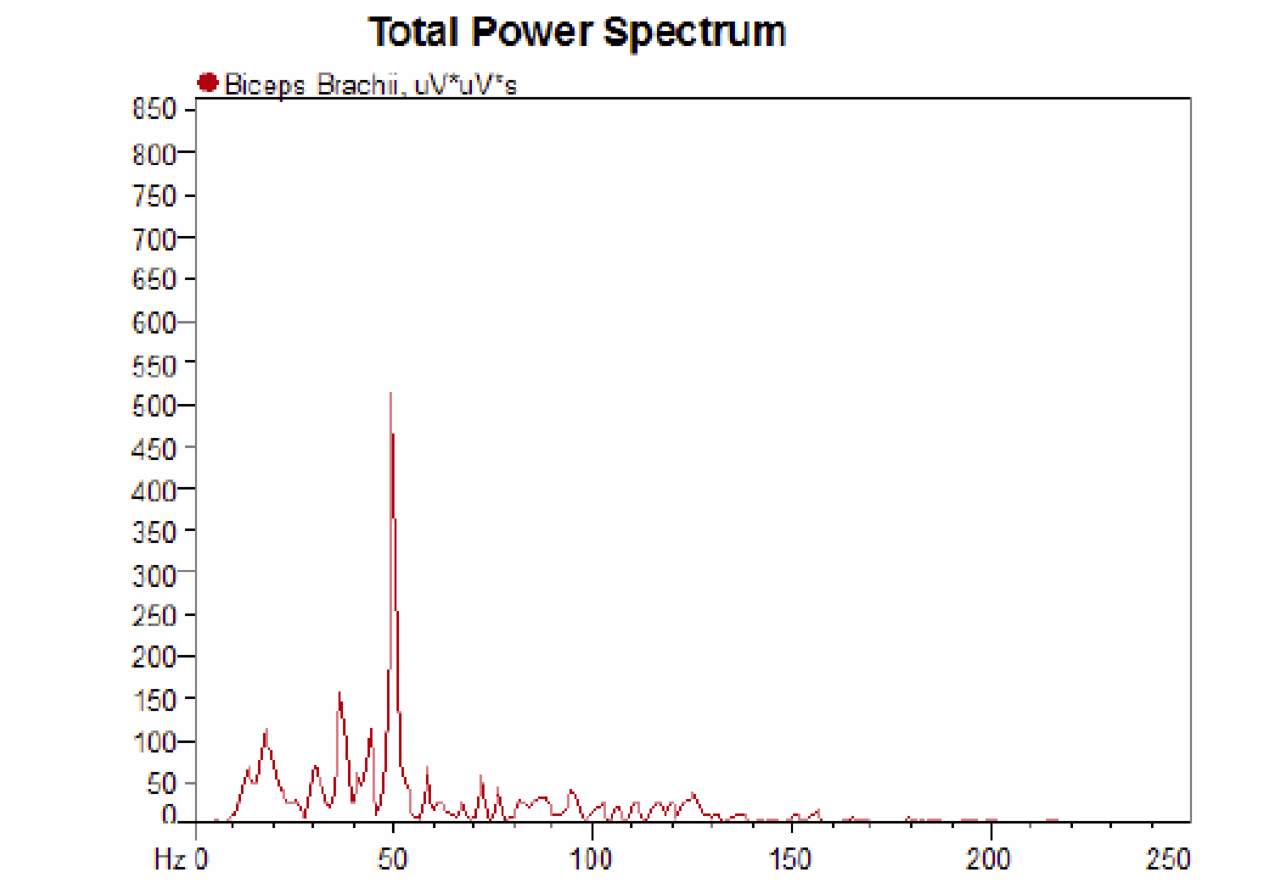


Fig. 31: The total power spectrum of a surface EMG recording: most of the signal power is located between 10 and 250 Hz.


Total Power Spectrum
Biceps Brachii, uV*uV*s
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Hz 0
50
100
150
200
250

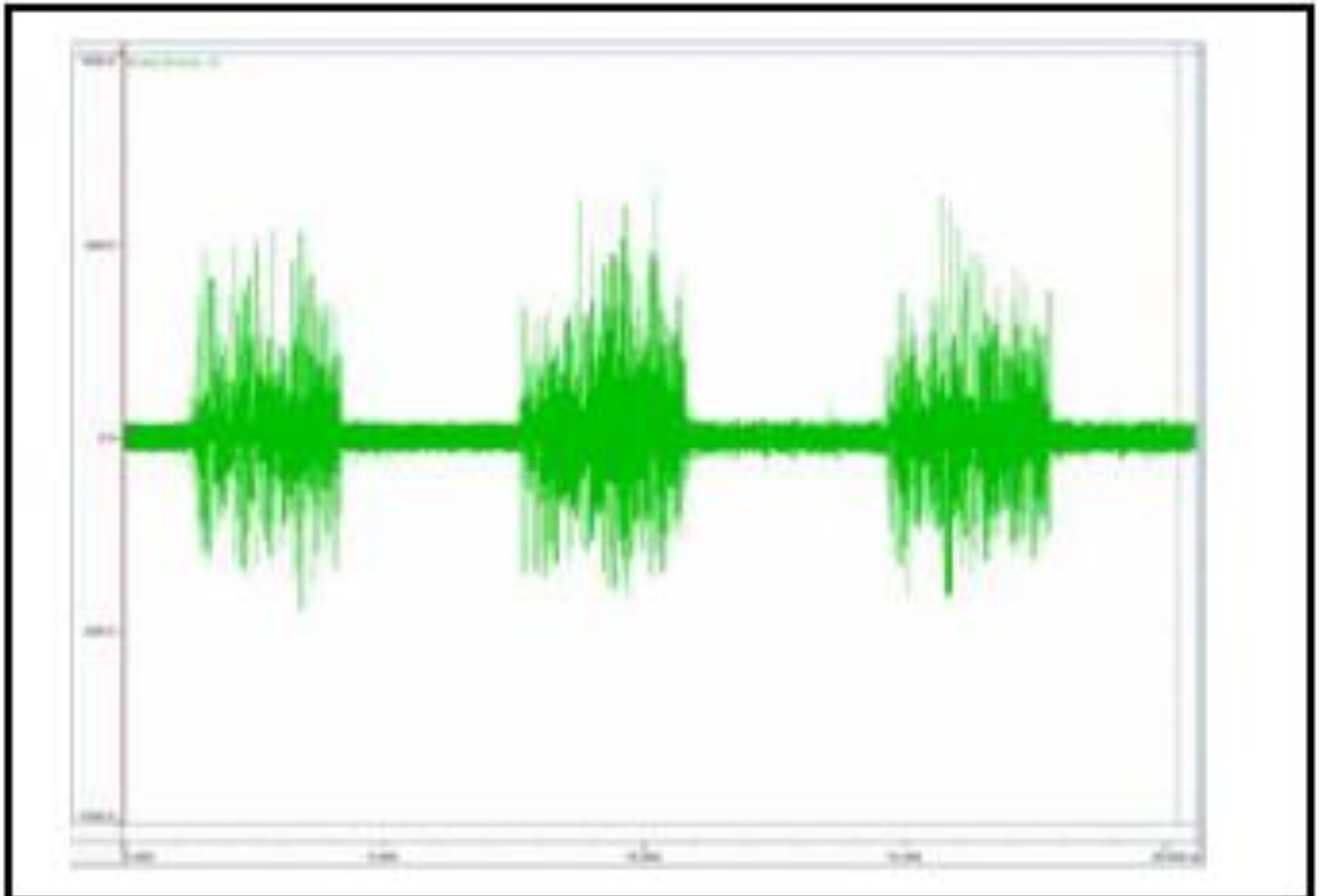


Fig. 33: EMG raw recording contaminated by power hum noise

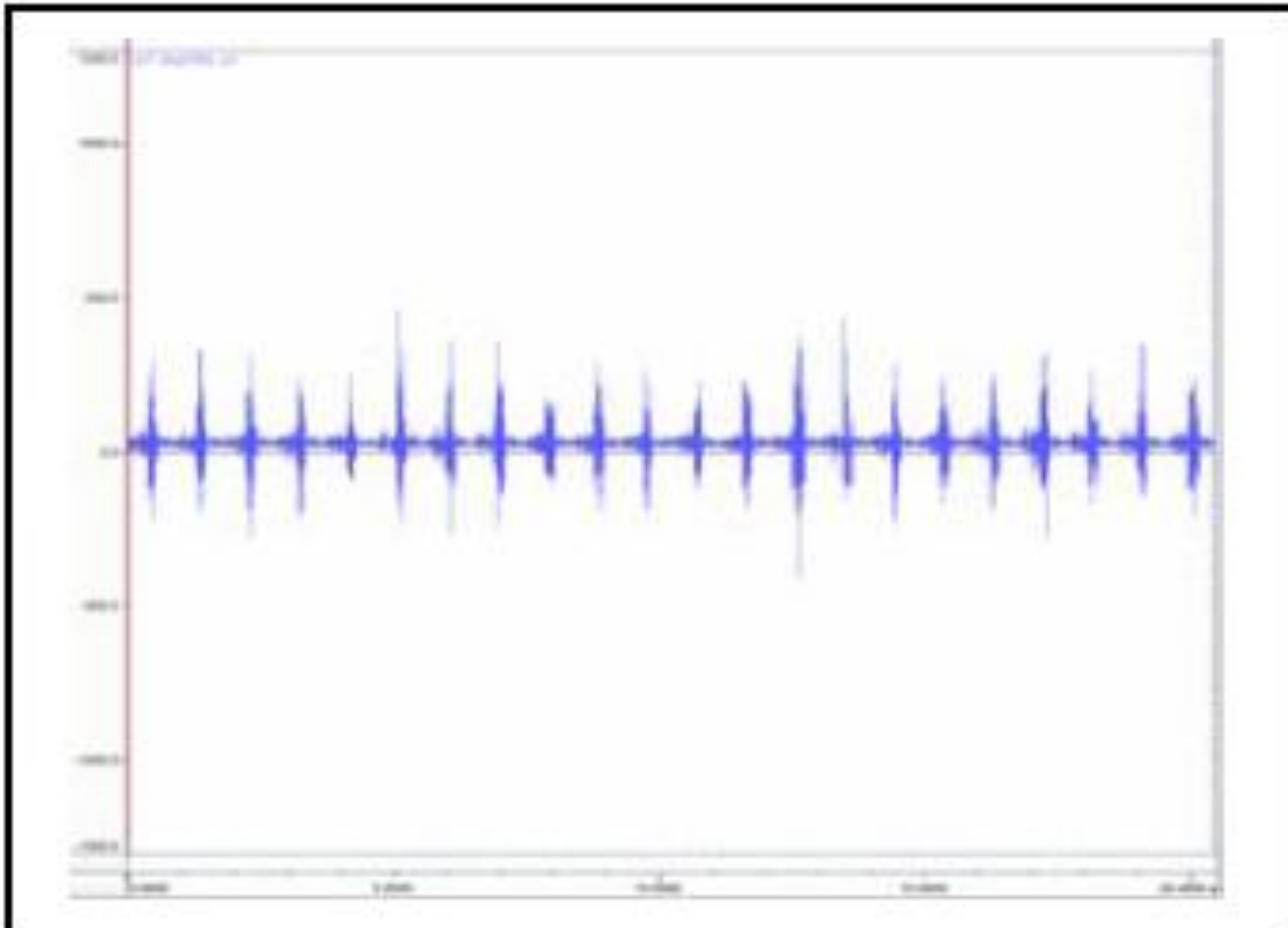


Fig. 34: EMG raw recording with offset shift positive side

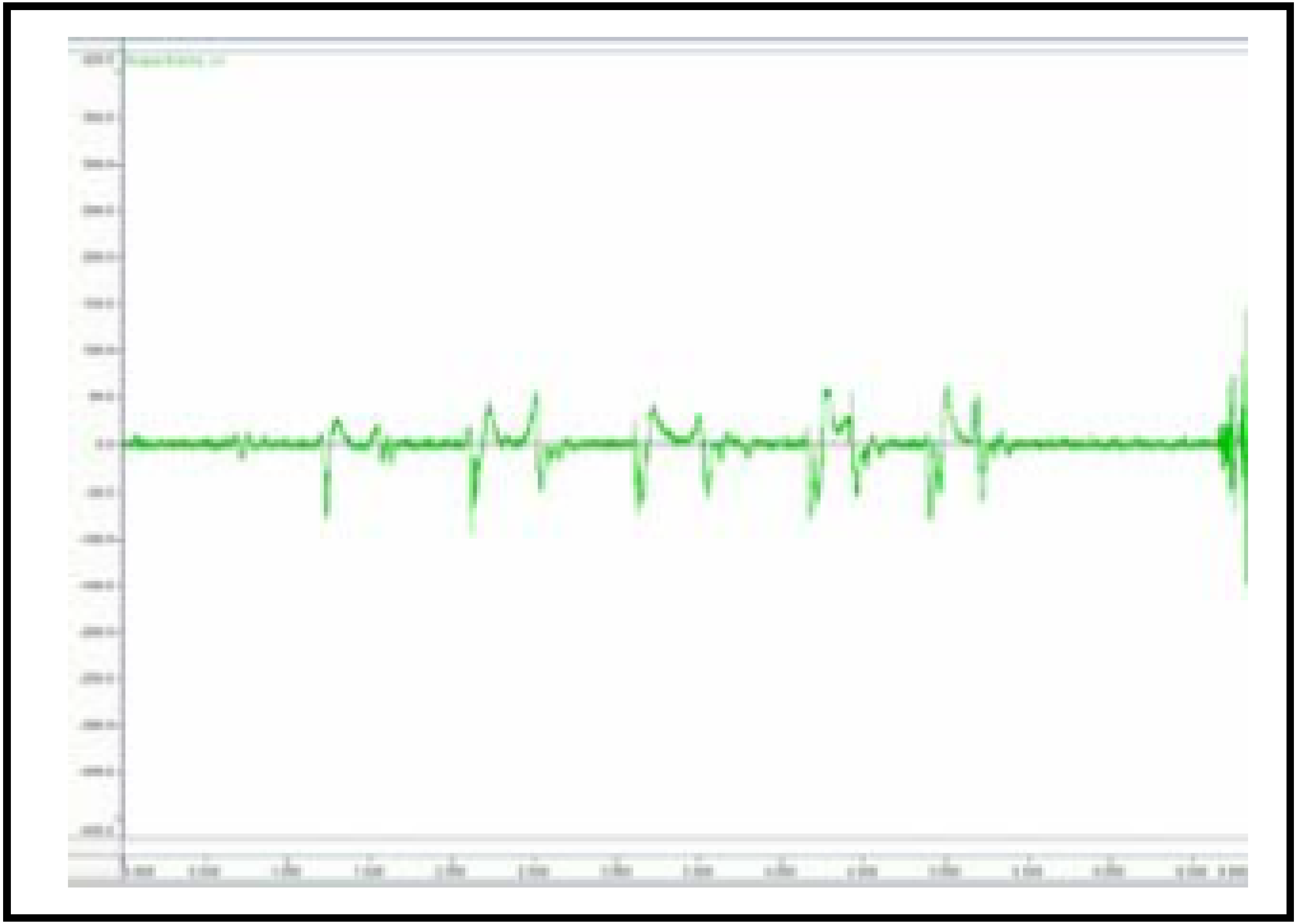


Fig. 35: EMG raw recording with cable movement artifacts

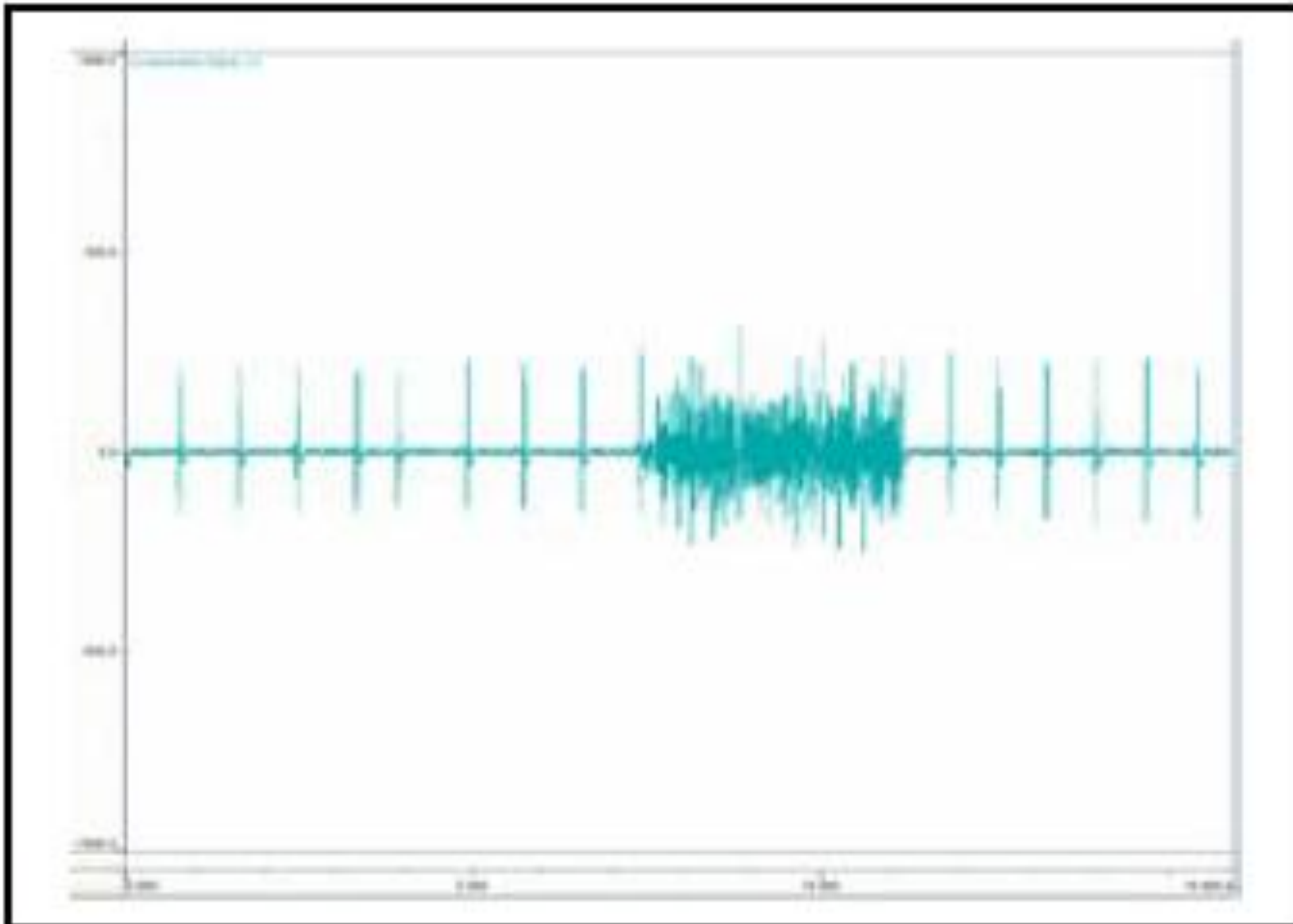


Fig. 36: EMG raw recording with ECG spikes

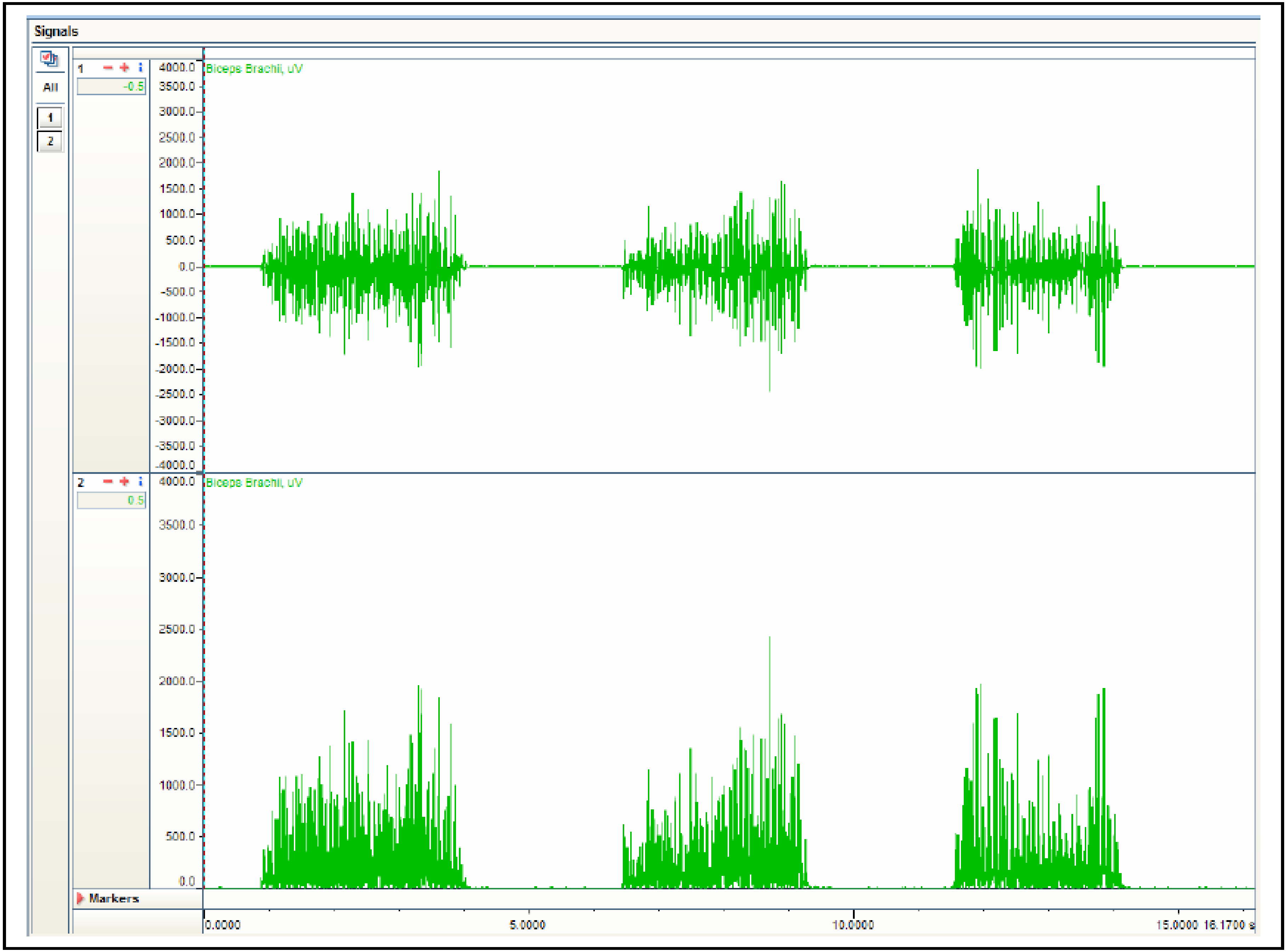


Fig. 37: EMG raw recording (upper trace) and rectified EMG recording (same signal, lower trace)

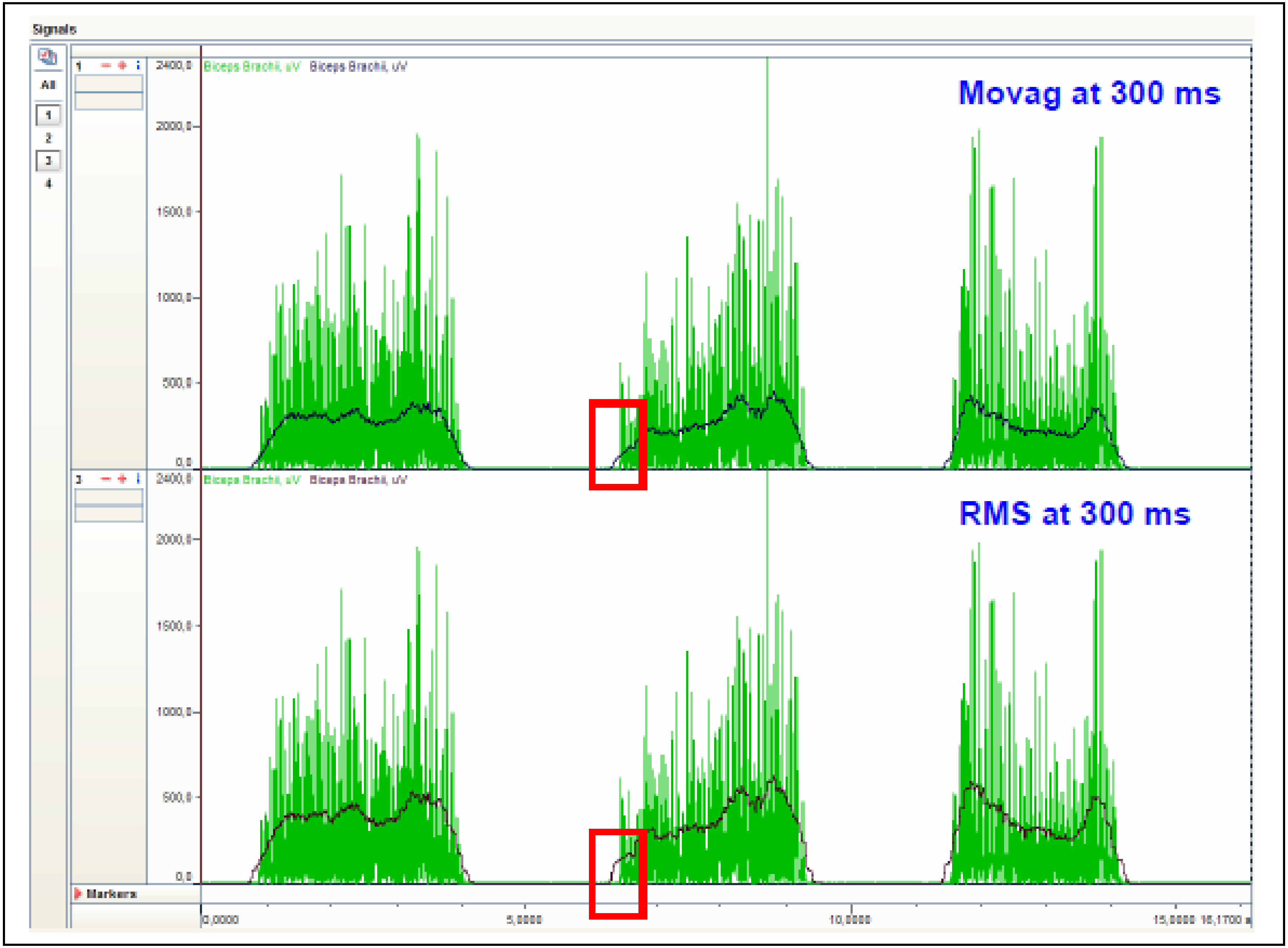


Fig. 38: Comparison of two smoothing algorithms using the same window width: Being very similar in shape, the RMS algorithm (lower trace) shows higher EMG amplitude data than the MovAg (upper trace)

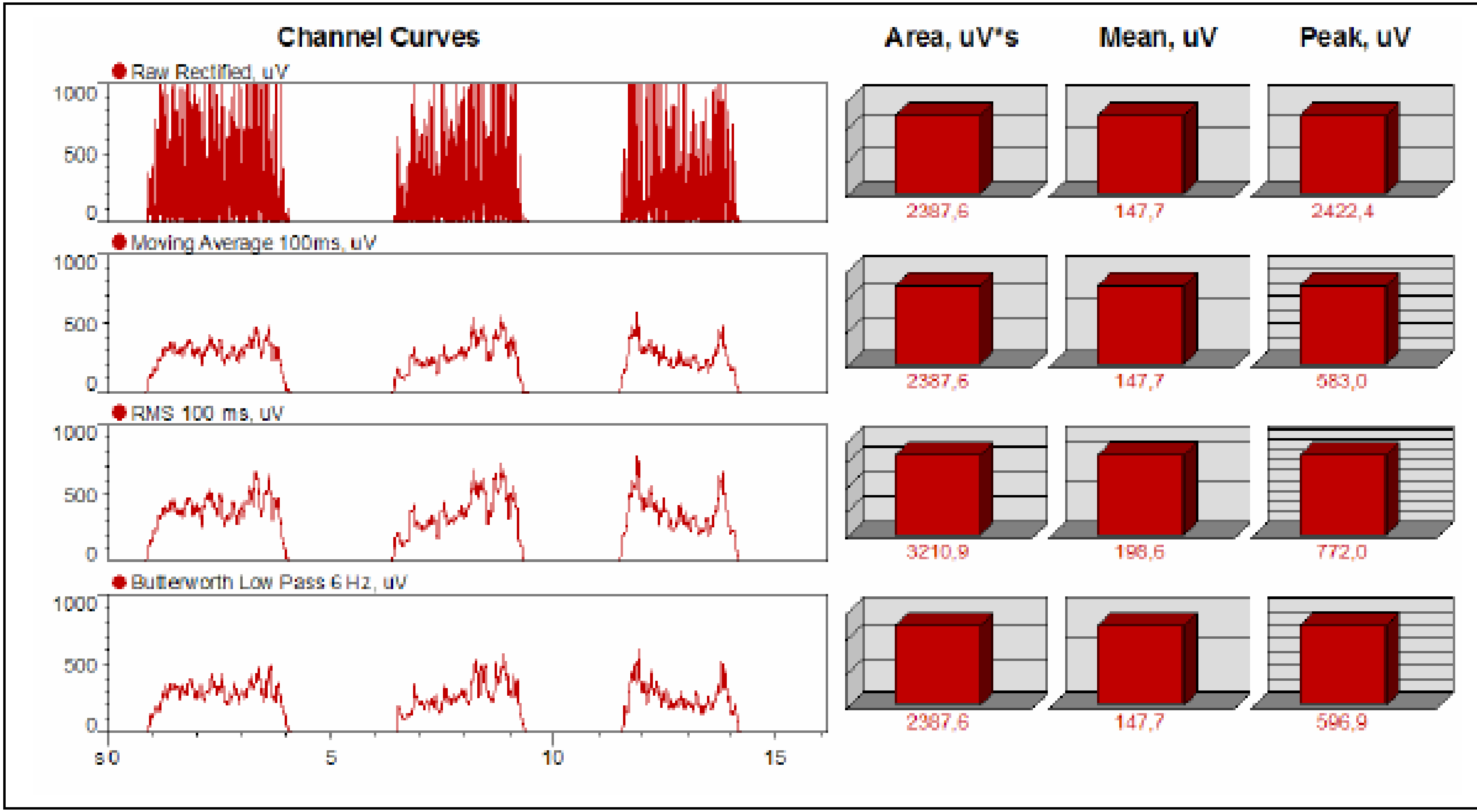


Fig. 39: Comparison of three smoothing algorithms and their effect on amplitude shape and statistics. The 6 Hz Butterworth Low Pass filter (lowest channel) compares to a Moving Average with 100ms window width. Both show the same shape and identical amplitude parameters

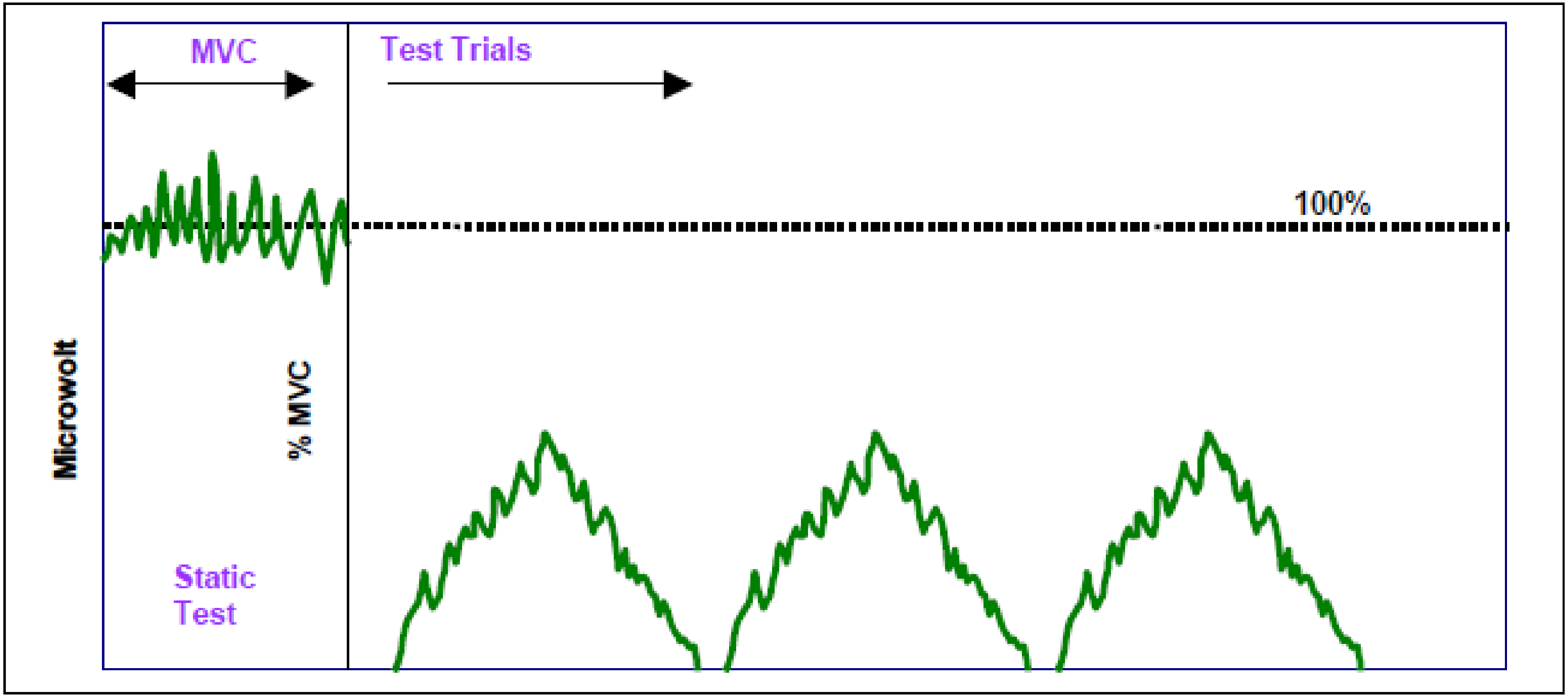
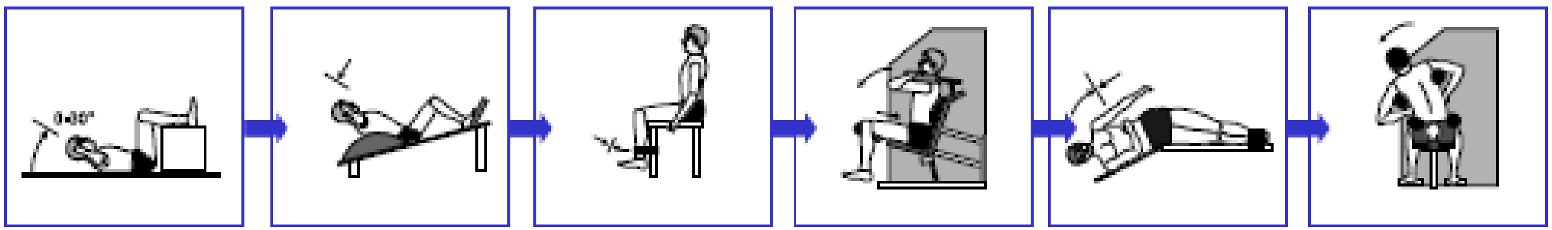


Fig. 40: The concept of MVC normalization. Prior to the test/exercises a static MVC contraction is performed for each muscle. This MVC innervation level serves as reference level (=100%) for all future trials

MVC-Test Sequence



MVC - "Hit-Quotes"

Rect. Abd.	3	5		2		
Obliquus		1		3	4	2
Rect.Fem.			10			

Fig. 41: MVC test sequence for trunk/hip flexor muscles (Rectus abd., Obliquus ext. abd., Rectus femoris). The numbers below each test exercise indicate how many of 10 subjects showed highest innervation at that exercise.

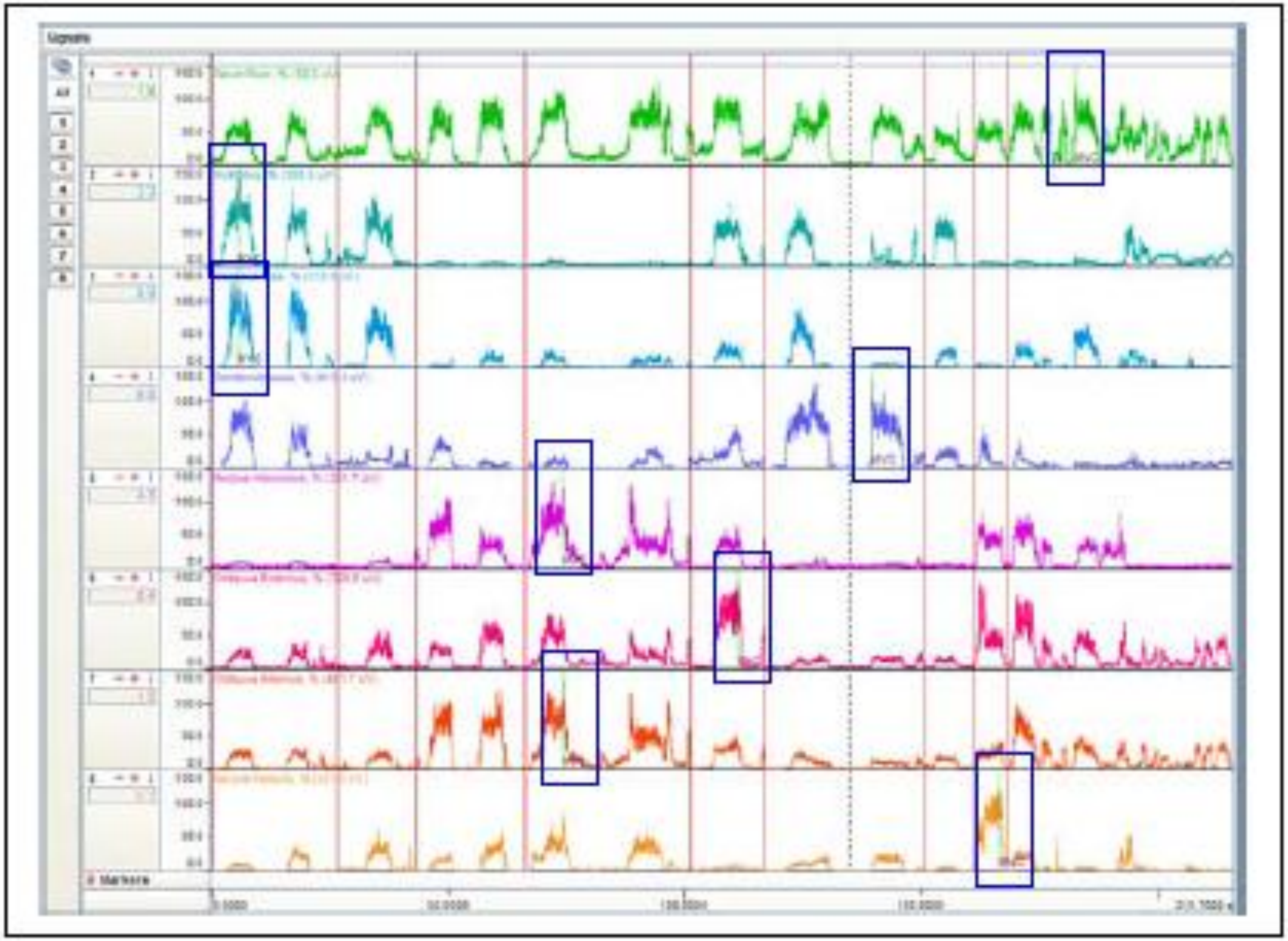


Fig. 42: Example for an 8 channel MVC test sequence. Each MVC – test is repeated as least one time, interrupted by a pausing (red lines). An automatic algorithm detects the highest EMG portions (green bars labelled “MVC”) and stores them for further use. System MYORESEARCH XP, NORAXON INC. USA

MVC Positions for forearm / shoulder muscles

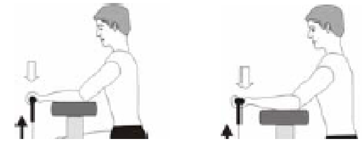
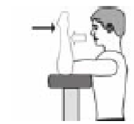
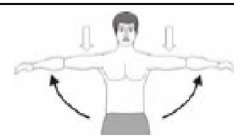
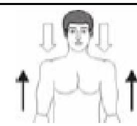
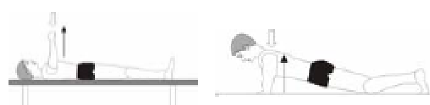
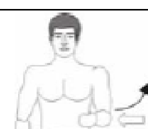
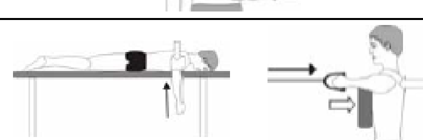
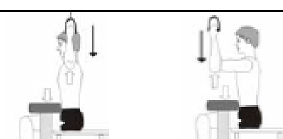
Muscle group	Exercise	Comments
Forearm flexors / extensors		Select a seated or kneeling position (in front of a bench) and arrange a stable forearm support. Manual resistance, barbells or cable/belts can be used. Consider using the latissimus d. and pectoralis major MVC test as a control exercise.
Biceps Brachii		A valid biceps b. MVC needs to be fastened securely at the elbow and trunk. The best arrangement is in a seated or kneeling position (in front of a bench). Consider using the latissimus d. MVC-test as a control exercise.
Triceps Brachii		Same instruction as biceps b.! Consider using the pectoralis major MVC-test as a control exercise.
Deltoideus		Select a seated position, if possible with the back in a fixed position. Fasten the straps near the arms close to the 90° position. The bilateral contractions guarantee a balanced force distribution for the trunk. The abduction works best for the pars acromialis of the deltoid muscle. Consider a flexion/extension position for the pars clavicularis.
Trapezius p. descendens		The MVC test can be performed with one side only. A static resistance can be arranged by manually restraining the arm or by arranging a large enough load to press the shoulder down (difficult).
Pectoralis major		Numerous test positions can be used! However, all of them need a very good shoulder/back resistance. The prone lying position would best be performed with a (fixed) long bar. The push up may work as an easy to set up alternative. Both positions should be performed in 90° elbow position.
Infraspinatus		Being the most important outward rotator of the shoulder cuff, any related outward rotation may work. Good results are achieved with uni- or bilateral manual resistance against the forearm
Trapezius p. trans. / Rhomboideus		The horizontal abduction best addresses the shoulder stabilization muscles. In the prone laying position a barbell or bilateral manual resistance can be used. The seated position requires the chest to be securely fastened and a cable or machine resistance (rowing machines).
Latissimus/Trapezius p. ascendence		The simulation of a pull-up produces the highest latissimus innervation. Consider/check a frontal and a lateral arm position at 90° elbow flexion. You may find MVCs for the biceps and the lower trapezius also.

Fig. 43a: Proposals for upper body MVC test arrangements. The black thin arrow indicates movement direction, the white thick arrows the resistance direction

MVC positions for trunk, hip and leg muscles

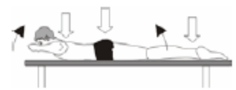
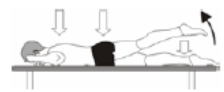
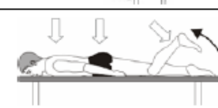
Muscle group	Exercise	Comments
Rectus abdominis / Obliquus internus abdominis	 	A valid MVC test for the abdominals is difficult to arrange. Sit-up styled movements with the legs securely fastened work the best. Let the spine flex by around 30° and use a belt or manual restraint for that position. The obliques may fire more when an additional trunk rotation is added to the flexion
Obliquus externus abdominis		This MVC test requires good coordinative skill. A side lying position with the leg and hip restrained is a good start position. Let the subject flex up and remain fixed early in the flexion position. An important check exercise is the MVC test for the rectus abdominis
Erector spinae / Multifidii	 	The prone lying position on a bench is a very productive MVC test position because all back muscles are facilitated within a muscle chain. MVCs for the erector spinae, the gluteus and the hamstrings are found here. A check exercise is the isolated back extension at a machine
Glutaeus maximus		A control exercise for the gluteus maximus muscle. It should be performed both in extended and flexed knee position with slightly outward rotated legs. The hyperextension position (~20°) is important.
Glutaeus medius		The hip abduction can be performed in fixed side lying position or supine position. Some subjects show higher EMGs in standing position
Mm. adductores		A stiff and large roll cushion is pressed between the flexed legs
Rectus femoris		An easy and beneficial exercise for all quadriceps muscles is a single leg knee extension between 90 and 70° knee flexion position.
Mm ischiocrurales		Isolated test for the hamstrings. Fasten the hip securely (belt/heavy person) and perform a unilateral knee flexion at ~ 20-30° knee flexion. An important check exercise is the prone lying MVC test for the erector spinae
Gastrocnemius		Being one of the strongest human muscles, the triceps surae group requires a very rigid (machine) resistance against the restrained hip. Perform an unilateral plantar flexion at 90° ankle position
Soleus		This is an important check exercise for the soleus muscle because the gastrocnemius is at a difficult work position. Perform a unilateral plantar flexion. The knee needs to be strapped down in a rigid position due to large forces.
Tibialis anterior		The tibialis anterior usually can be restrained by manual resistance, work unilateral

Fig. 43b: Proposals for trunk, hip and leg MVC test arrangements. The black thin arrow indicates movement direction, the white thick arrows the resistance direction

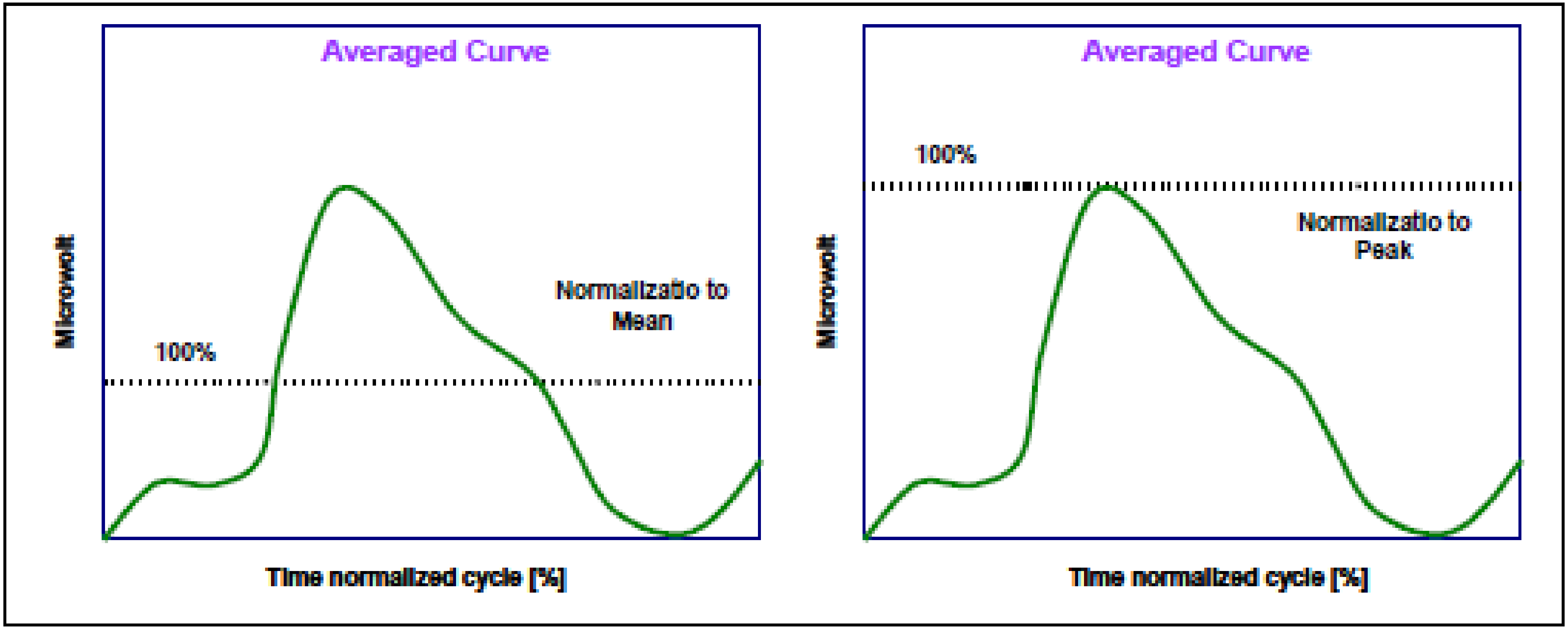


Fig. 44: Amplitude normalization to the test internal mean (left) or peak value (right) of the averaged curve.

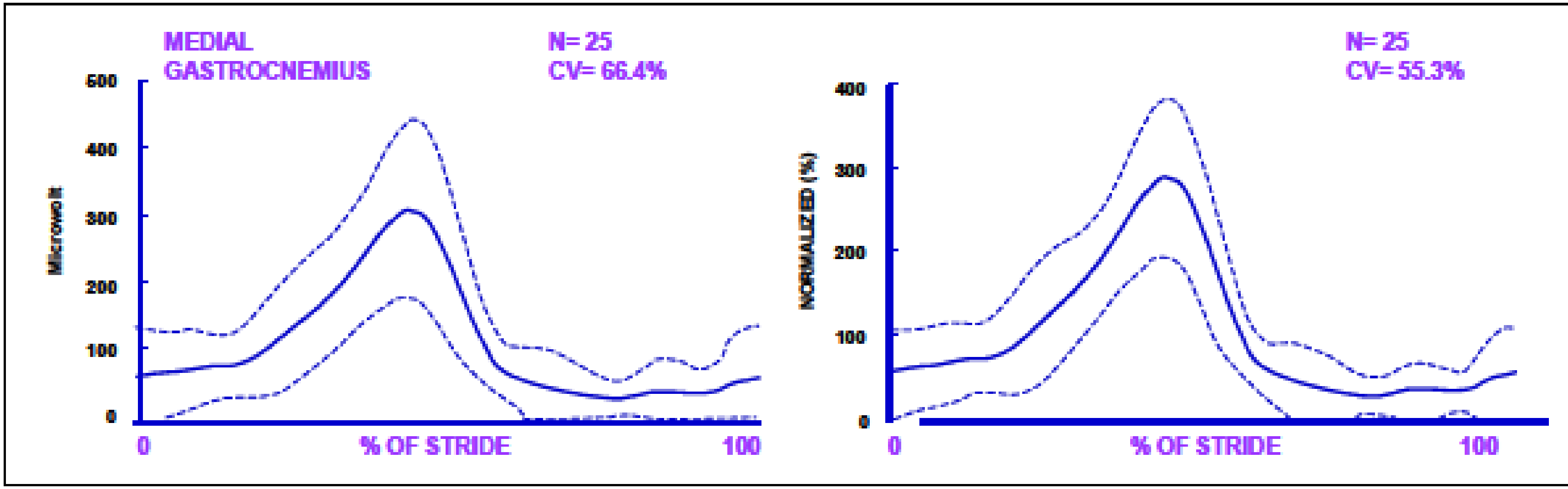


Fig. 45: Comparison of microvolt vs. mean value normalized ensemble averages of the medial gastrocnemius. The shape of the curve is not altered, but the variance (CV-coefficient of variance) is reduced due to mean normalization (left). Redrawn from 11, p. 64

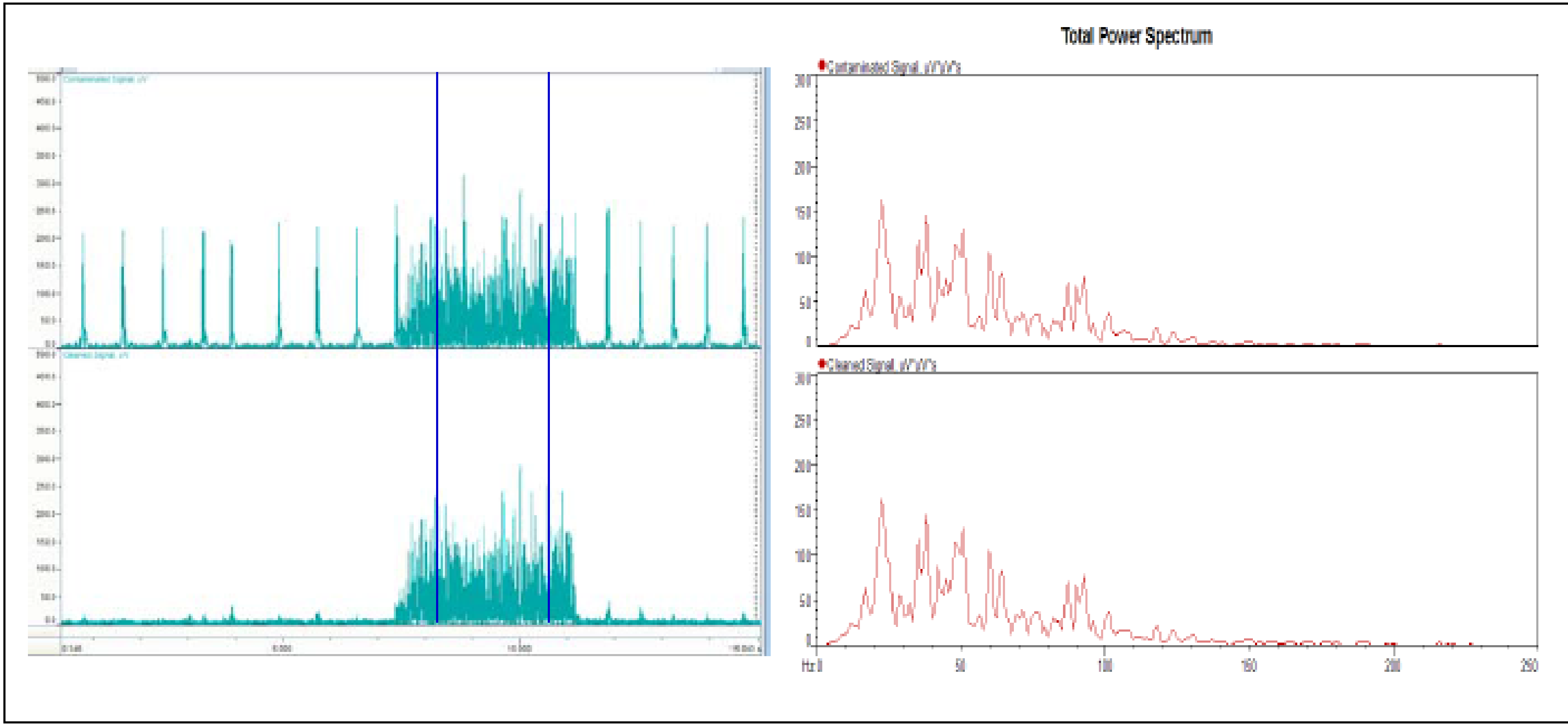


Fig. 46: Example of ECG affected EMG recording (upper trace) and the resulting signal after applying an ECG-reduction algorithm (lower trace). On the right side the FFT power spectrum of the interval between the two marks is shown. Note that both the EMG amplitude and the spectrum are not altered by the ECG reduction. System MyoResearch XP™, NORAXON INC USA

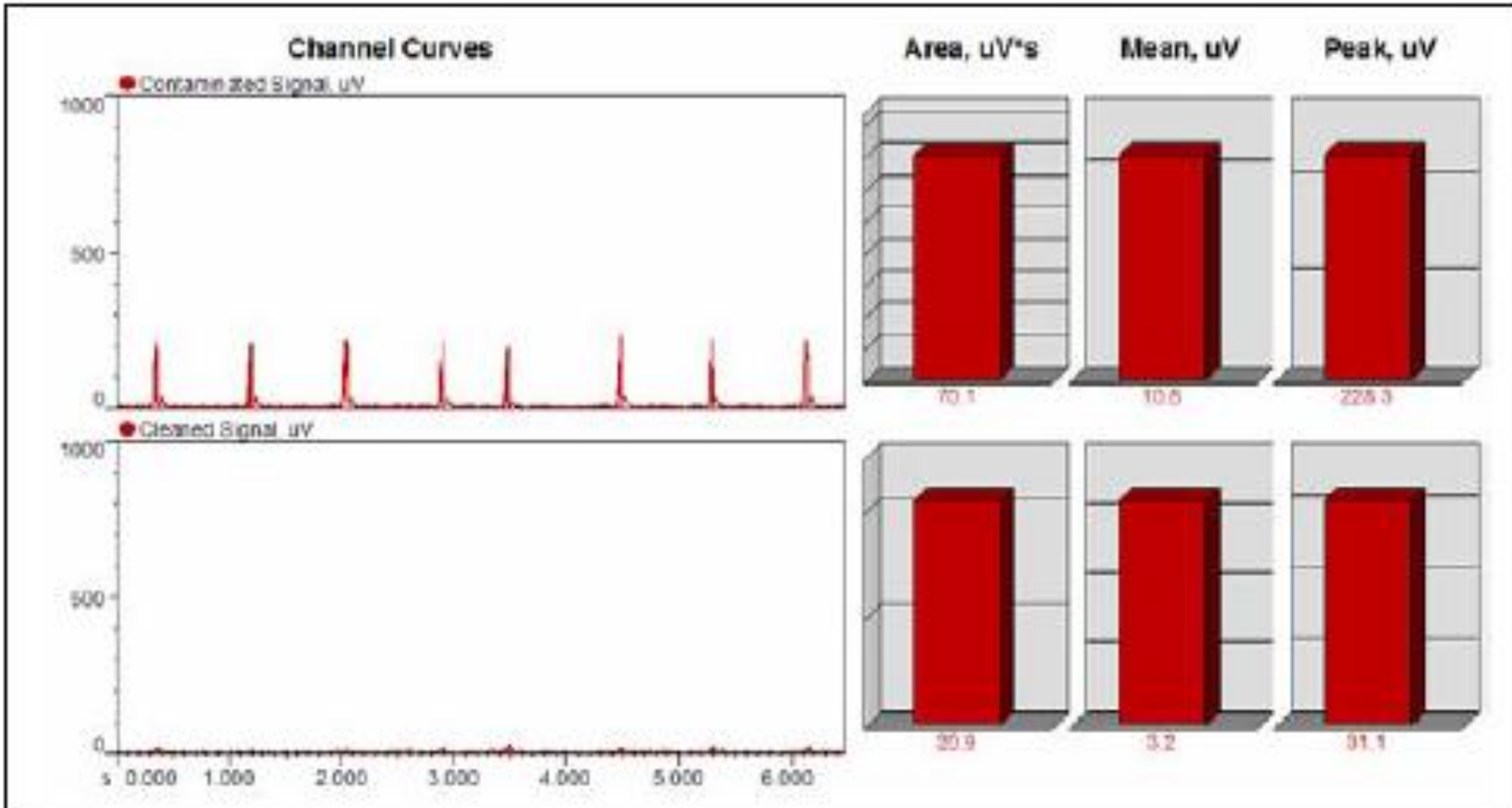


Fig. 47: Calculation errors produced by ECG interference on EMG traces near the rest line (relaxation studies). The amplitude mean value (MEAN) increases from 3,2 (cleaned) to 10.8 microvolt.

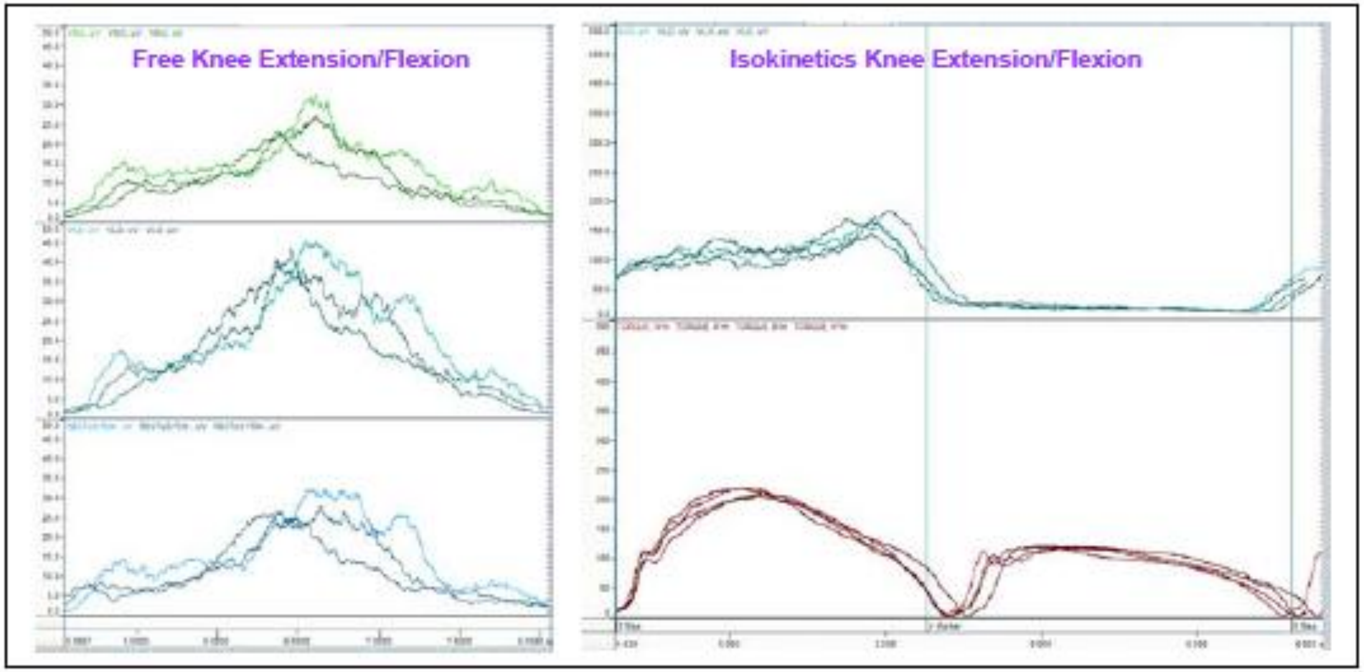


Fig. 48: Variability of single EMG patterns.
Left side shows a signal superposition of 3 repetitions for three knee extensors (vastus medialis&lateralis, rectus femoris) for a free squat movement. A considerable EMG variance between repetitions is visible.

On the right side, a signal superposition (3 repetitions) of the vastus medialis EMG (upper trace) and the resulting torque output curve (lower trace) is shown for a concentric/eccentric knee extension/flexion using an isokinetics device. The EMG variability is reduced - mainly due to the single joint character of the knee extension in seated position.

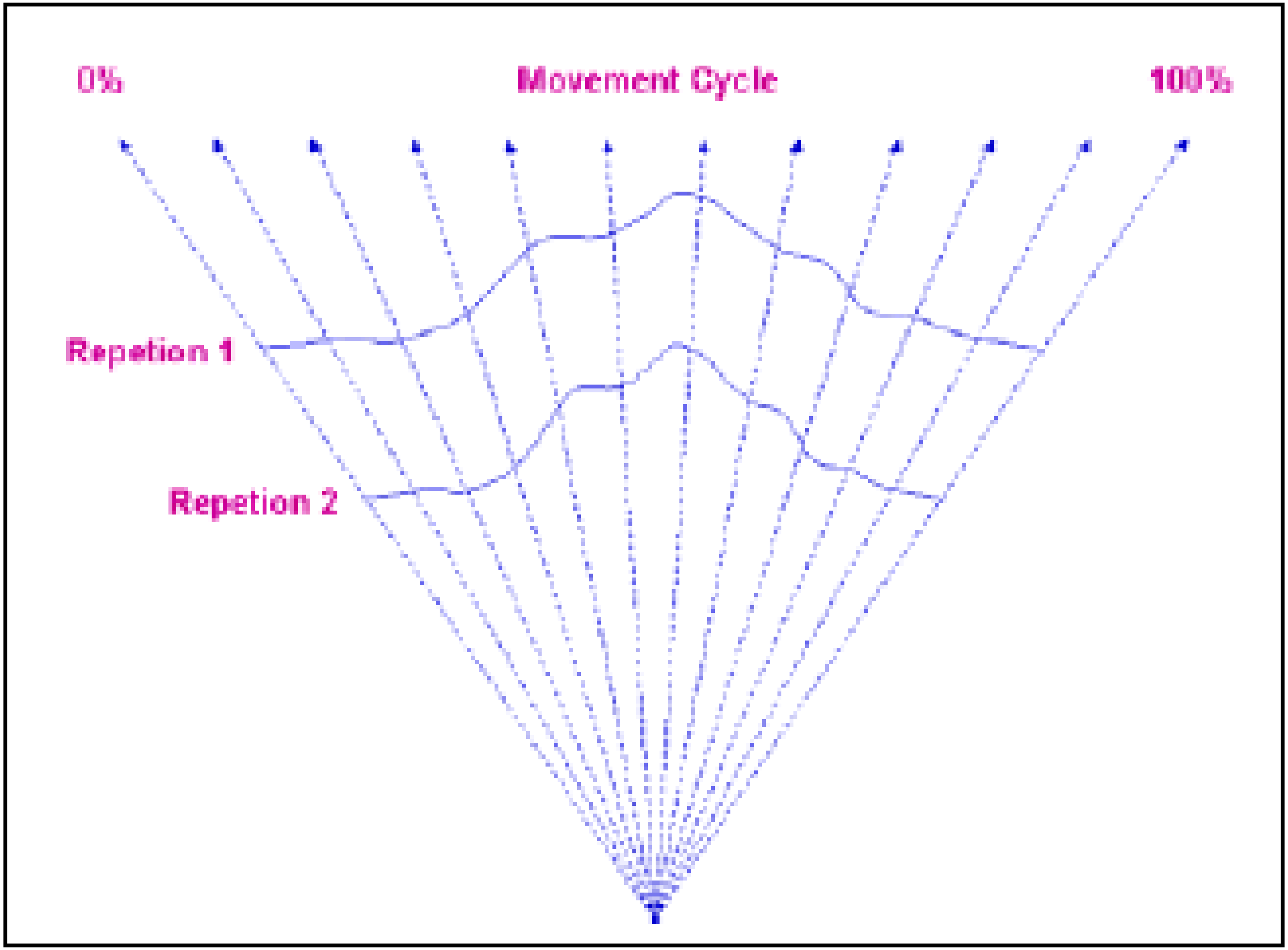


Fig. 49: The concept of time normalization for repetitions/interval of different duration. Each repetition is segmented in a certain amount of equal portions and the mean value of each portion is used for the averaging.

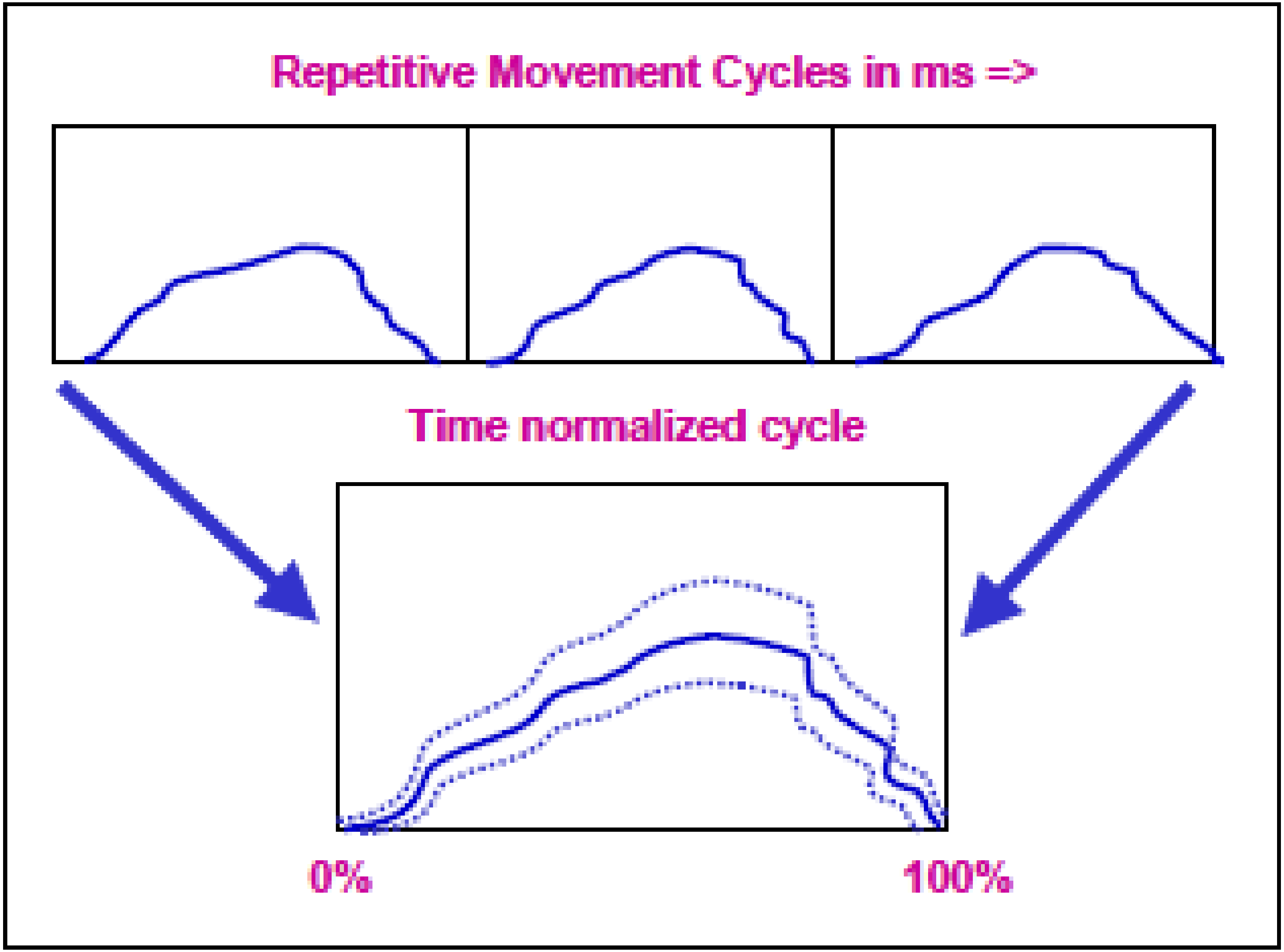


Fig. 50: Generation of an averaged curve within a time normalized frame ranging from 0 to 100%

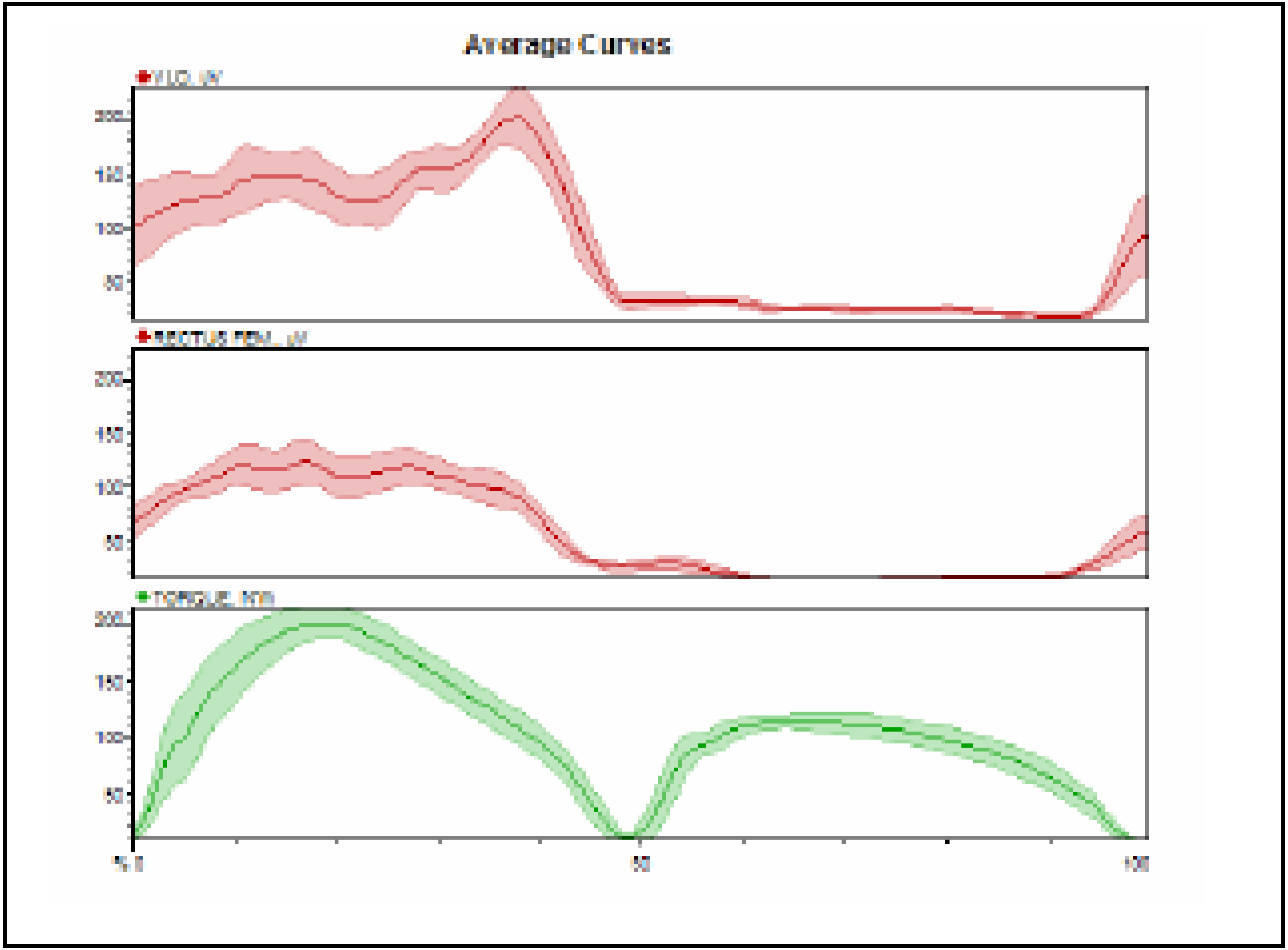


Fig. 51: Example of averaged curves, based on a isokinetic knee extension / flexion sequence at 60°/sec. Red= EMG, green=torque

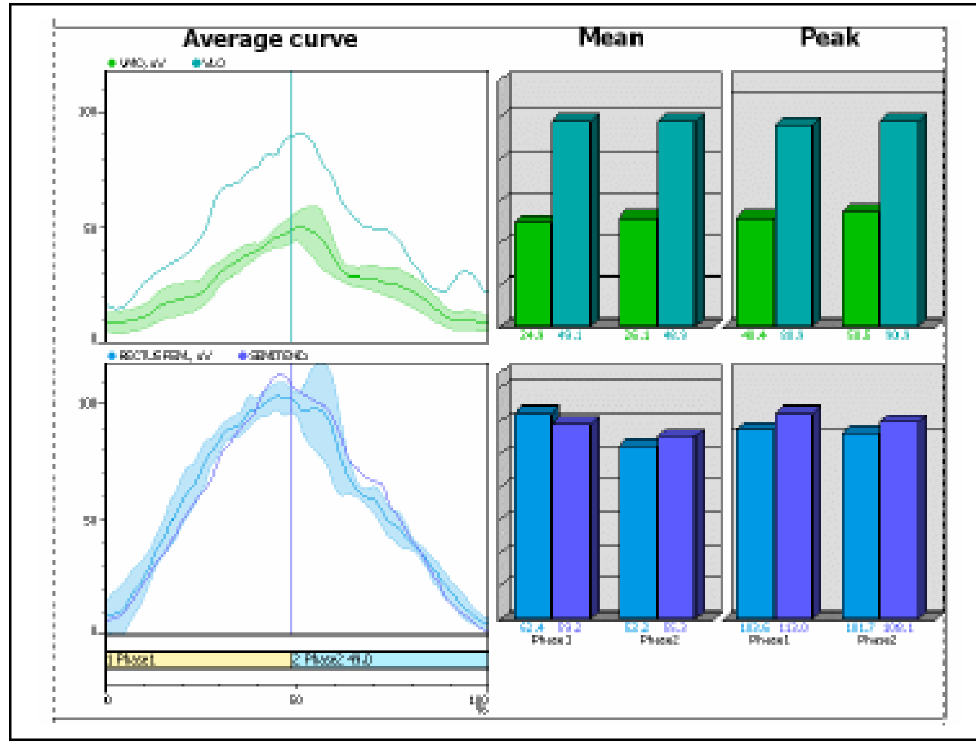


Fig. 52: Comparisons of average EMG curves within the unique time format resulting from time normalization. EMG Pattern difference can easily be detected, qualitatively described and quantitatively be calculated if the same muscle is investigated in two different test conditions. If muscles (=different detection conditions!) are compared, the quantitative comparison should be avoided and the focus is set to the "innervation behaviour".

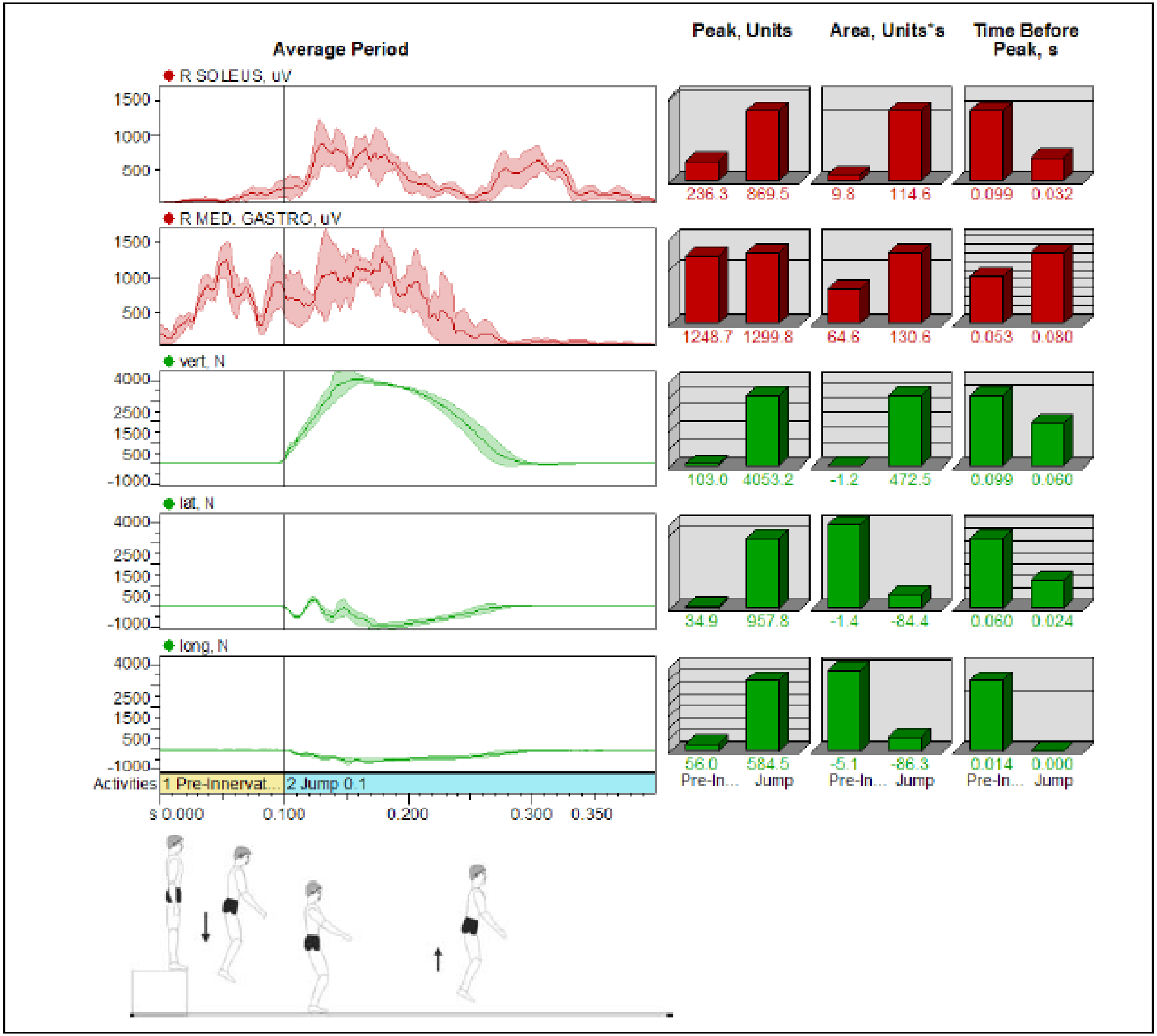


Fig. 53: Averaging without time normalization. A fixed interval before and/or after (blue activity section) a reproducible movement event (ground contact) is used as a standardized format for averaging. For the drop jump on a force plate, as shown above, a fixed interval of 100 ms is selected to describe the pre-innervation phase (yellow activity section), a 400 ms interval after the ground contact is used to describe the EMG activity (red curves) and impulse (green curves) of the jump.

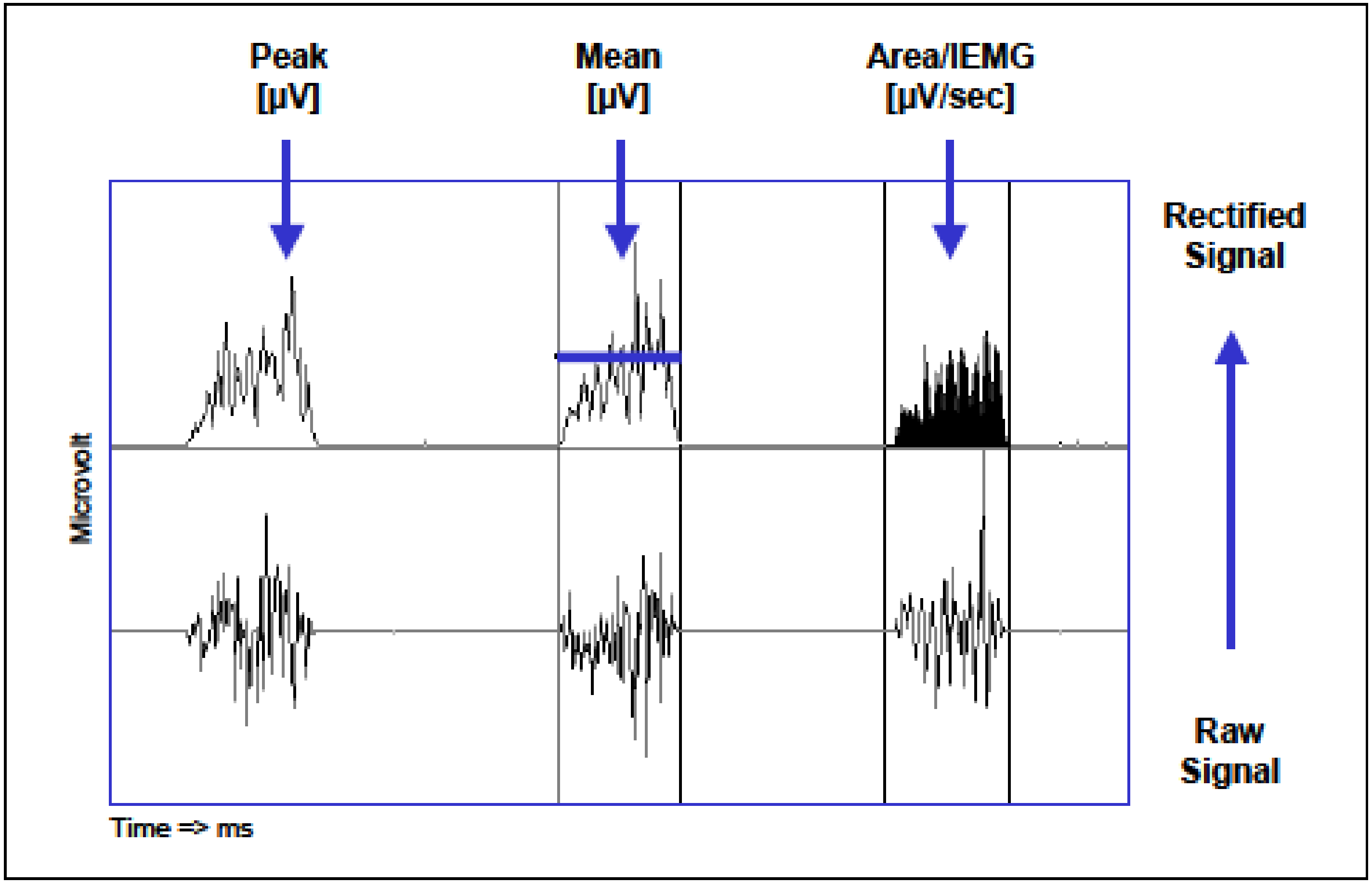


Fig. 54: EMG standard amplitude parameters based on the rectified EMG curve

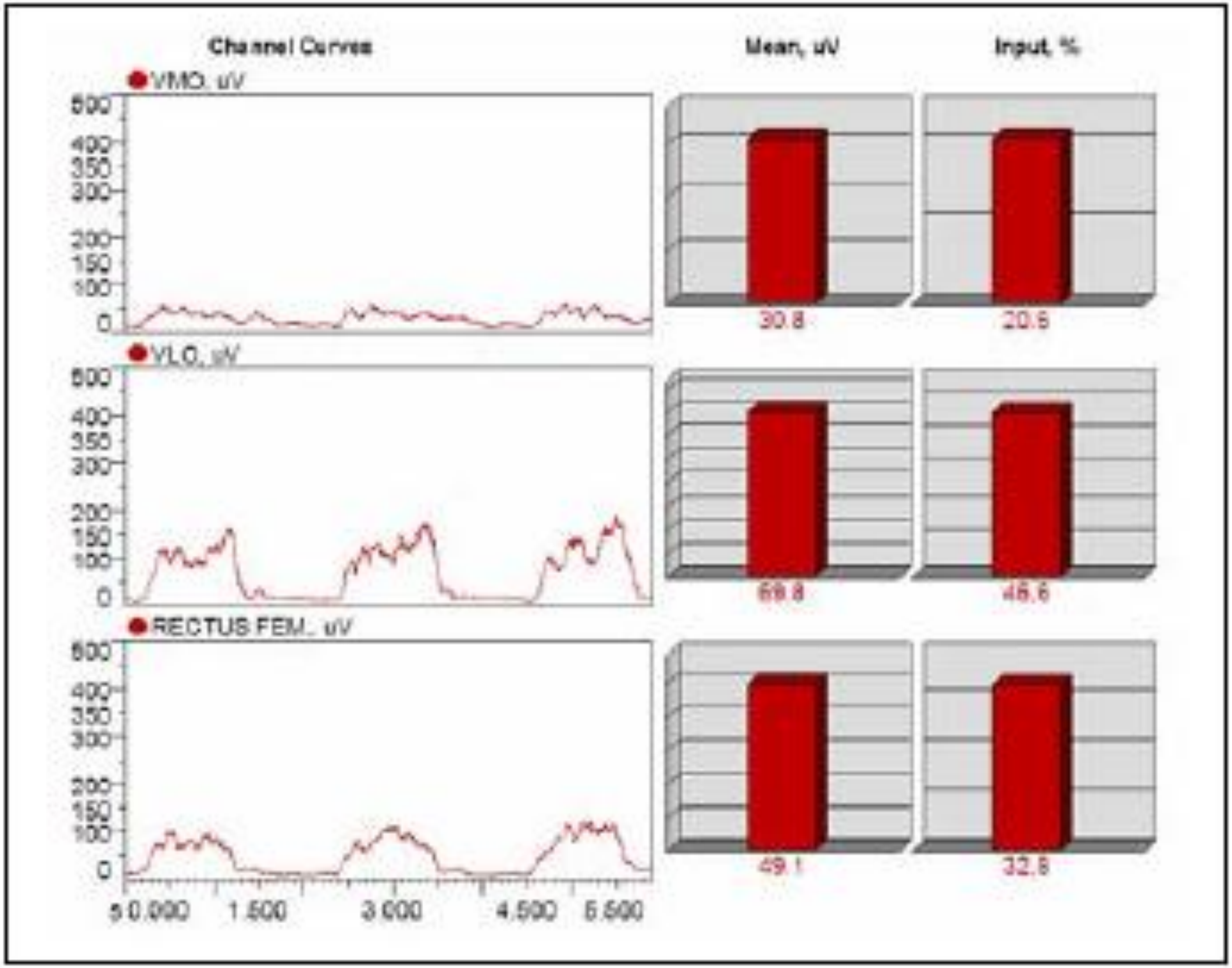


Fig. 55: The Mean value of an analysis interval is calculated for three muscles. All values are summed and defined as 100%. The Input% calculates the percentage amount each muscle contributed

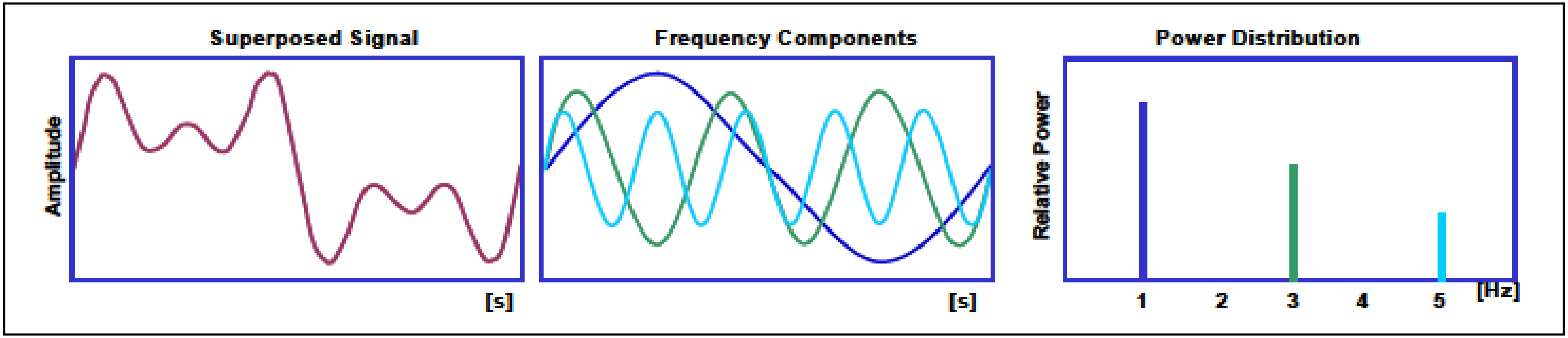


Fig. 56: Model of frequency related signal decomposition based on FFT. The signal on left side contains 3 underlying waves (middle): a sinus wave at 1 Hz, another at 3 Hz and finally one wave at 5 Hz. The power distribution (right) indicates Power of different magnitudes at these frequencies. Adopted & redrawn from 3, p. 24

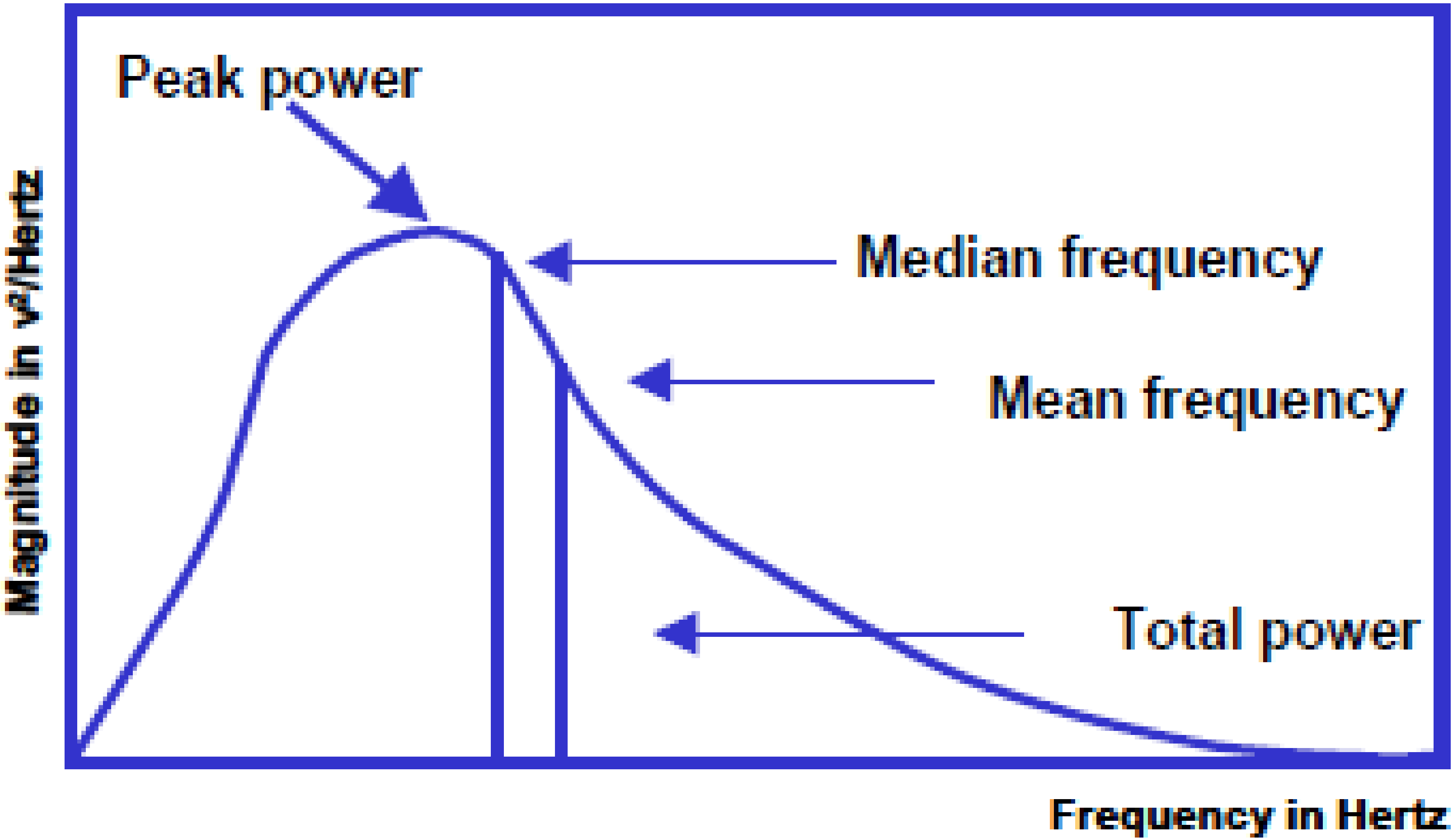


Fig. 57: EMG standard frequency parameters based on FFT calculations

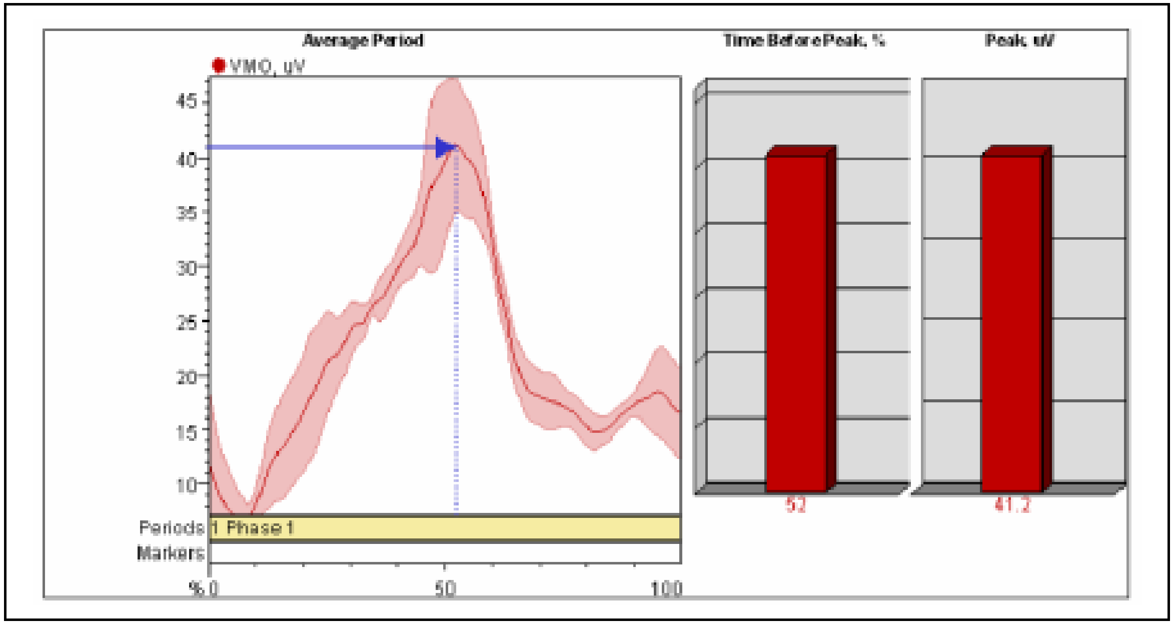


Fig. 58: Time to Peak calculation for an average curve. The beginning of the calculation period is the beginning of the movement cycle; the (time normalized) peak time point is an important parameter to describe average

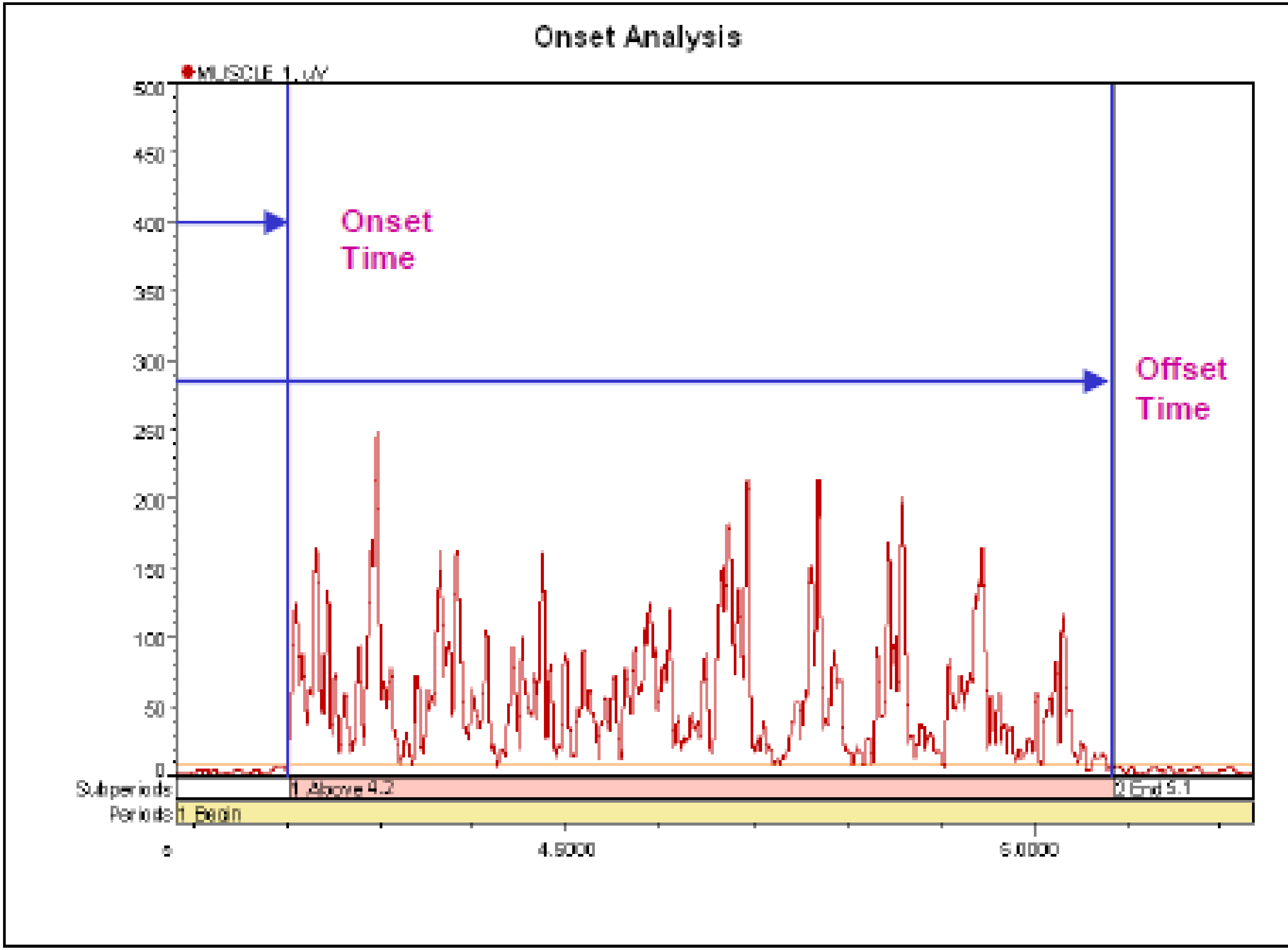


Fig. 59: Illustration of the Onset and Offset time period. Based on the beginning of an analysis period, a threshold criteria is applied to determine the Onset time of EMG. If the same threshold is passed again, the Offset time is reached

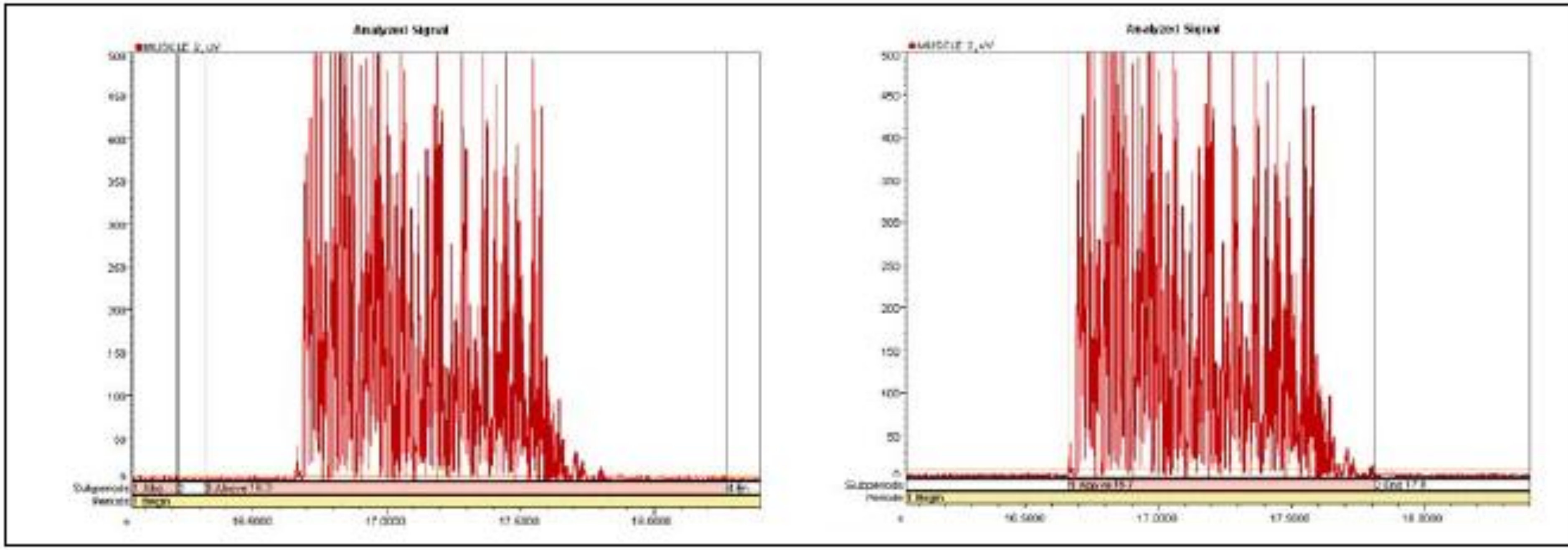
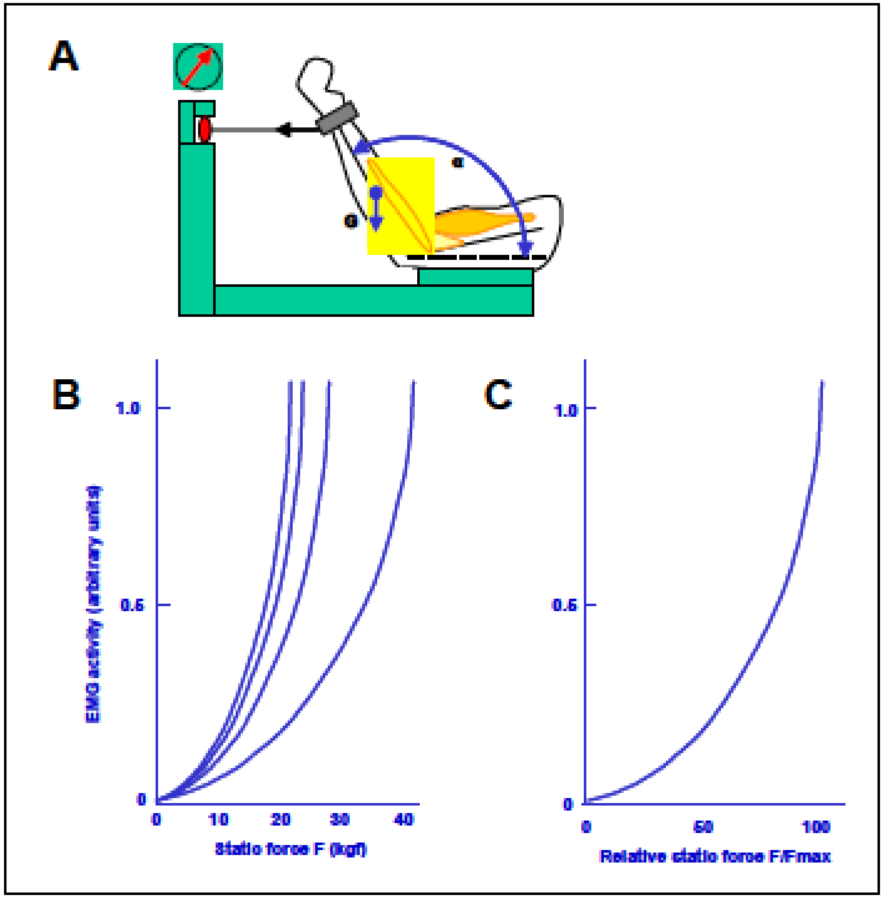


Fig. 60: Adjustment of the SD multiplication factor to determine a reliable threshold level for EMG onsets/offsets. The threshold on left side is set to 3 standard deviations and fails to detect a valid activation (marker lines and pink bars). The noise free baseline requires an increase to 8 times SD to detect the contraction onset/offset correctly.



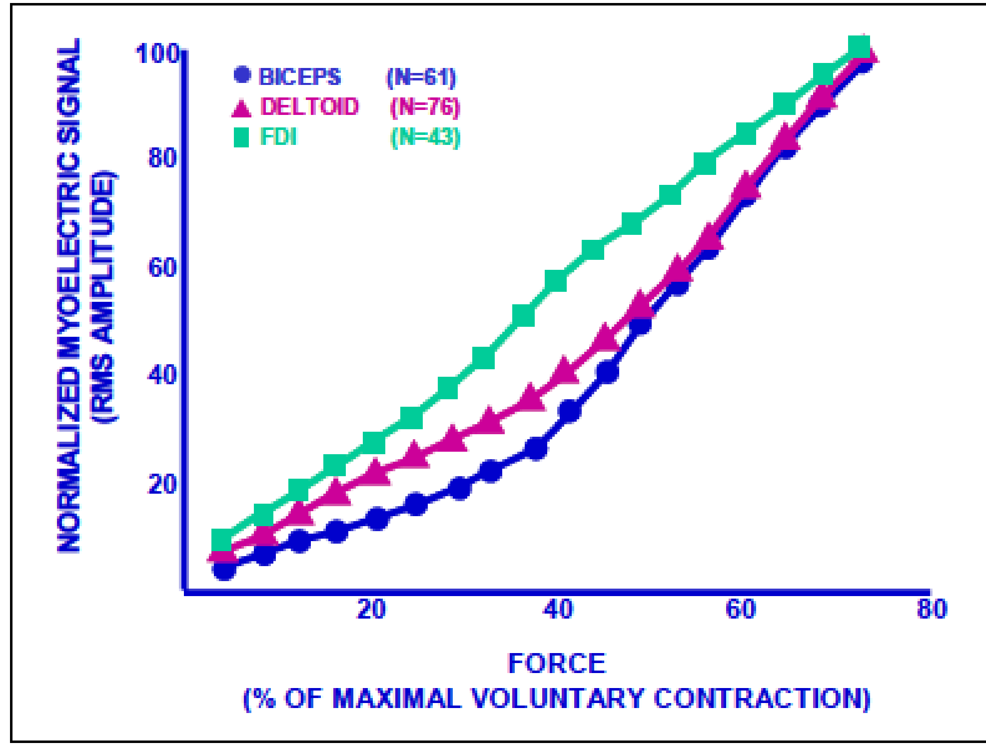


Fig. 61: Two classical static EMG/force experiments: The left figure (adopted & redrawn from 10, p. 110) shows the dependency of the EMG/force ratio from angle position (A,B), which can be eliminated by normalization of the MVC of force. The right figure (redrawn from 2, p. 193) shows EMG/force ratios of 3 different muscles for MVC normalized EMG and force output data

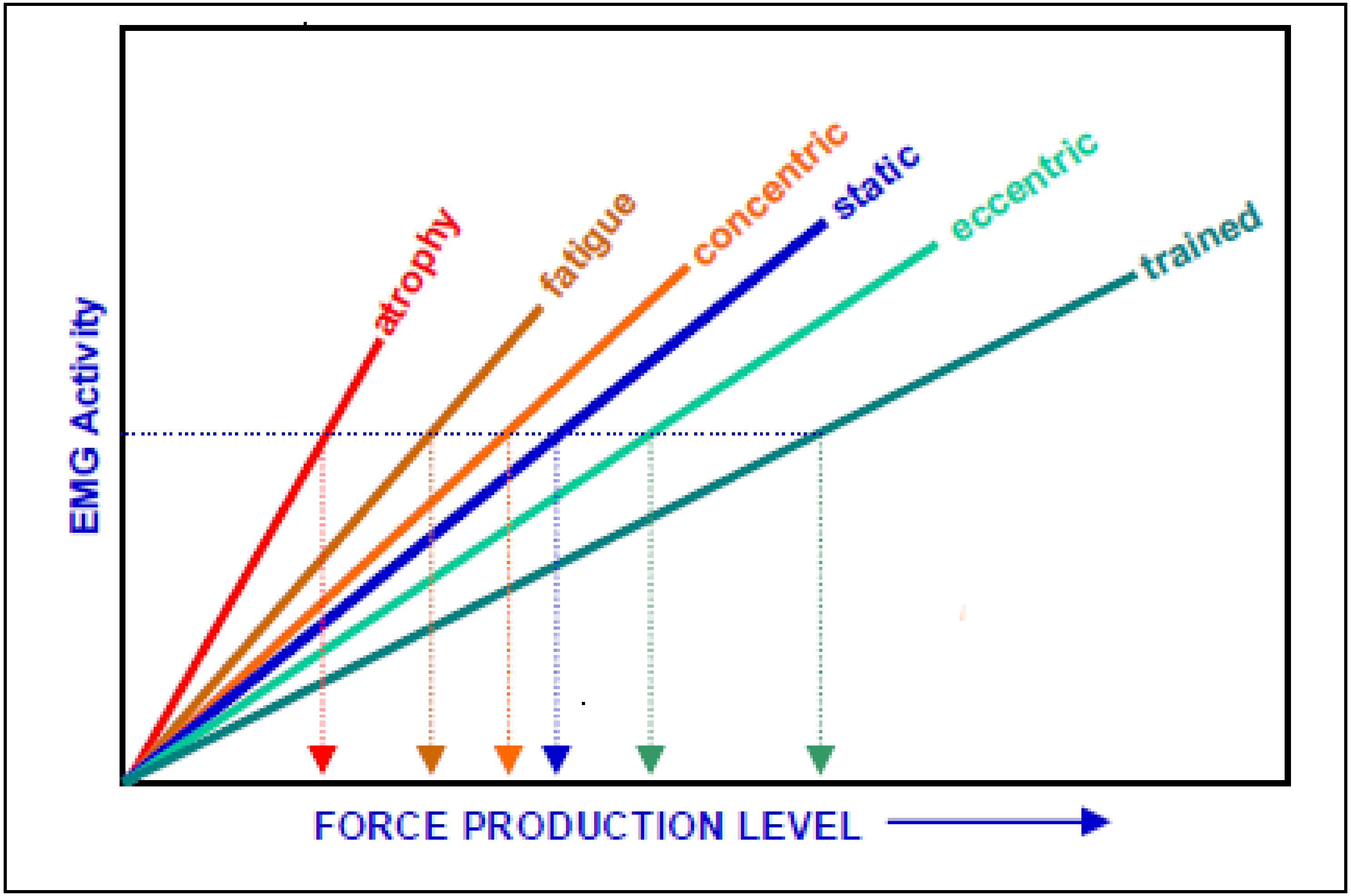


Fig. 62: Schematic EMG/force relationship in ramp contractions. Depending on the muscle condition and training status, the ratio can change. Trained muscles need less EMG for a given force output than atrophic or fatigued muscles.

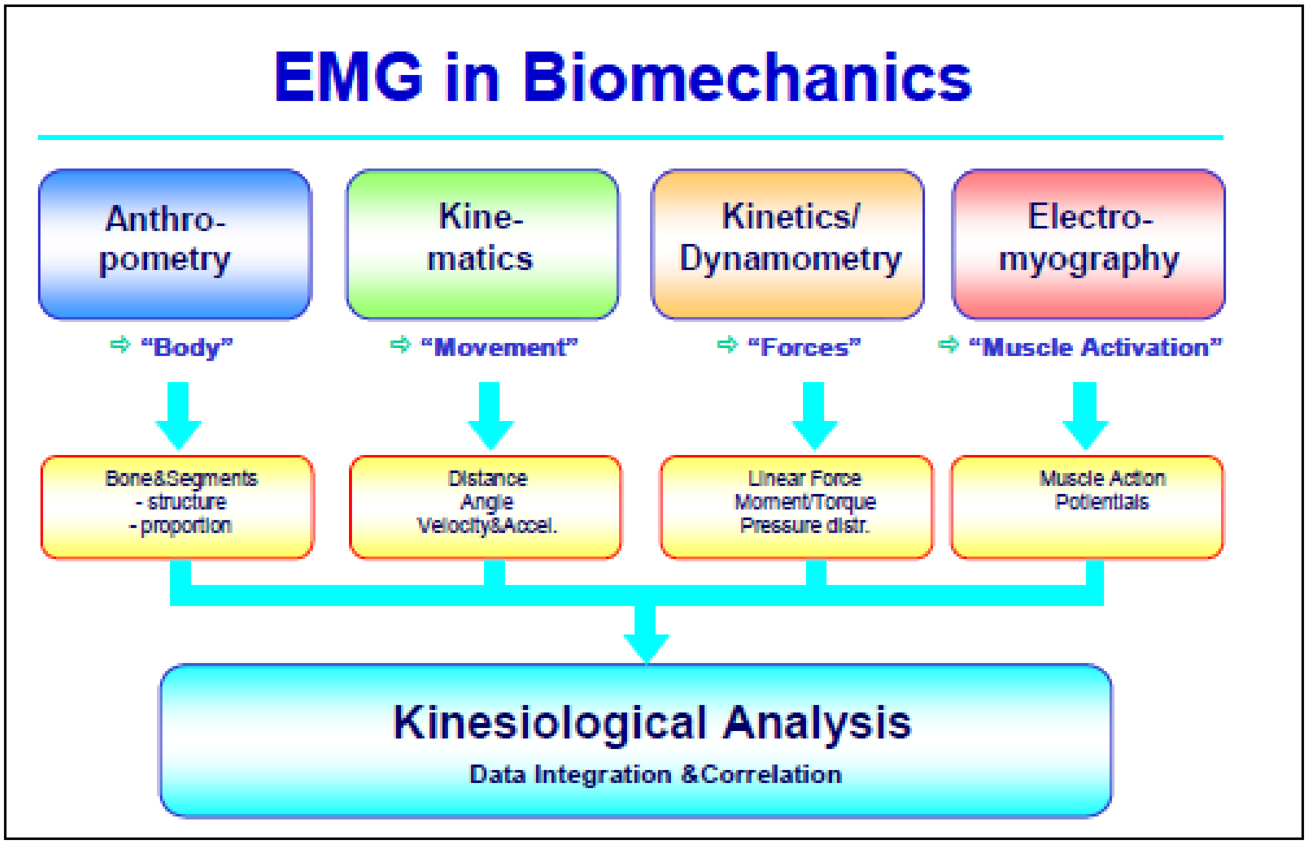


Fig. 63: The 4 major areas of biomechanical measurement methods. Based on Ball-reich/Baumann 1983

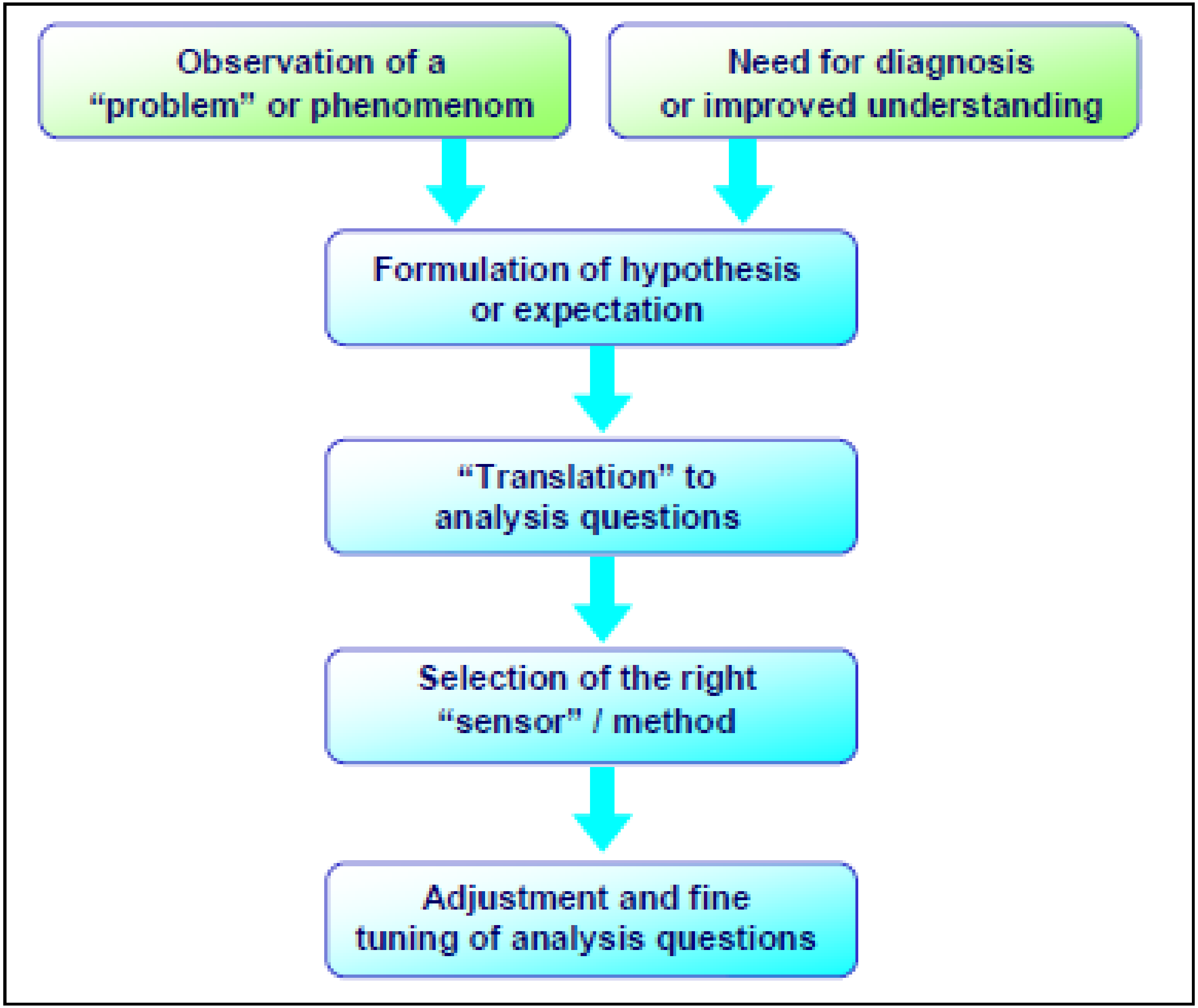


Fig. 64: Analytical questions are the basis of proper sensor selection within biomechanical methods

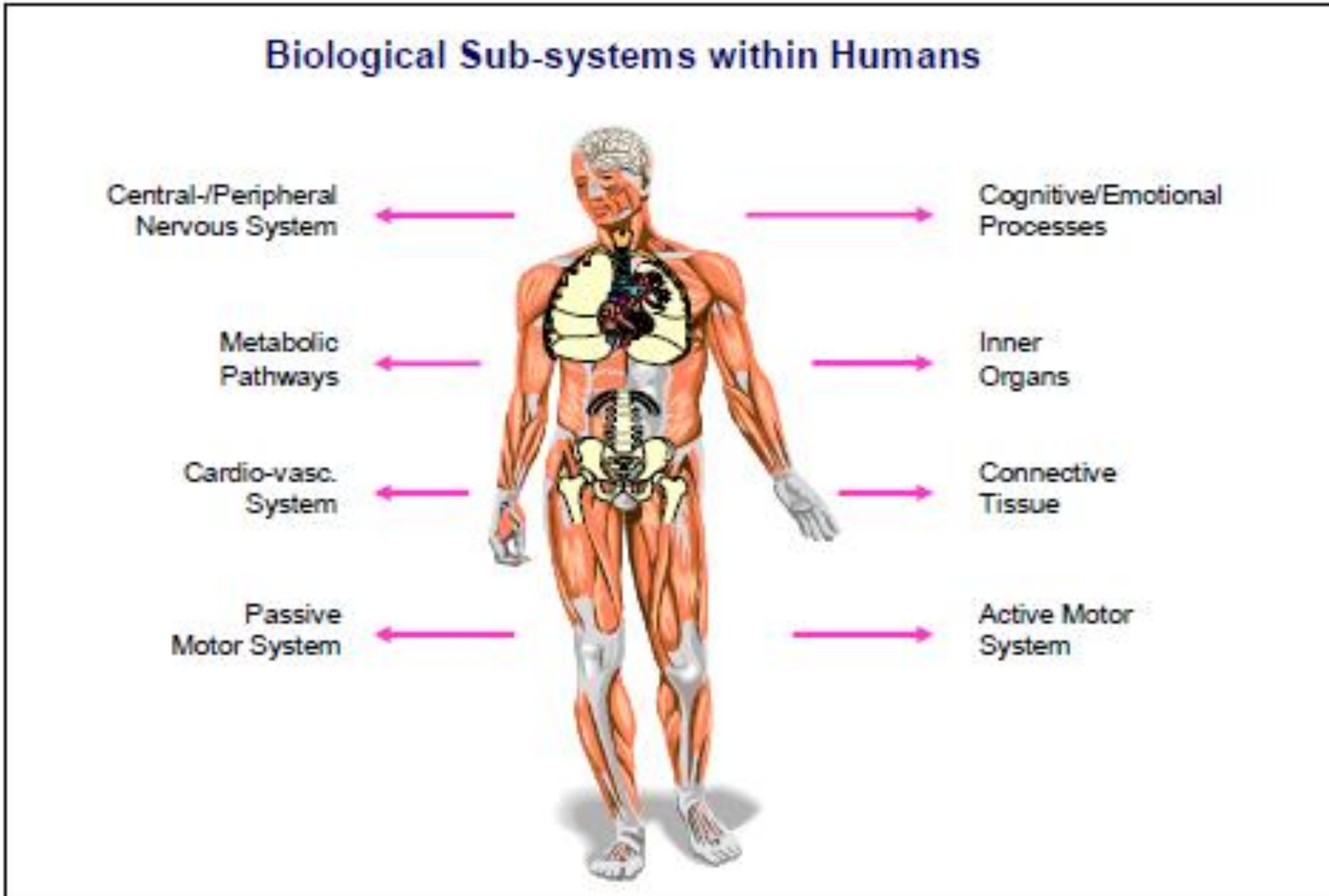


Fig. 65: Biological sub-systems that act in dependency to each other. A single finding within a selected subsystem does not reflect the whole system

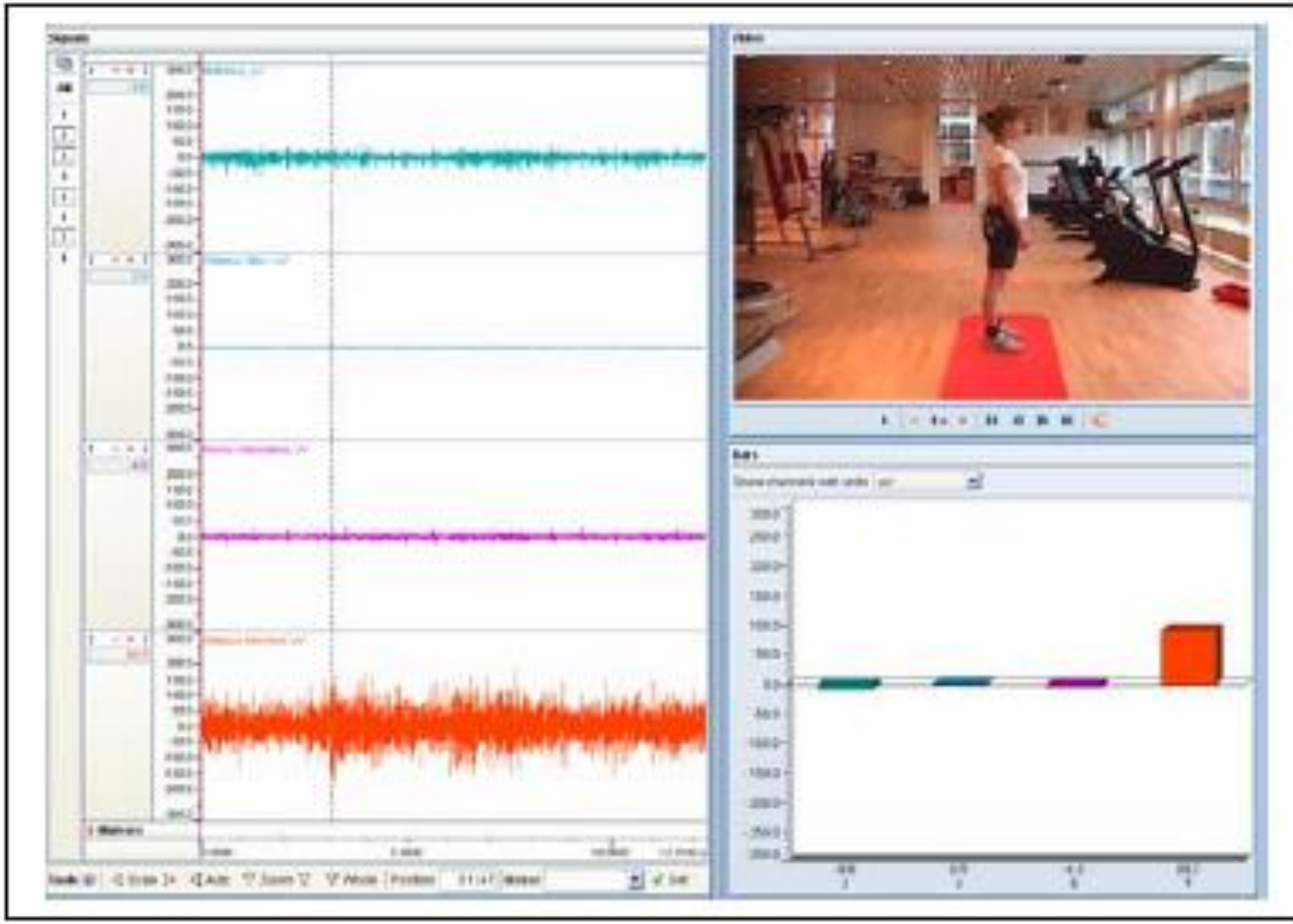


Fig. 66: EMG on/off-analysis of a regular upright standing / posture task. The multifidii (ch. 1) and internal obliques (ch. 4) show significant EMG activity (=on), whereas the glutaeus maximus (ch. 3) and rectus abdominis (ch. 4) are "off". The same finding is found on instable ground or one leg standing – indicating which muscles really contribute to postural stability

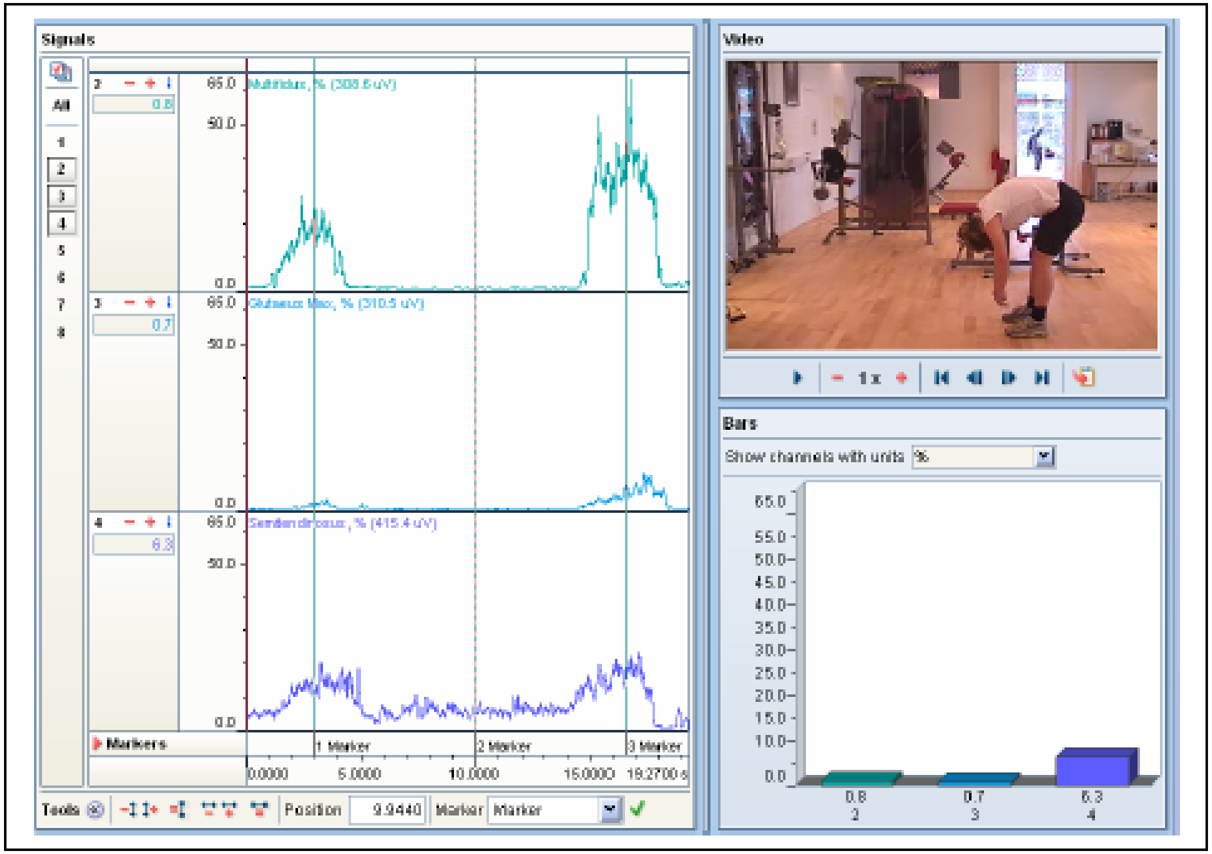


Fig. 67: The flexion-relaxation phenomenon. When slowly bending forward from an upright position, the back muscles (ch.1 multifidii) and hip extensors (ch. 2 gluteus maximus) turn off at the most flexed position (dashed vertical line and video picture). The limb momentum is held by passive structures like ligaments. When slowly extending back, both muscles start firing again. Other synergists (ch. 3 hamstrings) may be active all the time. Low back pain patients can lack this innervation silence due to dysfunction or pain.

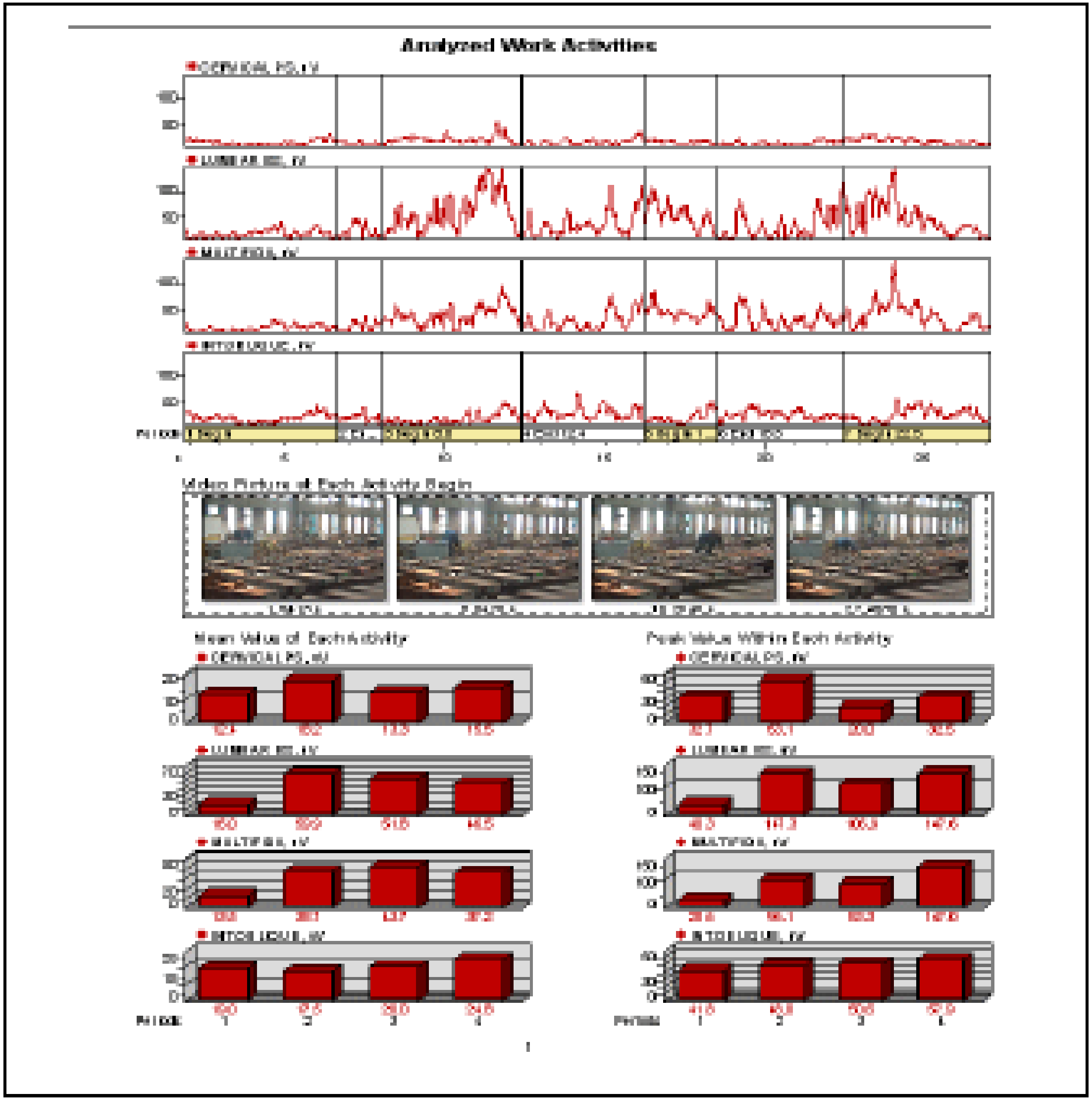


Fig. 68: Video-based EMG analysis of 4 different work activities (yellow intervals) measured in microvolts. Where is more or less EMG?

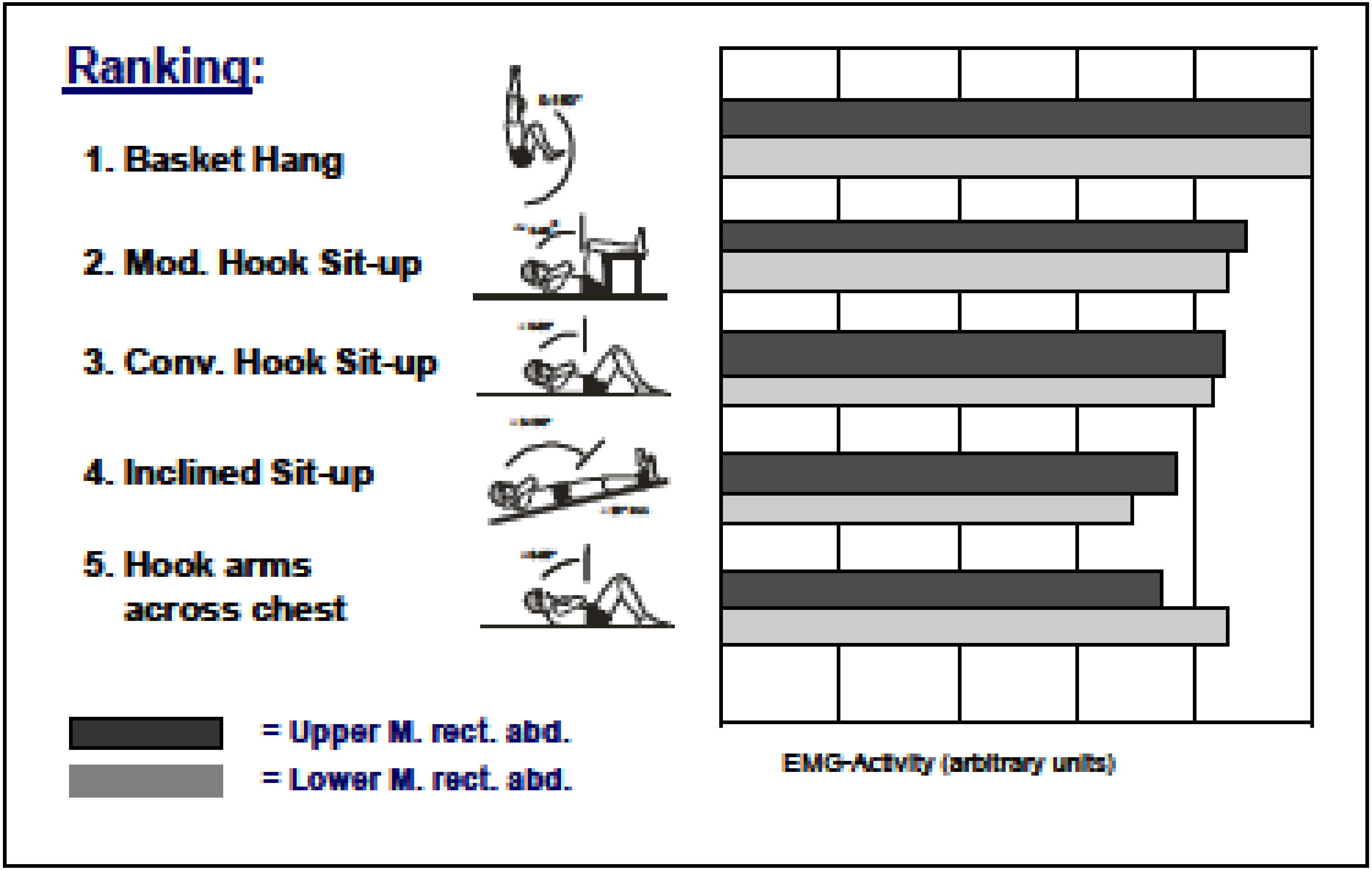


Fig. 69: EMG analysis of 5 abdominal exercises, ranked by the highest EMG found (basket hang) and scaled in arbitrary units. Data taken and rearranged from Gutin&Lipez, 1971

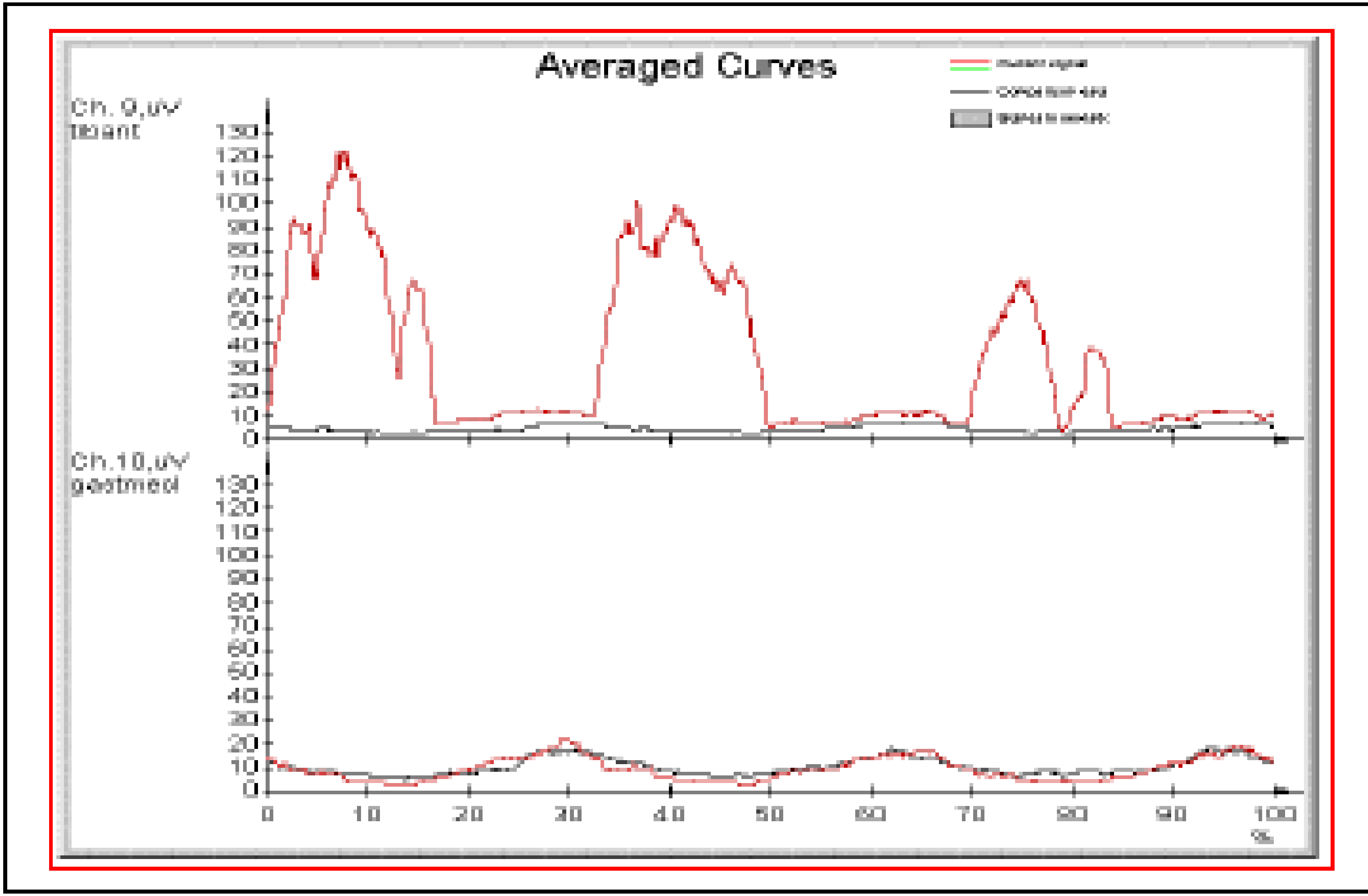


Fig. 70: Qualitative EMG analysis of the tibialis anterior (upper trace) and gastrocnemius medialis (lower trace) in left/right comparison of a spastic patient performing 3 squats. The more/less analysis focuses on side comparison and constancy between repetitions.

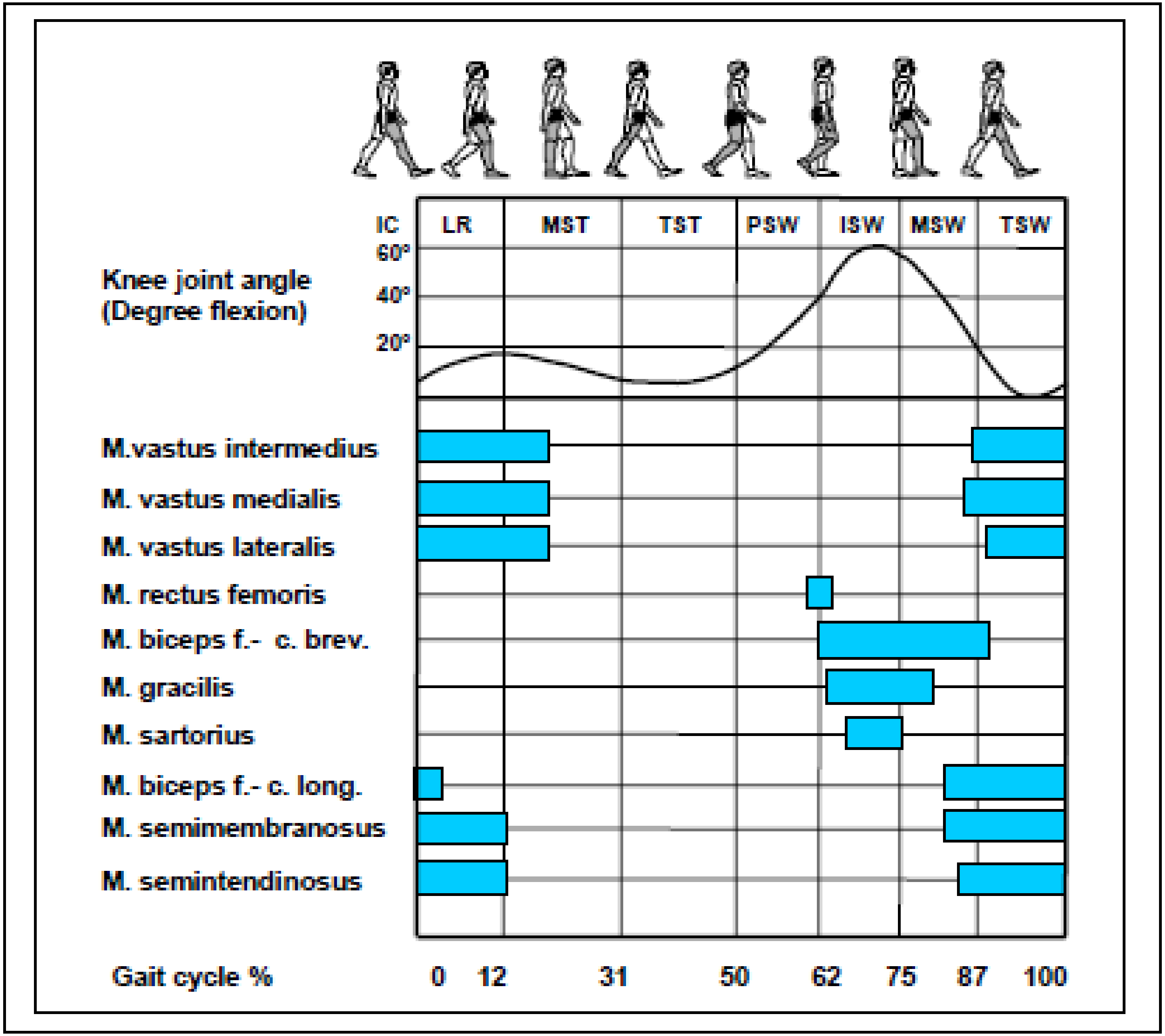


Fig. 71: On/Off timing pattern of ten lower leg muscles within a gait cycle. Blue bars indicate when the muscle is active. Adopted and modified from 8

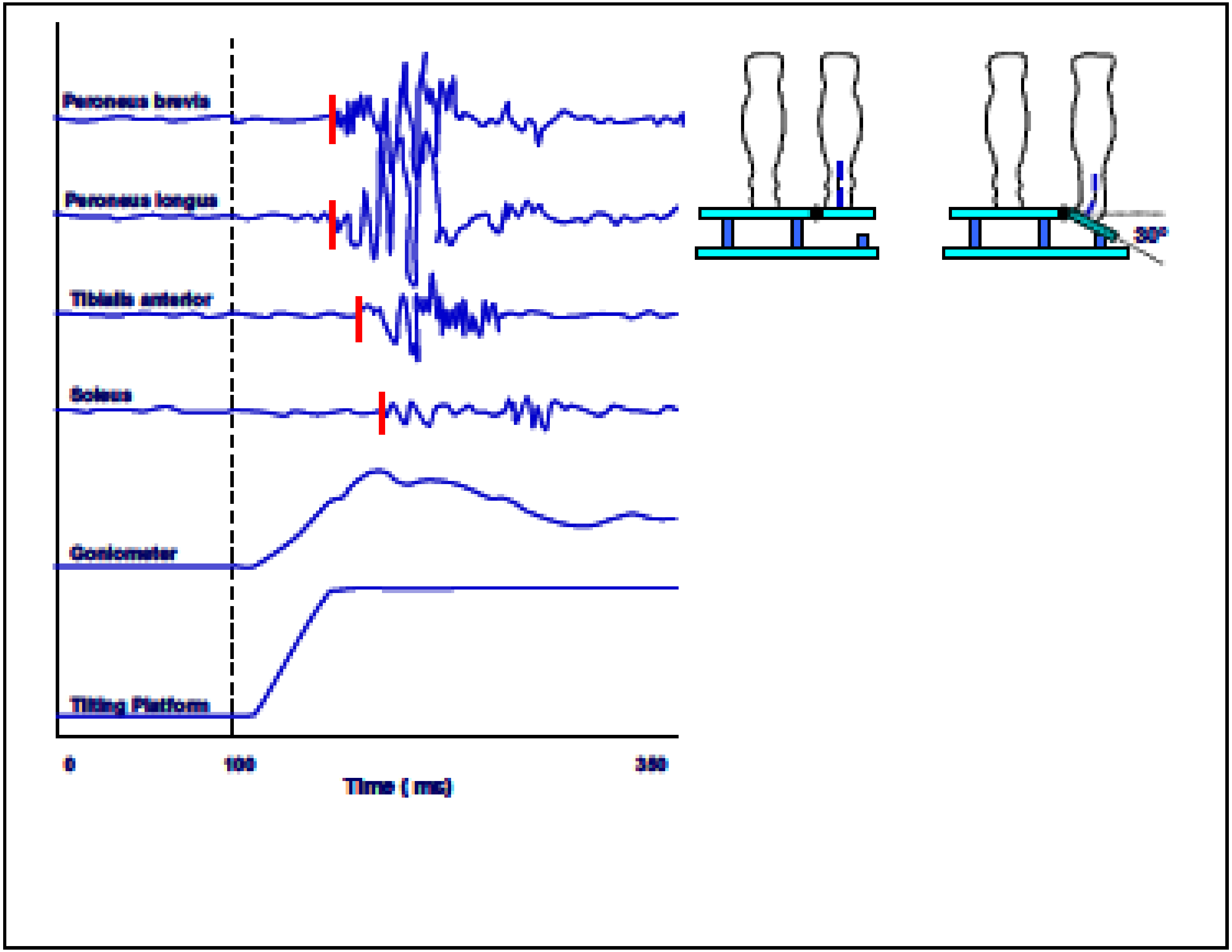


Fig. 72: EMG onset analysis on a tilting platform. The reflex induced onset of ankle stabilizers at unexpected tilt (dashed line) is calculated. Adapted and redrawn from Rosenbaum et al. 2000

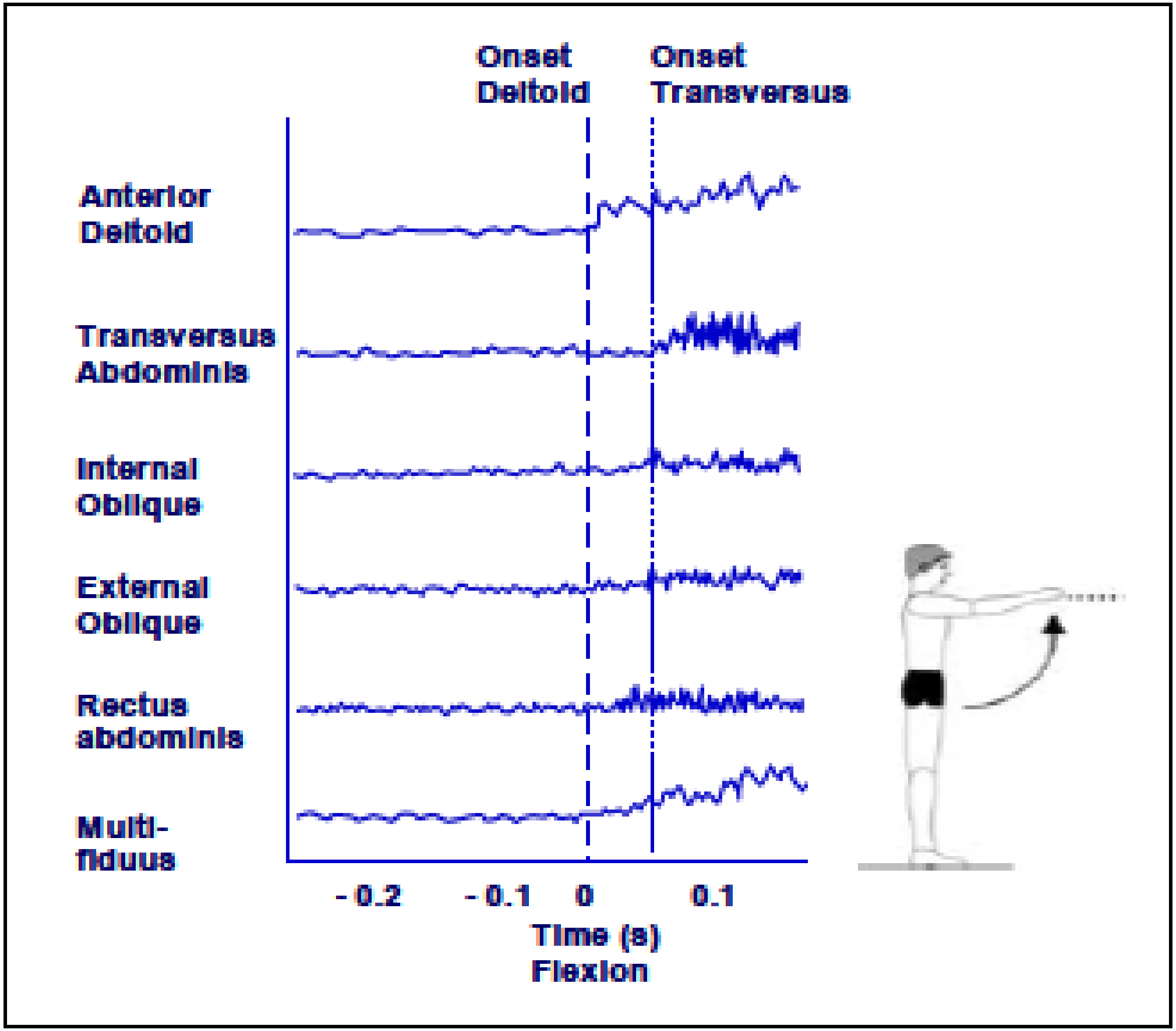
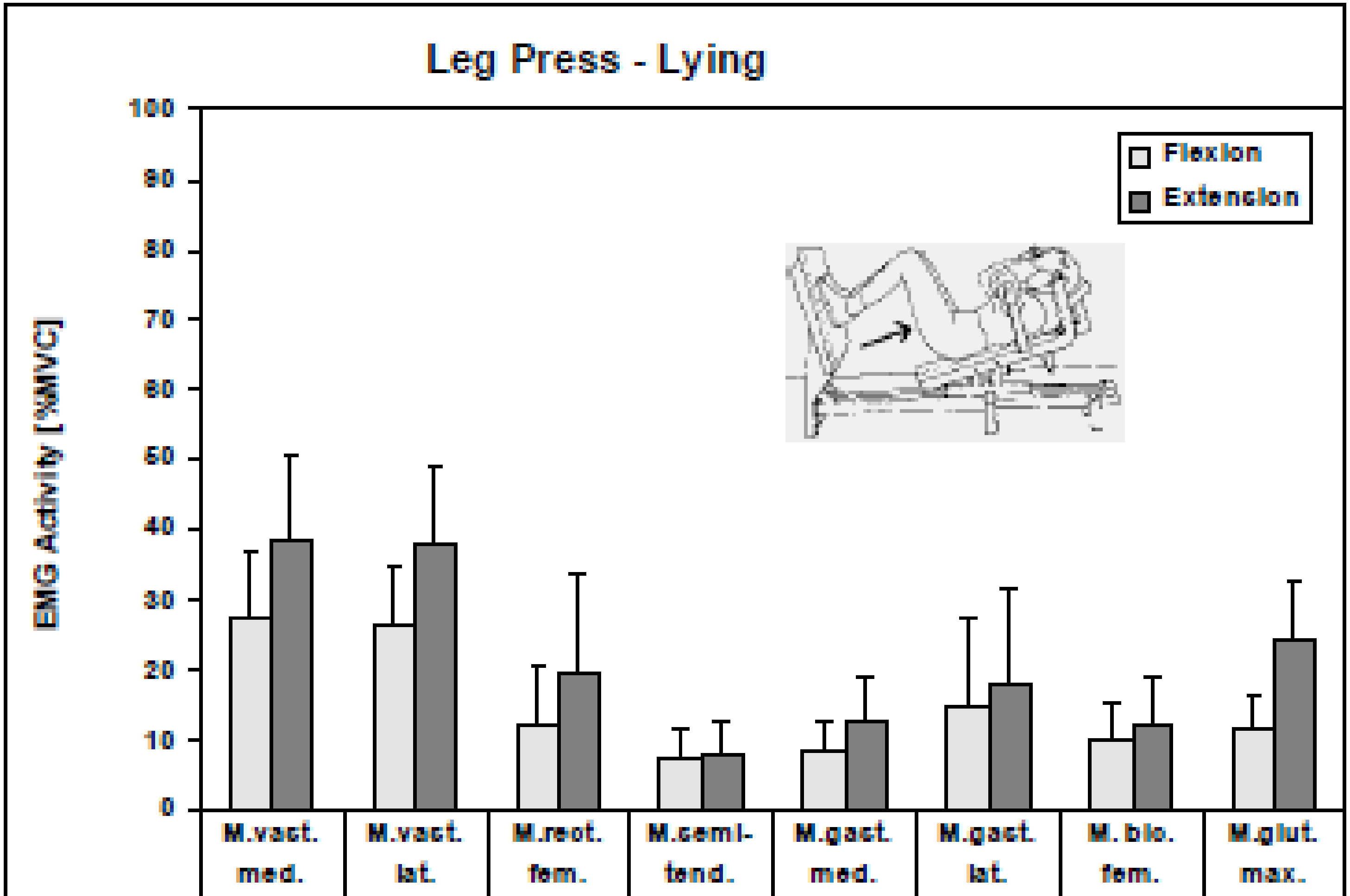


Fig. 73: Delayed innervation (narrow dash line) of lumbar segmental stabilizers (Transversus abdominis, Multifiduus) in ratio to the onset of the deltoid muscle (wide dash line) in rapid shoulder flexion done by a low back pain patient. Adapted & redrawn from 9, p. 62



	M.vast. med.	M.vast. lat.	M.rect. fem.	M.semi-tend.	M.gast. med.	M.gast. lat.	M. bic. fem.	M.glut. max.
Flexion	27,42	26,82	12,52	7,22	8,1	15,28	10,08	12,11
Extension	38,88	37,85	19,5	8,08	12,88	18,26	12,38	24,38

Fig. 74: Muscular innervation profile of 8 hip/leg muscles in the horizontal squat movement. Data shows the MVC normalized mean EMG of 6 extension and flexion periods measured for a group of 10 subjects at 40% of the individual for one repetition maximum.

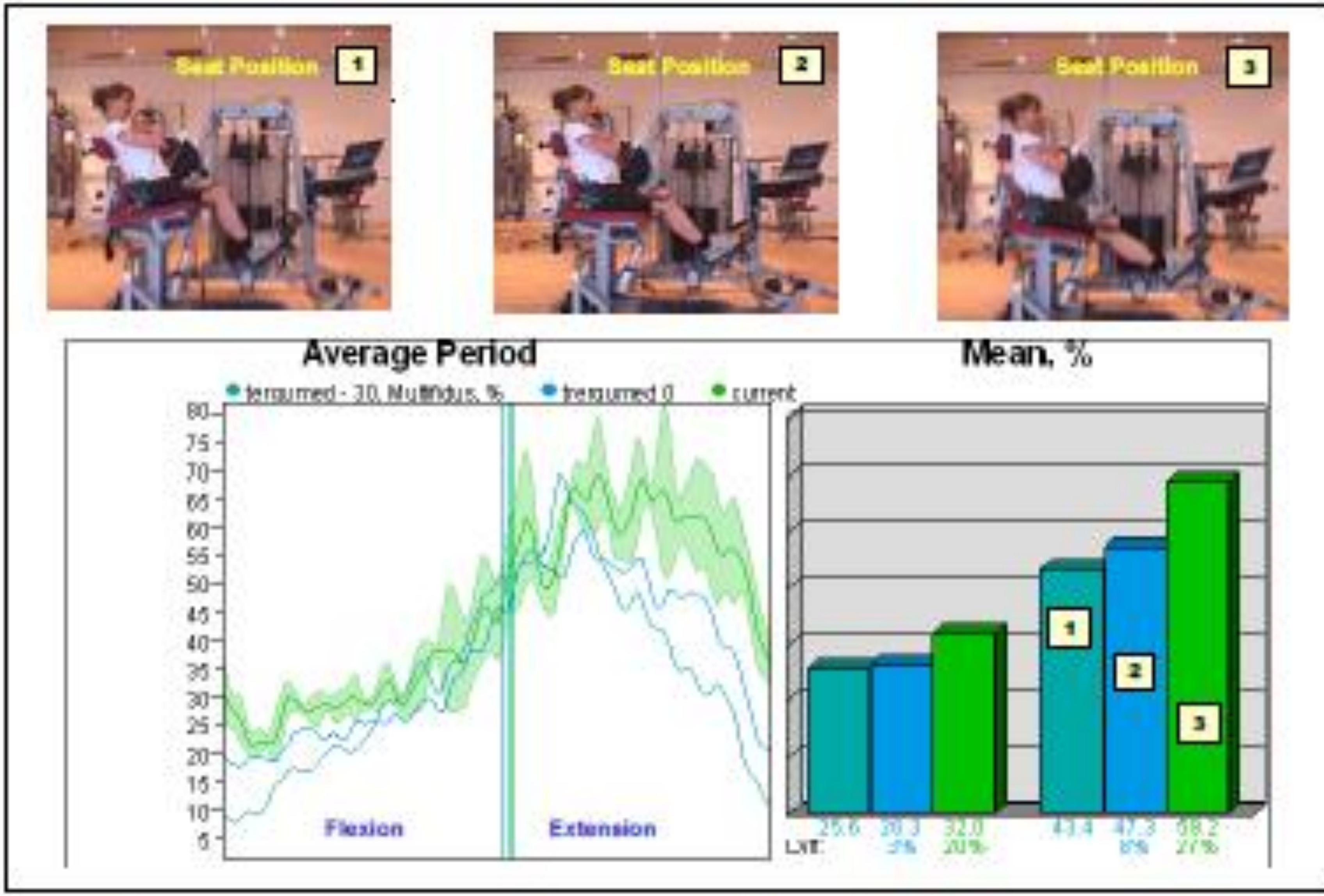


Fig. 75: EMG efficiency analysis for 3 different seat positions based on the MVC-normalized average curve of the multifidus muscle in a sequence of back flexion/extension cycles. At a given load (60% Max.), seat position 3 shows the highest EMG innervation.

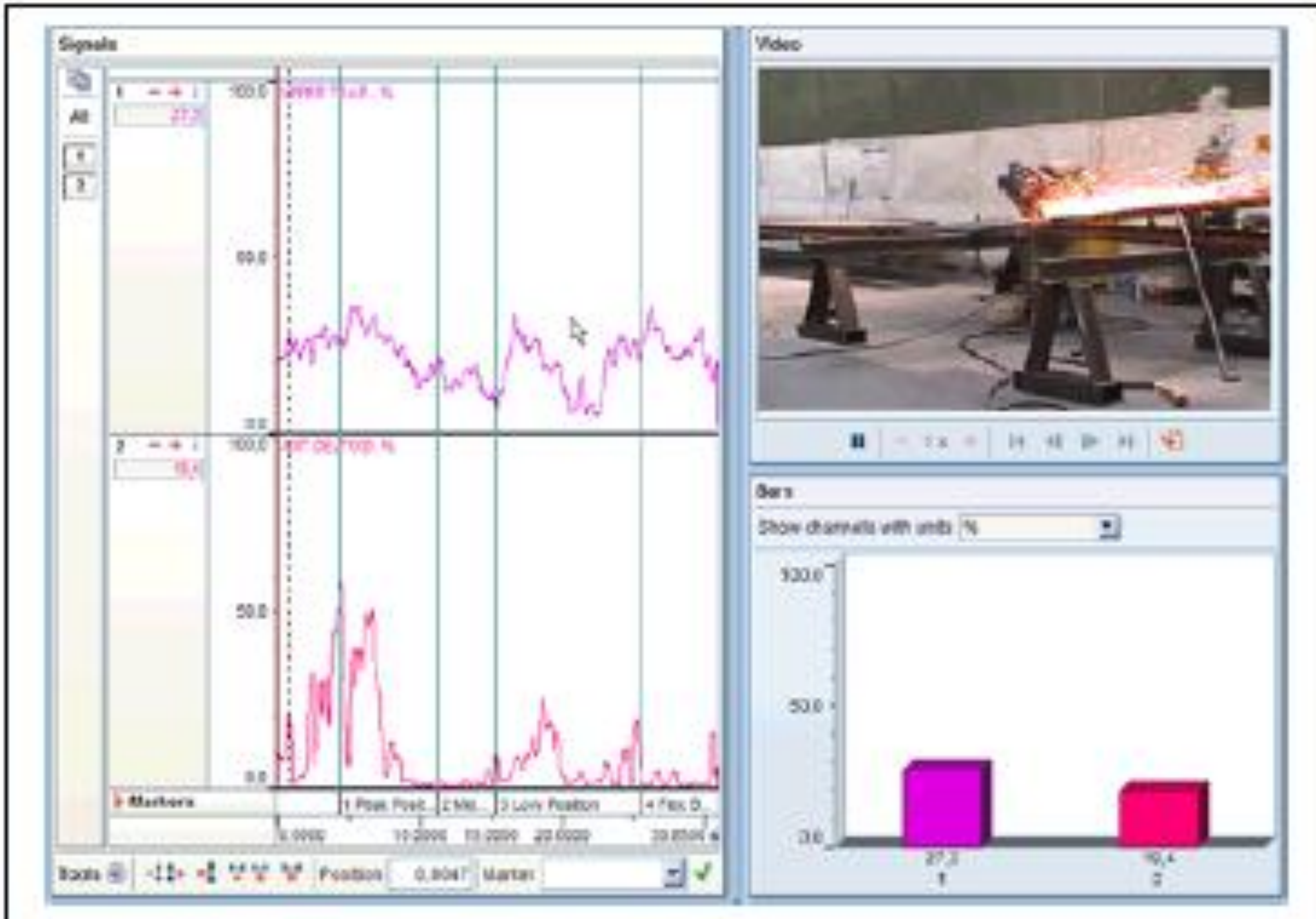


Fig. 76: Ergonomic EMG analysis of two shoulder muscles (upper trace - trapezius p. desc; lower trace - deltoideus anterior) in a work task in a steel production process. The MVC normalized signal shows the muscular demand in ratio to the given video picture

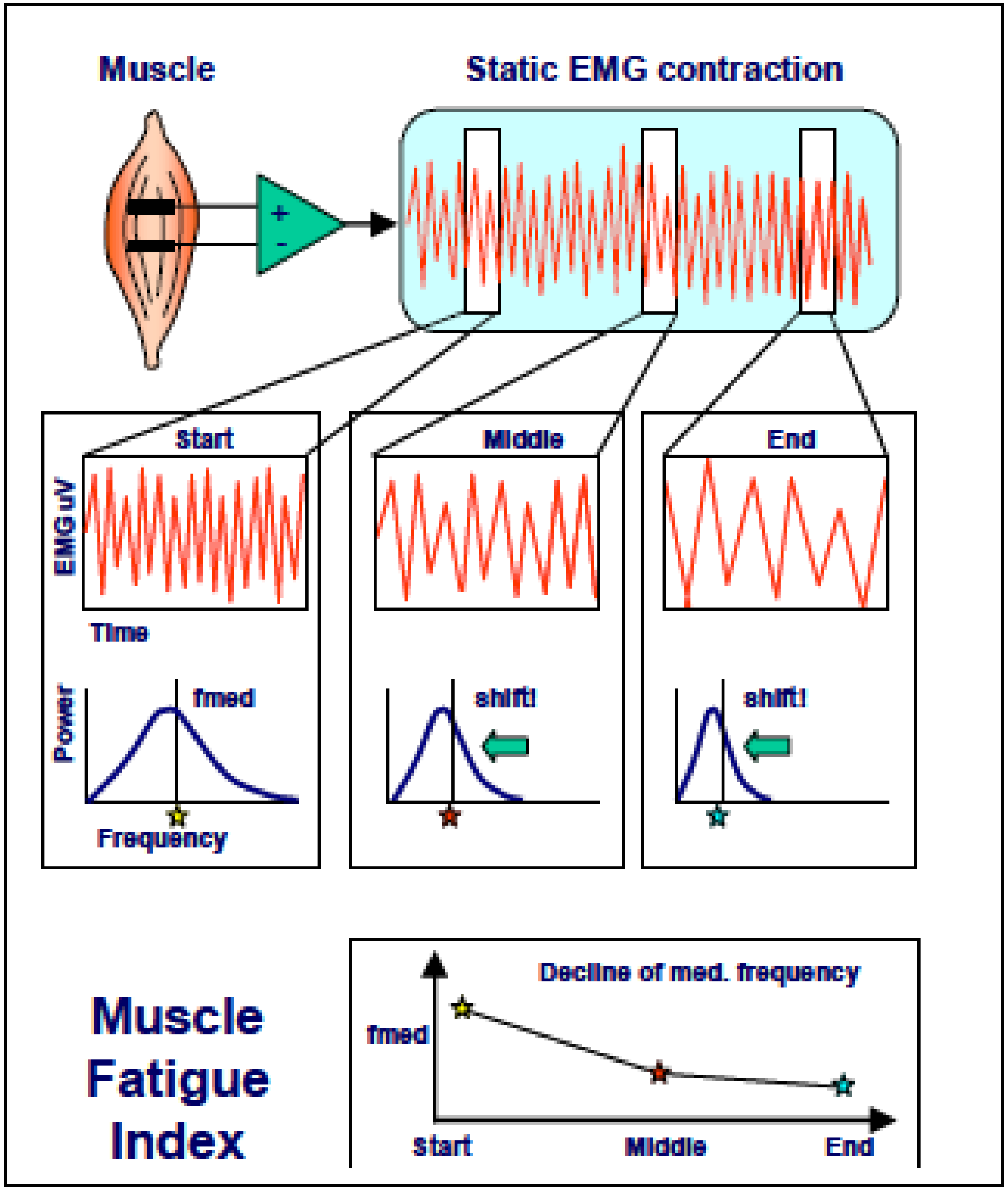
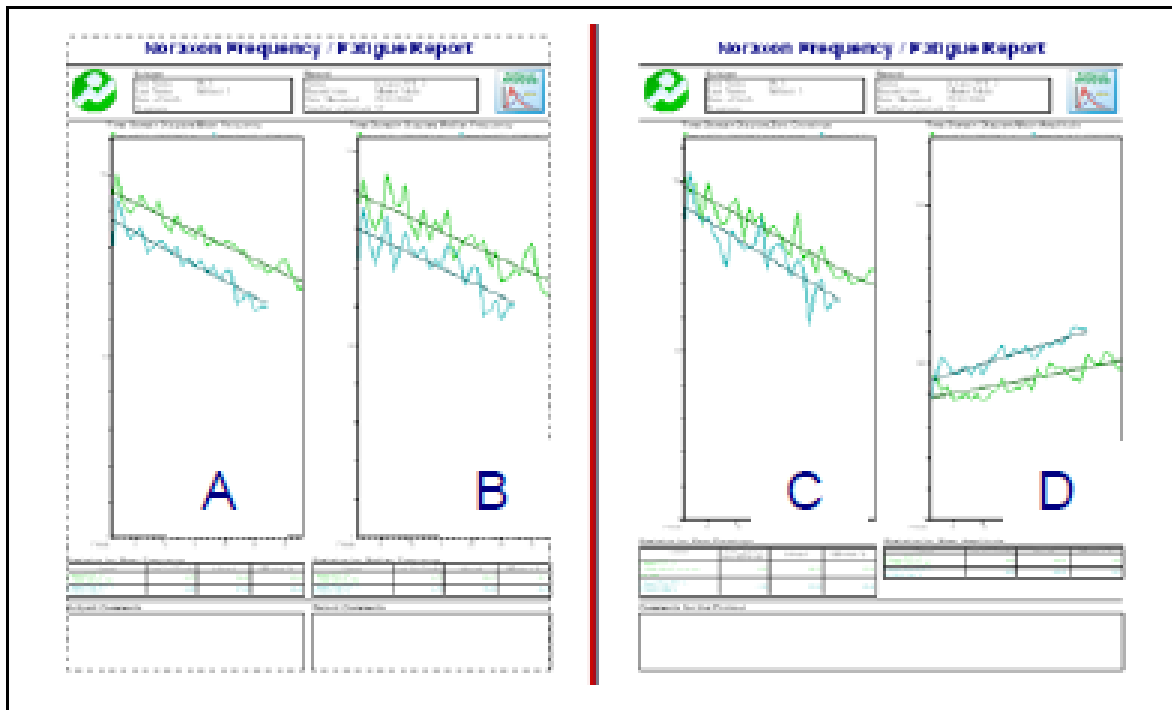


Fig. 77: Schematic illustration of the frequency shift towards lower frequencies in sustained contractions and calculation of the muscle fatigue index. Adopted and redrawn from De Luca

Fig. 78: Typical test arrangement and findings for static back endurance tests: Median (A), Mean Frequency (B), Zero Crossing (C) and Mean Amplitude (D), slope of a trained (green) and untrained (blue) subject, measured for the multifidus muscle.



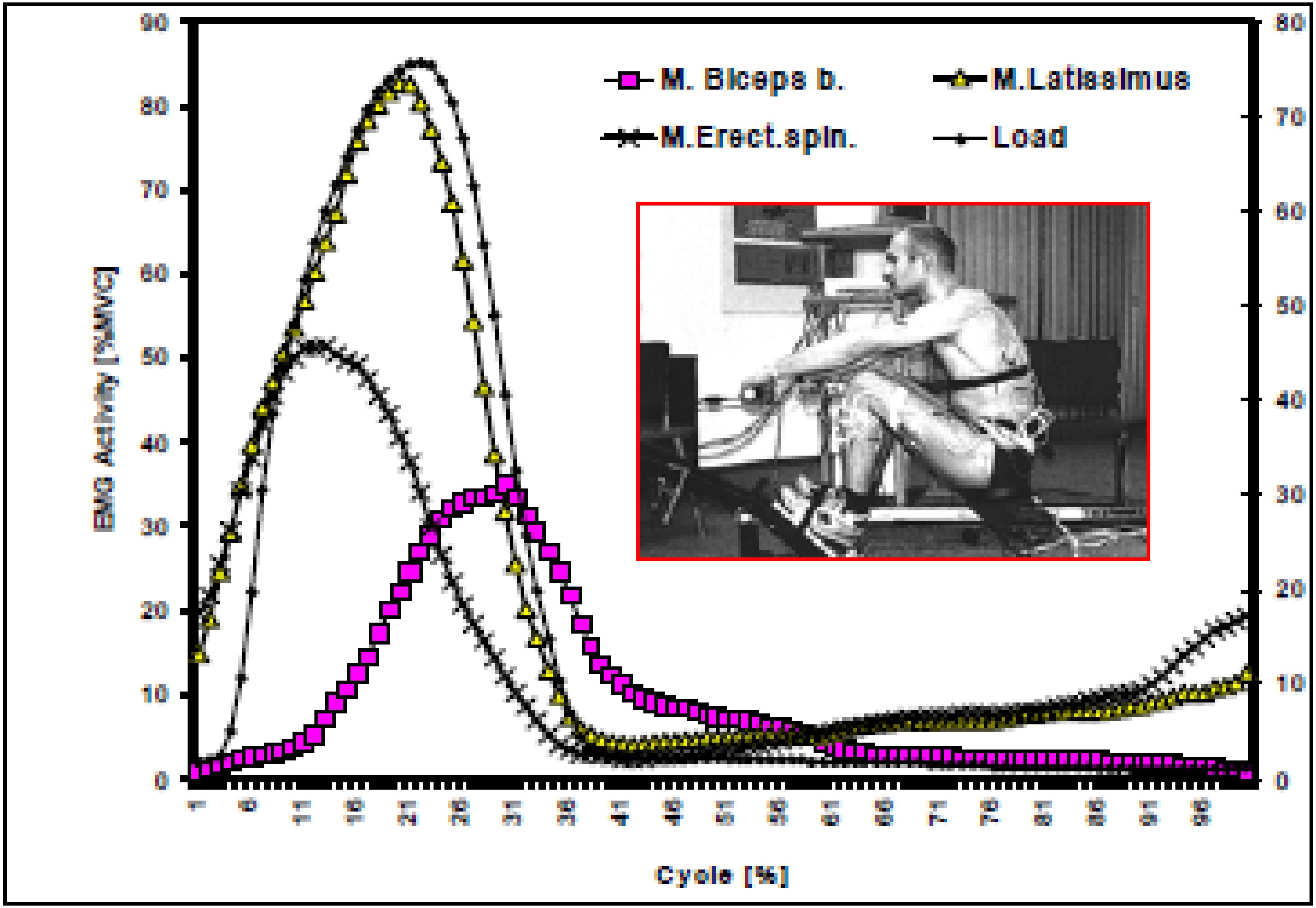


Fig. 79: Coordinative EMG analysis based on MVC normalized average curves (N=10, top rowers) over a sequence of 8 rowing cycles. The pattern analysis allows a precise description on how much and when a certain muscles fires within the investigated movement.

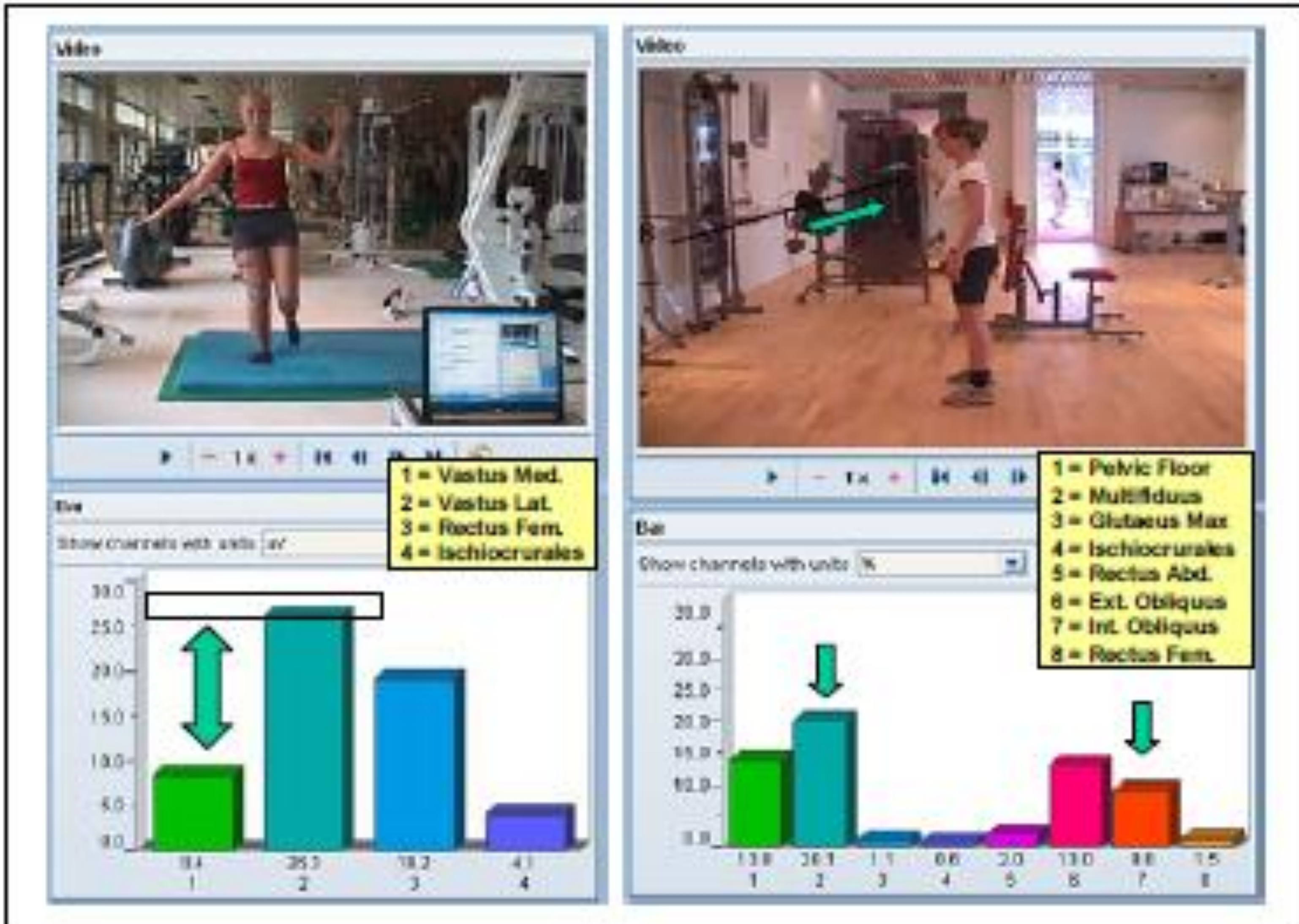


Fig. 80: Two clinical examples based on microvolt scaled RMS EMG analysis of muscle groups at video picture position. The left picture indicates EMG imbalance between the vasti within a knee stabilization task. The right pictures proves the appropriate innervation of lumbar stabilizers (multifidus, internal obliques) within a shoulder training exercise at a cable machine

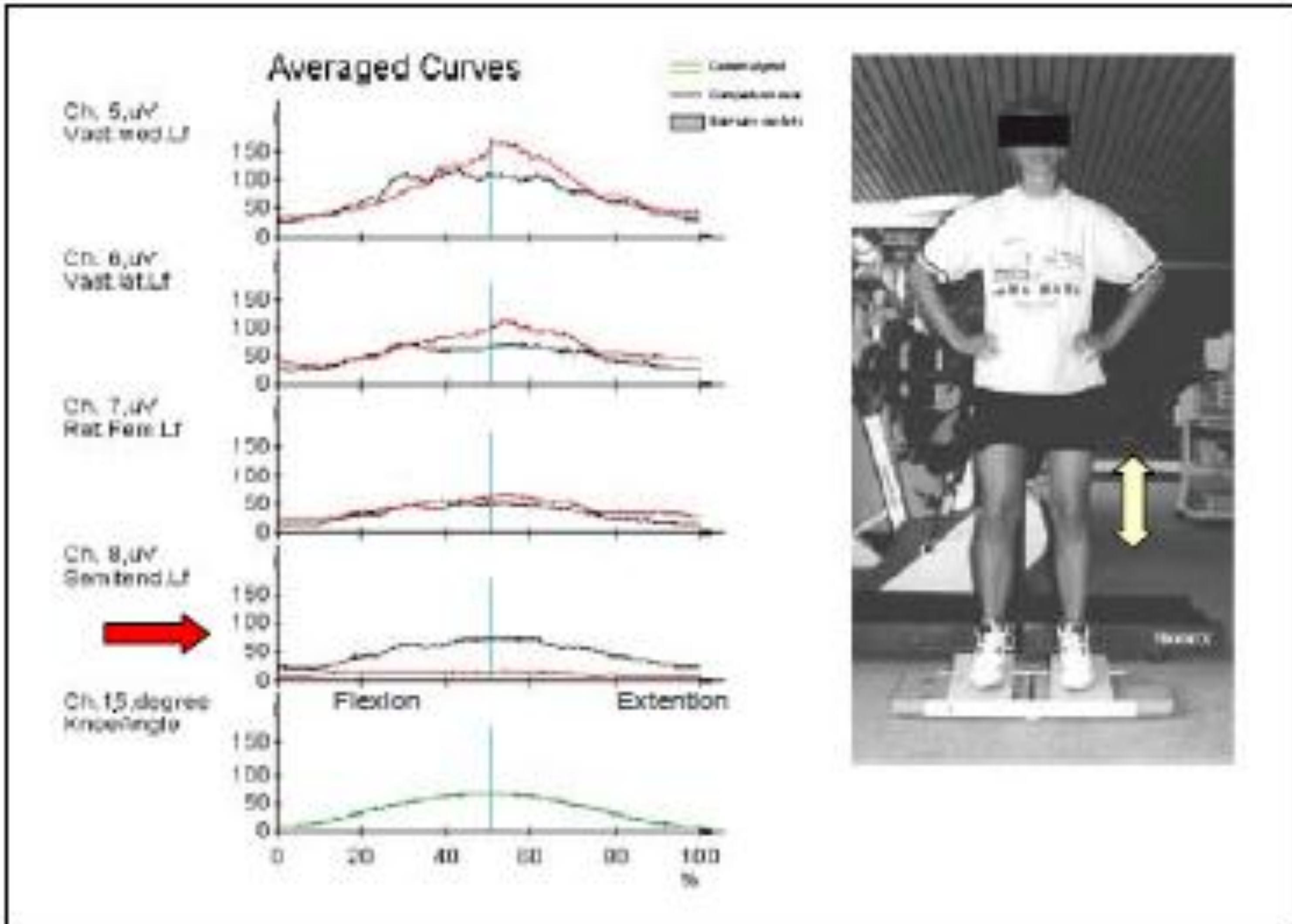


Fig. 81: Left/Right comparison of average curves (left side=black/injured) of 4 knee muscles within a free squat movement sequence (6 reps) of a patient 4 weeks after ACL- rupture and surgery. Due to mechanical knee instability, the flexors (ch. 8 hamstrings) act like agonists (black curve). Typically, minor innervation (red curve) is visible for this muscle group/exercise

Factor that influence a test exercise

Factor	Comments
Angle position in static tests	The angle and muscle length directly influences the EMG amplitude because the active muscle migrates below the electrodes and muscle mechanics change with different sarcomere – distance (besides other biomechanical aspects)
Range of motion (ROM) in dynamic tests	In analogy to the previous factor, a varying range of motion significantly increase the variability of findings and needs an appropriate standardization
Movement velocity in dynamic tests	Any repetition cycle means constant acceleration and braking, higher velocity means increased acceleration and more motor unit recruitment per time, which finally results in varying overall contraction times and innervation levels
Load or resistance	Without the understanding of a given load condition or the lack of repeatable resistance, it is not possible to perform e.g. test-retest designs or fatigue studies or other EMG test to test comparisons
Duration/Repetitions In static or dynamic tests	Beyond 30% MVC innervation intensity, the static contraction duration or amount of dynamic repetitions needs to be considered as a strong determining factor of influence (e.g. fatigue)
Preliminary status e.g. fatigue	The metabolic and central nervous conditions and also the time of day may be considered as a factor of uncontrolled variability.

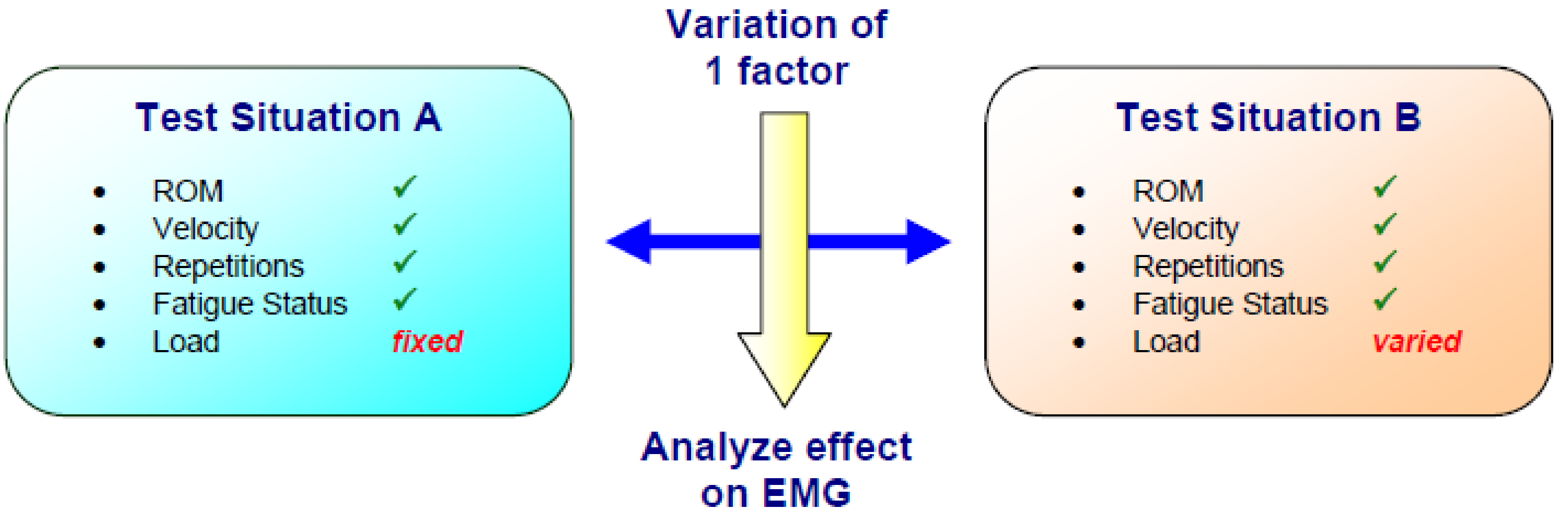


Fig. 82: Example of optimal test standardization. All factors except one are kept constant

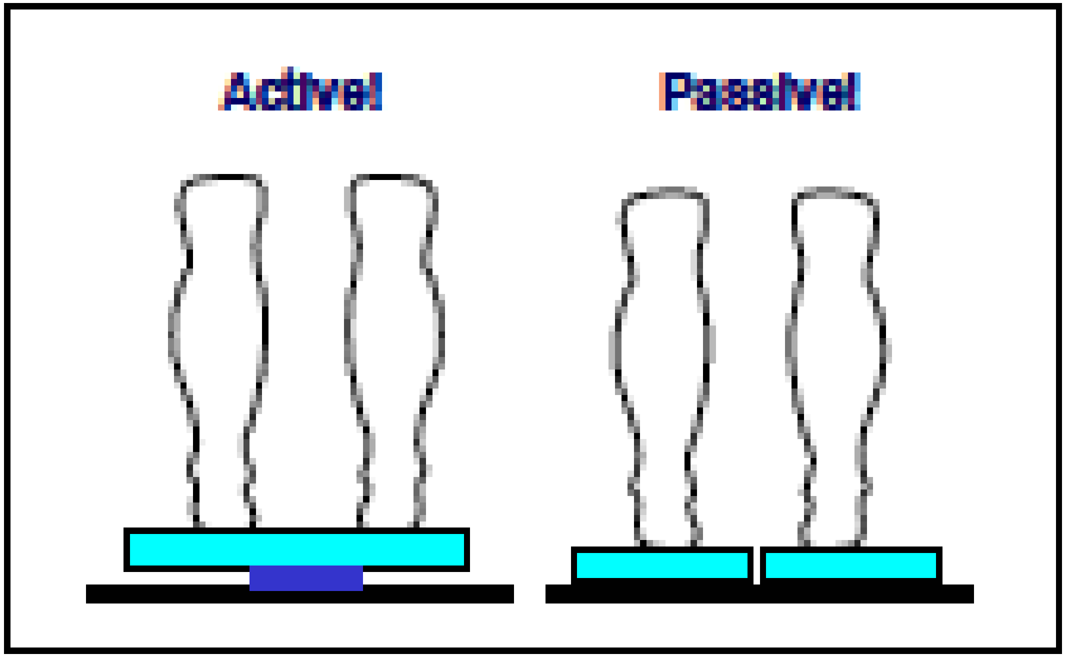


Fig. 83: Equal weight distribution by using two scales or a tilting plate

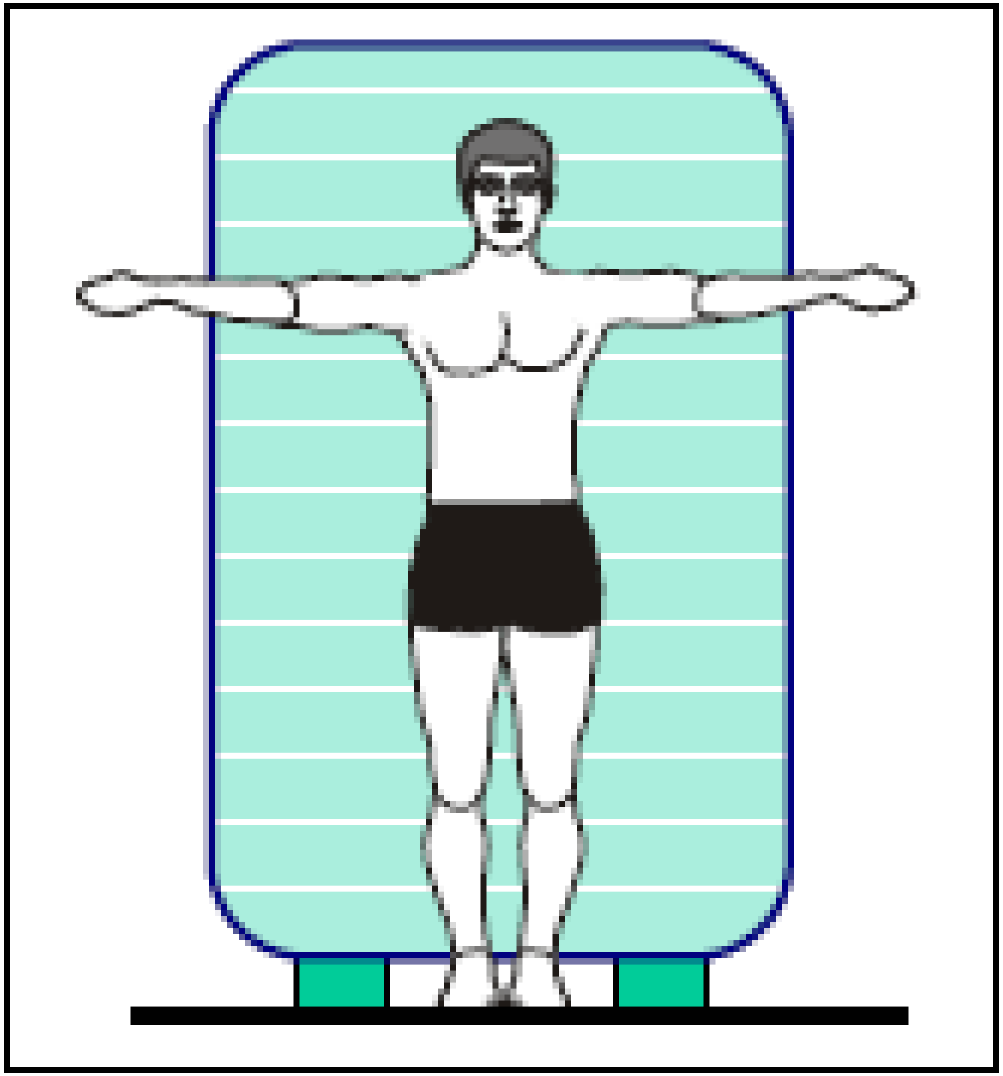


Fig. 84: Standardized ROM by using mirrors with grid lines

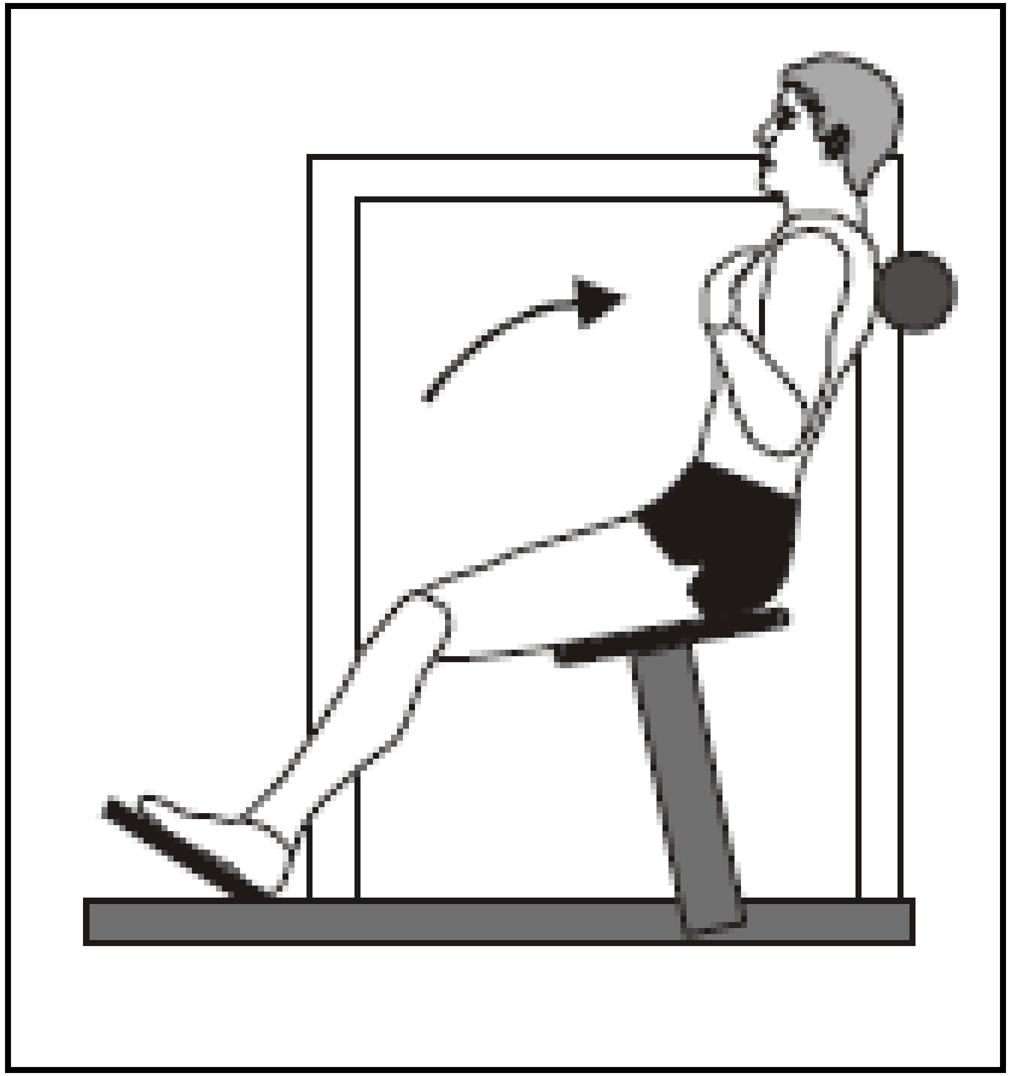


Fig. 85: Standardized ROM, body position and load by machines

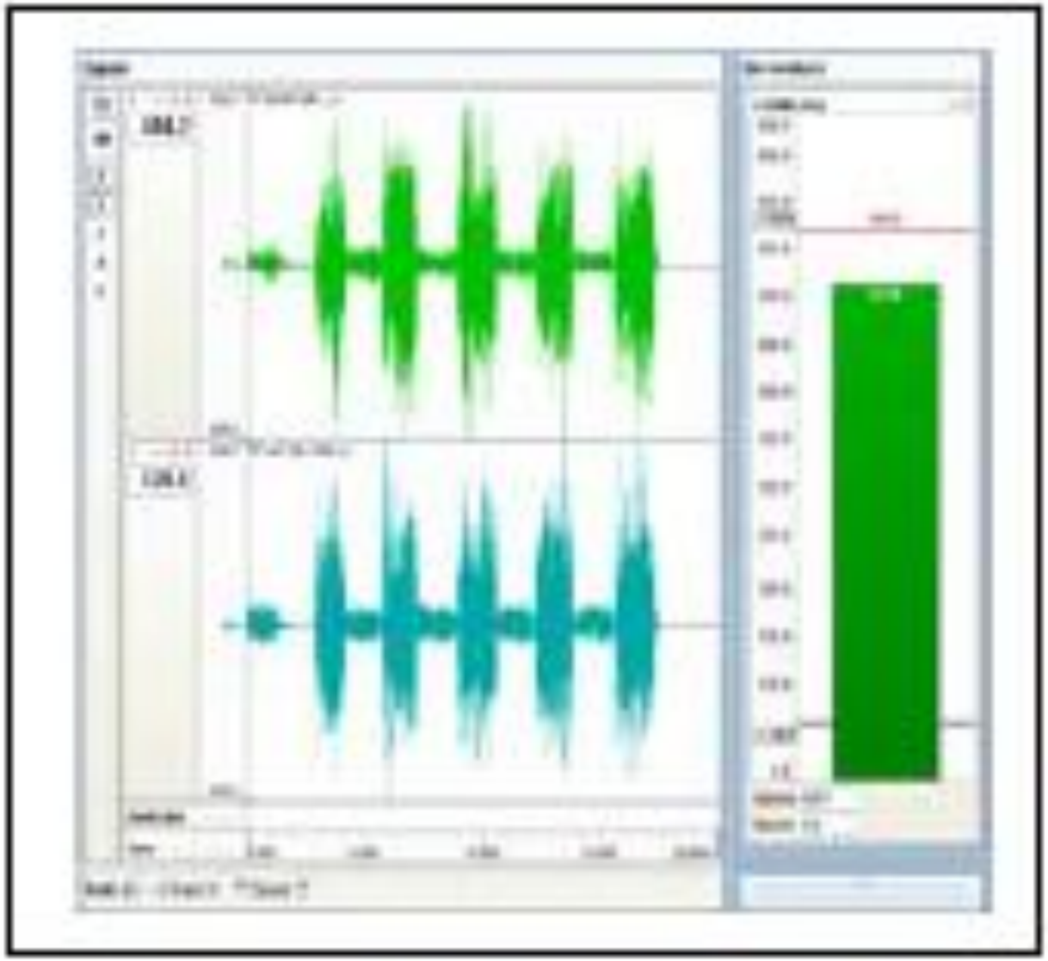
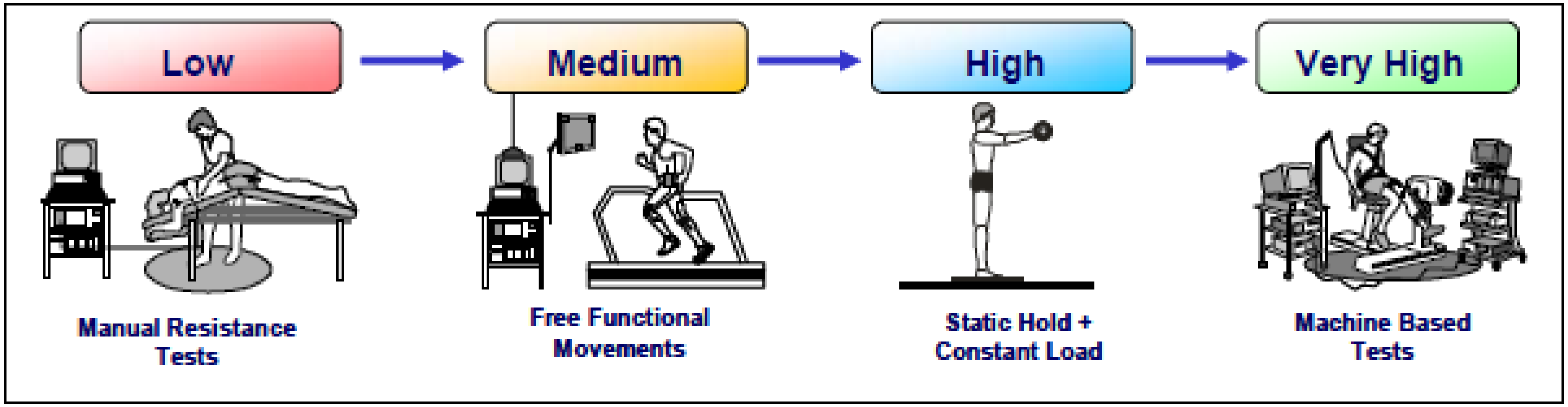
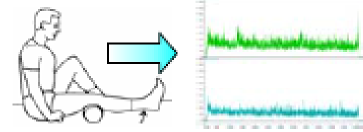
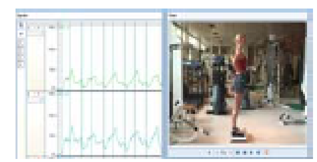
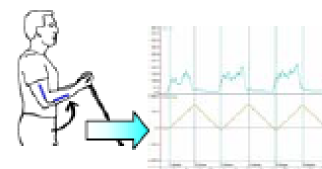
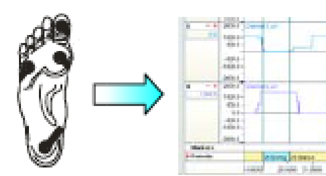
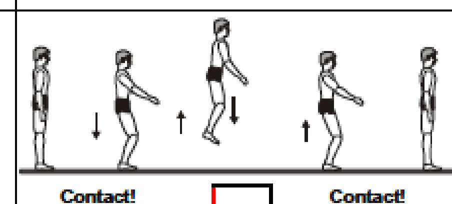


Fig. 86: Control of any movement parameter by biofeedback bars and predefined ranges

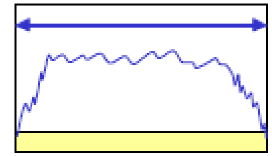
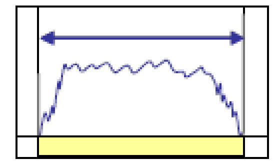
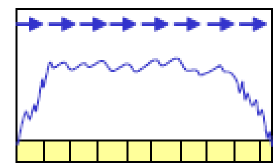
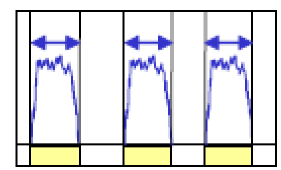
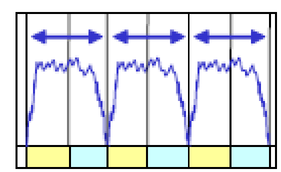
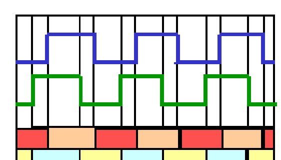
Fig 87: Different levels of standardization depend on the general test condition



EMG Triggered to Movement

Test within a reproducible **static** joint/ position	Simplest and easiest way to determine a movement position - no special marker or trigger routines is needed!	
Add **manual marker** lines in real-time	While recording, place manual markers in your record to indicate start and end of a movement phase - for slow movements only!	
Use synchronized **video** imag-ing to place event markers	Regular or High Speed video can be syn-chronized to EMG recordings to allow event definition	
Use **goniometers**, **inclinome-ters** or **accelerometers** on subject or built in machines	Mobile sensors can be attached to the sub-ject and will be recorded together with EMG. Attach goniometers/inclinometers to machine lever arms	
Apply **foot switches**	Foot switches are mounted below the feet in gait analysis or contact plates are used in jump testing	
Use **force plates** or contact plates	The ground reaction force signal and contact mats are a very good indicator of ground contact	

Period Definition For Analysis

Period Definition	Remarks	Illustration
Whole record	The start and stop of recording is arranged so that the complete record will be calculated as one period	
A single period selection within a record	One period, selected by two markers or a mouse-marked area, will be used as an analysis period. This allows the user to select a certain portion of interest within a record	
One period with a fixed step sequence of sub-phases	Within one selected analysis interval, a sequence of sub-phases starting from the beginning to the end of the interval is used. Typically used in static fatigue tests for the analysis of time domain changes	
Several periods within a record	Within a sequence of markers indicating the beginning and end of an activity, certain periods are selected for analysis. This mode allows, e.g. the comparison of activities recorded within one record	
Several periods with sub-phases	Within each period, two sub-phases such as stance-swing phase in gait or extension-flexion phase in free movements are determined	
Several periods with several sub-phases	Based on two trigger signals, sub-periods are defined: typical application is bilateral gait with left – right foot switches and side comparison	

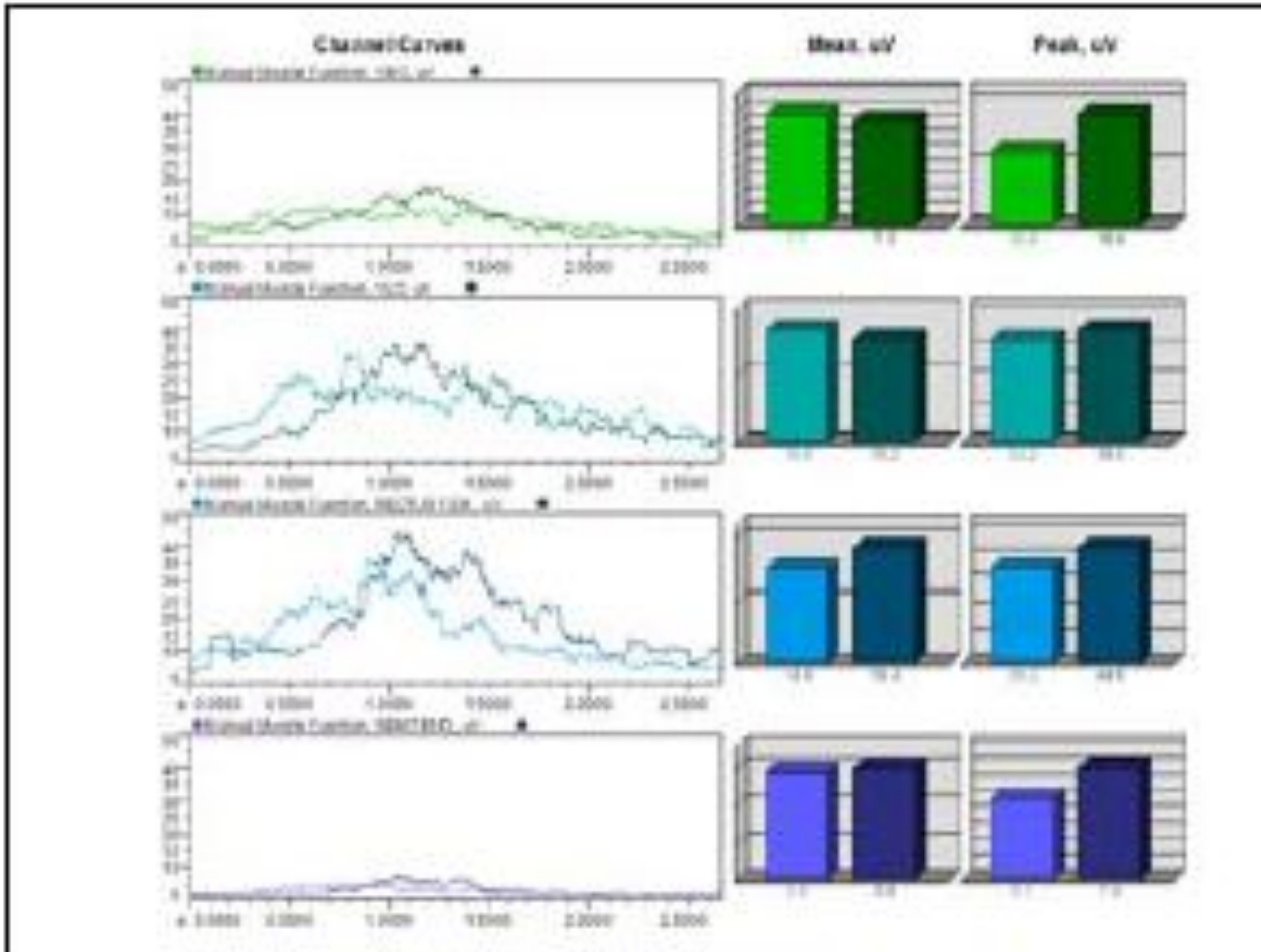


Fig. 88: Easy comparison analysis: two signal portions (e.g. from different tasks are shown in an over-plot and the differences are analyzed

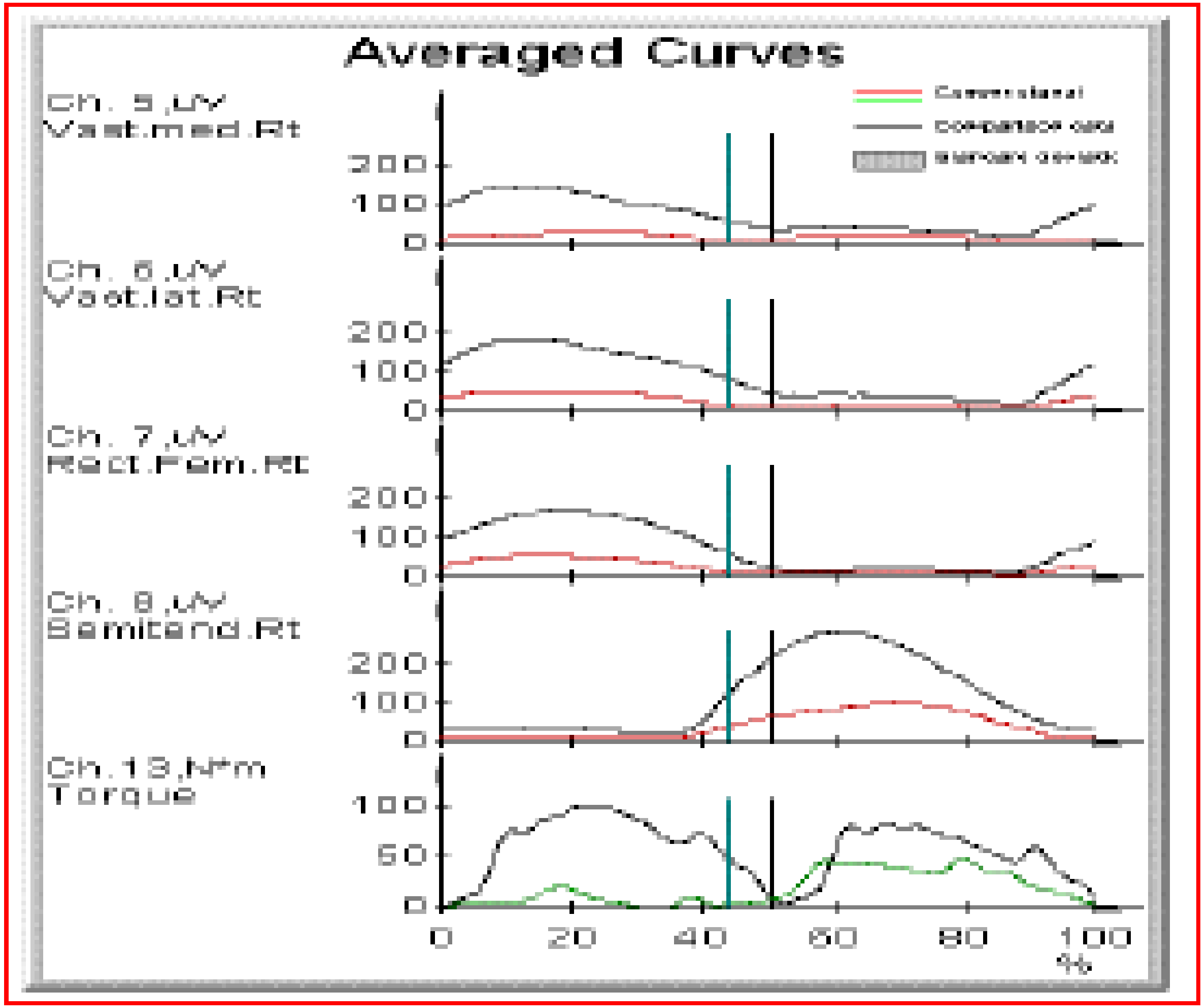


Fig. 89: Side comparison within isokinetic testing, based on averaged curves, with healthy and injured (red) side

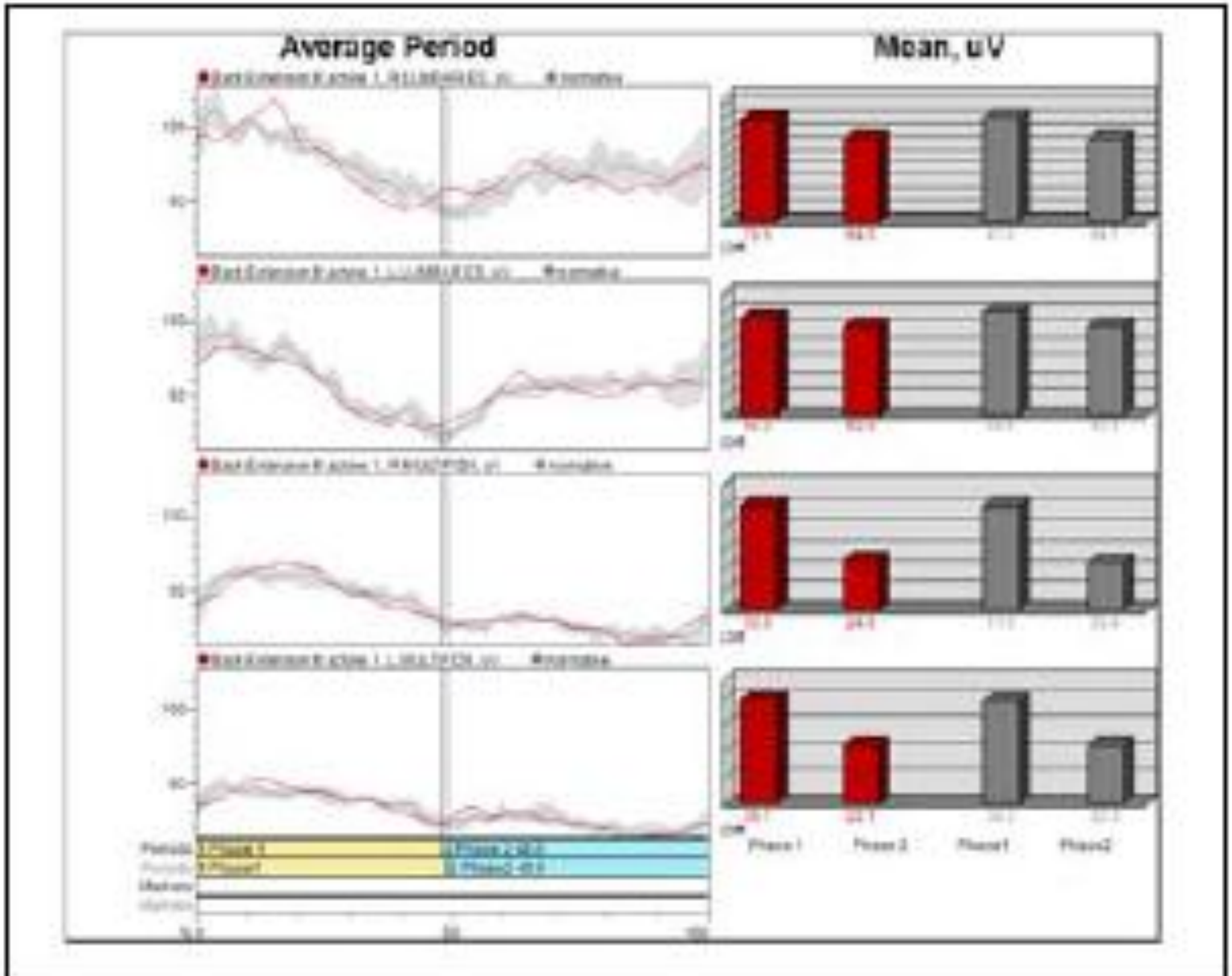


Fig. 90: Comparison of patients or subjects findings to normative curves, based on time normalized averaged curves

Comparisons Designs

Pre - test versus post - test	In a treatment, training or any other setup with interventions in between tests
Left Side versus right Side	Patients: healthy against injured side - analysis based on qualitative level
Activity 1 versus activity 2	E.g. analysis of exercises and their efficiency – *no normalization needed!*
Test portion 1 versus portion 2	Time domain changes of parameter e.g. fatigue studies - *no normalization needed!*
Muscle A versus muscle B	Coordinative aspects in muscle groups
Patient/Subject versus norm curve	Identification of abnormal patterns

Fig. 91: The major comparison designs used within kinesiological EMG studies

Complete Line of Surface EMG and Sensor Systems

Mobile Monitoring Concept and Connectivity

Real Time Monitoring of Muscle Activity and Performance