USER GUIDE v3.8
Report Descriptsions

NORAXON

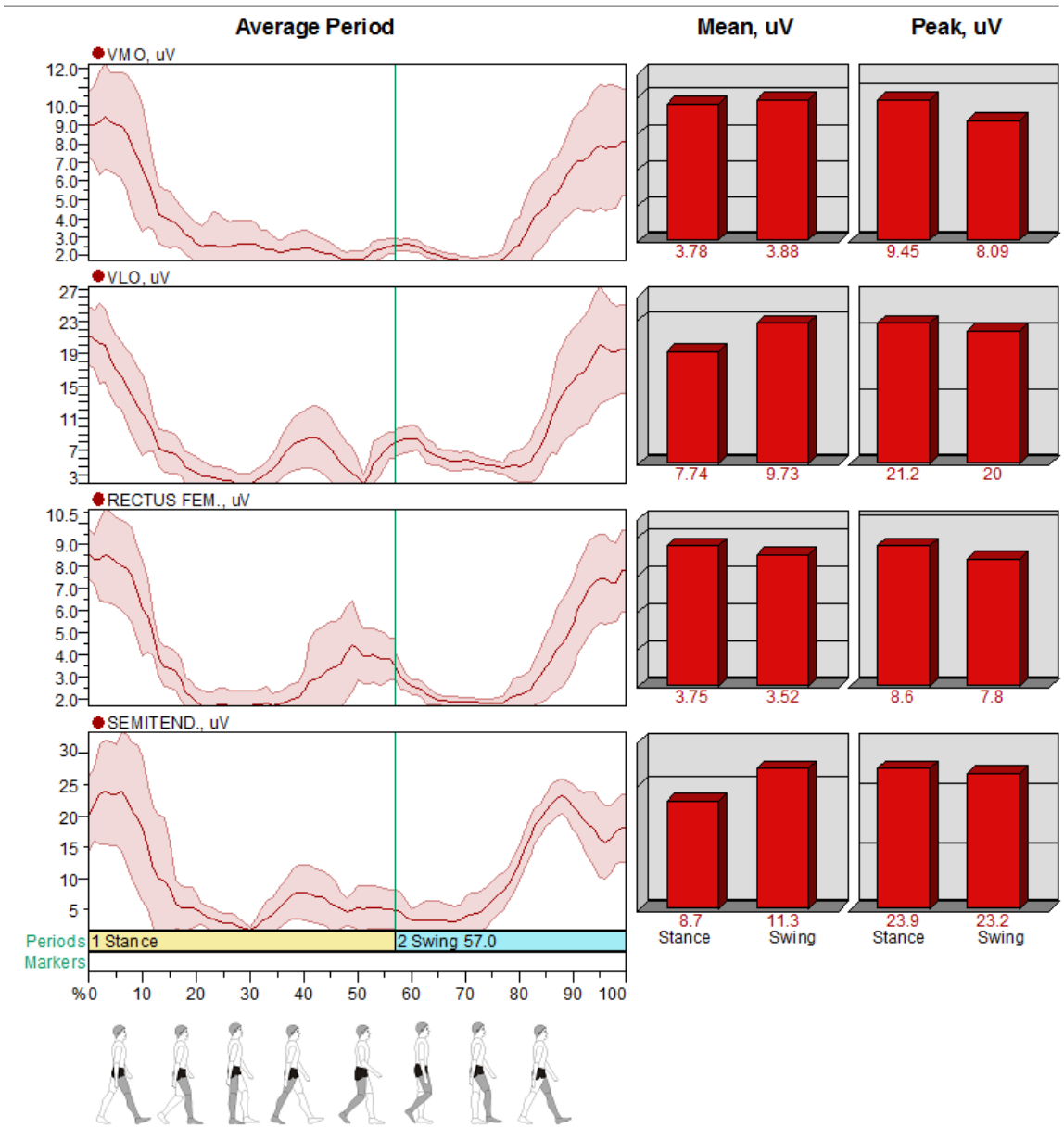
P-4338r Rev A (November 2015)

Contents

Appendix A: MyoMuscle Master Reports -

1) Unilateral Gait Report

This gait report is designed for unilateral investigation of EMG gait patterns in functional walking and running activity. A pressure signal produced by a foot sole foot switch of one leg is used to define each heel strike (start and end point of a gait cycle) and toe off (event within each gait cycle that separates stance and swing phase). Based on the gait phases the averaged EMG activation, patterns are shown in a time normalized gait cycle diagram.



Period Definition:

By TTL - Signal (foot switch) - Every Interval with Event

The period definition is done automatically by analyzing the foot switch TTL levels. The lower TTL means ground contact / stance period. TTL high means foot off the ground / swing phase. The toe off event separates stance and swing phase between two heel strike events. Each gait phase is indicated by yellow and blue bars within the period line of the record viewer

Recommended Signal Processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant

Report contents:

1. Page: Subject header, Averaged EMG signal screen, bar graph section showing the Mean, Peak values for stance and swing phase.

This analysis frame calculates the average EMG curve for all periods specified in the record and shows them in a time normalized window from 0 – 100% (data is presented in 1% steps). The red shaded area represents +/- one standard deviation. The red event line separates the curve into two sub phases (e.g. extension - flexion), indicated by yellow and blue bars in the period line within the x-axis.

Due to the averaging process the typical "behavior" of EMG activation is detected, the variability of each single repetition is "smoothed" to the typical shape of the activation pattern for this movement. Such EMG processing creates highly reproducible EMG patterns. Typically these patterns can easily be repeated in directly repeated measures and serve as a basis for test-retest comparison plots.

The averaging process detects the prototypical "behavior" of muscle activation as the variability between single repetitions blends into an average pattern for the movement. This method of EMG processing creates highly reproducible EMG patterns. These patterns can be replicated for repeated measurements and serve as a basis for test-retest comparison plots.

This graph can be used to analyze and interpret:

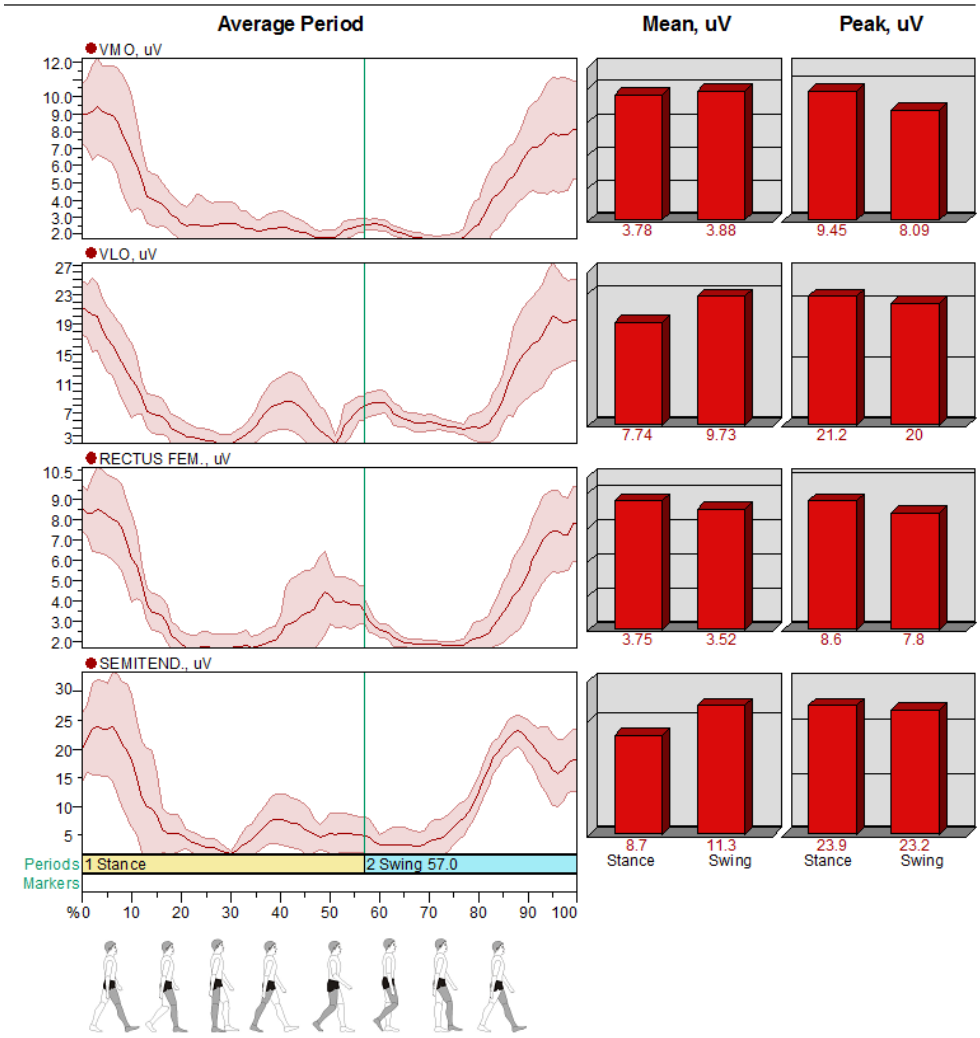
- The overall pattern and characteristics of EMG activity
- Upward or downward activation trends within the movement phase
- Comparison of the agonistic (first phase) and antagonist (second phase) firing pattern
- Comparison of muscle innervation in concentric or eccentric contraction phases
- Coordination of muscles

Signal statistics

By default, two amplitude parameters are calculated for each period of the average signals:

- **Mean** = the mean value of the EMG amplitude
- **Peak** = the peak value of EMG amplitude

These statistics quantify the difference of EMG activity between the muscles and the phases. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and choosing the Curve statistics tab. This analysis frame calculates the average EMG curve for all detected strides and shows them in a time normalized window from 0 – 100% (data are presented in 1% steps). The shaded red area represents the +/- one standard deviation. The red vertical event line divides the curve into stance and swing period - indicated by yellow and blue bars on the x-axis:



These statistics quantify the difference of EMG activity between the muscles and the phases. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and choosing the Signal statistics tab.

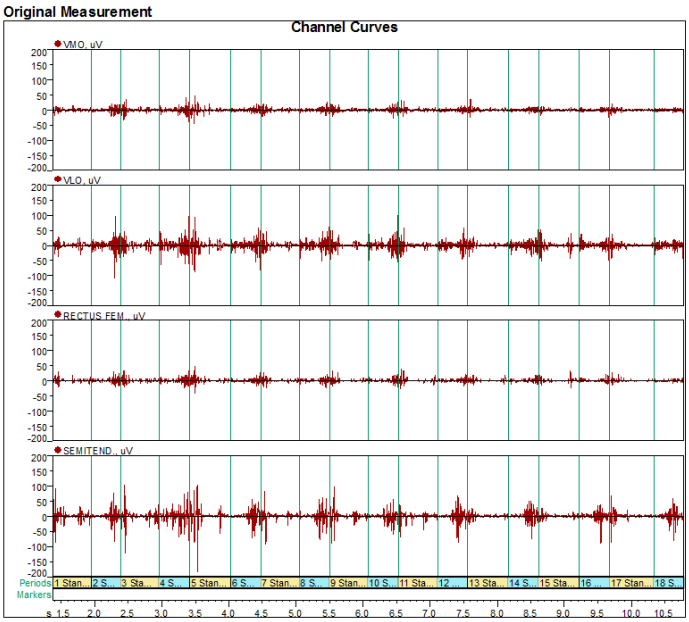
Analysis and interpretation:

The average EMG patterns show the typical activity characteristics and coordination of muscle groups during walking/running. With appropriate test standardization, the average EMG patterns are highly reproducible and can be used for left/right, pre/post test comparisons and development of normative databases. These data can be used to analyze and interpret various items:

- The overall pattern and characteristics of the muscle activity within gait
- Upward or downward activation trends within stance and swing phase
- Comparison of muscle activation under loaded (stance) and unloaded (swing) conditions
- Coordination between muscles

a) <u>Original Measurement</u>

This graph displays the original EMG traces and the sequence of detected gait cycles. It may be of interest and importance to check the conssistency of each firing burst and validity of the investigated gait sequence.



If invalid strides occur within the sequence, click "Reanalyze" to return to the period definition step, repeat it, and mouse drag any invalid periods away from the period bar. Optionally the processed version of the EMG traces can be shown: enter the analysis frame setup (right mouse click) and disable the check mark in "Always use raw data".

b) Statistics table for the processed measurement

This table refers to the processed signal (rectified / smoothed) and shows global statistic data of the selected record portion (from first to last stride).

Statistics for the Processed Measurement

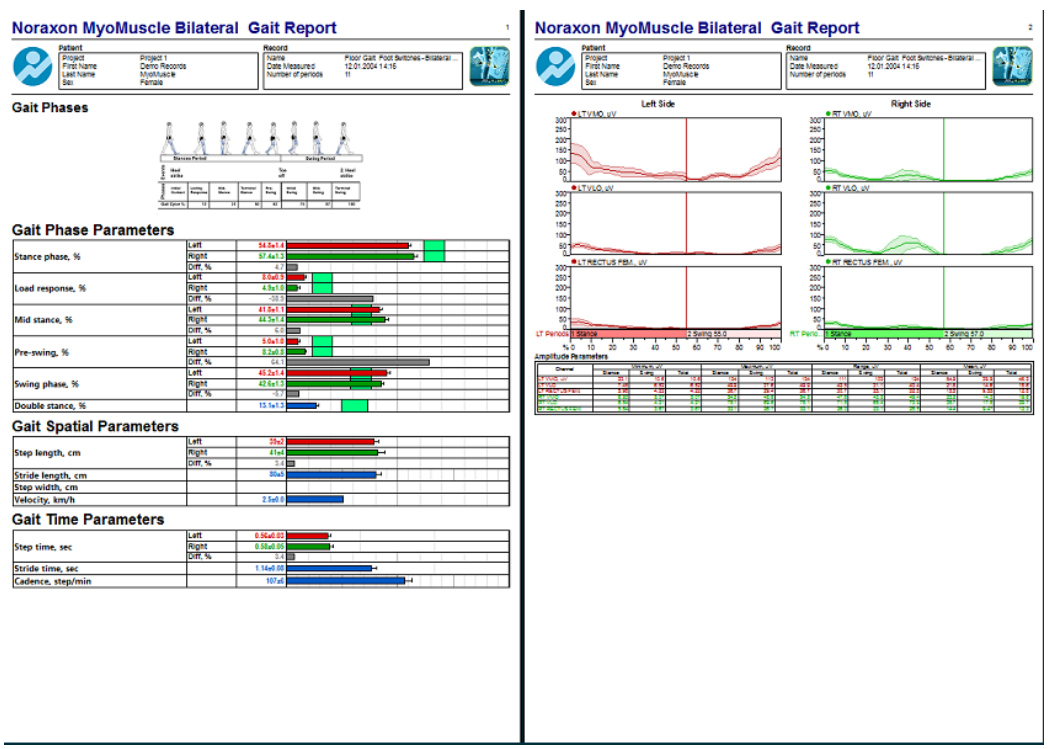
Channel	Mean, uV	Peak, uV
VMO, uV	3.81	16.4
VLO	8.57	31.8
RECTUS FEM.	3.64	12.8
SEMITEND.	9.78	43.5

Mean The mean amplitude value of all selected gait cycles
Peak The peak value of all selected gait cycles

These data allow a determination of EMG amplitude based parameters without cycle averaging as shown on page 1.

2) Bilateral Gait report – Foot Switches

This report is designed for gait activities operated with a foot sole or foot switch trigger system to detect gait phases and events (heel strike and toe off). Based on the foot switch events, stance and swing phase and gait subphases are determined. Spatial gait parameters based on a predefined walking distances are calculated as averaged values. EMG curves are averaged in a time normalized gait cycle from 0 to 100° gait cycle and shown as averaged curves plus or minus one standard deviation. An additional amplitude parameter table supports min, max, and range calculation separated by stance and swing phase.



Period Definition:

Rise/Fall by trigger channel – rise to rise with event

Trigger channels are the foot switch signals: the report setup is preconfigured to automatically analyze the gait events based on left and right foot switch signal.

Each stance phase (dark color) and swing phase (bright color) of each detected stride is marked in red (left side) and green (right side) bars. Period definition mode can be modified with "Change Period Definition" in the right tool bar of record viewer right after selecting the report

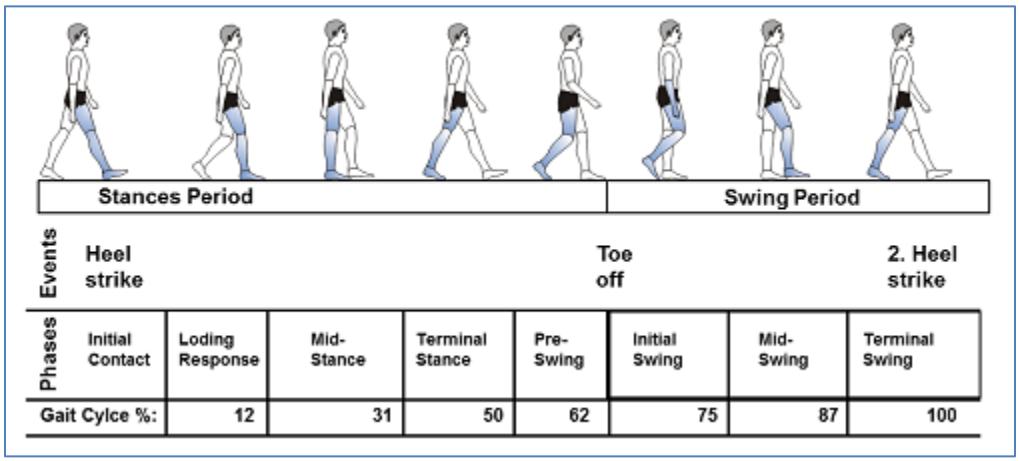
Report contents:

1. Page: Subject header, Gait Phase Diagram, Gait Phase-, Spatial- and Time-parameter table

2. Page: Average EMG curves. MyoMotion averaged angle and averaged force curves are added automatically if measured in multi-device setup configuration. Amplitude parameter table for all averaged signals.

Description of selected analysis frames

Page one refers to the classical gait parameters describing phase related temporal and spatial aspects of the gait performance related to gait events and gait sub phases. MR3 is using the gait phase definition established by J. Perry:



Gait phase parameters

Gait Phase Parameters

Stance phase, %	Left	65.5±0.7
	Right	65.9±1.8
	Diff, %	0.5
Load response, %	Left	16.8±2.0
	Right	14.7±0.5
	Diff, %	-12.2
Mid stance, %	Left	34.0±1.6
	Right	34.7±0.6
	Diff, %	2.1
Pre-swing, %	Left	14.6±0.3
	Right	16.5±1.9
	Diff, %	12.7
Swing phase, %	Left	34.5±0.7
	Right	34.1±1.8
	Diff, %	-1.0
Double stance, %		31.3±1.9

The green areas below the horizontal bars indicate a normal range for ground floor walking and is meant to be used for educational purposes only.

Phase in % cycle	Description
Stance Phase	Describes the period within a gait cycle during which the foot has contact with the ground.
Load Response	Describes the Load Response period within a gait cycle.
Mid Stance	Describes the period within a gait cycle during which the contralateral foot has no contact with the ground.
Pre-swing	Describes the pre-swing period within a gait cycle Pre-swing equals to terminal stance.
Swing Phase	Describes the period within a gait cycle during which the foot has no contact with the ground.
Double Stance	Describes the period within a gait cycle where both feet have ground contact.

Spatial Gait Parameters

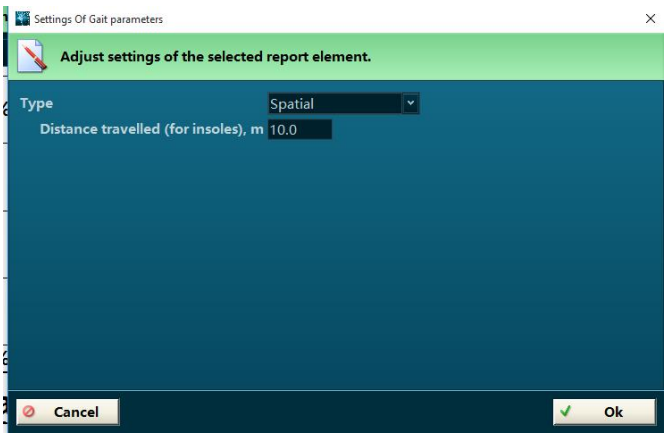
Gait Spatial Parameters

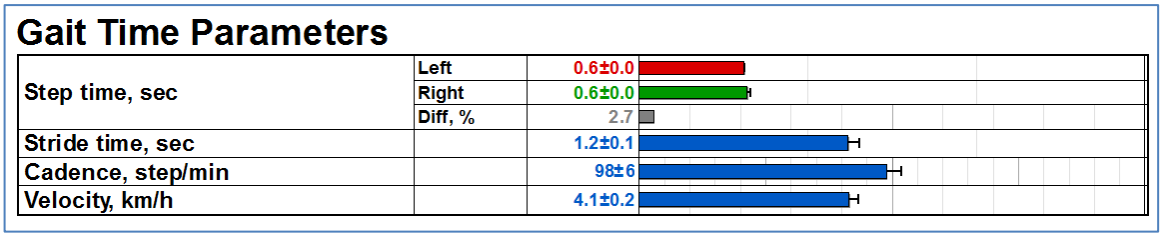
Foot rotation, deg	Left	4.0±3.2
	Right	5.9±0.5
Step length, cm	Left	73±1
	Right	69±1
	Diff, %	-6.1
Stride length, cm		141±2
Step width, cm		15±1

Spatial Parameter	Description
Foot Rotation (deg)	Angle between longitudinal foot axis and walking direction (plus = outside, minus = inside) *Not calculated for Insole measurements!*
Step Length (cm)	Shows the distance between the heel contact of one side of the body and the heel contact of the contralateral side.
Stride Length (cm)	Shows the distance between two heel contacts on the same side of the body.
Step width (cm)	Distance between left and right heel.

NOTE: The spatial parameters are calculated in relation to a 10 Meter walking distance!

To chance this distance, double click on the report element table and adjust **Distance travelled (for insoles), m** to the desired distance:



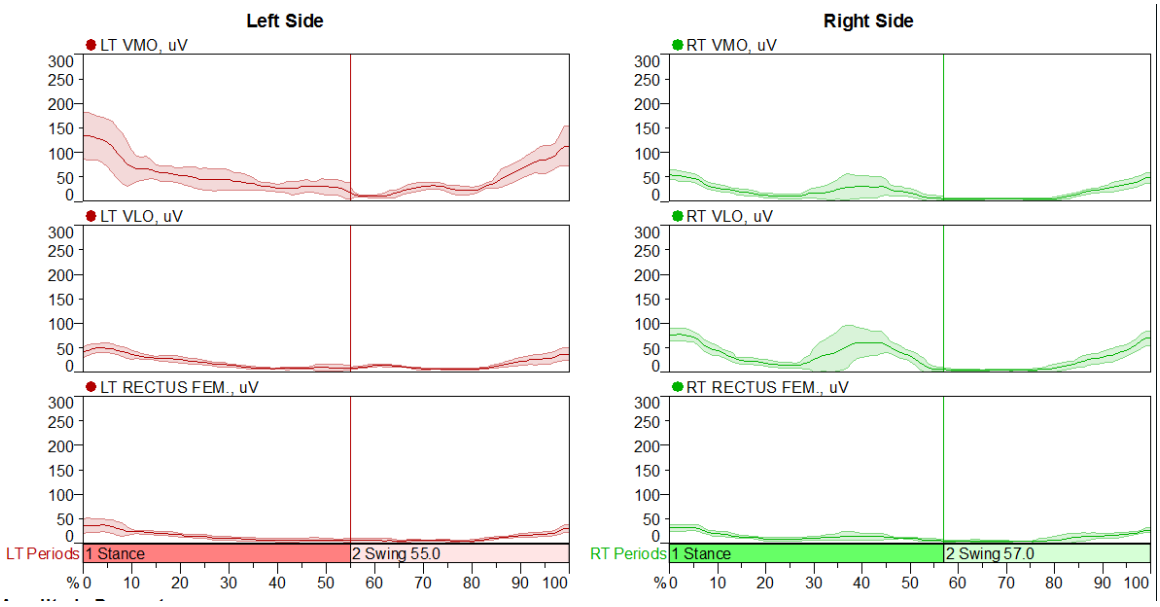


Spatial Parameter	Description
Step Time (sec)	Describes the period within a gait cycle between the heel contact on one side of the body and the heel contact on the contralateral side.
Stride time (sec)	Shows the distance between two heel contacts on the same side of the body.
Cadence (steps/min)	Shows the parameter steps/minute and is calculated from the reciprocal of the Stride Time.
Velocity	Average walking velocity over all strides.

NOTE: The velocity parameter is calculated in relation to a 10 Meter walking distance! Change this via the same steps as above.

c) <u>Average Period separated in left and right side</u>

This analysis frame calculates the average EMG curve for all detected strides and shows them in a time normalized window from 0 – 100% (data are presented in 1% steps). The shaded area represents the +/- one standard deviation. The vertical event line divides the curve into stance and swing period - indicated by red and green bars on the x-axis.



d) Amplitude Parameters

This table refers to the processed signal (rectified / smoothed) and shows global statistic data of the selected record portion (from first to last stride).

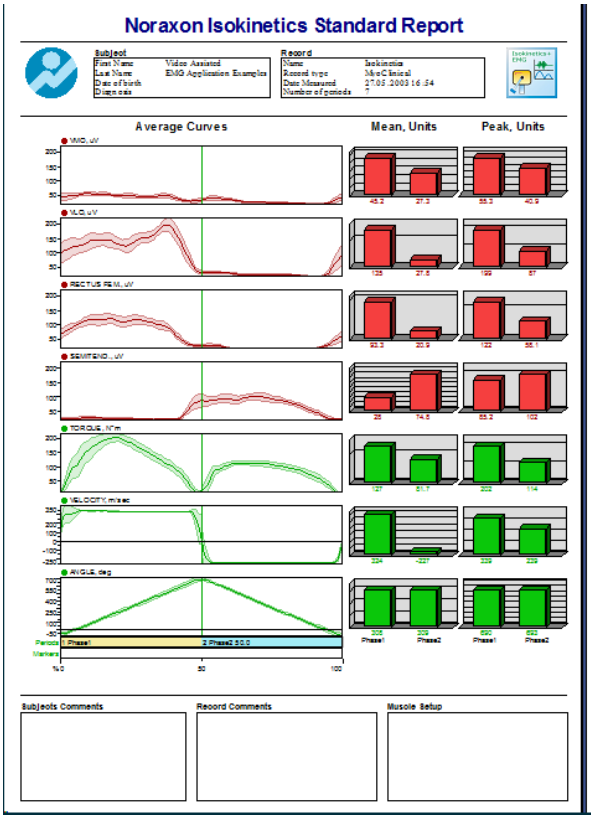
Amplitude Parameters

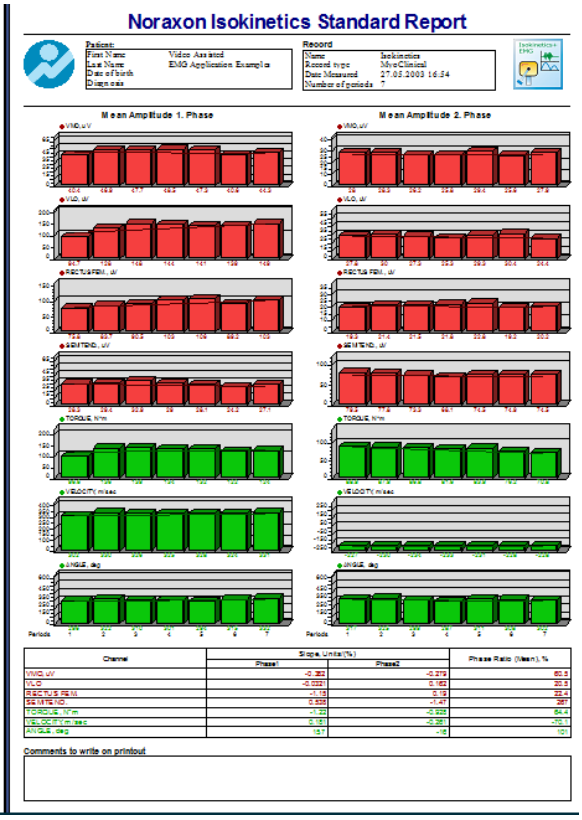
Channel	Minimum, uV			Maximum, uV			Mean, uV		
	Stance	Swing	Total	Stance	Swing	Total	Stance	Swing	Total
LT VMO, uV	23.1	10.6	10.6	134	113	134	54.9	39.9	48.2
LT VLO	7.45	6.52	6.52	49.9	37.6	49.9	21.8	14.6	18.6
LT RECTUS FEM.	5.98	4.22	4.22	36.7	29.4	36.7	15.5	9.55	12.8
RT VMO	6.93	5.07	5.07	54.5	48.6	54.5	23.5	14.3	19.6
RT VLO	6.54	4.21	4.21	78.1	69.6	78.1	38.7	17.8	29.7
RT RECTUS FEM.	5.84	3.67	3.67	32.1	26.7	32.1	14.4	9.47	12.3

Minimum The minimum amplitude value of all selected gait cycles.
Maximum The maximum amplitude value of all selected gait cycles.
Mean The mean amplitude value of all selected gait cycles.
Peak The peak value of all selected gait cycles.

3) Isokinetics Report

This report is designed for the analysis of synchronized measurement of EMG and biomechanical output signals (torque, angle, velocity) during any isokinetic activity. The isokinetics output signals need to physically connected and integrated into the EMG recording, at minimum the torque and the position signal has to be recorded. The report setup depends on the given isokinetics device and the predefined report setup may need some adjustments for the given isokinetics system.





Period Definition:

Mode: Min/Max by trigger channel, Min to Min with event (based on isokinetics angle signal)

Automatic period definition is based on a trigger detection algorithm, which typically uses the angle or velocity input signal. These settings can be adjusted in the next screen after selecting this report or via operating "Re-analyze" in the report preview menu. At least one repetition cycle of extension / flexion, ab- / adduction, in - / out rotation must be found. Detected periods are indicated by yellow (first phase) and blue (second phase) bars in the Viewer screen

Recommended processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with typically 50 to 100ms time constant. Bipolar torque curves should be rectified.

Report contents:

1. Page: Subject header, Averaged Curves screen with Mean and Peak value bar graphs
2. Page: Subject header, time domain changes bar diagram for Mean EMG and torque/angle for both motion phases (e.g. knee extension/flexion), time domain statistics table

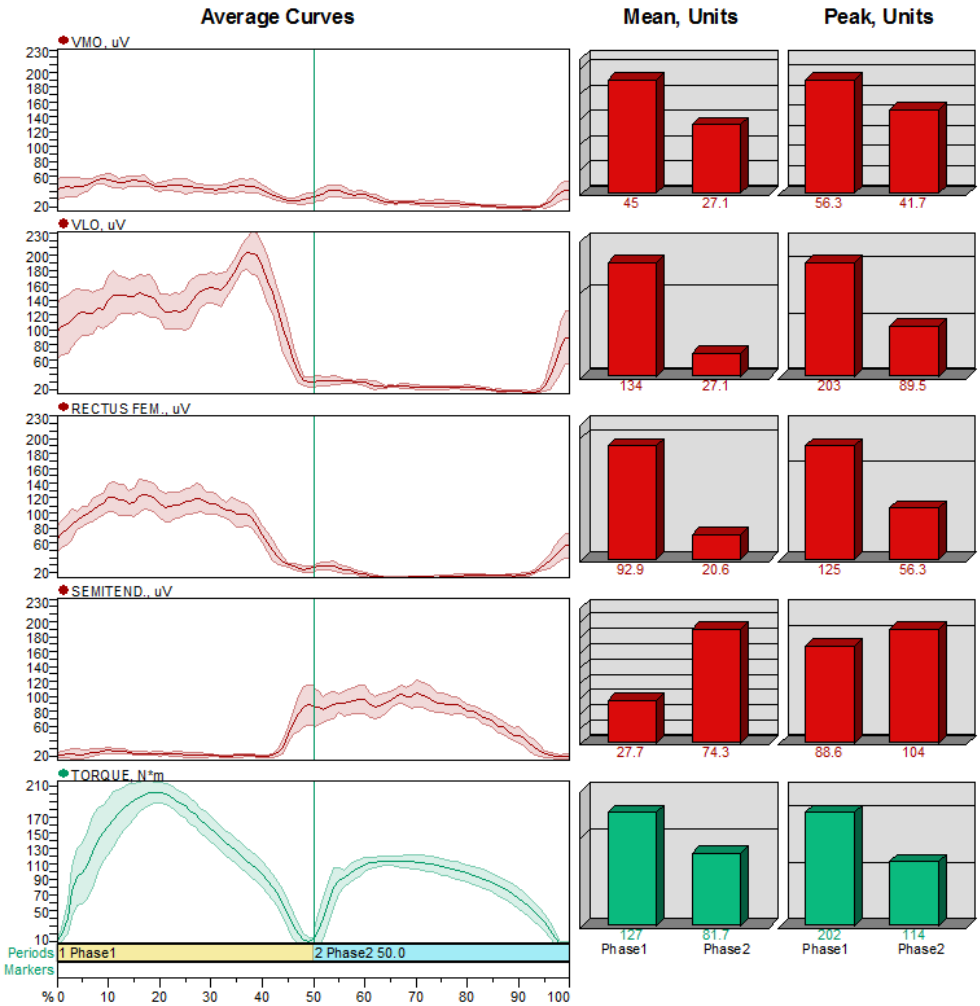
Analysis and interpretation

The main purpose of this analysis is to document the typical activation pattern and firing characteristics within each repetition cycle of the isokinetic activity (e.g. extension - flexion, abduction - adduction, in- / outward rotation, etc.). Angle, velocity, or direction signals derived from the isokinetics device are used to time normalize and average EMG patterns for comparisons with the average torque output curve. The second page of the report provides a time domain analysis of the amplitude mean and peak values in a parameter trend diagram. This analysis reflects the changes in the neuromuscular recruitment within the recorded test or training set.

Description of analysis frames

Average Curve

This analysis frame calculates the average EMG and torque curve for all detected repetitions and shows them in a time normalized window from 0 – 100% (data are presented in 1% steps). The red shaded area represents the +/- one standard deviation. The red vertical event line divides the curve into two sub phases (e.g. extension-flexion), indicated by yellow and blue bars on the x-axis.



Depending on the isokinetic protocol and activity type used, phases 1 and 2 can represent extension and flexion, abduction and adduction, inward and outward rotation, etc. Averaging detects the prototypical "behavior" of muscle activation as the variability between single repetition blends into an average pattern for the movement. This method of EMG processing creates highly reproducible EMG patterns. The patterns are replicated in repeated measures and serve as a basis for test-retest comparison plots. The user can compile customized normative databases by pooling the average curves of a specific group.
This graph can be used to analyze and interpret the following items and more:

- The overall pattern and characteristics of EMG activity.
- Upward or downward activation trends within the movement phase.
- Comparison of the agonistic (first phase) and antagonist (second phase) firing pattern.
- Comparison of muscle innervation in concentric or eccentric contraction phases.
- Coordination of muscles.
- EMG input versus torque output ratios.

Signal statistics

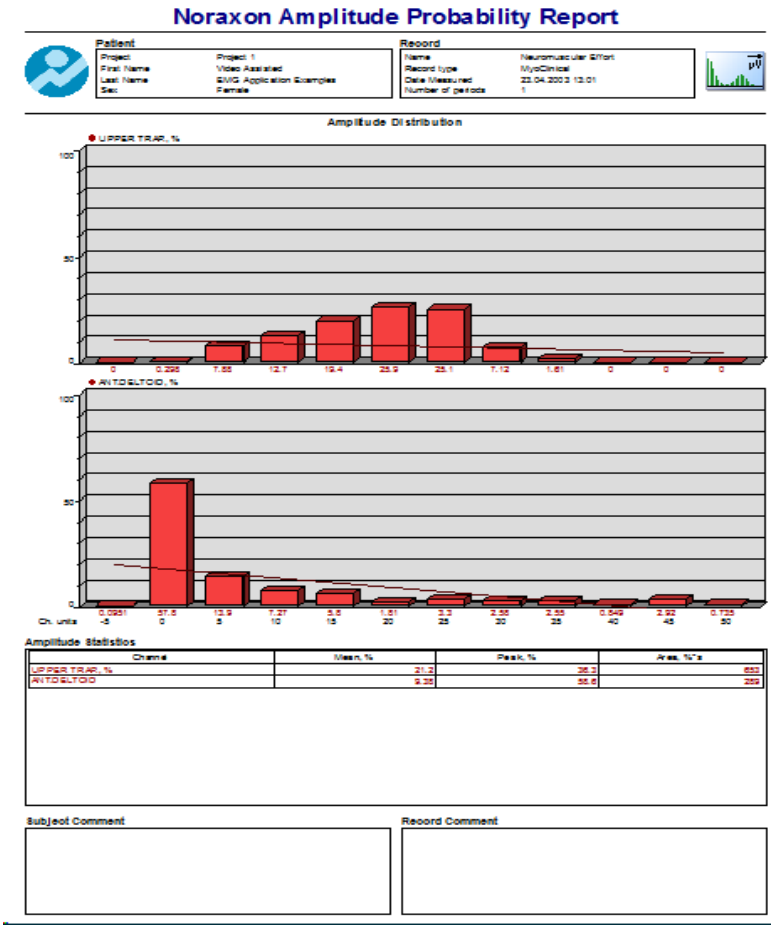
By default two amplitude parameters are calculated for each phase of the average signals:

- Mean = the mean value of the average EMG or torque amplitude
- Peak = the peak value of the average EMG or torque amplitude

These statistics quantify the difference of EMG activity between the muscles and the phases. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and choosing the Curve statistics tab.

4) Amplitude Probability Report

This report is designed for the analysis of the percentage distribution of amplitude increments for a given analysis period. The EMG - amplitude increments are shown by the X-axis, the percentage of time spent at a given amplitude increment is shown by the Y-axis. The one page report shows a graph of the amplitude distribution with bars of 10 microvolts range and an amplitude statistics table with the Mean, Peak and Area value of the total analysis period.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu. Only one consecutive area at a time can be defined for the analysis.

Recommended processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with typically 50 to 100ms time constant

Report contents:

1. Page: Subject header, Amplitude probability distribution diagram, amplitude statistics

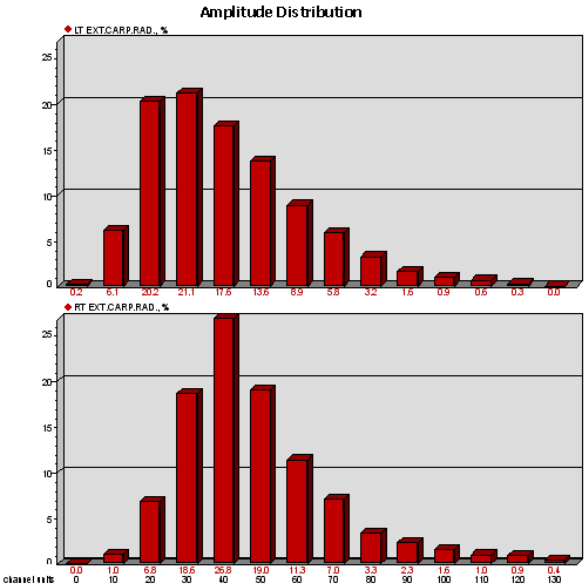
Analysis and interpretation:

The amplitude probability report is typically used in ergonomic studies. The basic idea is to evaluate how much time was spent at low EMG amplitude values (indicating resting periods or relaxation) and how much at higher values (typically the task-specific EMG). Any shift of the distribution in comparison of two records of the same task to the left indicates an economical effect, because "less EMG" is spent for the same task. If the left side bars become higher, more time was spent at "resting level" EMG, which is important to know to avoid the accumulation of fatigue effects. Depending on the signal characteristics, it may be necessary to decrease or increase the width of the amplitude increments to achieve a more suitable resolution of the distribution pattern. Typically 50ms RMS smoothed EMG data is used for the analysis. The report would also accept MVC-normalized records, but again it may be necessary to adjust the amplitude increment settings.

<u>Description of analysis frames</u>

Amplitude Distribution graph

By default, the amplitude increments are shown in increments of 10 "channel units", i.e. 10 microvolts in the case of non-normalized EMG:



The increments width has to be adjusted depending on the signal characteristics (tab - section Diagram settings/Resolution in the report element setup menu). The X-axis range is determined automatically and depends on the highest EMG amplitude. The time is shown as a percent of the total time. In the report element setup section this can be changed to seconds or "counts" (amount of data points within one amplitude increment).

Amplitude Statistics Table

A brief summary of the main amplitude parameters Mean, Peak, and Area value, calculated for the complete analysis period, is shown in the statistics table:

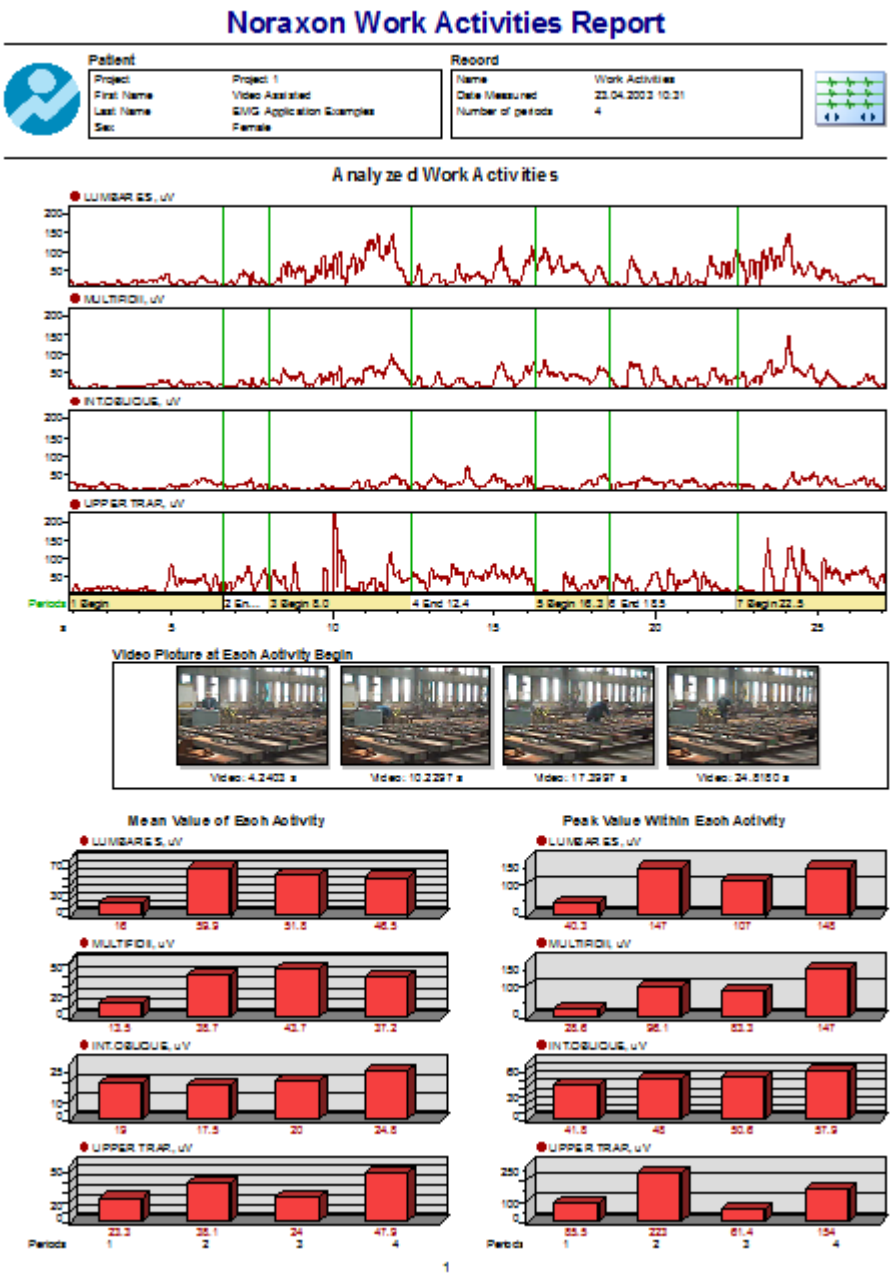
Amplitude Statistics

Channel	Mean, uV	Peak, uV	Area, uV*s
LT EXT.CARP.RAD., uV	45.3	126.9	407.5
RT EXT.CARP.RAD.	52.9	136.5	475.8

Use these stats for global comparison issues between records

5) Work Activities Analysis

This report is designed for the video based analysis of up to four different work activities and analyses the difference between them. A synchronized video is used to define the start and stop of each activity recorded within one record. A video picture documents the beginning of each activity period. The mean and peak amplitude values of each activity are calculated and displayed as a histogram diagram. The report can be used for both micro volt scaled or MVC - amplitude normalized EMG signals.



Period Definition:

Mode: By markers - Every other interval

Replay the video and stop at the first activity of interest, place a marker (left mouse double click or marker Set button), continue to play to the end of first activity, place a marker again, then let the video run to the next activity of interest, place markers and continue with this routine with up to 4 activities per record.

Recommended processing:

RMS EMG amplitude normalized to a MVC record or RMS EMG

Report contents:

1. Page: Subject header, signal screen for analysis period, sequence of video pictures from beginning of each activity, Mean and Peak value within each of the four selected activities

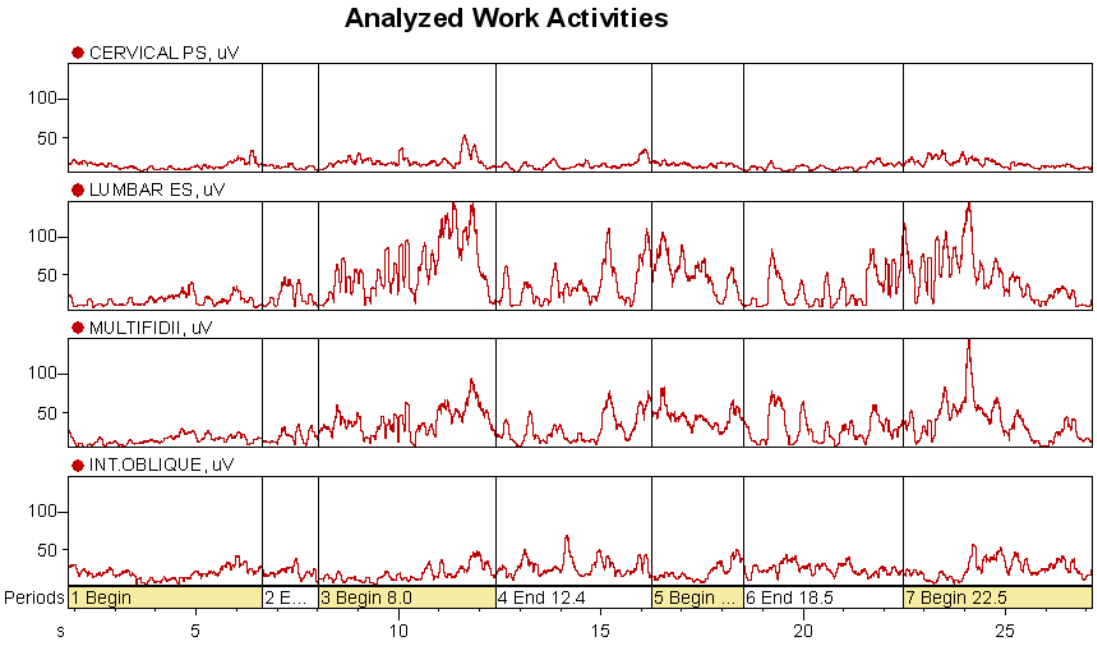
Analysis and interpretation:

This report allows you to compare as many tasks as you please. By comparing the EMG amplitude levels between the selected activities, a "neuromuscular work profile" can be established for a given work task. Prior to analysis, the raw EMG signals should be RMS smoothed and rectified, or an MVC normalization can be performed, which serves as a reference to normalize the EMG amplitude to. Without normalization, only related changes between tasks can be quantifies. In addition to allowing you to analyze different work activities, when used with MVC normalization, the report can also be used to compare the activity and also be repeated with modified work conditions or tools. The report graph shows the signal processed EMG traces and the location of each activity period. A sequence of video pictures document each position at the beginning of each activity. The Mean and Peak amplitude value of each activity and channel are calculated in a histogram diagram for easy and direct comparison.

<u>Description of analysis frames</u>

Analyzed Work Activities

The signal graphs show the signal processed EMG traces of the selected activities, which are indicated by yellow bars within the Periods status line below the graph:



The non - analyzed portions are indicated by white areas. These graphs serve as documentation of the complete sequence of activities.

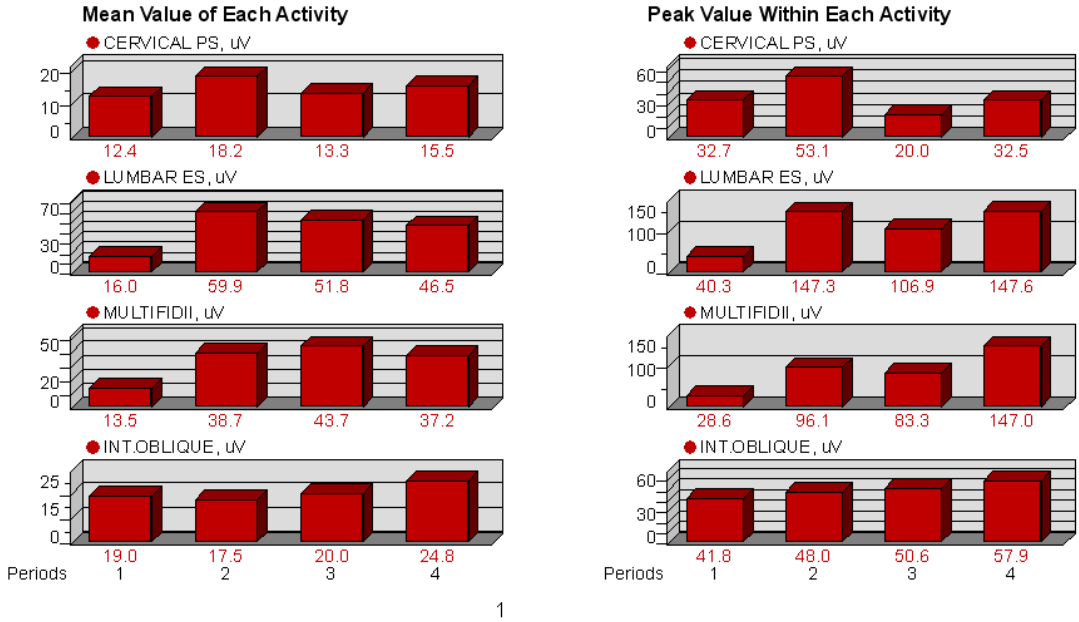
Video Picture at the start of Each Activity

The first marker of each activity is used to take a video shot of this activity:

These pictures are helpful for the documentation of the performed activities.

Mean and Peak Value Histogram graphs of each activity

The amplitude mean and peak value of each activity are calculated in a histogram graph:

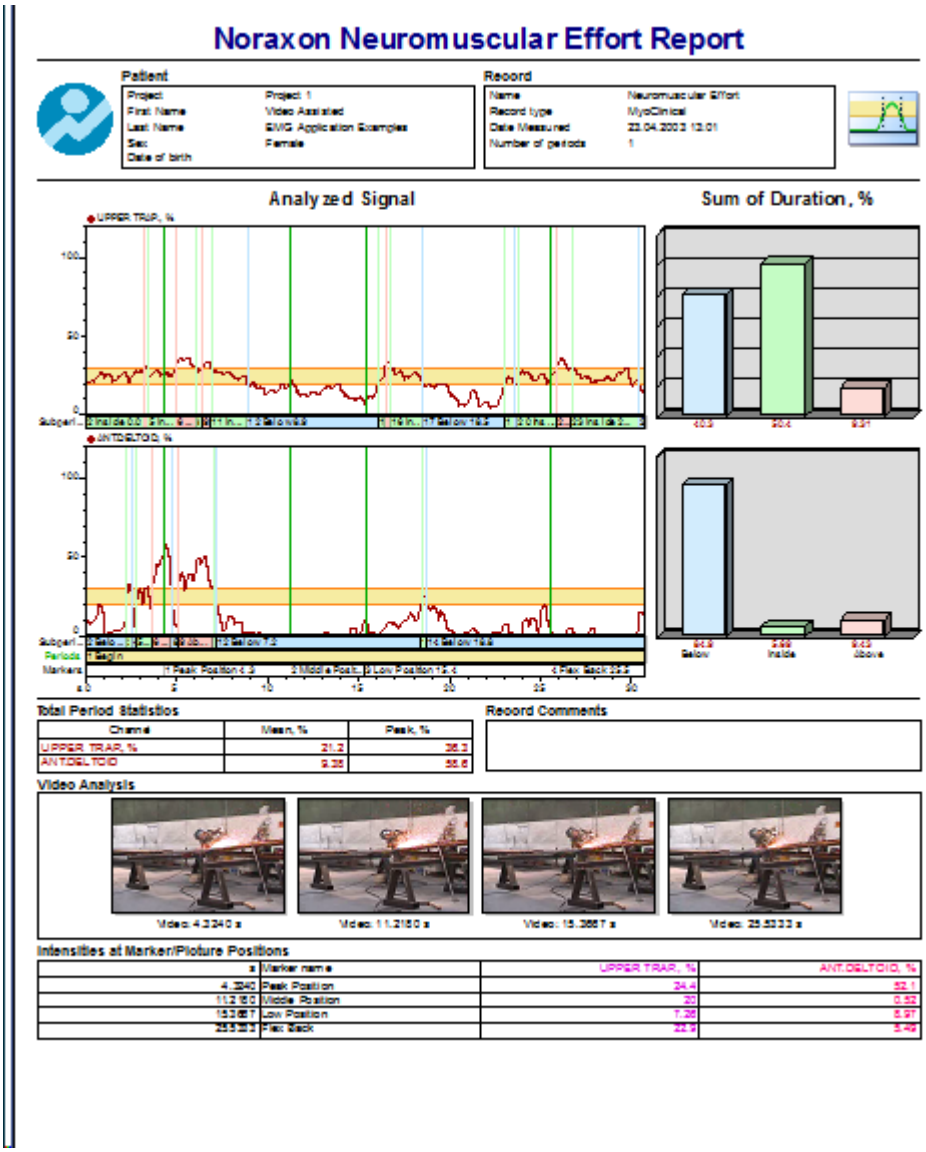


This presentation of numerical data allows a direct comparison of amplitude data between activities and helps to identify low/high level EMG activities. The Work Activities report can be accompanied by the Neuromuscular Effort Report, which allows for a more detailed analysis of one single activity.

6) Neuromuscular Effort Report

The report is designed for the video based analysis of the neuromuscular effort spent in a certain activity.

The report requires MVC amplitude normalized EMG records. The time duration spent in, above, and below a 20-30% MVC threshold range is presented. Certain events within the analysis period can be manually marked by markers. A video picture taken at this position and the intensities at all selected marker/video positions is summarized and is listed in a parameter table.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu. Up to four additional marker can be placed in the Viewer menu to determine video picture positions of interest.

Recommended processing:

50ms RMS smoothed EMG amplitude normalized to a MVC record.

Report contents:

1. Page: Subject header, threshold related signal graph with bar graph diagram statistics related to threshold video picture at each POI, total interval Mean and Peak EMG values, EMG amplitude intensity table related to POIs

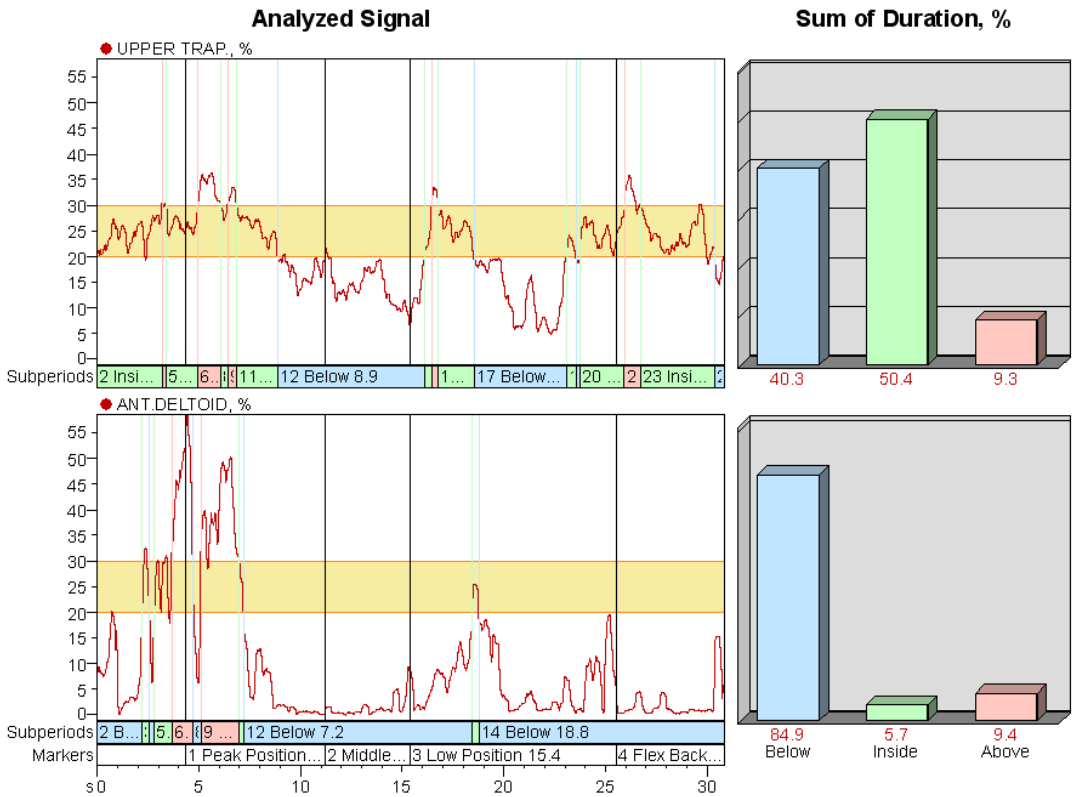
Analysis and interpretation:

This report analyzes and determines the neuromuscular effort spent performing a task. Prior to the analysis, an MVC reference contraction must be performed for each muscle being recorded and all signals must be smoothed and amplitude normalized in the Record Viewer/Signal Processing Menu. The report allows the user to determine if a given activity is to be considered as moderate, sub maximal, or heavy, in terms of neuromuscular effort. Depending on the specific work task, a predefined threshold range (20 - 30 % by default) can be adjusted to define minimal, sub maximal, and maximal exhaustion levels. The report graph shows the MVC normalized EMG traces in ratio to the threshold settings and the calculated time (normalized to the total time) duration that the signal remained in, above, and below the selected threshold setting. The records are video synchronized and based on the video pictures, interesting positions can be marked in the Record Viewer menu. A video picture and the actual EMG amplitude value at that position are also shown in the report. This function allows users to selectively analyze certain interesting positions/movements within the recorded task.

<u>Description of analysis frames</u>

Analyzed Signal Graph

The signal graphs show the processed EMG traces of the selected analysis/activity interval as a ratio of the predefined threshold range (yellow background area):



A colored sub periods line indicates the time segments of the signal staying **Below** (blue), **Inside** (green), and **Above** (red) the threshold range. The right side statistics bar calculates the summed time duration of each sub period, normalized to the total time of the analysis period. This parameter can be used to determine the neuromuscular effort of each investigated muscle: how much time was spent for low, medium, and high EMG levels.

The threshold can be changed by double clicking on the analysis element, which opens the setup menu. The tab section "Sub periods" allows the user to modify the threshold range settings (**Threshold Min/Max)**. By default the minimum **sub period duration** is set to 0.2 seconds, which means for this duration, a signal must stay in a certain threshold range to be accepted there. This value may be adjusted depending on the investigated activity. The vertical black lines show the marker positions which were set in the record viewer video analysis. Their time or text labels are shown in the **Markers** status line below the graph.

Total Period Statistics

Independent of any threshold range definition, a short statistics table for the whole activity is summarized in this parameter table. The Mean and Peak value of the selected activity is calculated for each channel:

Total Period Statistics

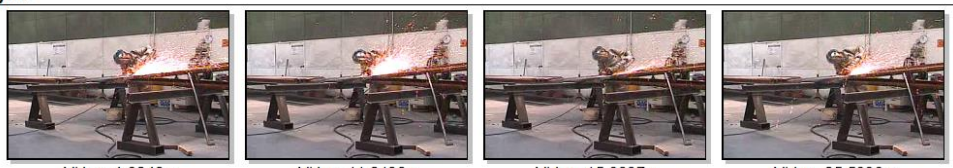
Channel	Mean, %	Peak, %
UPPER TRAP., %	21.2	36.3
ANT.DELTOID	9.4	58.6

This table is simply a helpful overview of the mean innervation level of the analyzed activity and its peak value.

Video Analysis

This sequence shows a video snap-shot for each marker position and provides visual documentation of important and interesting positions or movements. The report layout is arranged for 4 marker/pictures. When more than four markers are placed, the additional pictures may not be visible on the first page, but are included on the second page. To include them on the first page, you must change the width of the photos: double click on the video analysis element to open the setup menu and decrease the picture width.

Video Analysis



Video: 4.3240 s | Video: 11.2180 s | Video: 15.3667 s | Video: 25.5333 s

Intensities at Marker/Position

The amplitude and time values at each marker position are listed in this table:

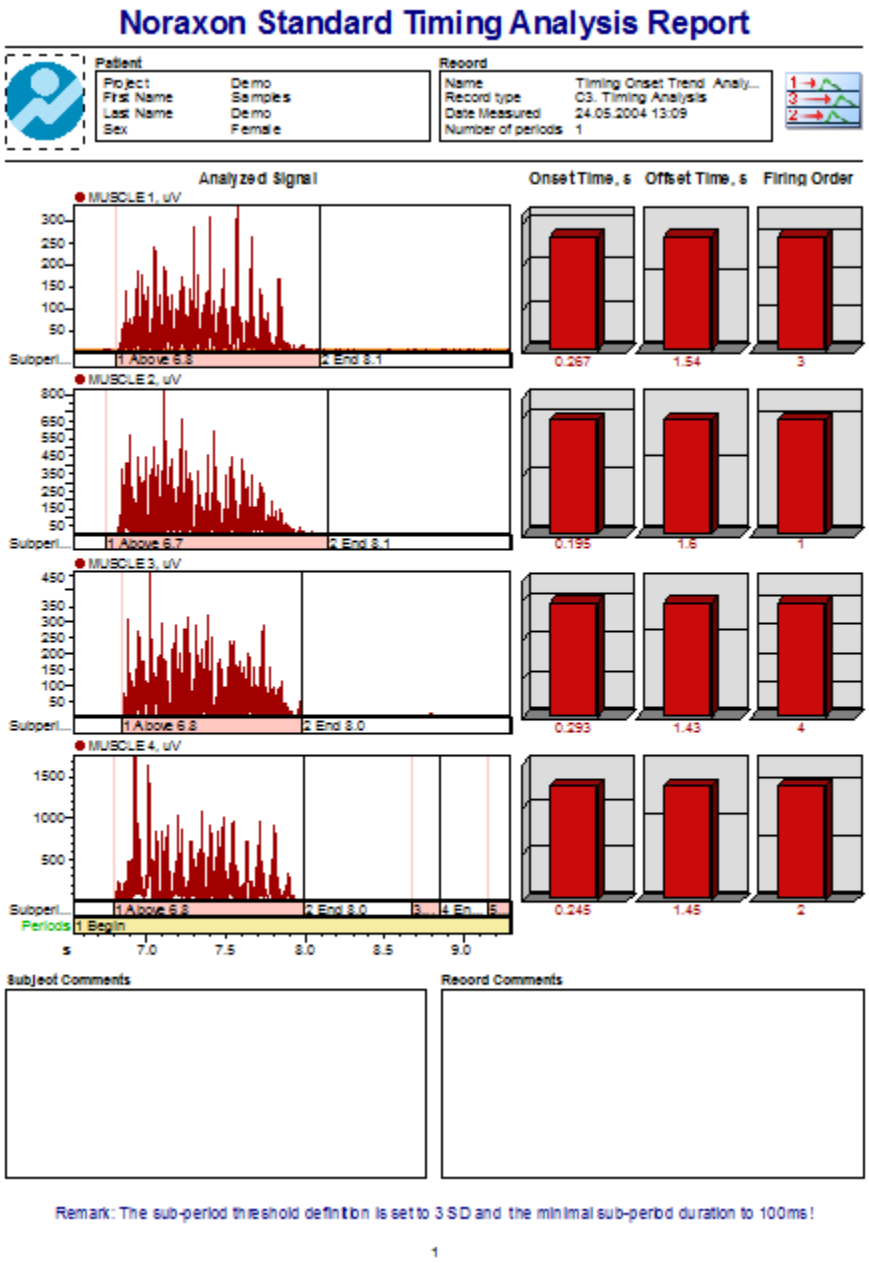
Intensities at Marker/Picture Position

s	Marker name	UPPER TRAP., %	ANT.DELTOID, %
4.2647	Marker	25.3	50.6
11.0607	Marker	16.5	0.1
17.7907	Marker	23.8	12.7
27.0520	Marker	26.1	0.4

The system of markers, synchronized video, and amplitude analysis allows the user to pick up certain critical or interesting events within the activity and document their neuromuscular input. If more than 4 markers are used, the parameter table is automatically continued on the next report page.

7) Standard Timing Analysis Report

The report is designed for onset/offset analysis of reflex studies or other timing related test setups. Based on a threshold definition, using the standard deviation of the EMG baseline (3 x SD by default), the Onset, Offset, and Firing Order of muscle activity is analyzed and shown as a colored sub period. Alternative threshold definition modes like “percent of local peak activity” or “to a fixed value” are also supported.



Period Definition:

Mode Mouse marked area

Mark the area of interest with left mouse button in the Viewer menu before entering the report menu and selecting this report. All timing calculations refer to the beginning of the selected signal portion. The Onset/Offset report is configured to analyze a single analysis period only.

Recommended processing:

Raw EMG or rectified and very softly smoothed EMG.

Report contents:

1. Page: Subject header, Onset sub period screen with Onset Offset time and muscle firing order as histogram bar graph

Analysis and interpretation:

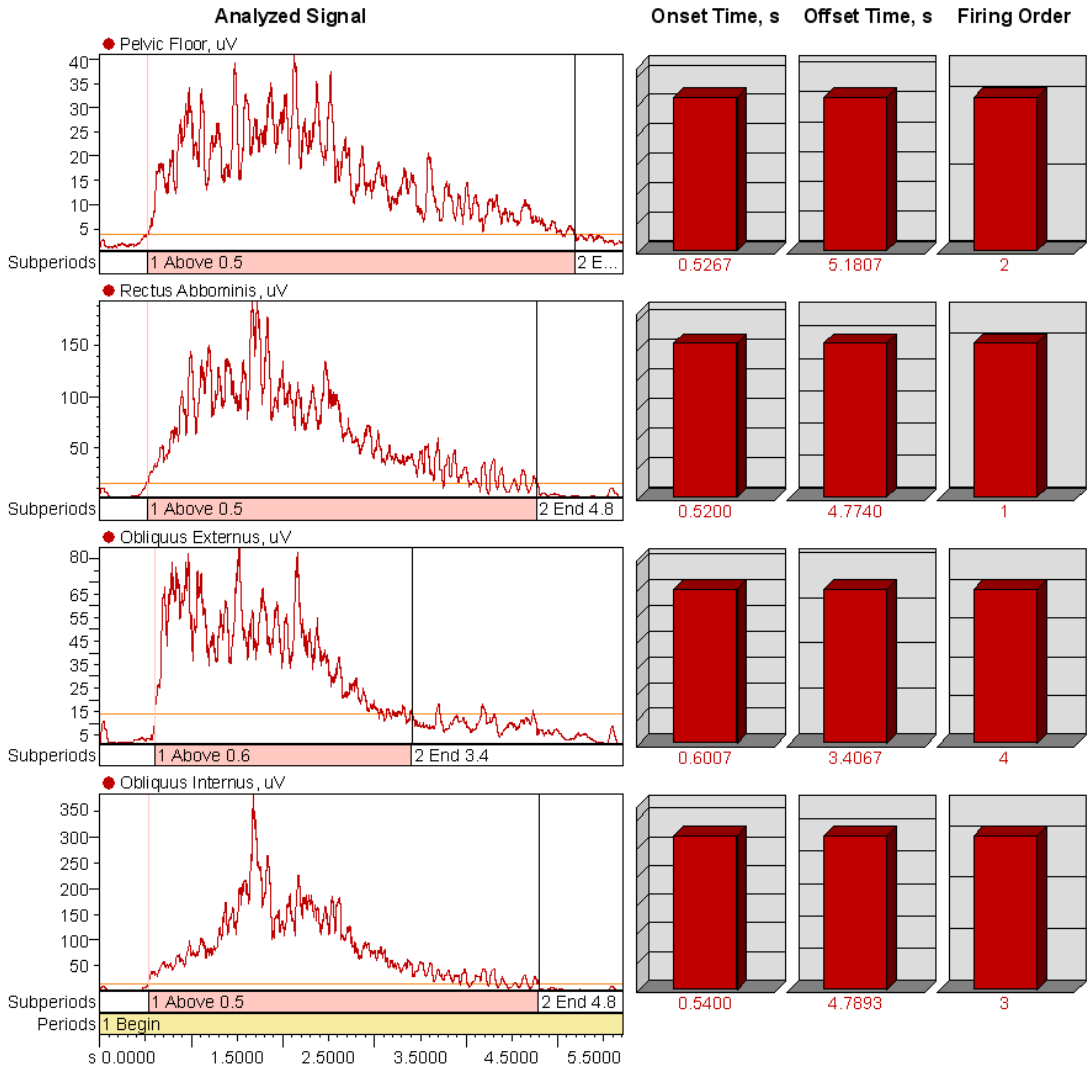
This EMG timing analysis can be applied to reflex studies or reaction time studies in regular movements. The Onset determination is used to show the reaction time needed for the muscle to be activated. Based on this calculation, the muscle firing order is determined. The offset time determines the time point when the muscles activity decreases below the threshold level. By default, the threshold definition mode to define the onset is set to 3 standard deviations (SD) of the EMG baseline amplitude, measured in intervals of 100 ms at the beginning of the analysis period. To prevent single spikes (artifacts) triggering the activity, a minimal sub period duration is set to 100 ms, which means within this period the signal has to stay over the threshold or at least pass it twice (in case of raw EMG). These default settings are rough guidelines. Depending on the signal quality, especially the baseline signal to noise ratio, a proper threshold definition should be arranged by a reasonable balancing of the SD multiplication factor, duration of minimum sub period duration, and the width of the SD-calculation interval. Instead of using a multiplication factor of the baseline SD, a percentage value of the local amplitude peak value or a fixed microvolts value can be used to define the onset-offset threshold. The one page report shows the analyzed curves and indicates the threshold line and sub period positions in pink colored lines/areas. By default the onset and offset parameter is displayed as a bar graph, but the analysis element setup menu offers alternative statistical calculations.

The threshold is drawn as a thin red line, running horizontally in each channel trace. A pink colored sub period bar and a vertical marker indicate the position of the sub period. Carefully study its location and validity and, if needed, adjust its settings by double clicking on the analysis element and modify the threshold definition setting in the tab section Sub Periods Settings. The definition of SD EMG baseline related threshold settings strongly relates to the noise level of the EMG baseline. Popular SD multiplication factors of 2 or 3 may be too low due to Noraxon's noise free baseline level. The SD threshold definition mode works both for raw EMG and processed (e.g. smoothed) signals! The statistics parameter Onset, Offset, and Firing Order are shown on the right side as bar graphs. If you want to load other statistics parameters, double click on the analysis element and enter the setup tab section Diagram Statistics.

Description of analysis frames

Analyzed Signal Graph

All channels in the selected analysis period are shown in the section **Analyzed Signal** on the left side:

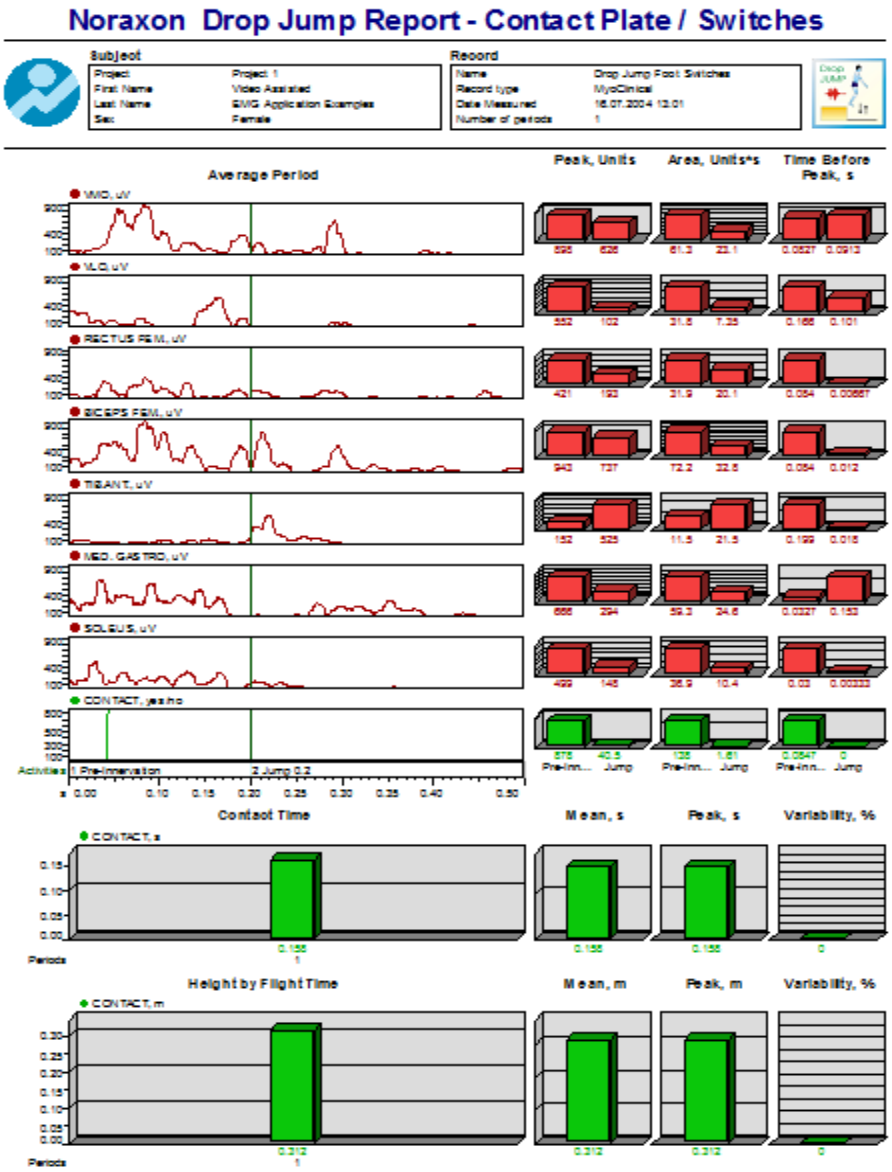


The threshold is drawn as a thin red line, running horizontally in each channel trace. A pink colored sub period bar and a vertical marker indicate the position of the sub period. Carefully study its location and validity and, if needed, adjust its settings by double clicking on the analysis element and modify the threshold definition setting in the tab section **Sub Periods Settings**. The definition of SD EMG baseline related threshold settings strongly relates to the noise level of the EMG baseline. Popular SD multiplication factors of 2 or 3 may be too low due to Noraxon's noise free baseline level. The SD threshold definition mode works both for raw EMG and processed (smoothed) signals! The statistics parameter **Onset**, **Offset,** and **Firing Order** are shown on the right side as bar graphs. If

you want to load other statistics parameters, double click on the analysis element and enter the setup tab section **Diagram Statistics**.

8) Drop Jump for Contact Plates

This report is designed for the analysis of drop jumps performed on contact plates or when using foot switches. Based on the first ground contact, the pre-innervation and jump EMG activity is detected and analyzed for single jumps or sequences of repeated drop jumps. For several drop jumps, all the signals are averaged and presented with plus/minus one standard deviation. The Peak amplitude, Time-to-Peak duration, and the Area are calculated and presented in a statistics histogram. Additionally, the contact time of the first landing and the flight height is calculated for each jump and is shown in trend diagrams with mean statistics. These report findings can be used to evaluate the reactive EMG activity in vertical jump tests.



Period Definition:

Mode: By TTL using the contact TTL, "Around Rise"

Pre-innervation phase, typically 100ms, jump phase typically 300ms. When several drop jumps are executed within one record, each jump activity recording needs to be paused in-between jumps, the subject needs to be repositioned, and then the recording needs to be started again. Each jump activity is separated by a red line in the Viewer menu. The entry line "Only once for each activity" needs to be checked when several jumps (activities) are performed.

Recommended Signal processing:

Rectified, softly smoothed (10ms RMS) EMG data

Report contents:

1. Page: Subject header, Averaged EMG activation signals with Peak, Time to Peak, Area of EMG bar diagram for pre-innervation and contact phase, flight time and flight height calculation with statistics

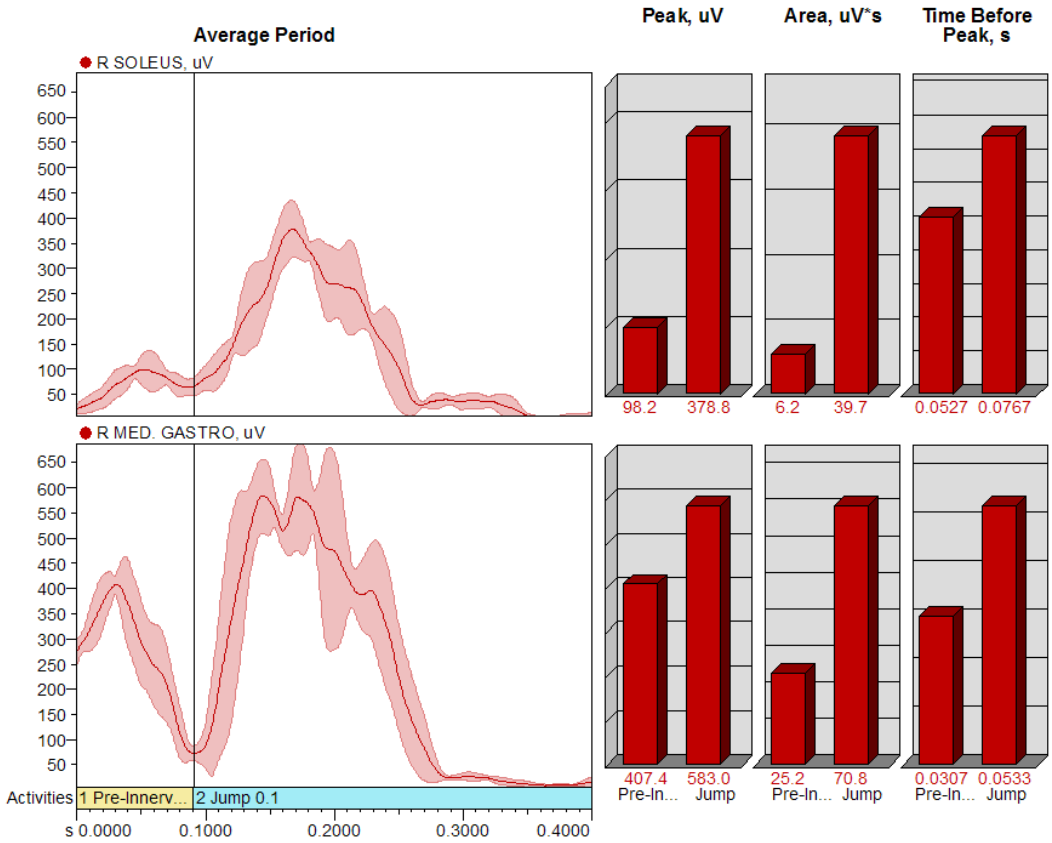
Analysis and interpretation:

Reactive contractions performed in the so called "stretching/shortening cycle" are the most important neuromuscular activities for lower extremity muscles (faster walking, running, and jumping). Due to the short reaction and contraction time in these activities, the involved muscles are pre-innervated prior to ground contact. This muscular "stiffness regulation" allows the muscles to store mechanical energy and enables a fast muscular response based on local reflex loops. The drop jump is the most popular test to check the reactive capabilities of muscles. By using drop heights between 0.1 and 1 meter, the subject lands on a force plate (first ground contact), directly jumps in a vertical direction (flight period) and finally lands a second time at the same position (second ground contact). The "extended" drop jump requires a second jump, performed immediately after the second landing.

Description of analysis frames

Average Period graph

This graph displays the averaged EMG curves of all selected jumps:



The first ground contact is indicated by a black event line and separates the pre-innervation phase from the jump phase. When averaging, the periods are not time normalized to avoid distortion of timing parameters. If your goal is to compare different jump tests, it is important to use the same time settings for all jumps. The plus/minus one standard deviation range is indicated by a light red shaded area. Based on the averaged data, the amplitude Peak and Area are calculated for each phase. The selection of statistical parameters can be changed by entering the Report Element Setup (left mouse double click) and adjusting the settings in the tab section **Diagram statistics**. The user can change the selection of displayed parameters by opening the Analysis Setup menu by double clicking the left mouse button. The data displayed in the diagrams can be exported by using the **Copy Element** function.

Basic analysis and interpretation strategies

1. Comparison of EMG amplitudes between muscles.

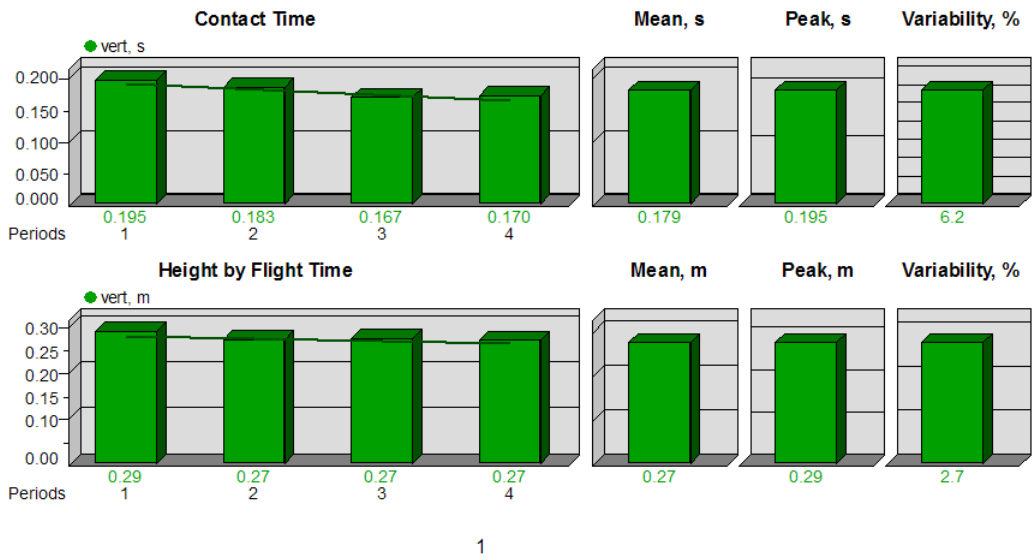
2. Comparison of EMG patterns and force curves through over treatment or training regimes.

3. Amount of EMG within the pre-innervation phase.

4. Time to Peak analysis in the jump phase indicating a proper muscular response to the jump impact.

Contact Time and Jump Height trend diagrams

These two bar graph diagrams calculate the contact time and jump height for each jump and summarizes them in an average mean and peak calculation.



The contact time is defined by the first "Rise" and "Fall' event in the contact signal. The flight height is calculated by the flight duration (time between the first "Fall' and the second "Rise" TTL event) using the formula:

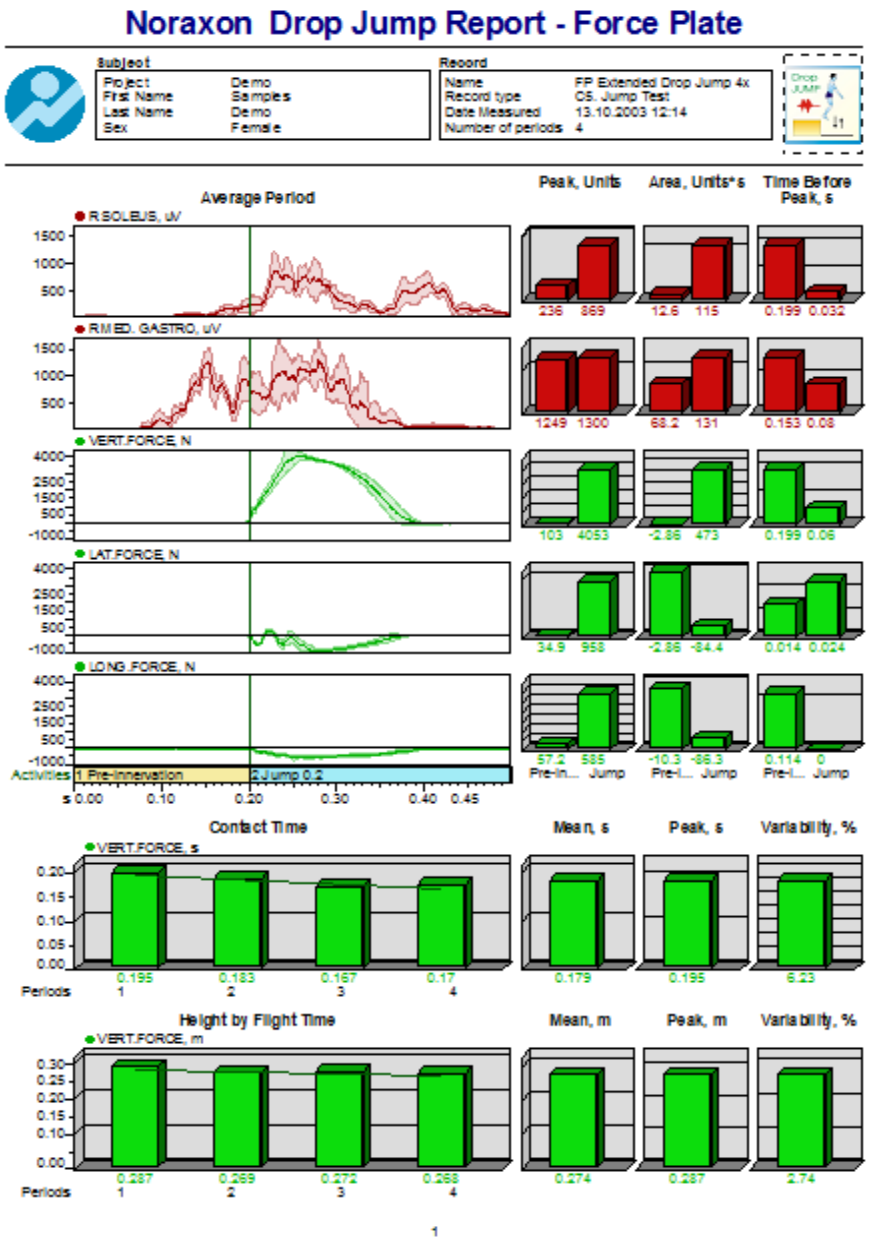
Flight height = $.5gt^2$, where g is the acceleration due to gravity and t is the flight duration.

This calculation requires identical segmental body positions both in the first and second landing and the center of gravity of the body must be at the same height level in both landing contacts. To enable this condition, usually a second jump is performed immediately after the first one. These calculations describe the

movement performance of each jump and may indicate trends of improvements when repeated at later stages in the training or rehabilitation process

9) Drop Jump for Force Plates

This report is designed for the analysis of drop jumps performed on force plates. Based on the vertical ground reaction force, the pre-innervation and jump EMG activity is detected and analyzed for single jumps or sequences of repeated drop jumps. For several drop jumps all the signals are averaged and presented with plus/minus one standard deviation. The Peak amplitude, Time-to-Peak duration, and the Area are calculated and presented in a statistics histogram. Additionally, the contact time of the first landing and the flight height is calculated for each jump and is shown in trend diagrams with mean statistics.



Period Definition:

Mode: Rise/Fall by trigger channel - Around marker with 0.1s pre-innervation and 0.3 s

The most reliable trigger channel is the vertical ground reaction force. The first landing contact defines the analysis period (around marker). It identifies the first ground contact (threshold: when 5% of the peak force curve is exceeded) and the analysis periods are placed around this force increase (mode: "Around Rise"). The pre-innervation period is typically set to 100 to 150 ms, the post event (first ground contact) is set to 300 or 400ms. In case of several drop jumps executed within one record each jump activity recording needs to be paused after the jump, the subject needs to be repositioned and then the recording needs to be started again. Each jump activity is separated by a red line in the Viewer menu. The entry line "Only once for each activity" needs to be checked when several jumps (activities) are performed.

Recommended processing:

Rectified and softly smoothed 10 ms RMS EMG.

Report contents:

1. Page: Subject header, signal documentation screen, bar graph section showing the Area, Peak and Time to Peak values both for the pre-innervation and the jump phase, Jump height and Fight time diagram with statistics data.

Analysis and interpretation:

Reactive contractions performed in the "stretching/shortening cycle" are the most important neuromuscular activities for lower extremity muscles (faster walking, running, and jumping). Due to the short reaction and contraction time in these activities, the involved muscles are pre-innervated prior to ground contact. This muscular "stiffness regulation" allows the muscles to store mechanical energy and enables a fast muscular response based on local reflex loops. The drop jump is the most popular test to check the reactive capabilities of muscles. By using drop heights between 0.1 and 1 meter, the subject lands on a force plate (first ground contact), directly jumps in vertical direction (flight period) and finally lands a second time at the same position (second ground contact). The "extended" drop jump requires a second jump, performed immediately after the second landing. This second jump is performed to guarantee the same segmental body positions as in the first landing. Typically, the second jump is not included in the analysis, but it is important for the correct calculation of the jump height. In order to achieve reproducible data, typically several jumps are performed and the results are averaged.

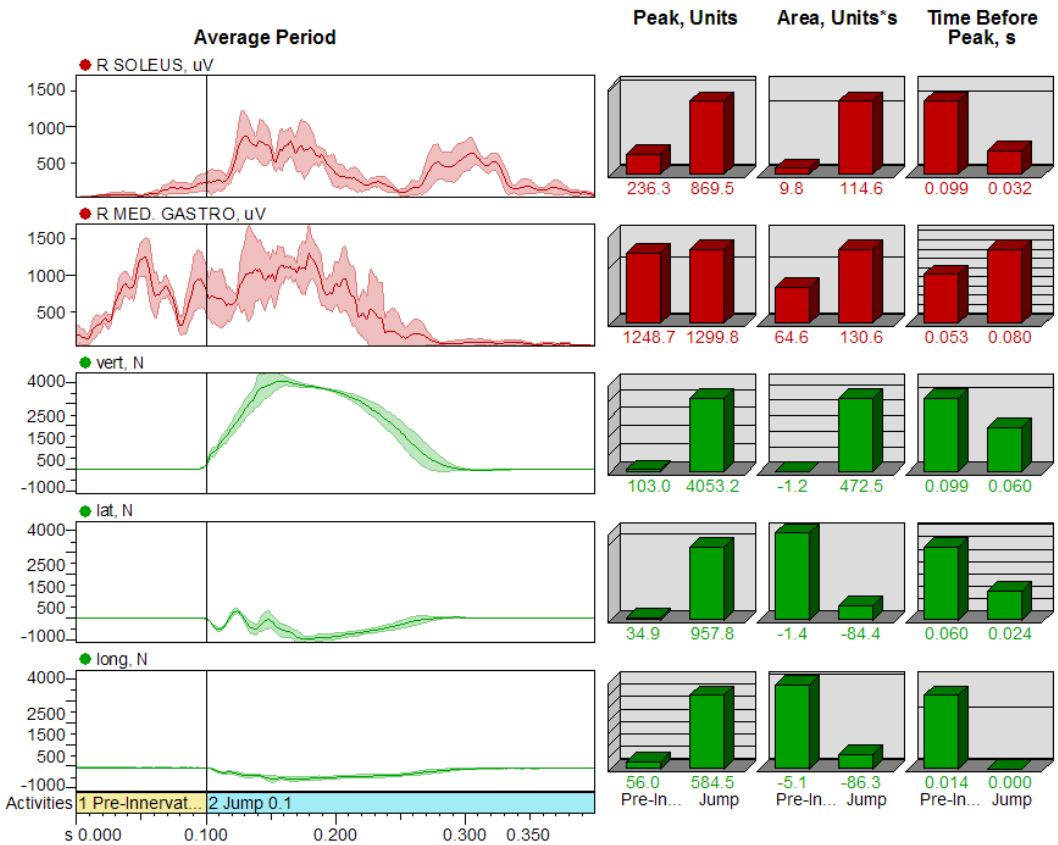
The one page report displays the reactive EMG patterns and synchronized force curves, which are automatically averaged if there are several jumps. Amplitude statistics can be used to study the characteristics in the pre-innervation and jump phase. A trend diagram analyzing the contact time of the first ground contact and the jump height of each single jump completes the report. The selection of parameters can be changed by entering the Setup menu of the Report Elements. The results can be exported to the clipboard or an ASCII text file for further statistical analysis. In both sports science and rehabilitation it is

important to evaluate the reactive contraction capabilities performed in the "stretching-shortening" cycle. This cycle is an independent muscular capability and it cannot be tested by regular concentric/eccentric contraction tests.

Description of analysis frames

Average Period graph

This graph displays the averaged EMG and force curves of all selected jumps:



The first ground contact, triggered by the 5% threshold of the vertical force curve, is indicated by a black event line and separates the pre-innervation phase from the jump phase. When averaging, the periods are not time normalized to avoid distortion of timing parameters. If your goal is to compare different jump tests, it is important to use the same time settings for all jumps. The plus/minus one standard deviation range is indicated by light red (EMG) or light green (force) shaded areas. Based on the averaged data, the amplitude Peak and Area are calculated for each phase. The selection of statistic parameters can be changed by entering the Report Element Setup (left mouse double click) and adjusting the settings in the tab section **Diagram statistics**. The user can change the selection of displayed parameters by opening the Analysis Setup menu by double clicking the left mouse button. The data displayed in the diagrams can be exported by using the **Copy Element** function.

Basic analysis and interpretation strategies

1. Comparison of EMG amplitudes between muscles.

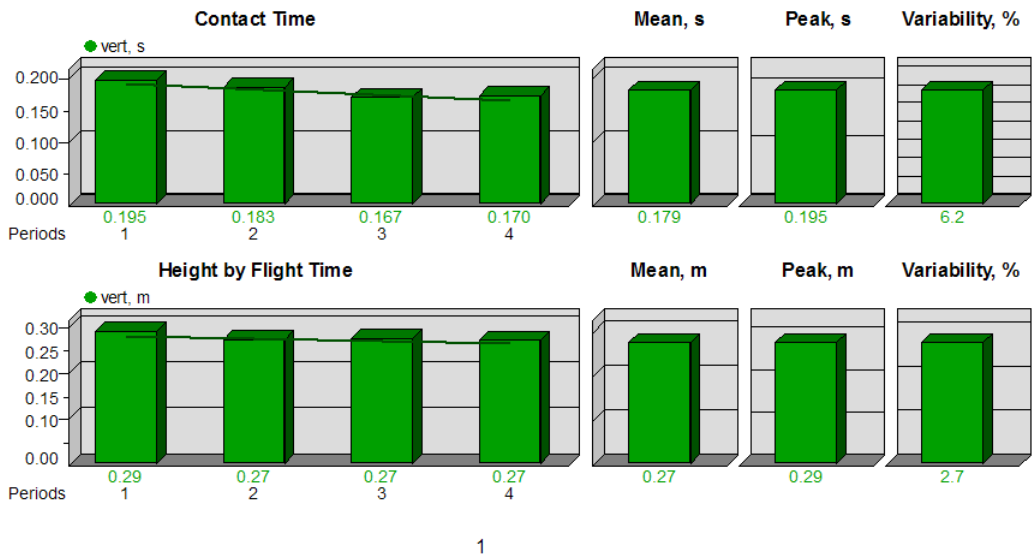
2. Comparison of EMG patterns and force curves through over treatment or training regimes.

3. Amount of EMG within the pre-innervation phase.

4. Time to Peak analysis in the jump phase indicating a proper muscular response to the jump impact.

Contact Time and Jump Height Trend Diagrams

These two bar graphs calculate the contact time and jump height for each jump and summarizes them in an average mean and peak calculation.



The contact time is defined by the "Rise" event (when the vertical force curve exceeds 5% of the local maximum force) and the "Fall" event (when the force curve falls below 5% of local maximum force) in the first vertical force impulse. The flight height is calculated by the flight duration (time between the two force landing impulses) using the formula:

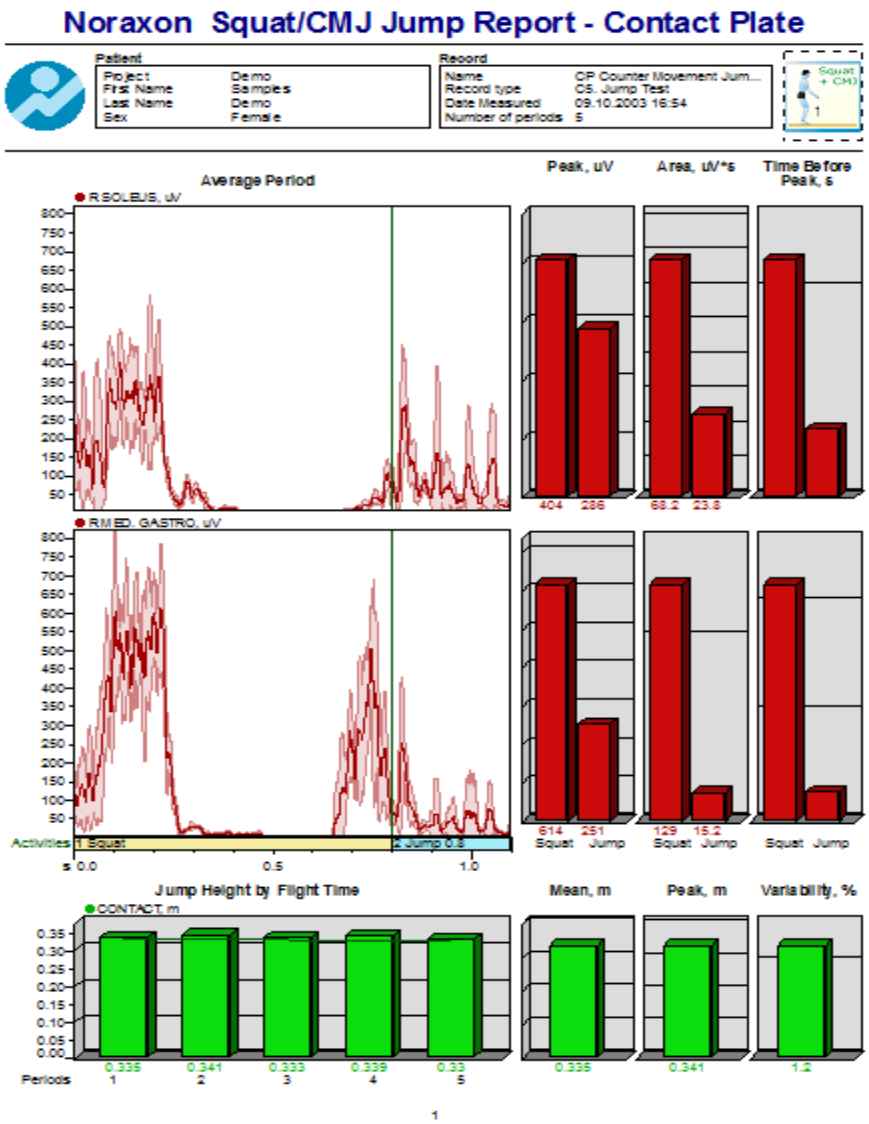
Flight height = $.5gt^2$, where g is acceleration due to gravity and t is the flight duration.

This calculation requires identical segmental body positions both in the first and second landing, and the center of gravity of the body must be at the same level in both contacts. To enable this condition, usually a second jump is performed

immediately after the first one. These calculations describe the movement performance of each jump and may indicate trends of improvements when repeated at later stages in the training or rehabilitation process.

10) Squat and Counter Movement Jumps for Contact Plates

This report is designed for the analysis of squat and counter movement jumps performed on contact plates. Based on the ground contact, the squat innervation, and jump EMG activity is detected and analyzed for single jumps or sequences of repeated jumps. When several jumps are performed, all signals are averaged and presented with plus/minus one standard deviation. The Peak amplitude, Time-to-Peak duration, and the Area are calculated and presented in a statistics histogram. Additionally, the flight height is calculated for each jump and shown in trend diagrams with mean statistics.



Period Definition:

Mode: By Rise/Fall TTL

The method used for period definition is based on the contact/switch signal. It identifies the first fall of the contact signal to zero (mode "Around Fall"). The squat period is usually set to 500 or 800 ms, the jump phase is set to 300 or 400 ms. When several jumps are executed within one record, each jump activity recording needs to be paused after the jump, the subject needs to be repositioned, and then the recording needs to be started again. Each jump activity is separated by a red line in the Viewer menu. The entry line "Only once for each activity" needs to be checked when several jumps (activities) are performed.

Recommended Signal processing:

Rectified and softly smoothed 10 ms RMS EMG.

Report contents:

1. Page: Subject header, signal documentation screen, bar graph section showing the Area, Peak and Time to Peak values both for the pre-innervation and the jump phase and Jump height diagram with statistics data.

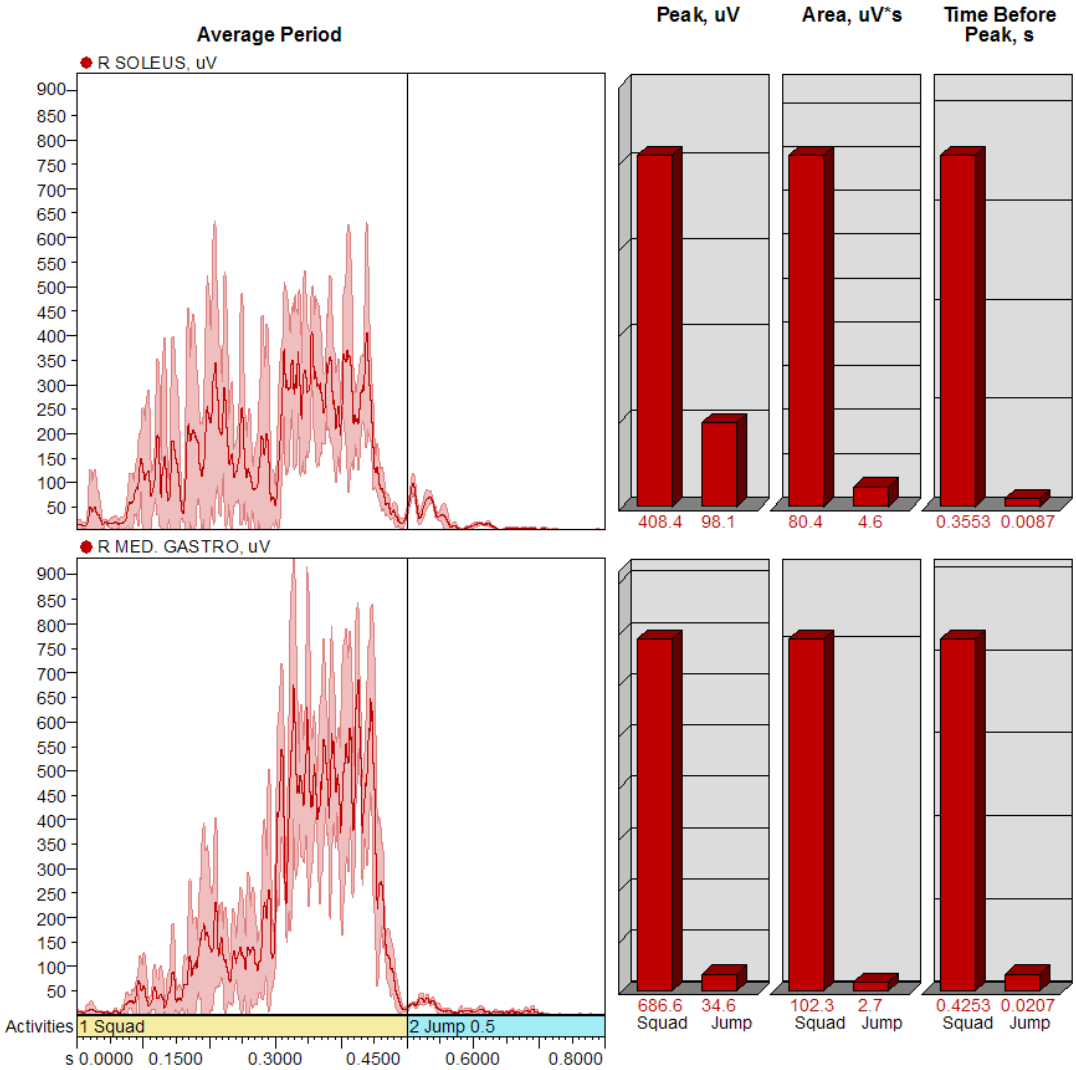
Analysis and interpretation:

Unlike reactive muscle contractions like drop jumps, hopping or running, squat jumps and Counter Movement Jumps are performed in regular eccentric/concentric contractions conditions, which exceed the typical duration of the "Stretching-Shortening cycle" (see Drop Jump Report). The Squat jump starts in a bent knee position and the muscle contraction type is pure concentric (knee/hip extension). In Counter Movement Jumps the legs are first in a bent position (eccentric counter movement) and then they are accelerated to knee/hip flexion (concentric squat). The contact signal is used to determine the jump phases. The "Fall" event of the contact signal is used to trigger the jump phases. In order to achieve reproducible data, typically several jumps are performed and the results are averaged. The one page report displays the reactive EMG patterns, which are automatically averaged when several jumps are performed. Amplitude statistics can be used to study the characteristics in the squat and jump phase. A trend diagram analyzing the jump height of each single jump completes the report. The selection of parameters can be changed by entering the Setup menu of the Report Elements. The results can be exported to the clipboard or an ASCII text file for further statistical analysis.

Description of Analysis Frames

Average Period graph

This graph displays the averaged EMG curves of all selected jumps:



The "take off" event at the beginning of the flight period is indicated by a black event line and separates the squat phase from the jump phase. When averaging, the periods are not time normalized to avoid distortion of the timing parameters. If your goal is to compare different jump tests, it is important to use the same time settings for all jumps. The plus/minus one standard deviation range is indicated by light red (EMG) or light green (force) shaded areas. Based on the averaged data, the amplitude Peak and Area are calculated for each phase. The selection of statistic parameters can be changed by entering the Report Element setup (left mouse double click) and adjusting the settings in the tab section **Diagram statistics**. The user can change the selection of displayed parameters by opening the Analysis Setup menu by double clicking the left mouse button. The data displayed in the diagrams can be exported using the **Copy Element** function.

Basic analysis and interpretation strategies

1. Comparison of EMG amplitudes between muscles.

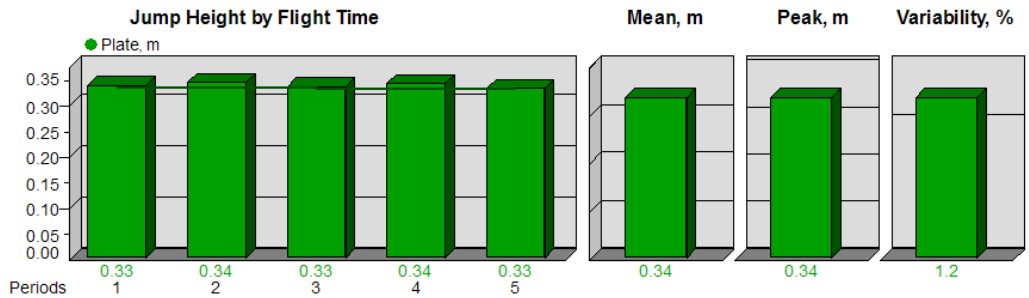
2. Comparison of EMG patterns through over treatment or training regimes.

3. Amount of EMG in the squat phase.

4. Time to peak analysis in the squat phase.

Jump Height trend diagrams

This bar graph calculates the jump height for each jump and summarizes the data in an average mean and peak calculation.



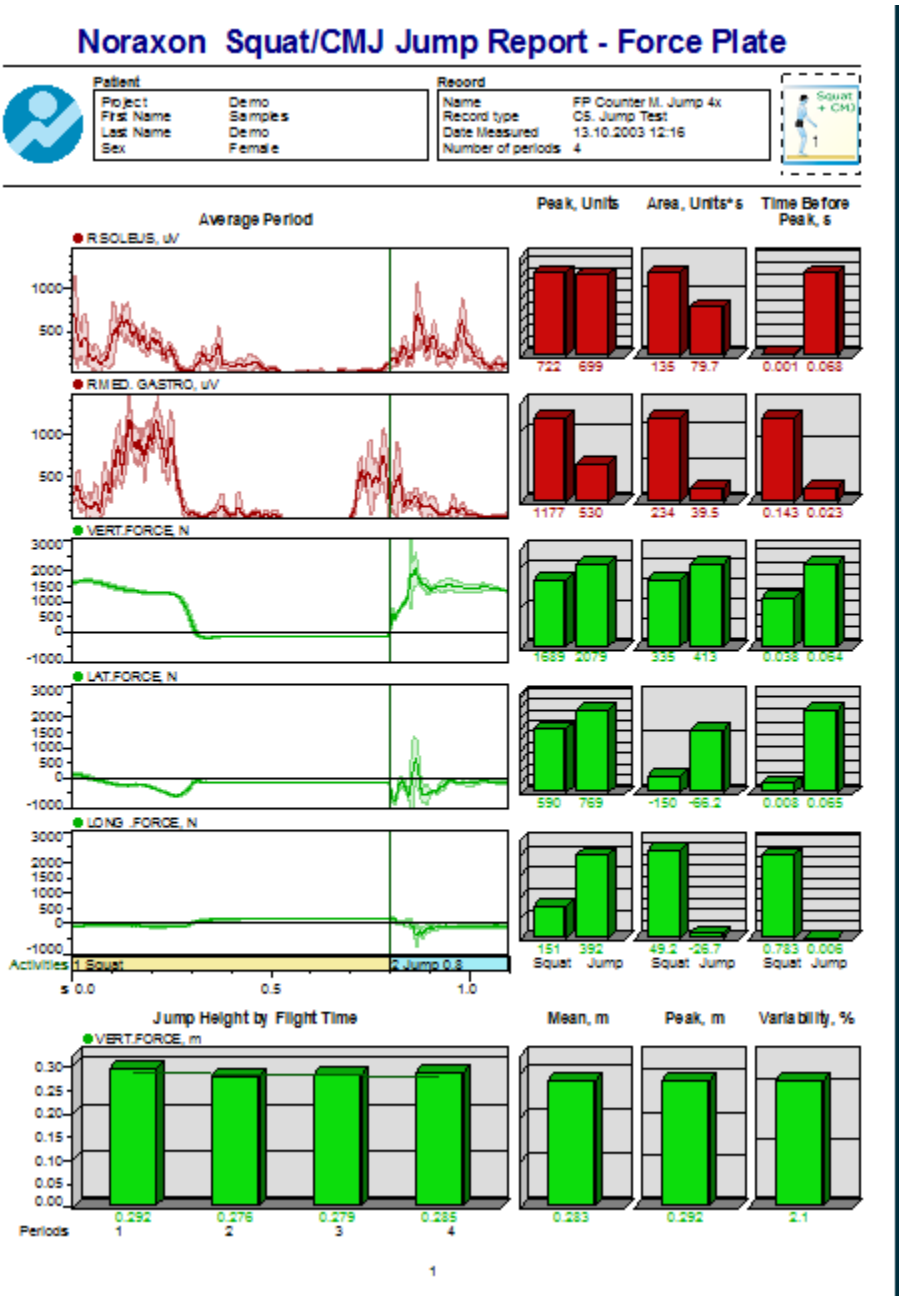
The flight height calculated by the flight duration (time between the first contact "Fall" and next contact "Rise" event) using the formula:

Flight height = $.5gt^2$, where g is the earth acceleration and t is the flight duration.

This calculation requires identical segmental body positions both in the first and second landing, the center of gravity of the body must be at the same height level in both positions. This calculation describes the movement performance of each jump and may indicate trends of improvement when repeated at later stages in the training or rehabilitation process.

11) Squat and Counter Movement Jump for Force Plates

This report is designed for the analysis of squat and counter movement jumps performed on force plates. Based on the vertical ground reaction force, the squat innervation and jump EMG activity is detected and analyzed for single jumps or sequences of repeated jumps. When several jumps are performed, all signals are averaged and presented with plus/minus one standard deviation. The Peak amplitude, Time-to-Peak duration, and the Area are calculated and presented in a statistics histogram. Additionally, the flight height is calculated for each jump and shown in trend diagrams with mean statistics.



Period Definition:

Mode: By Rise/Fall TTL

The method used for period definition is based on the vertical ground reaction force signal. It identifies the first fall of the vertical force signal to zero (mode "Around Fall"). The squat period is typically set to 500 or 800 ms, the jump phase is set to 300 or 400 ms. When several drop jumps are executed within one record, each jump activity recording needs to be paused after the jump, the subject needs to be repositioned and then the recording needs to be restarted again. Each jump activity is separated by a red line in the Viewer menu. The entry line “Only once for each activity” needs to be checked when several jumps are performed.

Recommended processing:

Rectified and softly smoothed 10 ms RMS EMG.

Report contents:

1. Page: Subject header, signal documentation screen, bar graph section showing the Area, Peak and Time to Peak values both for the pre-innervation and the jump phase and jump height diagram with statistics data

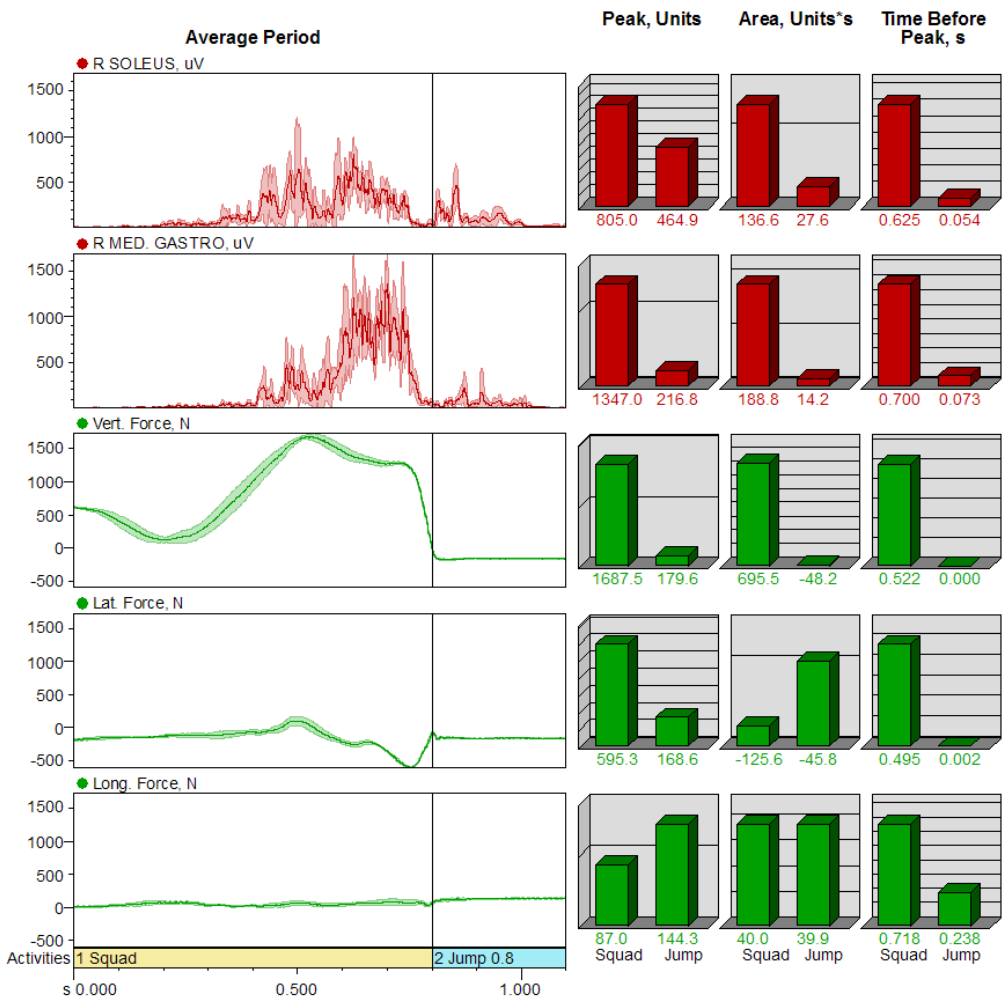
Analysis and interpretation

Unlike reactive muscle contractions like drop jumps, hopping or running, squat jumps and counter movement jumps are performed in regular eccentric/concentric contraction conditions, which exceed the typical duration of the "Stretching-Shortening cycle" (see Drop Jump Report). The squat jump starts in a bent knee position and the muscle contraction type is pure concentric (knee/hip extension). In Counter Movement Jumps the legs are first in a bent position (eccentric counter movement) and then they are accelerated to knee/hip flexion (concentric squat). The vertical force signal is used to determine the jump phase. At zero vertical force the body leaves the ground and the "Fall" event of the force curve down to zero is used to trigger the jump phases. In order to achieve reproducible data, typically several jumps are performed and the results are averaged. The one page report displays the reactive EMG patterns, which are automatically averaged for the case of several jumps. Amplitude statistics can be used to study the characteristics in the squat and jump phase. A trend diagram analyzing the jump height of each single jump completes the report. The selection of parameters can be changed by entering the Setup menu of the Report Elements. The results can be exported to the clipboard or an ASCII text file for further statistical analysis.

Description of analysis frames

Average Period graph

This graph displays the averaged EMG and force curves of all selected jumps:



The "take off" event at the beginning of the flight period is indicated by a black event line and separates the squat phase from the jump phase. When averaging, the periods are not time normalized to avoid distortion of the timing parameters. If your goal is to compare different jump tests, it is important to use the same time settings for all jumps. The plus/minus one standard deviation range is indicated by light red (EMG) or light green (force) shaded areas. Based on the averaged data, the amplitude Peak and Area are calculated for each phase. The selection of statistic parameters can be changed by entering the Report Element Setup (left mouse double click) and adjusting the settings in tab section **Diagram statistics**. The user can change the selection of displayed parameters by opening the Analysis Setup menu by clicking the left mouse button. The data displayed in the diagrams can be exported with the **Copy Element** function.

Basic analysis and interpretation strategies

1. Comparison of EMG amplitudes between muscles.

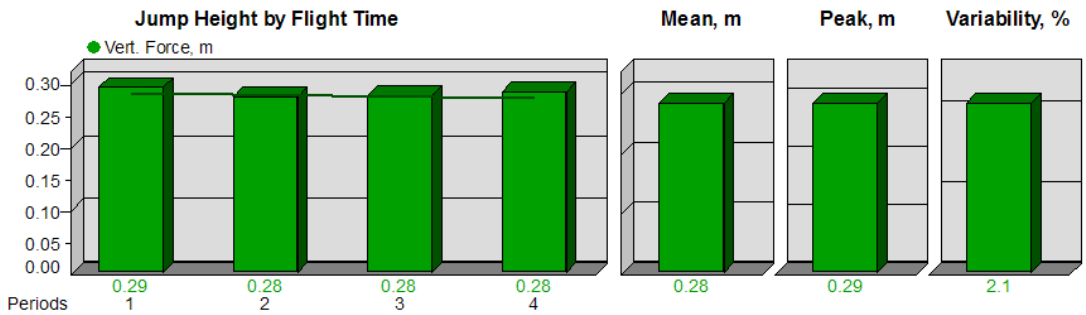
2. Comparison of EMG patterns and force curves through over treatment or training regimes.

3. Amount of EMG in the squat phase.

4. Time to peak analysis in the squat phase.

Jump Height trend diagrams

This bar graph diagram calculates the jump height for each jump and summarizes the data in an average mean and peak calculation.



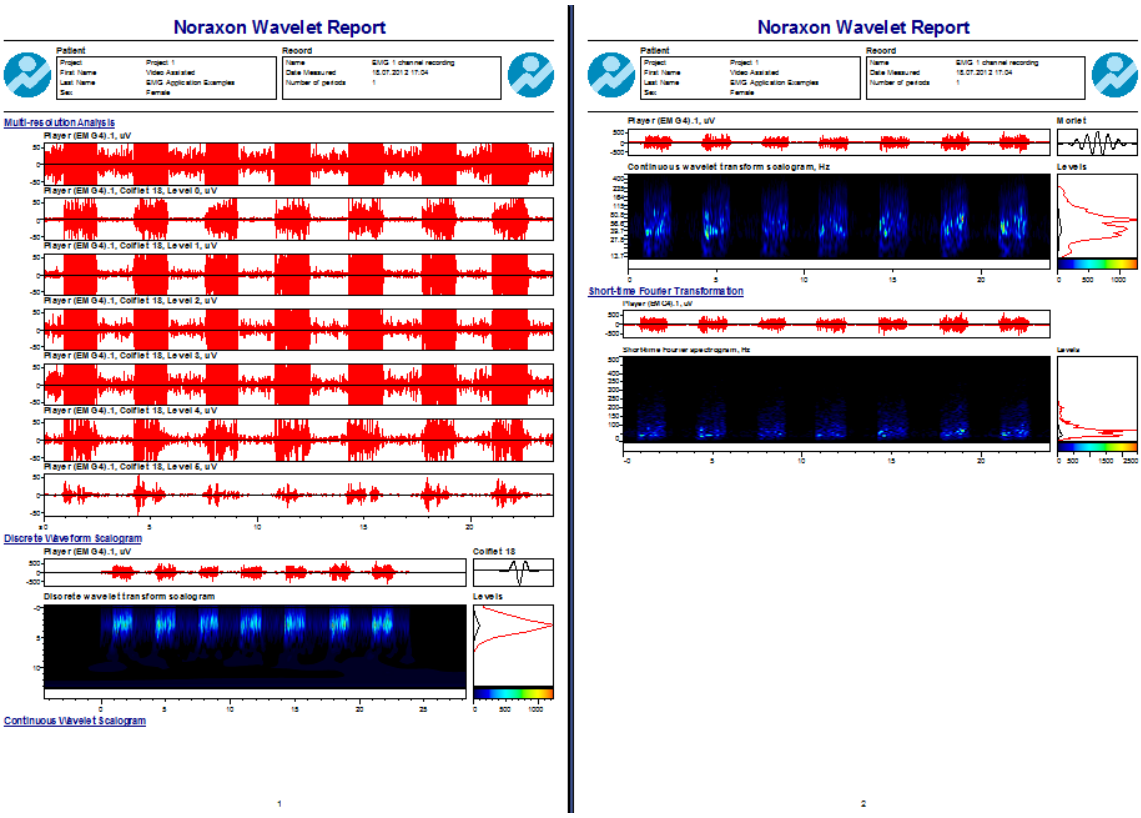
The flight height calculated by the flight duration (time between zero vertical force and next force "Rise" event) using the formula:

Flight height = $.5gt^2$, where g is the acceleration due to gravity and t is the flight duration.

This calculation requires identical segmental body positions both in the first and second landing, and the center of gravity of the body must be at the same height level in both positions. This calculation describes the movement performance of each jump and may indicate trends of improvement when repeated at later stages in the training or rehabilitation process.

12) Wavelet Tool Box Report

The report is designed for the analysis of the signal frequency contents in adjustable time resolution settings. Several sophisticated methods are supported: Short Time Fourier Spectrograms, Continuous Wavelet Scalograms (Morlet, Mexican Hat), Discrete Wavelet Scalograms (Coiflet, Symmlet, Daubechies), and Multi Resolution Analysis.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in the Viewer screen shown before entering the report menu. Only one consecutive area at a time can be defined for the analysis.

Recommended processing:

Raw EMG records are required - no processing

Report contents:

1. Page: Subject header, Multi Resolution Analysis, Short Time Fourier Spectrograms, Continuous Wavelet Scalograms, and Discrete Wavelet Scalograms

Description of analysis frames

SPECTRUM CURVE

The Fourier transform approximates the source signal with a sine curve taken at different frequencies and phases, and the contribution of the curve of each frequency is declared to be the frequency component of the source signal.

Even if you have already analyzed the power spectrum and frequency bands report elements, it is still good to note that the result is calculated with a 50% overlapped window, then averaged. To avoid the spectrum distortion caused by the abrupt edges of the window, we are using the Hann window, which is normalized to minimize the total power reduction.

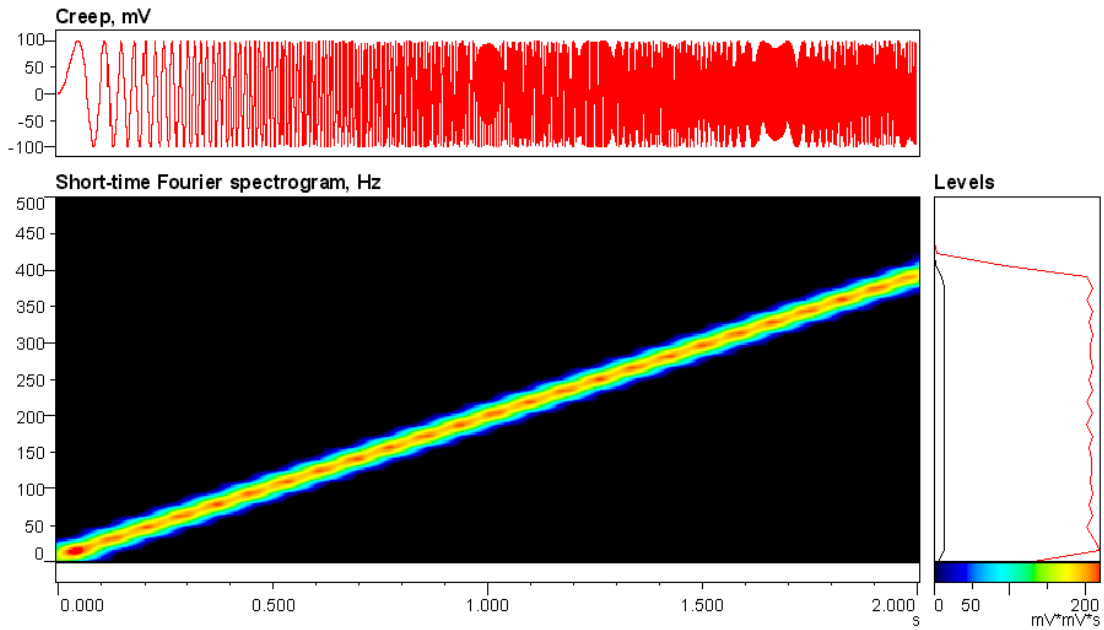
SHORT-TIME FOURIER SPECTROGRAM

In the Fourier transform the sine curves go from the beginning to the end of the analyzed interval, resulting in a diagram that shows how much of the total signal each frequency component represents. However, it does reveal where in the signal this frequency component was active.

The Short-Time Fourier Transform (STFT) was introduced as an easy method of localizing the frequency component activities. It simply takes the Fourier transform periodically in short intervals, resulting in an overview of the frequency dynamics of the signal spectrum.

The report element "STFT Spectrogram" calculates power spectrum using a fixed window in 50%-overlapped steps. The spectrum generated at each step is presented in the spectrogram as a column of colored pixels, the color shows the intensity of each spectral component. Essentially representing how a signal’s frequency spectrum changes in time.

The following picture shows the result of analysis of a sine creep with the frequency increasing linearly from 20 Hz to 400 Hz.



On top of the spectrogram the program shows the analyzed signal, on the right side it shows the color legend of the spectrum intensities and two curves: the red one represents the *peak* value and the black one represents the *average* value of each spectral component over the interval. The black line is identical to the report element *power spectrum*.

Similar to the spectrum curve calculation, this report element uses the normalized Hann window to avoid spectrum distortion caused by the abrupt edges of the viewing window.

The calculation settings of the report element are as follows:
Window NNN points defines the size of the analysis window in points. If "auto" is selected, the program takes the window size to make the vertical and horizontal resolution of the resulting picture as small as possible.

The output settings are as follows:
Color scale: auto/manual defines how the colors are matched to the values of the spectrogram. If the color scale is set to "auto," the program automatically matches the color scale to the minimal and the maximal values of the spectrogram; if the setting *global scale* is on, the maximum limits for all analyzed signals will be used; and if the color scale is set to manual, the next two settings (min and max) are used to set the limits manually. This may be needed to compare the results of analysis of different signals.

Height - is the height of the entire record element in mm.

Split vertical and *split horizontal* - are used to define the size of the bottom and the right sub-elements.

Space is the space between sub-elements.

Title font and *ruler font* define fonts used for the titles of the sub-elements and the rulers.

Restrict all calculations to activity and *restrict all calculations to phase* are used to perform calculations only over certain activities and period phases of the complete analyzed interval.

Use raw signals defines whether all calculations must be performed on the raw (unprocessed) version of the signals.

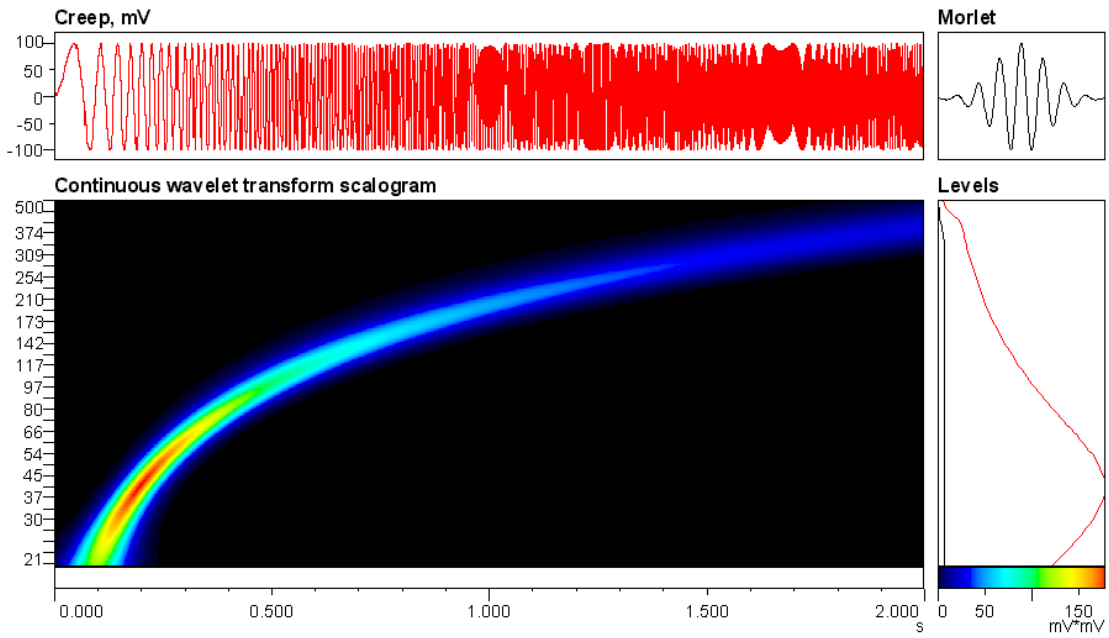
Restrict calculations to channels is used to override the analyzed channels defined in the report configuration wizard.

CONTINUOUS WAVELET TRANSFORM SCALOGRAM

The Short-Time Fourier Transforms only generates a rough overview of the spectrum dynamics because the time resolution is constant for all frequencies and it is defined by the length of the analysis step, but higher frequencies have more oscillations in a time interval and they need more precise localization than the lower frequencies. Also, in STFT the shorter analysis step leads to reduction of the frequency resolution.

The Continuous Wavelet Transform (CWT) is a method that is able to locate short activity bursts (wavelets) with only few oscillations: he higher the frequency, the better time localization. Different Continuous Wavelet Transforms differ in the shape of wavelets that they are using for calculation.

One common wavelet is the Morlet wavelet, which is produced from the same sine/cosine curves used for the Fourier transform. However, the Morlet wavelet contains only few of their oscillations, the others are faded-out. The Morlet wavelet is convenient as it is similar to the Fourier transform curve (it provides similar information), but the Morlet wavelet also allows for arbitrary frequency and selectable bandwidth. Here is the output of the report element "CWT scalogram" with Morlet curve selected for calculation.



The input signal on top of the scalogram is the same 20 to 400 Hz creep that was used for the STFT spectrogram above. The top right picture gives overview of the wavelet used for calculation. The curves on the right side again show the maximum (red) and average (black) values of the calculated levels. STFT has a linear scale, i.e. each next frequency is the previously frequency plus a fixed increment. CWT, however, has a logarithmic frequency scale: each frequency is the product of the previous frequency and a fixed coefficient. The Morlet transform is convenient when it is necessary to explore a known set of frequencies in a signal with the time localization better than STFT allows. This is particularly useful for short analysis intervals.

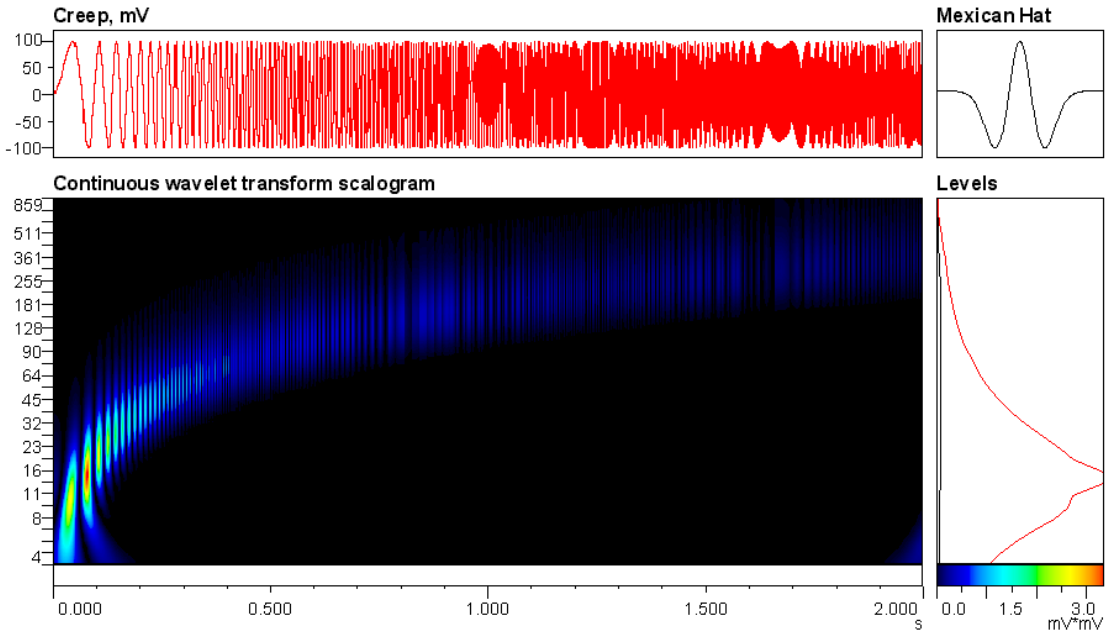
The calculation settings of the Morlet transform are:
Begin frequency – the center frequency of the first calculated voice.
End frequency – the center frequency of the last calculated voice.
Number of voices – ["number of bands"] is the number of calculated frequencies.
Voice bandwidth – ["Bandwidth"] defines the bandwidth of the voice; the value above 100% means that the neighboring frequencies are overlapped, the value below 100% means that there is some uncovered frequency range between the neighboring frequencies.

Note: the narrower the bandwidth, the more oscillations the wavelet contains, and the worse time localization will be.

The output options for the report element "CWT scalogram" are the same as for the report element "STFT spectrogram".

Another common CWT type is called the Mexican Hat Transform. It received this name due to the resemblance of its wavelet to a long-brimmed hat. It has a relatively low bandwidth (about 4 voices per octave), which is constant and cannot be changed, but a good time localization resolution, making it useful for

tracking sharp frequency changes. It does not have the phase (complex) component, and the result looks like a sequence of "drops." Here is the output of the report element "CWT scalogram" with Mexican Hat wavelet selected for calculation on the same 20 to 400 Hz creep.



The shape of the Mexican Hat wavelet is displayed in the right-top element.

The Mexican Hat Transform has the following calculation parameters:
Begin frequency – ["Window"] the center frequency of the first calculated voice.
Number of octaves – the number octaves that are calculated. Octave defines the frequency range, where the next octave begins with twice frequency of the previous octave's initial frequency.
Voices per octave – number of voices calculated in each octave.

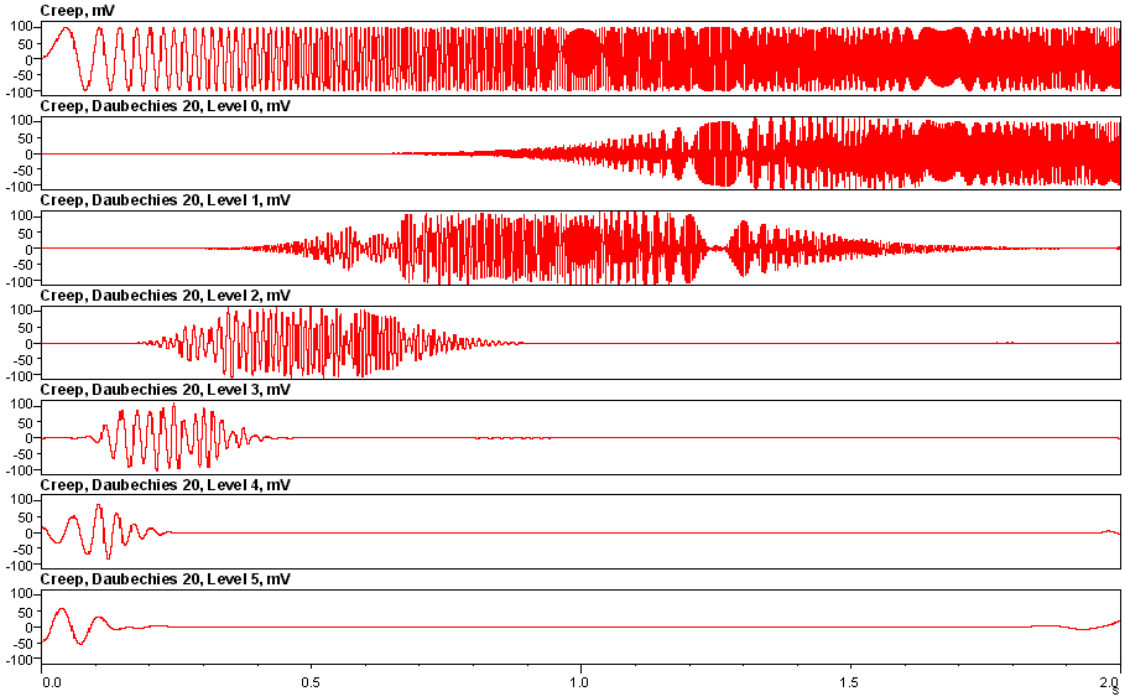
DISCRETE WAVELET TRANSFORM, DWT SCALOGRAM AND MULTI RESOLUTION ANALYSIS

The Discrete Wavelet Transform (DWT) is based on the same idea of locating a short activity burst of known shapes as with the Continuous Wavelet Transform, but the algorithm is optimized to minimize the calculations and to extract just enough information from the signal to reconstruct it. If the wavelet used for the calculations describes the shape of the analyzed signal well, the result will contain only a small number of significant coefficients, which can be effectively compressed. In some cases, DWT can provide much more efficient and much faster compression than Fourier transformation is able to do.

Another application of DWT is noise cleaning: low or short activities are considered to be noise, which are then simply located and erased from the

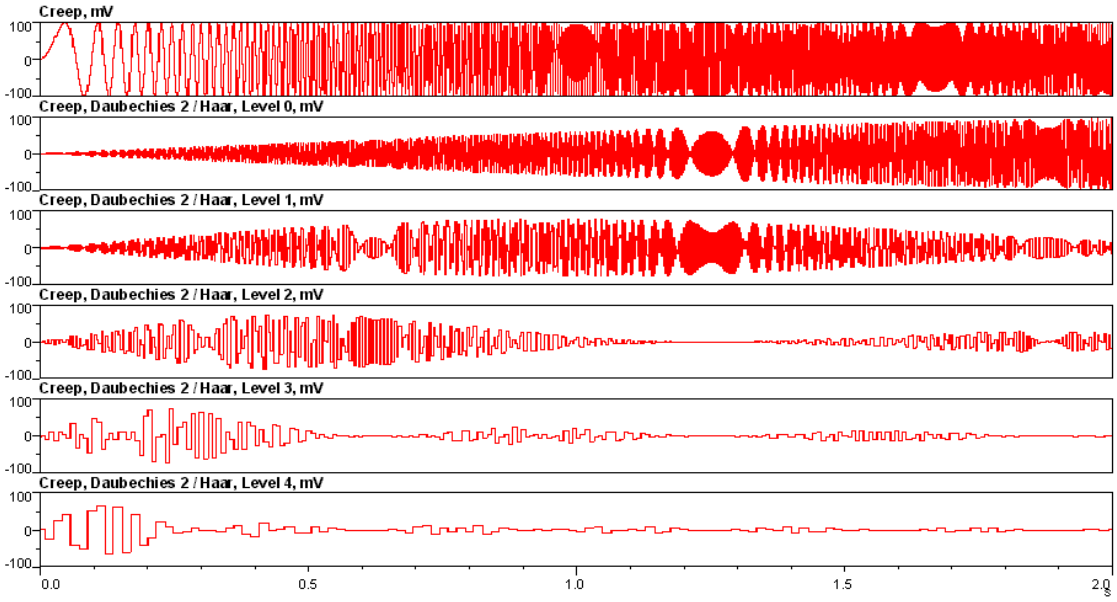
transformed data, and the signal can then be restored back without significant change in its shape and with more consistent frequency characteristics.

To achieve fast calculation speed, DWT defines a special algorithm that requires wavelets conforming to certain criteria. The report element "MRA" (Multi-Resolution Analysis) offers a set of commonly-used wavelets suitable for DWT, such as Coiflet, Symmlet, and Daubechies. MRA separates the analyzed signal to their approximations by the selected wavelet taken at different frequency levels. The sine creep signal used in the above sections analyzed with the wavelet "Daubechies 20" will produce the following result:



The first graph shows the original signal. The other graphs are the first 6 levels of approximation by the chosen wavelet.

Here is the same signal, but analyzed with the wavelet "Daubechies 2/Haar":



The report element "MRA" has the following settings:
Wavelet type selection – selects wavelet shape for analysis.
Min Level, Max Level – defines the displayed approximation levels.

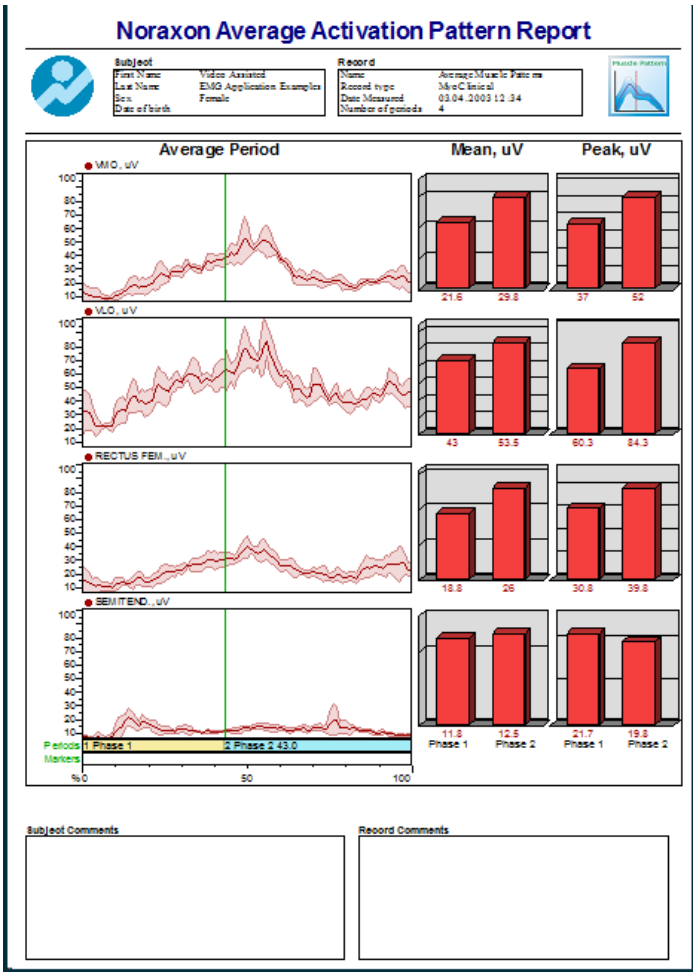
All other settings are similar to the settings of the report element "Channel curves".

The report element "DWT scalogram" presents the same data as "MRA", but in the same scalogram output type that is used for CWT (please see the previous section).
"DWT scalogram" offers the same set of wavelets as "MRA", but it calculates and shows all possible approximation levels.

Appendix B: MyoMuscle Clinical Reports

1) Average Activation Report

The report is designed to provide time normalized average EMG patterns for repetitive movements (e.g. extension/flexion). It displays EMG patterns averaged across repetitions (ensemble average) +/- 1 SD as well as corresponding statistics (mean and peak amplitudes) for each muscle and motion phase.



Period Definition:

Mode: Interval with Event

At least three markers must be placed to run an analysis. The first marker defines the start of the first repetition. The second marker (event) is the turning point within each movement, such as toe-off in gait cycles or the highest pedal position in cycling. The third marker serves both as the end of the first repetition and the start point of the second repetition. In the Viewer set-up window (next screen after selecting this report) the two phases of the movement (extension/flexion) are separated by the event marker

and further indicated on the bottom of the screen by horizontal yellow and blue bars, respectively.

Recommended Signal processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant

Report contents:

1. Page: Subject header, Averaged EMG signal screen, bar graph section showing the Mean, Peak values for both motion phases

Analysis and interpretation:

Due to the averaging process the typical "behavior" of EMG activation is detected, the variability of each single repetition is "smoothed" to the typical shape of the activation pattern for this movement. This kind of EMG processing creates highly reproducible EMG patterns. Typically, these patterns can easily be repeated in sequential measurements and serve as a basis for test-retest comparison plots.

The averaged curves can be used to analyze and interpret:

- The overall pattern and characteristics of EMG activity.

- Upward or downward activation trends within the movement phase.

- Comparison of the agonistic (first phase) and antagonist (second phase) firing pattern.

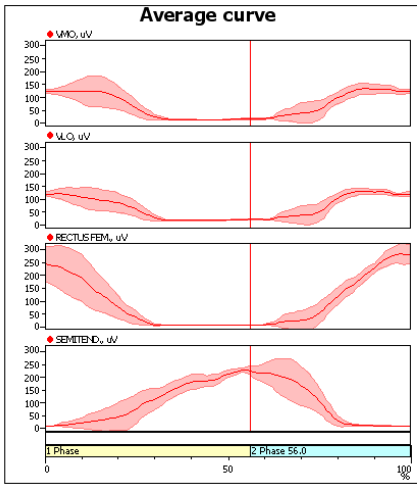
- Comparison of muscle innervation in concentric or eccentric contraction phases.

- Coordination of muscles.

Description of analysis frames

Average Curve

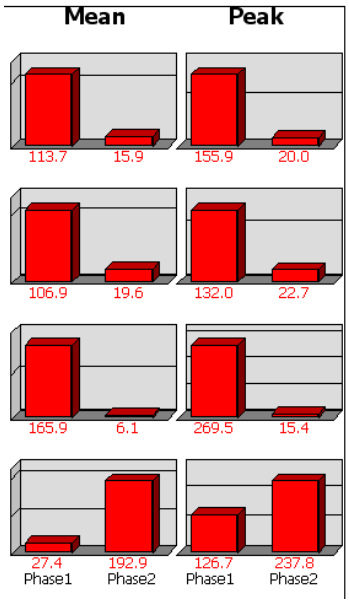
This analysis frame calculates the average EMG curve for all periods specified in the record and shows them in a time normalized window from 0 – 100% of the entire signal (data is presented in 1% steps). The red shaded area represents +/- one standard deviation. The red event line separates the curve into two sub phases (e.g. extension - flexion), indicated by yellow and blue bars in the period line within the x-axis.



Due to the averaging process the typical "behavior" of EMG activation is detected, the variability of each single repetition is "smoothed" to the typical shape of the activation pattern for this movement. This kind of EMG processing creates highly reproducible EMG patterns. Typically these patterns can easily be repeated in directly repeated measures and serve as a basis for test-retest comparison plots.

Signal statistics

By default, two amplitude parameters are calculated for each period of the average signals:



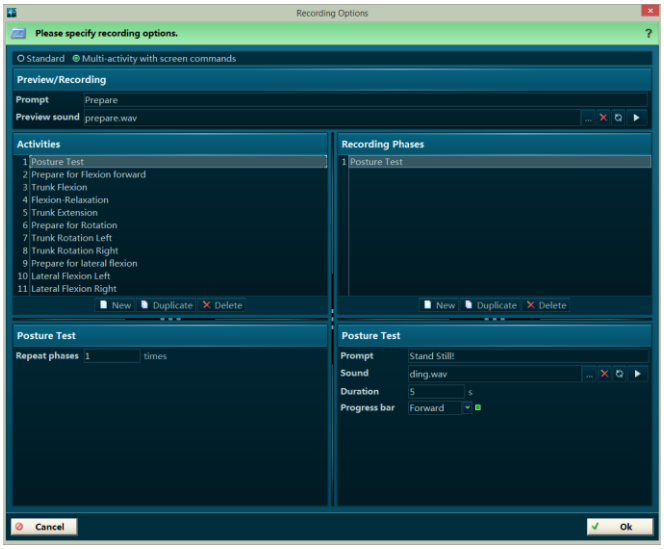
Mean = the mean value of the EMG amplitude.

Peak = the peak value of EMG amplitude.

These statistics quantify the difference of EMG activity between the muscles and the phases. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and choosing the Curve statistics tab.

2) Low Back sequence test report

Requires records measured with the Low Back Sequence Test measurement setup. This measurement setup utilizes the recording option **Multi-activity with Screen Commands:**



This test sequence is designed as a screening tool low back muscles, operated in the following sequence of motions:

- Stand Still

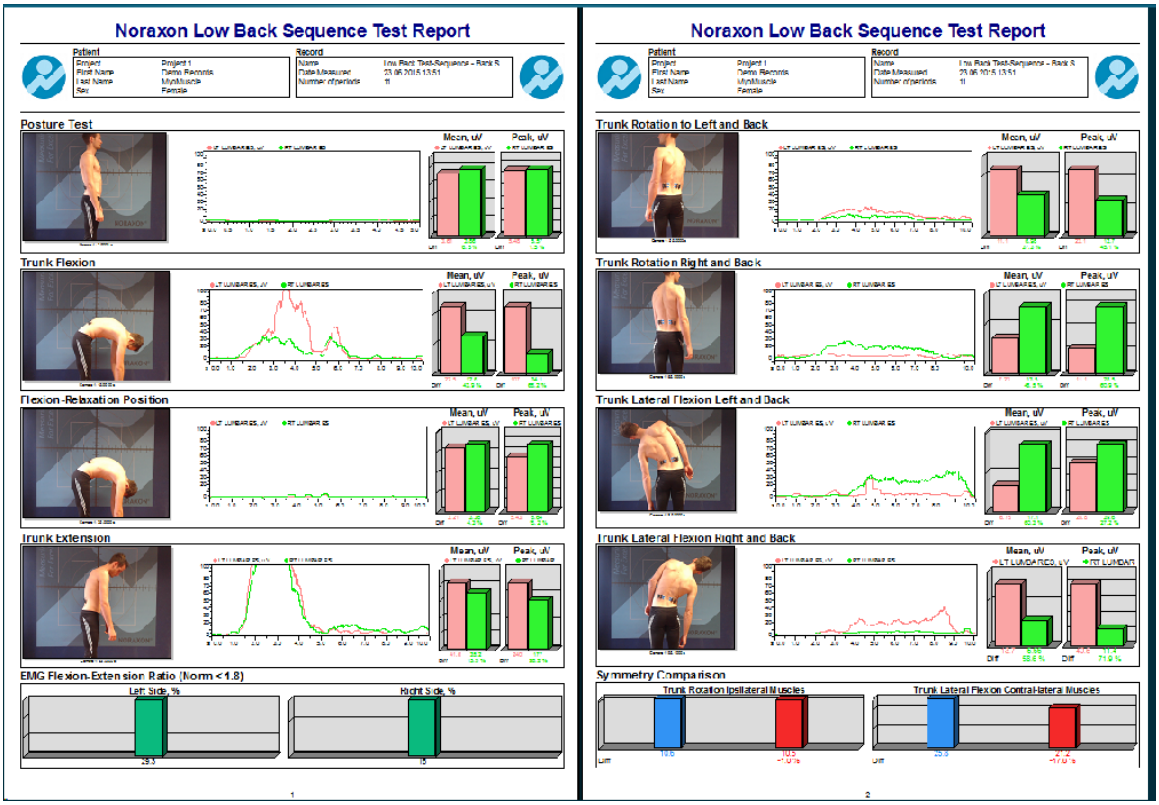
- Trunk Anteflexion

- Flexion Relaxation Position

- Trunk Extension back to Neutral

- Trunk Rotation to left and right side

- Trunk Lateral Flexion to the left and right side



The screen command system guides you through the whole sequence of test activities.

Attention: To keep compatibility to the predefined analysis report, don't change the setup settings for the pre-defined activities.

Period definition:

Whole record, each activity will automatically be analyzed separately without any further period definition

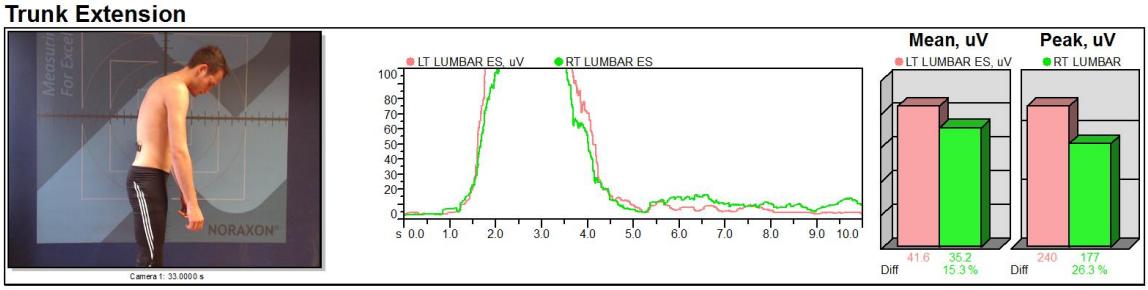
Recommended Signal processing:

Real time EMG RMS processing. Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant.

Description of analysis frames

Combined Video/signal/diagram Statistical Analysis

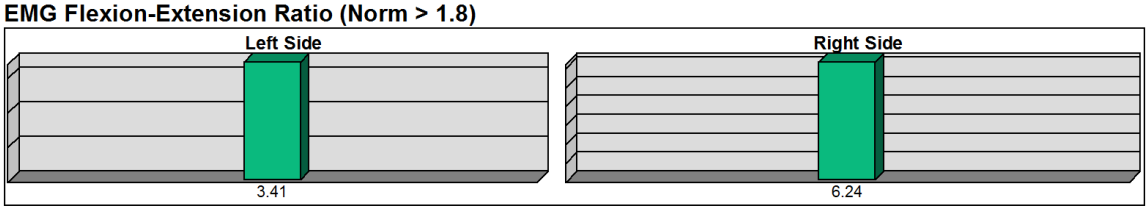
Each activity will be analyzed separately:



The video picture gives a documentation of patient performance at 50% of a given activity period. The EMG traces (RMS EMG) are presented as a left/right signal overlay for the whole activity. Mean and Peak value of this activity plus side difference in percent are calculated in the diagram statistics

EMG Flexion-Extension Ratio

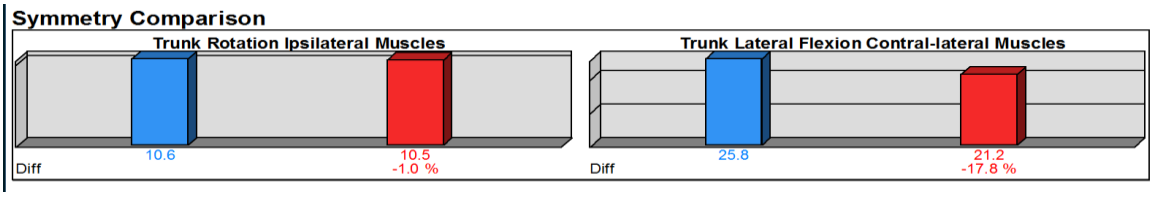
For the trunk flexion and trunk extension period a special calculation is presented that describes the ratio of extension (concentric contraction phase) vs flexion (eccentric contraction phase). Typically this ratio is equal to 1.8 or higher.



Background of this analysis is to check if the eccentric EMG tends to be too high because of underlying neuromuscular problems related to back pain.

Symmetry Comparison

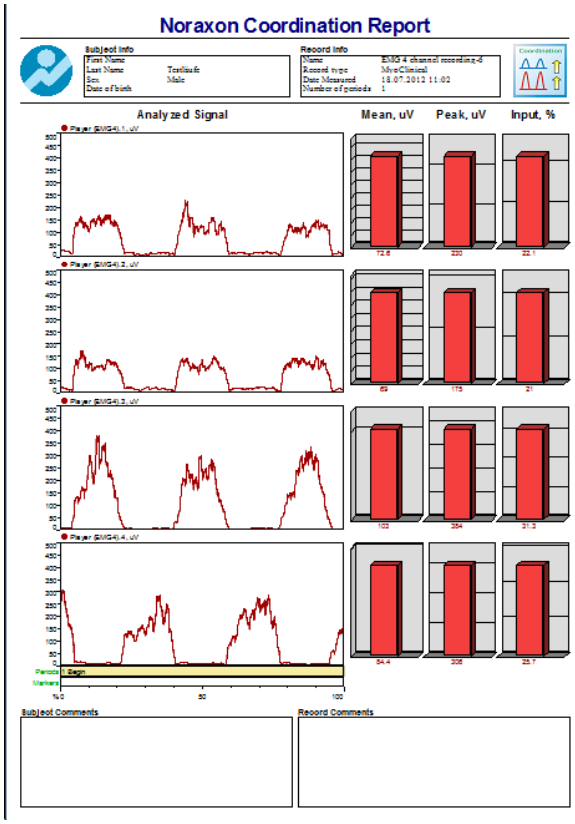
For trunk rotation and lateral flexion, a special analysis is performed that calculates the EMG amplitude difference when muscles act ipsilateral to the direction of motion (agonistic EMG) and contralateral to the direction of motion (antagonistic EMG):



Side differences are expressed in percent difference of the higher value.

3) Coordination Report

This report is designed for records measuring muscle activity around one joint region or on one side of the body (unilateral movements) in single test activities.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu. Only one consecutive area at a time can be defined for the analysis.

Recommended Signal processing:

Real time EMG RMS processing. Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant.

Report contents:

1. Page: Subject header, signal documentation screen, bar graph section showing the Mean, Peak and Input% values for the selected analysis period

Analysis and interpretation:

In a clinical setting, Coordination reports can be used to document muscle activation during various therapeutic exercises, muscle function tests, and treatment techniques. The analysis and interpretation typically focuses on the coordination of the agonist and antagonist muscles of one joint region. The results can be used to analyze and interpret:

- The consistency of firing patterns across the sequence of repetitions.

- The on/off characteristics of the prime movers.

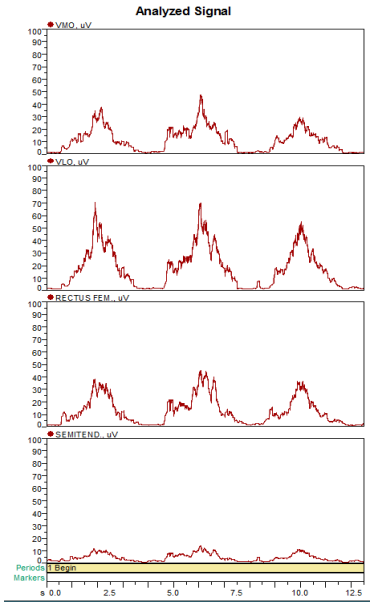
- The nature of firing in the postural muscles.

- The coordination of different muscles.

Description of analysis frames

Analyzed Signal

This graph displays the processed EMG traces separately for each muscle.

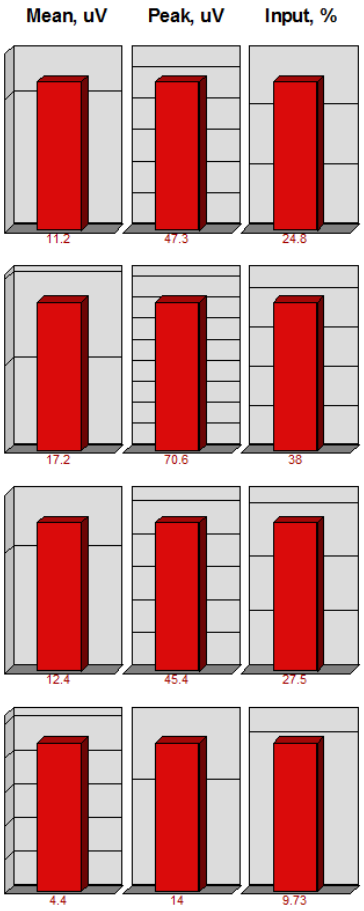


This graph can be used to analyze and interpret:

- the consistency of firing patterns across the sequence of repetitions
- the on/off characteristics of the prime movers
- the nature of firing in the postural muscles
- the coordination of different muscles

Curve statistics

The following two amplitude parameters are calculated for the selected portion of the recording.

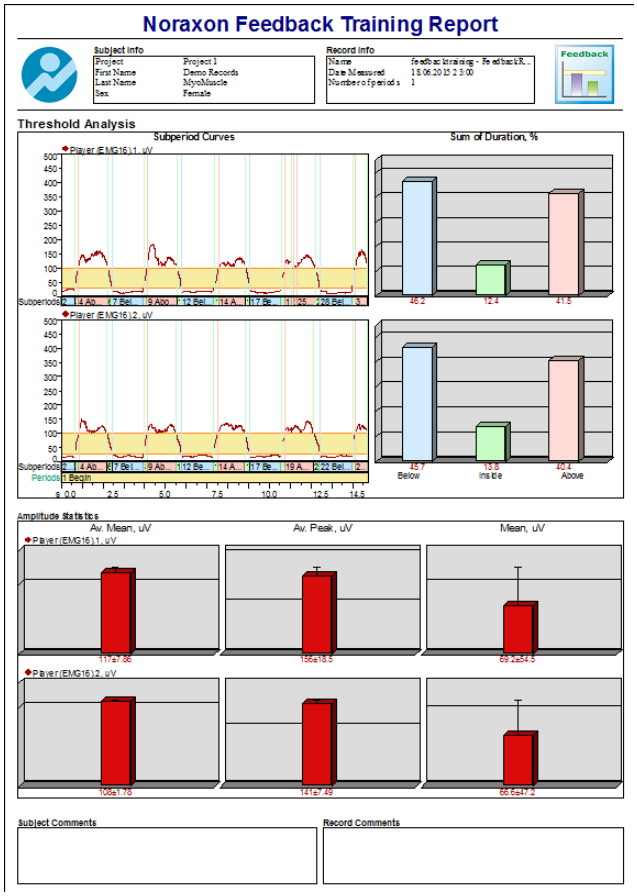


- **Mean** = the mean value of the EMG amplitude
- **Peak** = the peak value of EMG amplitude
- **Input%** = relative contribution of each muscle, when the summation of all recorded muscle activity is defined as 100%.

These statistics can be used to quantify the differences of EMG amplitudes between the muscles. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and selecting the Curve statistics tab.

4) Feedback Report

This report is designed for the analysis of biofeedback training records. It uses a real time bar graph to indicate the activity level for each muscle in relation to user defined threshold settings. The one-page report displays a graphical documentation of each contraction cycle and provides average mean and peak amplitude values in a table format.



Recommended Signal processing:

Real time EMG RMS processing. Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant

<u>Period definition</u>

Method: Mouse marked area

Default is to analyze the whole feedback session. By marking (left mouse button) an area within the record viewer the analysis can be restricted to a user-defined interval. Only one analysis interval can be defined within one report run.

The one-page report provides a graphical documentation of the complete feedback session and an analysis of mean and peak amplitude values within each set.

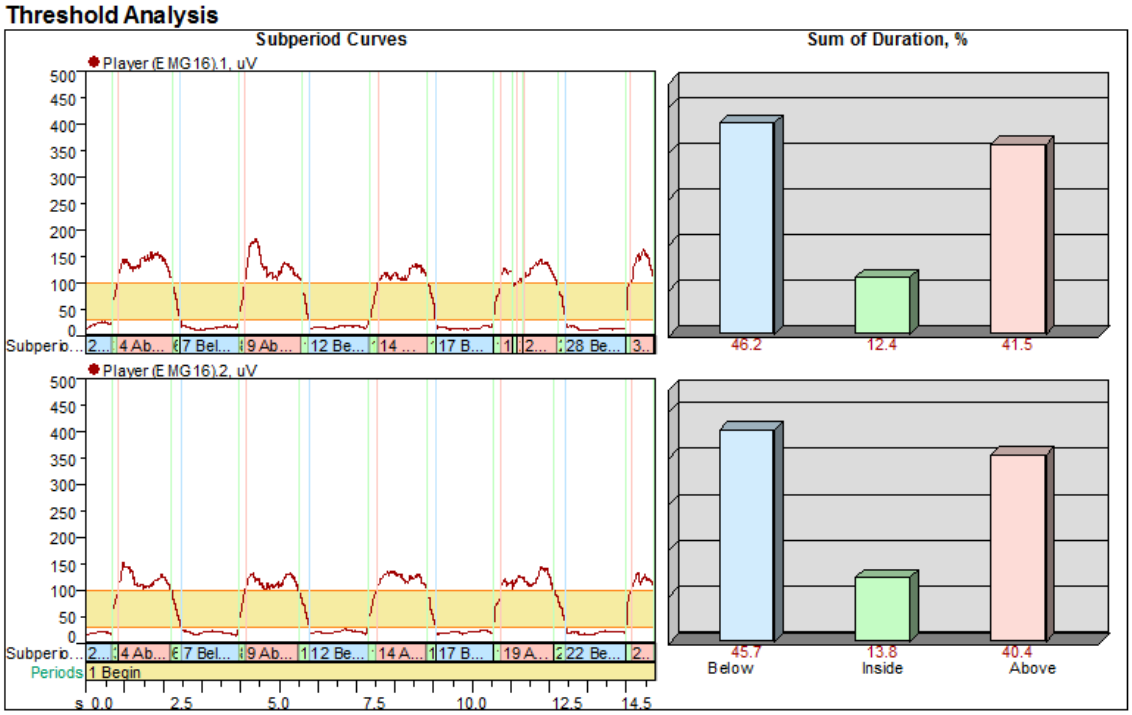
Analysis and interpretation

Feedback training can be used to train one or more muscles in a computer controlled feedback loop. The online processed (RMS - smoothed / rectified) raw EMG signals are converted to an increasing/decreasing activity histogram. The activity level is displayed in ratio to a threshold range, which is defined by fixed microvolt values ("Target uV" - protocols) or actual activation maximum. The direct feedback control of the muscle activity allows for effective and targeted training of selected muscles for conditioning, stabilization, coordination or relaxation goals. The one-page report gives a complete graphical documentation of each contraction cycle performed within the session and calculates the mean and peak amplitude values.

Description of analysis frames

Complete Biofeedback Session

This graph summarizes all contractions done within the recorded feedback sessions. The shaded yellow background behind the traces indicates the threshold ranges used for this protocol.



Sum of Duration % statistics

This analysis calculates for each muscle, how long in % of total time the EMG signal did stay **Below**, **Inside**, or **Above** the selected threshold range.

Several criteria for analysis and interpretation can be applied:

- Did the EMG activity reach the desired threshold range?
- Did the EMG activity show constancy, i.e. staying within the threshold range?
- Is the timing (onset/offset of muscle activity) fast enough?
- Is the relaxation level appropriate?

For 2 muscle setups several other analysis approaches apply:

<u>A) Left/right activation training (involved vs. uninvolved side):</u>

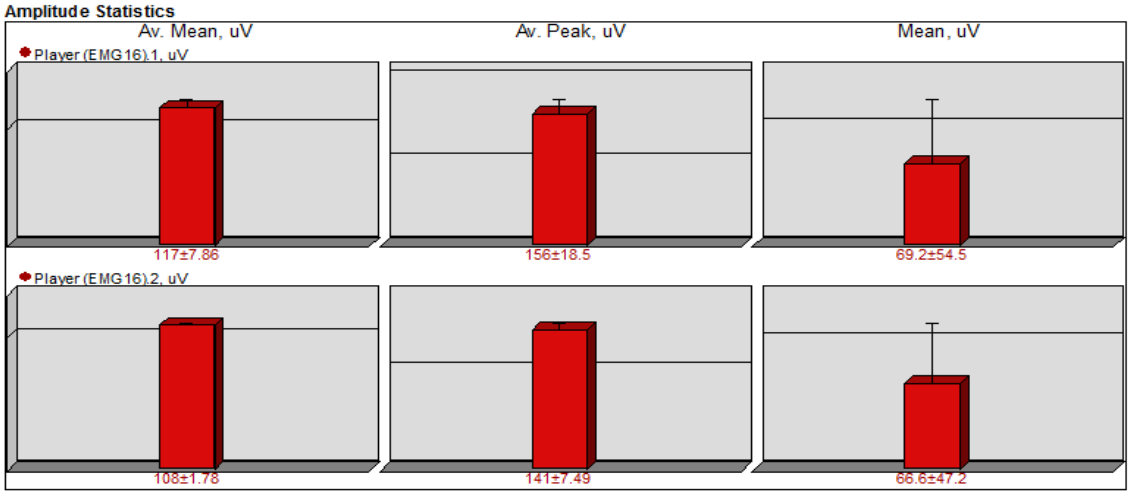
- Did the involved side reach the activation level of the uninvolved side?
- Was the timing between these two muscle well synchronized?

<u>B) Agonist/antagonist or agonist/synergist training</u>

- Were the activity levels in agonist, antagonist, and/or synergist muscles appropriate?
- Was the coordination between the muscles sufficient?

Amplitude Statistics

The statistics refer to the complete recorded feedback session (as shown in the graph above). Three amplitude-based parameters are calculated:



Av.Mean = the amplitude mean value of the active EMG-bursts (without relaxation EMG)

Av.Peak = the averaged amplitude peak value

Mean = the mean value of the whole record (contractions plus relaxation periods)

These statistics summarize the mean active EMG input (especially Avg.Mean) or goal (Avg.Peak) reached within the analyzed feedback session.

5) Incontinence Report

Requires records measured with the Incontinence test measurement setups. This report is designed for the analysis of pelvic floor muscle testing and biofeedback training records. Either vaginal or anal probes are used to record and analyze muscle activity in the pelvic floor during single or multiple activities.

The record displays the following activities:

- Relaxation

- Quick Flicks

- Contract up and down 5x for 5 seconds

- Static Hold - hold a high activation level for 30 seconds

Period definition:

Whole record, each activity will be analyzed separately without any further period definition

Analysis and interpretation:

The online processed EMG signal is displayed as a smoothed tracing as well as in the form of a shrinking/expanding biofeedback circle. EMG activity level is also displayed numerically in relation to the threshold range. This ratio can serve as a training goal for each individual session. The entire testing/training procedure is guided by an automatic protocol that provides a comprehensive analysis at the end of the session. A Test-Retest Comparison can be done to analyze differences between testing sessions or individual recordings. The results provide information about both the contraction and relaxation capacity of the pelvic floor muscles

Baseline Test

- The ability of the muscles to relax is documented by the EMG baseline level.

Quick Flicks

- The patient performs a sequence of quick and brief contractions with a 5 -10 second pause between each contraction.

Maximal Contractions

- The patient performs a sequence of 5 maximal contractions, each lasting for 10 seconds with 10 seconds of rest in between.

Endurance Hold

- A sustained contraction of 60 seconds to test the muscular endurance.

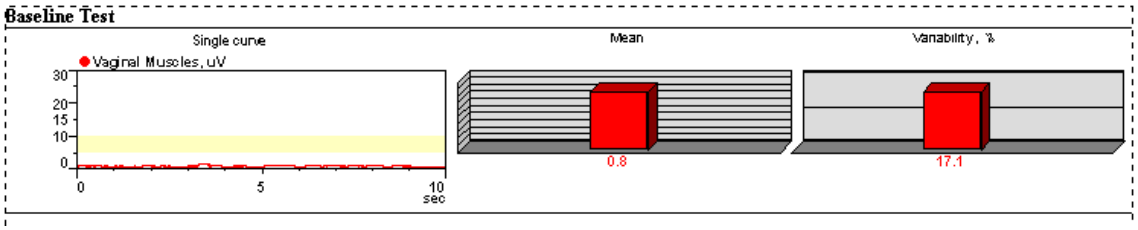
Resting Tone

- Immediately following the endurance contraction the relaxation characteristics are determined by a baseline test of 60 seconds.

Description of Analysis

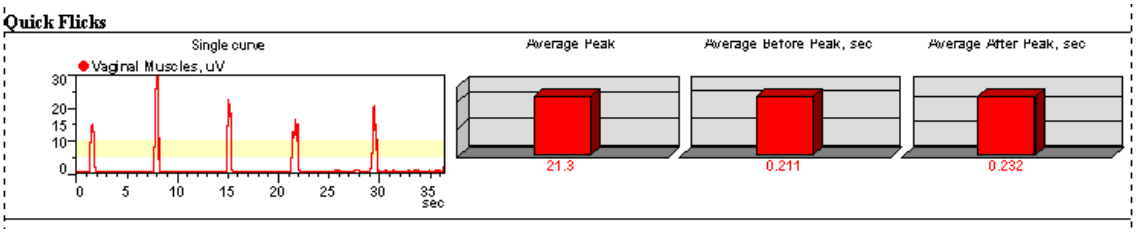
Because the type of probe used can largely affect the results, the following statements about expected values should be regarded as rough guidelines only.

Baseline Test:



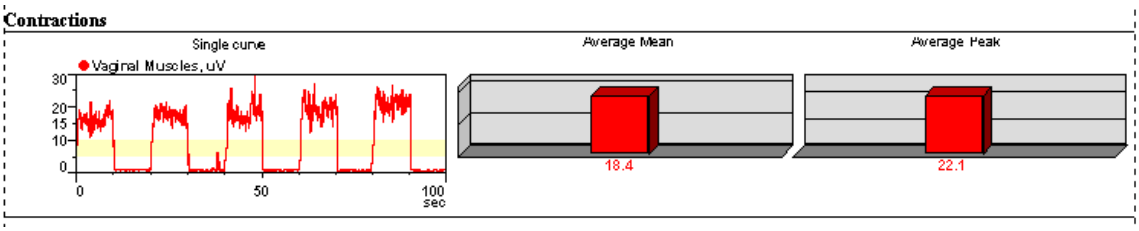
The main focus of this analysis is the baseline level, which is expressed as the mean value of the EMG amplitude. A visual inspection of the curve should be done to check for spikes or other inconsistencies. Typically a mean value of 2.5 microvolts can be considered a normal EMG resting level. The variability parameter refers to the coefficient of variance, which is typically less than 20%.

Quick Flicks



The Quick Flicks sequence analyzes the ability to quickly contract the muscles. The average peak parameter calculates the mean of all peak-values within this activity. In a normal population this value is typically higher than 15 uV. The parameter "Average before Peak" calculates the average time required to reach the peak value, "Average after Peak" calculates the time required to relax the muscle from peak activation to the rest level. Values under 0.5 seconds can be considered normal.

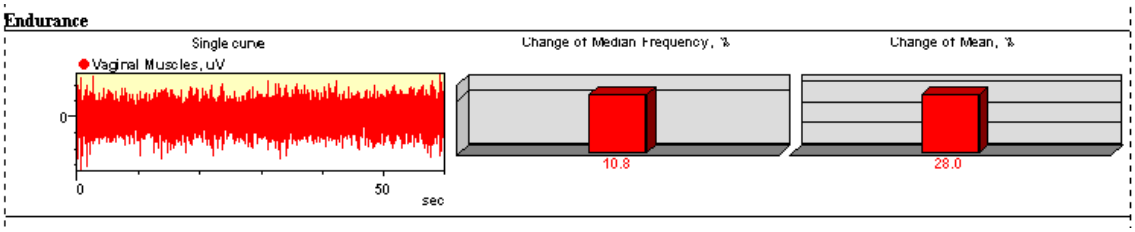
Contractions



The functional capacity of the muscles is best described by the average contraction level during a sequence of maximal contractions. The average mean is the summarized mean of the active part of each contraction. In a normal population, subjects typically reach mean values of 10 uV or higher. The average peak value is typically 20 uV or more.

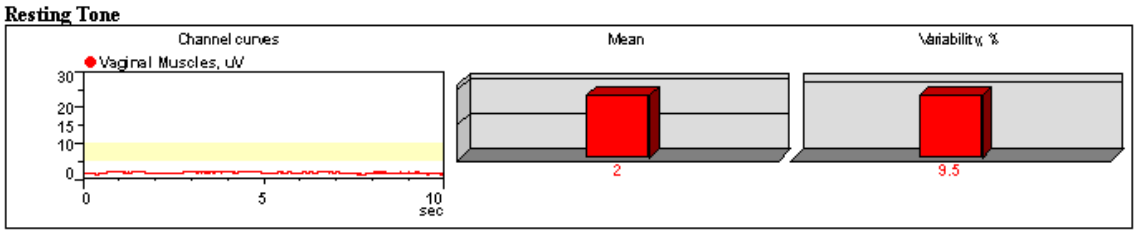
Endurance Hold

Attention: this analysis requires EMG devices with raw recording capacity and should be ignored by clinical DTS system users.



Time domain changes in the median frequency calculated from the power spectrum (Fast Fourier Transformation) are an indicator of local fatigue, reflecting the frequency shift towards lower frequencies. The changes in Mean (amplitude) values indicate fatigue related recruitment of muscle fibers. No norms have been published yet. The user can establish a custom database for comparisons.

Resting Tone



The resting tone evaluation is compared with the baseline test. In a normal population the mean amplitude value should return to the baseline level. The variability in the resting tone increases even in normal populations, but should not exceed a range of approximately 40%.

6) Point of Interest Report

The report is designed for video assisted EMG recordings including a sequence of different activities or motion phases. Based on user defined points of interests (POI) the EMG activation level around each POI is compared between activities. This concept allows us to easily study the EMG reaction or input to a given exercise or treatment condition. If video recording was associated, the video picture at each POI is automatically inserted to the report.

Recommended Signal processing:

Real time EMG RMS processing. Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with typically 50 to 100ms time constant

Period Definition:

Mode: Point of Interest - marked with the "**Add to Report Button**" in Viewer

After selecting the POIreport you enter the Record Viewer again. Review your record, move cursor to a POI and click the orange button "**Add to Report**" to include this activity position to the report. Continue to the next POI and click "Add to report again". Repeat this procedure until all activities or test phases are analyzed. The amplitude value of 100ms around each POI marker will automatically be calculated

Report contents:

1. Page: Subject header, video picture (if measured), and horizontal bar graph with the Mean (EMG) amplitude of an 100ms period around each point of interest

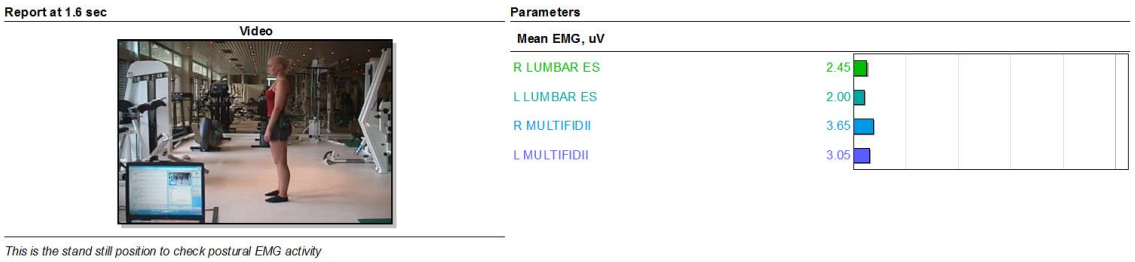
Analysis and interpretation:

The idea is to record 2 - 5 different activities, conditions, exercises or therapeutic interventions and directly compare the EMG activation within each of these activities. Based on a representative POI a direct comparison of EMG data can be operated via horizontal bar graphs

Description of analysis

Combined Video and EMG parameter analysis

Each POI time position and video picture is specified in the POI title:

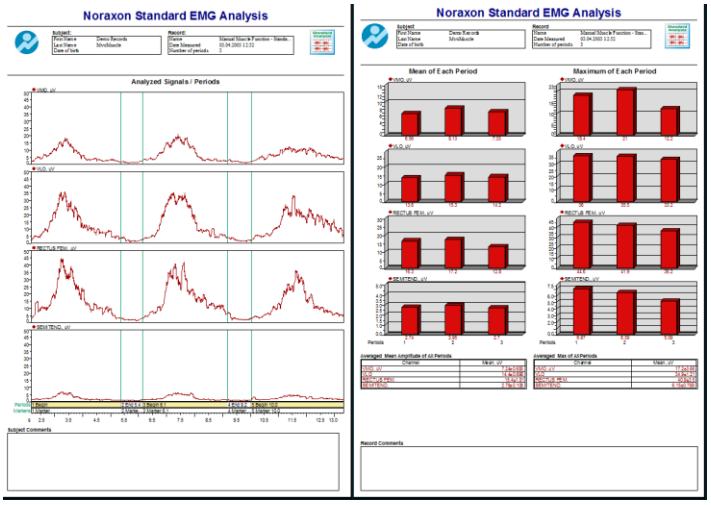


On right side under parameters the EMG activation is presented as a bar graph and amplitude value. If other signals are measured in multi-device setups they are automatically integrated and listed below the EMG data.

Picture comments can be added in record viewer when creating POIs: after placing a POI, click Marker menu in the right tool bar, select the option comment again, and add a text comment here.

7) Standard amplitude report

Standard amplitude is a universal report to analyze mean and max values of rectified EMG and other biomechanical signals between 2 markers or sequences of marker pairs placed in the Viewer menu.



Period Definition:

By markers, mode "every other interval".

In the next screen after selecting this report place a marker at each beginning and end of a given analysis interval by using left mouse double click or Marker/SET button in record viewer. The period between first marker pair and second marker pair will not be included in the analysis (every other interval), between the third and fourth marker pair, and so on.

Recommended processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant

Report contents:

1. Page: Subject header, signal documentation screen, subject comments

2. Page: Subject header, analysis period histogram graph for mean and max amplitude value, summary statistics table for mean and max

Analysis and interpretation:

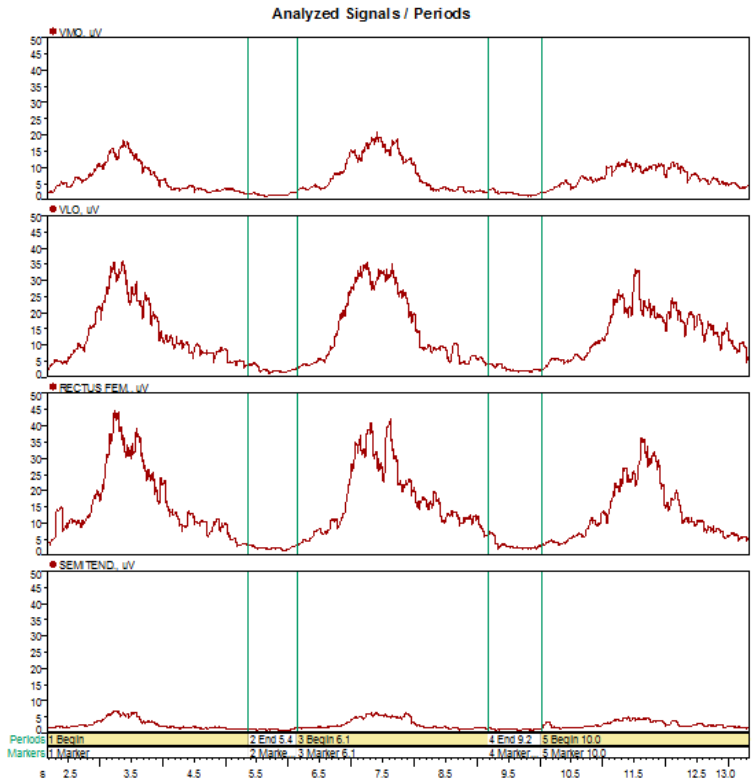
The standard EMG report is best suited for analyzing the area and mean amplitude within a sequence of user defined time/analysis periods. This analysis can be used to investigate the amplitude differences of several activities or test conditions performed within this record. In addition to a graphical illustration of the analyzed signals, the two-page report provides bar graphs depicting the amount and/or time dependent trend of

the chosen parameters. The selection of parameters can be changed by entering the setup menu of the report elements. Alternatively, frequency or time parameter calculations can be performed and viewed on the report. The results can be exported to the clipboard or an ASCII text file for further statistical analysis.

Description of analysis frames

Analyzed Signals/Periods (Page 1)

This graph displays the entire recording with the markers in place. The yellow horizontal bars on the bottom of the graph indicate which periods have been selected for the subsequent analyses (the default setting analyzes every other interval).

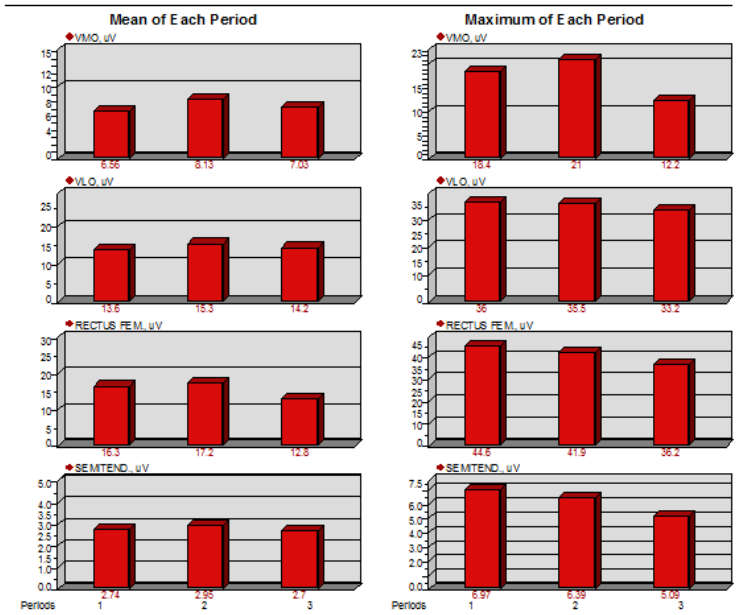


This graph is used mainly to document the pattern of the analyzed signal and the location of the analysis periods. The user can customize the display settings by right mouse clicking on the graph. The setup menu provides options such as showing the raw signal instead of the processed signal, hiding event and marker lines or displaying only the selected periods

Mean and Maximum of each Period (Page 2)

These two bar graph diagrams calculate the area and the mean amplitude. Each bar represents a period defined by the vertical marker lines set in record viewer.

Corresponding numerical values for the selected parameter are displayed below each bar.



Basic analysis and interpretation strategies

1. Comparison of EMG amplitude differences between several activities.

2. Comparison of EMG activity of all muscles during one period, which typically is defined as a single contraction or execution of a given task.

3. Time domain changes in muscle activity over a set number of periods, which can serve as basis for analysis of recruitment, neuromuscular coordination changes, fatigue, etc.

The user can change the selection of displayed parameters by opening the analysis setup menu with a left mouse double click. The setup menu also provides options for line diagrams and parameter tables. The data displayed in the diagrams can be exported with the Copy Element function.

Averaged Mean and Max Amplitude of all periods (Page 2)

Based on the mean and maximum amplitude calculation for each period, this table performs a statistical summary by calculating the overall mean and peak value for both parameters.

Averaged Mean Amplitude of All Periods

Channel	Mean, uV
VMO, uV	7.24±0.655
VLO	14.4±0.698
RECTUS FEM.	15.4±1.91
SEMITEND.	2.79±0.109

Averaged Max of All Periods

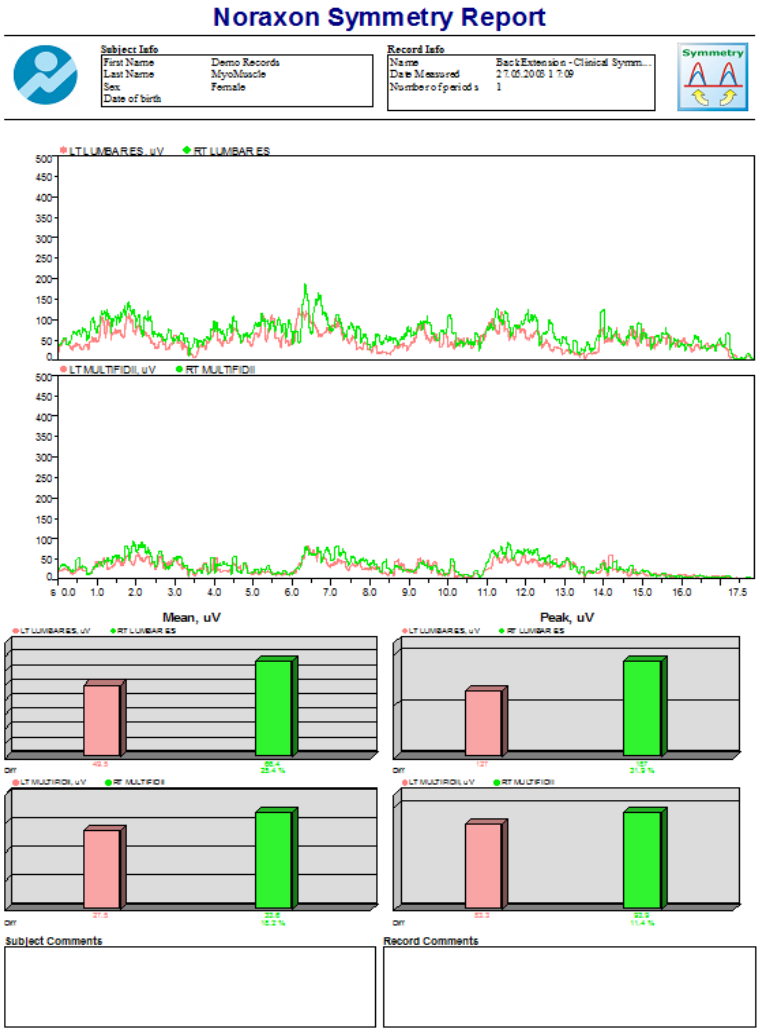
Channel	Mean, uV
VMO, uV	17.2±3.66
VLO	34.9±1.21
RECTUS FEM.	40.9±3.5
SEMITEND.	6.15±0.788

This calculation enables an overview of the EMG data over all analyzed contractions.

The user can change the selection of displayed parameters by opening the analysis setup menu with a left mouse double click

8) Symmetry Report

Symmetry reports are designed for clinical EMG evaluation of bilateral muscle activity patterns and amplitudes within symmetrical movements. The activity patterns of each muscle pair (the same muscle on the left and right side of the body) will be automatically displayed on top of each other and amplitude values (mean, peak) analyzed for left/right asymmetry. Typically a joint region on the injured side is compared to the uninvolved side.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu. Only one consecutive area at a time can be defined for the analysis.

Recommended processing:

Real time EMG RMS processing. Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with typically 50 to 100ms time constant

Report contents:

1. Page: Subject header, signal documentation screen, bar graph section showing the Mean, Peak values for the selected analysis period

Analysis and interpretation:

The main function of the symmetry comparison between left and right body side is to study the difference of the injured side in comparison to the healthy side. If EMG data were not MVC normalized this comparison can only be operated on qualitative level.

The data can be used to analyze:

- The consistency of firing patterns across a sequence of repetitions.

- The on/off characteristics of the prime movers.

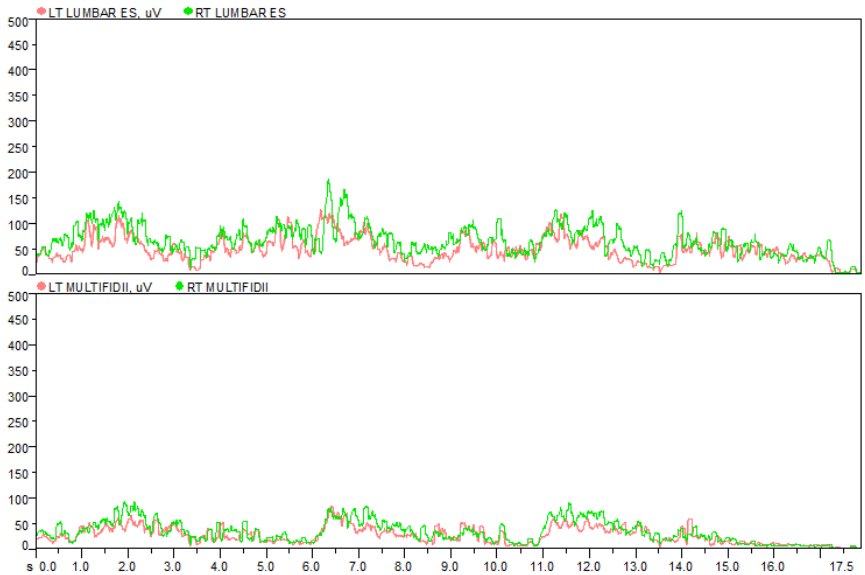
- The EMG pattern shape and characteristics.

- The potential differences in firing between the involved and uninvolved side.

Description of analysis frames

Analyzed Signals

This graph displays the online processed EMG traces for each muscle pair. EMG tracings from the left and right side of the body are superimposed on each other to facilitate comparison.

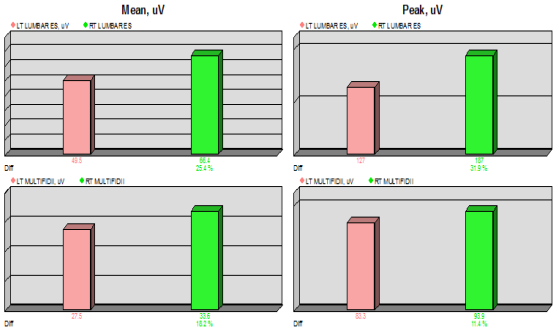


This graph can be used to analyze

- the consistency of firing patterns across a sequence of repetitions
- the on/off characteristics of the prime movers
- the nature of firing in the postural muscles
- the potential differences in firing between the involved and uninvolved side

Signal Statistics

The following two amplitude parameters are calculated for the selected portion of the recording:



Mean = the mean amplitude value

Area = area under the curve, calculated as the mathematical integral
(labeled "IEMG" in older EMG literature)

These statistics can be used to quantify the difference of EMG activity between the two sides. The Input% calculation estimates the role of a given muscle in the overall activity and is typically used to communicate the results to the patient.

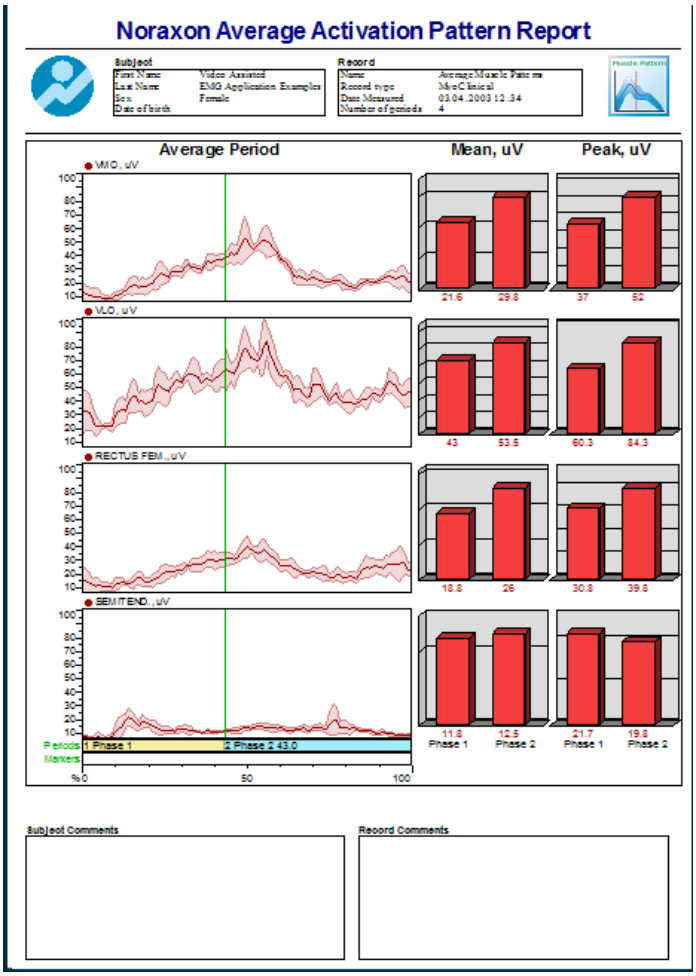
A difference calculation (Diff:) is performed separately for each muscle pair. The default setting uses the higher parameter value within the pair as 100% and displays the difference between the two muscles in percentage units of that value.

The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click. The Curve statistics tab allows the user to change analysis parameters and the Output options tab to change the formula used for the difference calculation.

Appendix C: MyoMuscle Essential Reports

1) Average Activation Report

The report is designed to provide time normalized average EMG patterns for repetitive movements (e.g. extension / flexion). It displays EMG patterns averaged across repetitions (ensemble average) +/- 1 SD as well as corresponding statistics (mean and peak amplitudes) for each muscle and motion phase.



Period Definition:

Mode: Interval with Event

At least three markers must be placed to run an analysis. The first marker defines the start of the first repetition. The second marker (event) is the turning point within each movement, such as toe-off in gait cycles or the highest pedal position in cycling. The third marker serves both as the end of the first repetition and the start point of the second repetition. In the Viewer set-up window (next screen after selecting this report)

the two phases of the movement (e.g. extension/flexion) are separated by the event marker and further indicated by the horizontal yellow and blue bars on the bottom.

Recommended Signal processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with a 50 to 100ms time constant

Report contents:

1. Page: Subject header, Averaged EMG signal screen, bar graph section showing the Mean, Peak values for both motion phases

Analysis and interpretation:

Due to the averaging process the typical "behavior" of EMG activation is detected, the variability of each single repetition is "smoothed" to the typical shape of the activation pattern for this movement. This kind of EMG processing creates highly reproducible EMG patterns. Typically these patterns can easily be repeated in sequential measurements and serve as a basis for test-retest comparison plots.

The averaging process detects the prototypical "behavior" of muscle activation as the variability between single repetitions blends into an average pattern for the movement. This method of EMG processing creates highly reproducible EMG patterns. These patterns can be replicated for repeated measurements and serve as a basis for test-retest comparison plots.

The averaged curves can be used to analyze and interpret:

- The overall pattern and characteristics of EMG activity.

- Upward or downward activation trends within the movement phase.

- Comparison of the agonistic (first phase) and antagonist (second phase) firing pattern.

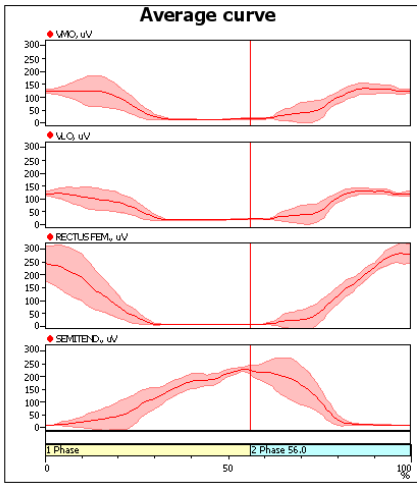
- Comparison of muscle innervation in concentric or eccentric contraction phases.

- Coordination of muscles.

Description of analysis frames

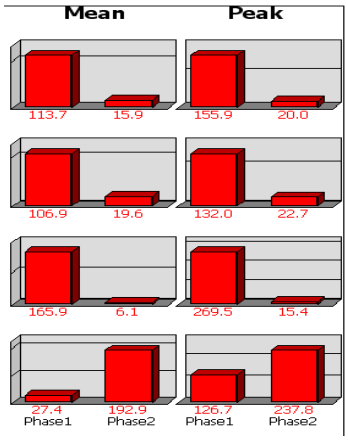
Average Curve

This analysis frame calculates the average EMG curve for all periods specified in the record and shows them in a time normalized window from 0 – 100% of the total signal window (data is presented in 1% steps). The red shaded area represents +/- one standard deviation. The red event line separates the curve into two sub phases (e.g. extension/flexion), indicated by yellow and blue bars respectively in the period line within the x-axis.



Due to the averaging process the typical "behavior" of EMG activation is detected, the variability of each single repetition is "smoothed" to the typical shape of the activation pattern for this movement. This kind of EMG processing creates highly reproducible EMG patterns. Typically, these patterns can easily be repeated in simultaneous measurements and serve as a basis for test-retest comparison plots.

Signal statistics



By default two amplitude parameters are calculated for each period of the average signals:

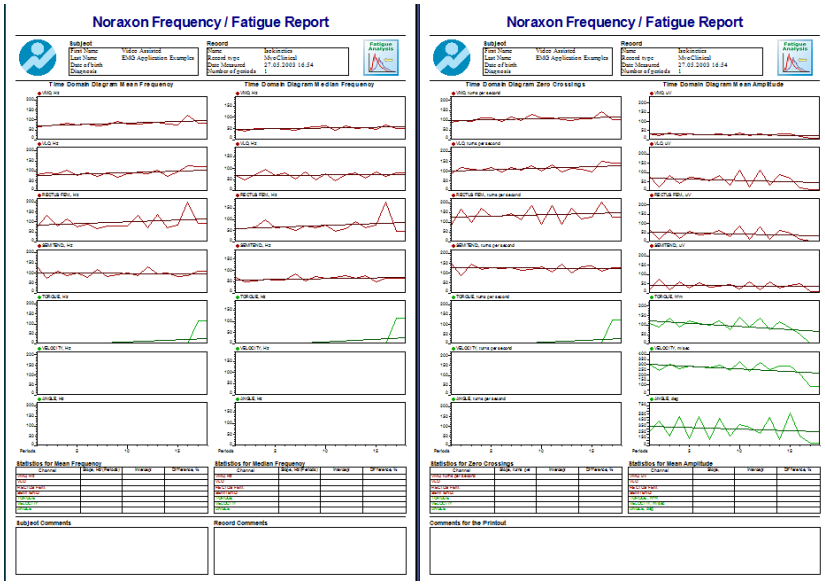
Mean = the mean value of the EMG amplitude

Peak = the peak value of EMG amplitude

These statistics quantify the difference of EMG activity between the muscles and the phases. The user can change the selection of displayed parameters by opening the analysis setup menu with a right mouse click and choosing the Curve statistics tab.

2) Frequency/Fatigue Report

The report is designed for tracking and analyzing fatigue related changes in the neuromuscular recruitment. Changes in the frequency (Median and Mean frequency) and amplitude parameters (Zero crossing and Mean absolute) can be used to determine local fatigue. These time domain calculations are operated in 1 sec step intervals from the beginning to the end of selected analysis period



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu.

Recommended processing:

All EMG signals should stay unprocessed.

Report contents:

1. Page: Subject header, Mean and Median frequency bar or line diagram, slope statistics table

2. Page: Subject header, Zero Crossing and Mean absolute Amplitude bar or line diagram, slope and statistics table

Analysis and interpretation:

EMG frequency power spectrum is expected to shift to lower frequencies during fatiguing contractions and the Median and Mean frequency analysis can be used to estimate the

magnitude of that shift. This phenomenon is well established for static contractions at constant load levels and believed to reflect local fatigue. While this analysis can also be applied to dynamic contractions, the user would have to take into account various factors affecting the reproducibility and validity of the data under those conditions

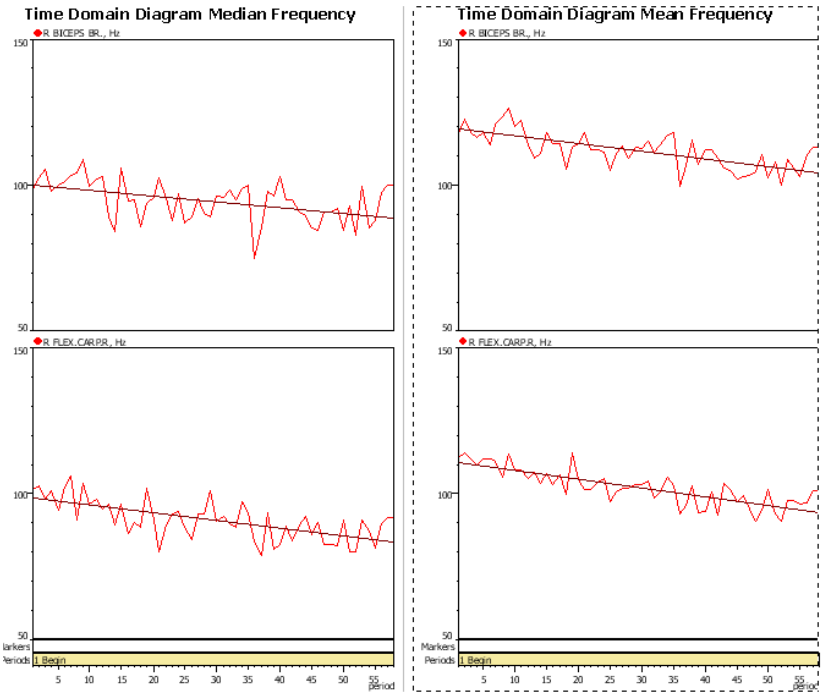
Zero crossings of the raw EMG are highly correlated to frequency parameters such as Mean and Median frequency and can serve as an alternative calculation of frequency characteristics.

The trend in mean amplitude reflects the recruitment characteristics within the pool of motor units measured. In typical submaximal fatigue experiments, there is an increase in recruitment, which can be observed as an increase of the amplitude mean value and/or the total power. The mean amplitude may decrease for contractions near the maximum effort. The total power can be added to the analysis in the setup menu of this analysis frame.

Description of analysis frames

Time domain diagram for Median Frequency and Mean Frequency

Total power spectrum is calculated for each period (1000 ms steps) and individual median and mean frequency parameters are plotted in a time domain diagram:



Linear regression line is included to illustrate the general trend.

When only a few periods are analyzed, it may be more meaningful to display the result in bar graph format. The user can modify the display format by right clicking on the graph, selecting the "**Output Options**" tab and changing the display style to **"Histogram".**

Statistics for Median Frequency and Mean Frequency

The time domain diagrams of the frequency parameters are supplemented with statistics tables.

Statistics for Median Frequency

Channel	Slope	Intercept	Difference, %
R.BICEPS BR., Hz	-1.05	105.21	-6.8
R.FLEX.CARP.R., Hz	-0.80	102.47	-5.7

Statistics for Mean Frequency

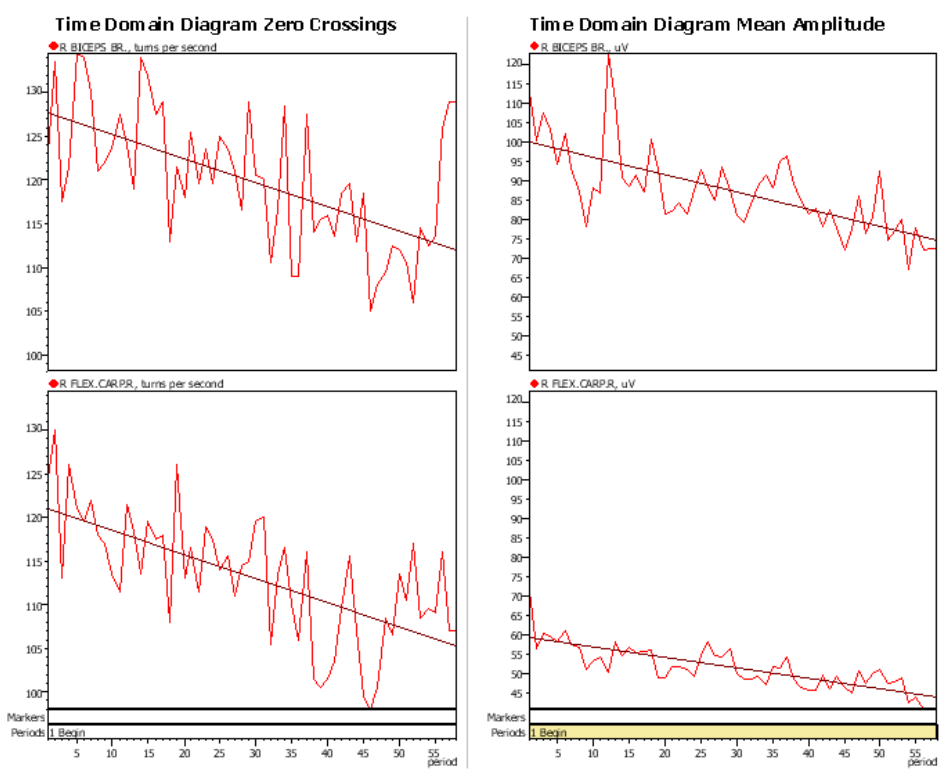
Channel	Slope	Intercept	Difference, %
R.BICEPS BR., Hz	-0.74	121.35	-4.9
R.FLEX.CARP.R., Hz	-0.73	112.39	-5.4

- **Slope** The regression coefficient of the linear regression line.
- **Intercept** The frequency value (in Hz) where the regression line meets the y-axis.
- **Difference** The difference in % units between the average of first 3 and the average of last 3 period values.

EMG frequency power spectrum is expected to shift to lower frequencies during fatiguing contractions and the Median and Mean frequency analysis can be used to estimate the magnitude of that shift. This phenomenon is well established for static contractions at constant load levels and believed to reflect local fatigue. While this analysis can also be applied to dynamic contractions, the user would have to take into account various factors affecting the reproducibility and validity of the data under those conditions

Time domain diagram for Zero Crossings and Mean Amplitude

Two alternative parameters are calculated in the time domain of selected interval:



Zero crossings of the raw EMG are highly correlated to frequency parameters such as Mean and Median frequency and can serve as an alternative calculation of frequency characteristics.

The trend in mean amplitude reflects the recruitment characteristics within the pool of motor units measured. In typical submaximal fatigue experiments there is an increase in recruitment, which can be observed in increase of the amplitude mean value and/or the total power. The mean amplitude may decrease for contractions near the maximum effort. The total power can be added to the analysis in the setup menu of this analysis frame.

Statistics for Zero Crossing and Mean Amplitude

Statistics for Zero Crossings

Channel	Slope	Intercept	Difference, %
R.BICHPS BR., turns per second	-0.19	124.41	-3.4
R.FLHXC ARPR., turns per second	-1.00	123.48	-4.9

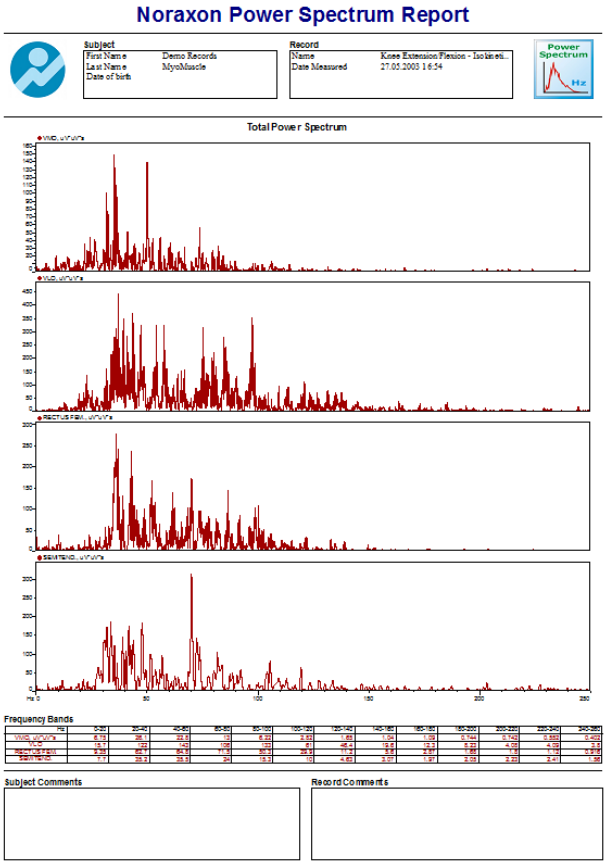
Statistics for Mean Amplitude

Channel	Slope	Intercept	Difference, %
R.BICHPS BR., uV	0.57	93.42	9.3
R.FLHXC ARPR, uV	-0.54	58.89	-7.2

- **Slope** The regression coefficient of the linear regression line
- **Intercept** The frequency value (in Hz) where the regression line meets the y-axis
- **Difference** The difference in % units between the average of first 3 and the average of last 3 period values

3) Spectrum Report

Based on a Fast Fourier Transformation, the total power spectrum of the raw EMG is calculated for a selected interval within the record. The power distribution is listed in a frequency band table.



Period Definition:

Mode: Mouse marked area or whole record

The report defaults to analyzing the entire measurement. The user can limit the analysis to a specific part of the recording by dragging the mouse across that area in Viewer screen shown before entering the report menu.

Recommended Signal processing:

All EMG signals should be unprocessed.

Report contents:

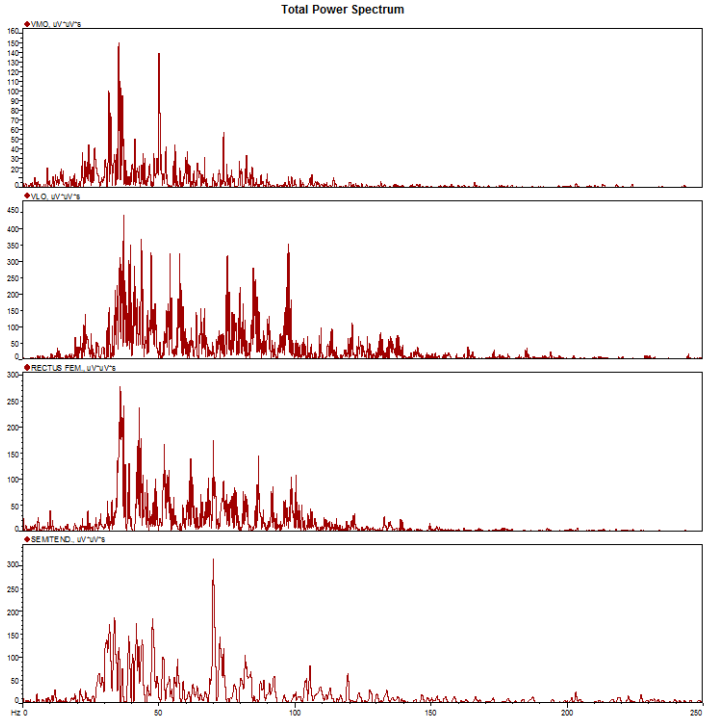
1. Page: Subject header, Power distribution diagram, frequency distribution table

Analysis and interpretation:

This analysis can be used to check the quality and normality of the EMG signal. Typically, the frequency power of surface EMG is located between 20 and 150 Hz, only minor components are found beyond 250 Hz. The center frequencies are typically located between 80 and 120 Hz for normal sub-maximal contractions. The power spectrum curve can vary considerably depending on the contraction level. Even within static contractions there is a time domain change towards lower frequencies due to fatigue (frequency shift, see Frequency - Fatigue Protocols). Another important checkpoint is the 50 (in Europe) or 60 Hz power content, which increases when external ground noise (e.g. originating from the local power lines) is present. The frequency range to be used for the spectrum curve can be modified in the analysis setup window (double click on the Power spectrum graph)

Description of analysis frames

The power spectrum is calculated for the 0 to 250 Hz range by default, but can be customized by the analysis setup options (right mouse button).



Frequency Bands Table

A numerical table for the frequency power separated in bands is shown below the graph:

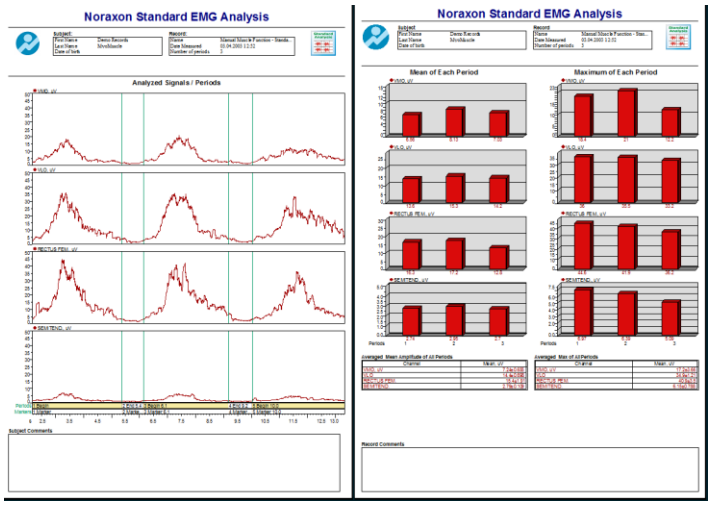
Frequency Bands

Hz	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260
VMO, uV*uV*s	6.75	26.1	22.8	13	6.22	2.82	1.65	1.04	1.09	0.744	0.742	0.552	0.402
VLO	15.7	122	143	106	133	61	46.4	19.6	12.3	8.23	4.08	4.09	3.8
RECTUS FEM.	9.35	62.7	64.8	71.5	50.3	29.9	11.2	5.6	2.87	1.68	1.8	1.12	0.916
SEMITEND.	7.7	35.2	35.5	24	15.3	10	4.63	3.07	1.97	2.05	2.23	2.41	1.56

The bands settings can be customized in the table setup (right mouse button).

4) Standard amplitude report

Standard amplitude is a universal report to analyze mean and max value of rectified EMG and other biomechanical signals between 2 markers or sequences of marker pairs placed in the Viewer menu.



Period Definition:

By markers, mode "every other interval".

In the next screen after selecting this report, place a marker at each beginning and each end of a given analysis interval by using left mouse double click or Marker/SET button in record viewer. The period between first marker pair and second marker pair will not be included in the analysis (every other interval).

Recommended processing:

Bipolar (raw) EMG signals need to be rectified and smoothed with a moving average or RMS algorithm with typically 50 to 100ms time constant.

Report contents:

1. Page: Subject header, signal documentation screen, subject comments

2. Page: Subject header, analysis period histogram graph for mean and max amplitude value, summary statistics table for mean and max

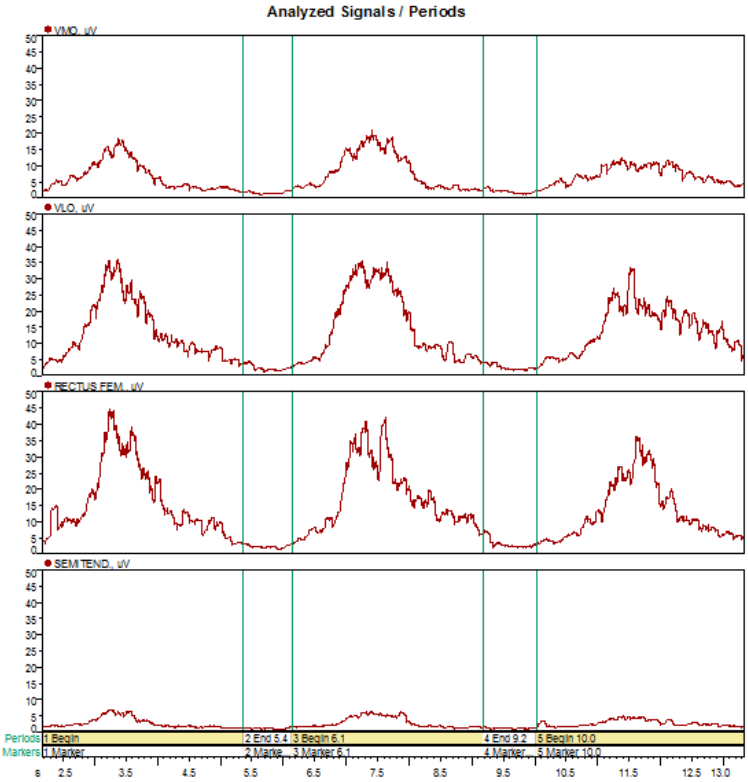
Analysis and interpretation:

The standard EMG report is best suited for analyzing the area and mean amplitude within a sequence of user defined time/analysis periods. This analysis can be used to investigate the (EMG) amplitude differences of several activities or test conditions performed within this record. In addition to a graphical illustration of the analyzed signals, the two-page report provides bar graphs depicting the amount and/or time dependent trend of the chosen parameters. The selection of parameters can be changed by entering the setup menu of the report elements. Additionally, frequency or time parameter calculation can be calculated and viewed in the report. The results can be exported to the clipboard or an ASCII text file for further statistical analysis.

<u>Description of analysis frames</u>

Analyzed Signals /Periods (Page 1)

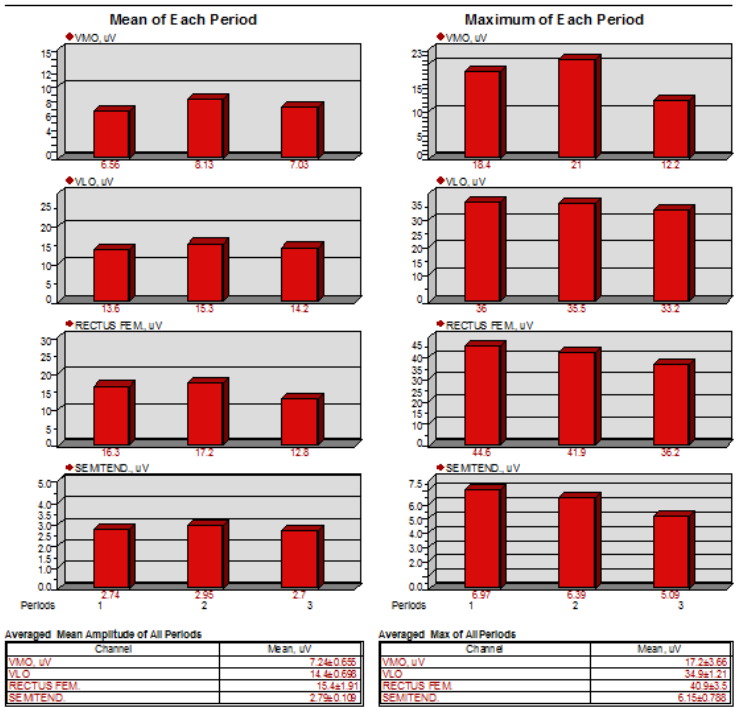
This graph displays the entire recording with the markers in place. The yellow horizontal bars on the bottom of the graph indicate which periods have been selected for the subsequent analyses (the default setting analyzes every other interval).



This graph is used mainly to document the pattern of the analyzed signal and the location of the analysis periods. The user can customize the display settings by right mouse clicking on the graph. The setup menu provides options such as showing the raw signal instead of the processed signal, hiding event and marker lines, or displaying only the selected periods.

Mean and Maximum of each Period (Page 2)

These two bar graph diagrams calculate the area and the mean amplitude. Each bar represents a period defined by the vertical marker lines set in record viewer. Corresponding numerical values for the selected parameter are displayed below each bar.



Basic analysis and interpretation strategies

1. Comparison of EMG amplitude differences between several activities.

2. Comparison of EMG activity of all muscles during one period, which typically is defined as a single contraction or execution of a given task.

3. Time domain changes in muscle activity over a set number of periods, which can serve as basis for analysis of recruitment, neuromuscular coordination changes, fatigue etc.

The user can change the selection of displayed parameters by opening the analysis setup menu with a left mouse double click. The setup menu also provides options for line diagrams and parameter tables. The data displayed in the diagrams can be exported with the Copy Element function.

Averaged Mean and Max Amplitude of all periods (Page 2)

Based on the mean and maximum amplitude calculation for each period, this table performs a statistical summary by calculating the overall mean and peak value for both parameters.

Averaged Mean Amplitude of All Periods

Channel	Mean, uV
VMO, uV	7.24±0.655
VLO	14.4±0.698
RECTUS FEM.	15.4±1.91
SEMITEND.	2.79±0.109

Averaged Max of All Periods

Channel	Mean, uV
VMO, uV	17.2±3.66
VLO	34.9±1.21
RECTUS FEM.	40.9±3.5
SEMITEND.	6.15±0.788

This calculation enables an overview of the EMG data over all analyzed contractions.

The user can change the selection of displayed parameters by opening the analysis setup menu with a left mouse double click.