



# LACTATE MEASURING

Meaning,  
Applications and  
Measurement





# Lactate

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Measurement



# LACTATE

## MEANING, APPLICATIONS AND MEASUREMENT

### 1. General meaning of the lactate parameter

1.1. The basic energy support of our organism takes place in the muscle cells. When the body is at rest, or at a low activity level and not stressed, the muscle cells regenerate itself primarily through the aerobic metabolism. The regular uptake of oxygen by breathing is sufficient. At this level, the continual lactate production is low (approx. 0,5 - 2,2 mmol/l, depending on individuals metabolism) and well balanced.

1.2. At higher body activities (caused by sports, fat nutrition, stress, infections or organ malfunction), the aerobic metabolism cannot deliver sufficient energy by breathing normally. The anaerobic metabolism takes higher part, supporting energy by glycolysis (setting free the "stored" energy). As a result of this increased anaerobic metabolism, lactate is produced at higher rates herein.



*To improve the training results, sports scientists are operating with lactate control*

1.3. The aerobic metabolism eliminates the produced lactate again, but this procedure takes time. During moderate activities, the lactate level does not grow significantly (continually balanced around 2-3 mmol/l), and can be metabolized quickly. But at higher effort levels, the lactate production increases much more. High lactate levels include risks for individuals health, if not conditioned for (as sprinters or race horses, trained for high tolerance and high elimination of lactate). The relation of activity level and lactate production depends on individuals aerobic capacity and metabolism conditions. Both can be improved e.g. by continual training and healthy lifestyle.

1.4. High lactate levels mean an over-acidation of the muscle cells, harming the health in many relations. Enzymes will be shifted out from their range of pH optimum causing to diminished activities, so e.g. fat burning (one of the main reasons for sports activities) is reduced also. The immunological system will be harmed strongly, expanding the risk of infections. In extreme, even the mitochondria (the place of the energy metabolism) can be damaged, and the aerobic capacity will be decreased (which will increase immediately the lactate production vice versa) The diagnostic of lactate (and of aerobic capacity, as a fixed relation to) allows to check the physical condition for several applications, as a "vital sign" for oxygen debt, shocks or body stress generally.

1.5. Caused by the availability of lab analyzers only, lactate measurement was established long time ago in professional sports exclusively. As a leading brand, the Eppendorf EBIO and the modern EKF BIOSEN devices are very popular herein, combining highest accuracy and sensitivity with comfort handling by chip-sensors. Introduced in 2004, the Lactate SCOUT pocket device opens the diagnostic field additionally by its unique features. The lowest sample volume of a half microliter only, quick results in 15 sec, a wide measurement range of 0.5 to 25.0 mmol/l, many electronic features incl. PC link help to adapt this pocket device for many existing and new applications. Former pocket devices as the Roche AccuSport and the Lactate Pro are based on old technology and cover neither the growing demands of private customers nor the specific needs of scientific experts.

## 2. Lactate in Sports

2.1. To improve the training results, sports scientists are operating with lactate control. Lactate levels are needed to determine proper training paces. The training is most effective when it is done near the maximum lactate steady state ("maxlass", the highest stable or balanced lactate level, in average about 4,0 mmol/l).



*Lactate measuring  
for the exact  
training planning  
and control in  
competitive sports*

2.2. To find out the precise individual maxlass, a step test is to carry out, during which lactate is measured several times at gradually increasing effort levels. The shape and direction of the lactate curve will be used to determine the best training paces. The step test is to be repeated within a few weeks. If the training was successful, the aerobic capacity will be improved and the lactate value increases at higher effort level than before, which shows that the sportsman is more fit than before.

2.3. Lactate control is much more informative than heart rate monitoring, because the lactate level is a direct result of the whole metabolism condition, as an immediate response of muscle cells. Measuring heart rates only (and carrying out heart rate based training methods) can lead to wrong results easily. Typically, owners of the Lactate SCOUT "calibrate" their individual, optimum heart rate (for daily training use of a pulse watch) with frequent lactate step tests. For serial measurements or top-level coaching, the EKF BIOSEN is used by universities and olympic centres, setting standards in professional sports diagnostic.

## 3. Lactate in Animal Sports

Typical lactate values of animals are different. E.g. race horses have a very high "maxlass" above 20 mmol/l. The Lactate SCOUT is the only pocket device with an equivalent measuring range for this application,

which is established by many horse coaches. The Lactate SCOUT also compensates the hematocrit-influence as an important parameter in the veterinary field. As confirmed in several studies (University Cordoba and Minnesota), the higher viscosity of the blood of animals is not critical herein. The very low sample volume of 0,5 µl recommends the Lactate SCOUT also for small animals, as mice and pets, or canine and falcon sports.

*Lactate  
in Animal  
Sports*



#### **4. Lactate in Diabetics, Physiotherapy, Rehabilitation**

Diabetic people are very often overweight. Here it is not the target to improve the endurance or the power, but it is essentially to learn “healthy move” again. These patients will be trained at the aerobic level (below 3 mmol/l) only, to avoid critical effects of oversized effort (see 1.4). Featured similar to typical Glucose meters, the Lactate SCOUT fits perfectly the demands herein. Many doctors are supporting their patients with the Lactate SCOUT; the University Cologne and other institutes use the Lactate SCOUT as the reference device in training projects for overweight people, including adolescents and children. Applications in pediatrics are reported as well.

*Lactate in  
Maternity Hospitals  
Birth Medicine*



#### **5. Lactate in Maternity Hospitals / Birth Medicine**

That is a pioneer application for lactate testing. As recognized by current research studies e.g. in Australia, Sweden and Germany, high lactate levels of pregnant mothers and babies are indicating the need of medical support, to reduce some risks in the birth process (as collapsing metabolism of the stressed baby, or to proceed by sectio caesarea). In future, this method will help also in ambulance and local services, nurses etc. New research results will be published soon.



*Lactate in  
Emergency units/  
Intensive/Critical  
Care, Cardiology  
and Gerontology*

## **6. Lactate in Emergency units / Intensive / Critical Care, Cardiology and Gerontology**

All the named applications use lactate diagnostics as a “warning parameter” for general health problems. Organic malfunctions, potential collapses, even infections can be detected in an early stage by increasing lactate values in rest. This relation is caused by higher (compensating) body activities or shocks, reducing the aerobic support. Slightly increased body activities (at lower lactate levels) can be generated also by meals or by stress, pain, drugs and pharmaceuticals. Established in the cardiology, lactate diagnostics is meanwhile also used for medical check-ups, in nursing stations as well as for the supervision of intensive care patients.



*New prospects:  
Continual lactate  
monitoring*

The Biguanid-therapy can be improved by supplemental lactate diagnostics significantly: The risk of a lactate acidosis (e.g. during the Metformin-treatment of insulin-injecting Diabetics) can be analyzed reliably. There will be no need to interrupt (as usual) the therapy or to postpone surgeries, prejudicing the success of treatment. To detect immature compensation mechanisms of (especially premature) infants, lactate handheld analyzers are an alternative solution to common blood-gas-analyzers, designed for more complex analysis and requiring bigger sample volumes. As marker for a defective homoeostasis, lactate values have an informative value e.g. in pediatric surgery, emergency care, general wards and foster homes. Herein, high lactate values in rest may point to serious intestinal diseases.

## **7. Continual lactate monitoring**

During intensive care operations (and up to 12h afterwards), sudden death cases can be caused by a quick and significant decrease of

glucose or by unexpected malfunctions of metabolism, signaled by high lactate values. The importance of the continual monitoring of these parameters is well known and gets more and more popular in modern hospitals. With the CLAMP system, EKF offers an innovative diagnostic system for continual monitoring of glucose for clinical use. SensLab, a member of EKF-Group shares also research activities for continual monitoring with portable units in the CliniCip.org-project of the European union. Please note, the current SensLab products are not authorized officially yet for use as critical components in life support devices. With growing market demand, suitable certified product solutions will be realized and available in future.

## **8. Industrial applications (food and beverages, blood donor services, quality control)**

Lactate diagnostic opens a wide range of special applications for industrial needs. E.g., if liquids, natural ingredients or additives are contaminated by bacteria (consuming oxygen or producing lactate itself), it can be detected by an increased lactate level. The main challenge herein is to figure out an optimal sampling and dilution method. Regarding the limitations of dry chemistry / test strip analyzers (designed for specific viscosity and sample contents), the BIOSEN analyzers are the best choice to operate with different sample types. Depending on market volume, test strip or cuvette systems can be applied on demand for selected applications, e.g. quality control for blood donor services.

As a known fact, the quality of blood bottles is lowered by prolonged storage, related to significantly increased treatment risks for patients. The typical time shift from blood donation to infusion is approx. three weeks, against what first impairments of blood bottle quality are detectable after 10 days already. But this rating cannot be related to a defined storage time exclusively (many blood bottles are fine even after weeks): To avoid needless shortages in medical supply herein, before transfusions it is recommended to analyze the lactate concentration of blood bottles as a supplemental quality control.

## **9. Discussion: “Bloodless” lactate measurement**

Regarding the remaining risks by handling of blood and the pain of puncturing, non-invasive methods of lactate measurement are in discussion repeatedly. Indeed, the lactate content in saliva is related (but in significant lower amounts) to the lactate content in blood. Unfortunately, there's a time delay from lactate production in muscle cells and the lactate level in saliva - but the biggest problem are interferences in sample, caused by the wide range of substances, uptaken by food and drinks and resting in the mouth. As shown by a scientific study at Texas A&M University in 2005 and 2007, the tested people had to avoid all regular nutrition. Meaningful results were only possible by a long-term and exclusive support with especially prepared liquids - contrasting totally to the origin target of an improved measurement comfort. Combined with reduced sample volumes (below 0,5 µl), interstitial fluid is a promising kind of sample for future glucose monitoring - but caused by big time shift as well, it corresponds too less to the lactate content in blood and can be easily contaminated by the additional, very high lactate content of sweat.

## **10. Misunderstanding of lactate readings**

To avoid confusion by unexpected high or low lactate values, it is essential

to know potential influences causing to wrong results. The main reason for wrong lactate readings is the contamination of the blood sample by sweat. Human skin is always (!) covered with sweat, which contains a great deal of lactate. Disinfection or alcohol pads do not dissolve the lactate of sweat properly, and dilute the blood drop. In addition, it is not recommended to use saliva for cleaning, because it also contains lactate. The safest way is to clean the sampling area (fingertip or the earlobe) by pure water before each puncturing / sampling, and to dry afterwards. EKF / SensLab has published general sampling notes, to download e.g. from [www.lactatescout.com](http://www.lactatescout.com). As explained in 1.2, the lactate production is related to the glycogen reserves of the body. If they are reduced (by intensive activities or diet) or expanded significantly (e.g. by food), the lactate level in rest will also be lower or higher temporarily. The grade of this influence depends on the individual physiology and metabolism, but it should disappear within 24 hours latest. As a well known influence concerning the heart rate, the lactate level can be increased temporarily also by stress situations, drug consumption (as tea or coffee also), pain and similar "stimulations". For a qualified diagnostic it is strictly recommended to combine the lactate value with additional parameters (as heart rate or EKG), to get more detailed information about individuals condition. Lactate analyzers can be applied as a very helpful diagnostic tool, but they do not replace additional, proofed and established diagnostic methods. Medical treatments cannot be based on lactate results only. Lactate shows only "if" something happens (or not), but it does not lead directly to the specific reasons. Vice versa, it makes no sense to reduce the lactate level artificially e.g. by special drugs. Even if the over-acidation can be stopped, the further circumstances and the total metabolic situation has to be respected carefully.

## LACTATE SCOUT FAQ AND FEATURES

### 1. Basic principles

1.1. The Lactate SCOUT measurement system operates on the base of enzymatic-amperometrical detection, comparable to modern glucose meters. The device reads the electric signal given by the immediate reaction of the sample with the biochemical reagent of the inserted test strip. This signal corresponds directly with the lactate concentration of the sample.



1.2. The Lactate SCOUT uses disposable test strips, taking up the required sample volume precisely and automatically by capillary power, to avoid wrong results by oversized samples. To avoid other interferences,

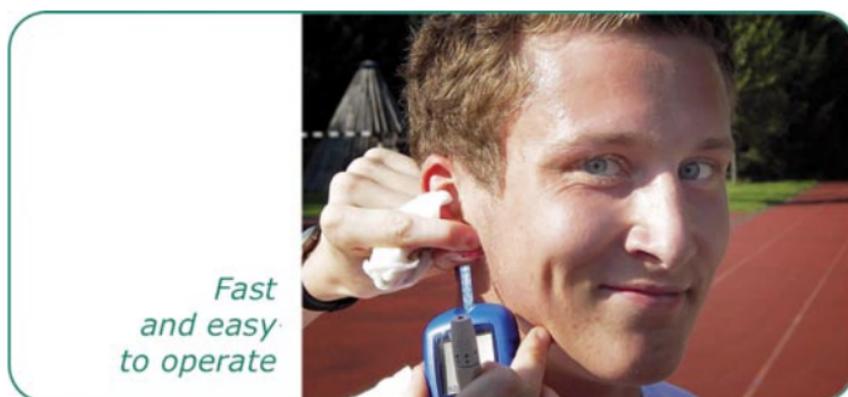
it is recommended to uptake the sample directly from body (without any vials, or capillary tubes). The test strip must be inserted before into the device. It is not possible to get readings from pre-filled / used test strips afterwards, because the biochemical reaction will be finished and the reagent is not usable again.

1.3. Calibration procedures are neither accessible nor required. All factors for reliability and accuracy depend on the pre-calibrated test strips (for single use only). To harmonize the test strips of a vial with the device, a two-character calibration code (as printed on the vial label) must be entered manually in the device before by "set code" settings. All 12 readings, the device reminds to check the code settings with the used test strip vial, for confirmation or correction. Wrong code settings may cause wrong results +/- 1 mmol/l.

1.4. The reagent of test strips is very sensitive related to light, humidity and temperatures higher than 10 degree Celsius. So it is recommended to take out from the vial single test strip only, for immediate use within the next 10 minutes. Non required test strips must be stored into the closed vial, in a suitable environment. In sunlight or during car transport, high temperatures are possible and may harm the test strips seriously! For longer periods, a fridge is the best place to store closed test strip vials and to save their quality. Please note to remove the test strip vial from the fridge 20 min before next use, because the test strips and the device must have the same temperature in operation.

1.5. The power supply of the Lactate SCOUT is given by batteries exclusively, and sufficient for 12 months at least. Do not use the socket of the Lactate SCOUT for external power supplies. This socket is only for use with the optional PC cable. Any non-defined electric signals can damage the device, and the warranty will be void.

1.6. The uptake of samples has to be carried out with inserted, new test strips. Filling the device with samples directly (e.g. into the test strip slot) may damage the device. If happened, the device should be sent to the manufacturer for repair service. Any trials of cleaning or repair by customer may increase the damage.



## 2. Applications

2.1. Generally, test strips are designed for specific sample quality, e.g. of human whole blood. Other samples, e.g. centrifuged blood / serum, liquids and buffer solutions have different characteristics in their viscosity, biochemical content etc. These differences will reduce the accuracy of readings significantly, but do not touch the high accuracy of the Lactate

SCOUT for its main application. This also explains different results by using the Lactate SCOUT test solution. It's only for function control, without any relation to the real accuracy.

2.2. Scheduled, extended versions of the Lactate SCOUT will be switchable for different kind of samples (whole blood or serum), but principal differences of test strip systems to lab systems cannot be eliminated.

2.3. By this reason, test strips systems react much more sensitiv to interferences of samples. After sampling, whole blood changes its characteristics within seconds. Immediate sampling with fresh blood is strictly recommended! Rests of disinfection liquids, stimulating cremes, dried blood and especially continually generated sweat must be always removed with clean water from the sampling area.

2.4. By influence of pharmaceuticals, drugs, special nutrition or special health conditions, the blood may also have different characteristics (high / low viscosity, high hematocrit values etc), leading to unexpected results.

### 3. Accuracy

3.1. Additional to an extensive validation, following defined regulations and directives for medical devices, the Lactate SCOUT and its test strips are involved in continual quality control, combined with external and independent reference studies.



3.2. The variation of coefficiency depends generally on the lactate concentration. The Lactate SCOUT has a VC of 3-8% in a measurement range from 0,5 - 25,0 mmol/l. This means a "lab-like" accuracy of this pocket device even for readings in high concentrations and for special applications.

3.3. Low variations during repeated measurements are not caused by potential inaccuracy. As mentioned before, the sample quality also variiies by metabolic processes (continual production or elimination of lactate), increased cleaning effect by repeated wiping of blood or new generated sweat on the skin.

3.4. To reduce additional influences, do not change the sampling area. Different finger tips or change from the finger tip to the earlobe may cause different results. Different readings caused by different test strip batches are very low, as also known by lab analyzers.

3.5. Caused by the high potential of interferences in lactate measurement (much bigger than in glucose measurement) and the specific characteristics of different analyzers, no “gold standard” is defined in the market yet. For comparison reasons, the general impression of the characteristics and trends of lactate curves (given from step tests) is much more meaningful than a comparison of fixed values. Established worldwide, the EKF BIOSEN devices are used as “quasi-standard” for the calibration of Lactate SCOUT-test strips.

3.6. Independent reference measurements and studies show a good correlation of the Lactate SCOUT to lab analyzers from EKF BIOSEN, Eppendorf EBIO, Radiometer ABL, Yellow Springs (YSI), Hitachi and Analox.

## 4. Trouble shooting

4.1. The main problem are significant high values in rest or at moderate effort level, caused by sweat contamination. Simple cleaning with alcohol swabs is not sufficient (and dilutes the blood drop additionally). Sweat can be removed with water only! All Lactate SCOUTs are delivered with a water spray bottle, to use before each sampling again. After cleaning, the puncture area must be dried.

4.2. High resting values may also caused by general stress, metabolic or health problems, by diet or meals before. Usually, the values will come to a regular level (about 2 mmol/l) during the first training steps. If the values are continually high or significantly increasing (regardless the sampling procedure was correct), the step test should be aborted for a medical check of the patient.

4.3. As shown by experiences, the lactate content in a fresh blood drop is not concentrated equally always. Thus it is recommended to generate only small blood drops (“pinheads”) when using test strips for measurements with reliable results. Analyzing bigger blood drops (as usual for lab devices, requiring bigger sample volumes) may lead to significant variations of readings.

# BIOSEN C\_/S\_line

## FUNCTION AND FEATURES

### 1. Pocket or lab device?

For regular diagnostics, it makes no real difference which kind of device is used (regarding the generally limited comparability of readings, caused by different device characteristics). The decision depends much more on economical views (device costs and costs per tests) and the frequency of measurements. If more than 200 measurements per month are carried out, and portability does not matter, an automatic lab analyzer like the BIOSEN should be preferred. They are very comfort to use with touchscreen display, automatic control mechanism and easy maintenance. As explained above, lab devices are also the best choice for industrial applications, if different kinds of sample must be handled, or if a wider measurement range is required.

As well as the Lactate SCOUT, the BIOSEN devices operate on the base of enzymatic-amperometrical detection as an established measurement method also for lactate diagnostics. If the sample content reacts with the biosensor (coated with the enzyme lactate oxidase), an electric signal will be generated and read by the device. An alternate method is the photometric detection. Hereby the sample reacts with a optoactive reagent. Lighten by a small lamp (LED), a photo cell behind a prism reads the optical refraction. Only few old lactate analyzers use photometric detection, with low comfort and high risk of wrong readings. Modern photometric analyzers for convenient use are build e.g. for hemoglobin and hematocrit measurements. A very popular and well established device is the EKF Hemo\_Control.



### 2. Sample handling

In difference to test strip devices, samples for lab devices has to be uptaken by sip-in capillary tubes (typically 20 µl volume). These tubes must be filled properly, without enclosed air bubbles. Sample rests on the outside of the tube must be wiped away carefully. After sampling, the tubes will be deposed into pre-filled reaction cups. Closing the cup and shaking three or four times (avoid foaming!), the liquid in the cup dilutes the sample. Now the sample is hemolyzed and ready for measurement. Especially by using the reaction cups of EKF it's also possible to collect the samples (e.g. during an outdoor-step test) and to carry out the measurements in the lab afterwards (within 24 h, or 5 up to 14 days if stored refrigerated or frozen). The samples are stabilized on a special way herein, what's very useful and a big advantage regarding the general high instability of lactate samples. Depending on demand,

the devices can be designed for measurements of 1 or 5 cups (for GPs or small labs), or featured with removable sample trays for 15 up to 63 cups. The results of each measured sample cup get an own ID and will be stored completely in the device memory, to recall by touchscreen or by connected PC with suitable software tools. For additional sample or measurement information, BIOSEN devices can also be featured with an internal Barcode reader.

### 3. Wet chemistry operation: Advantages and special notes

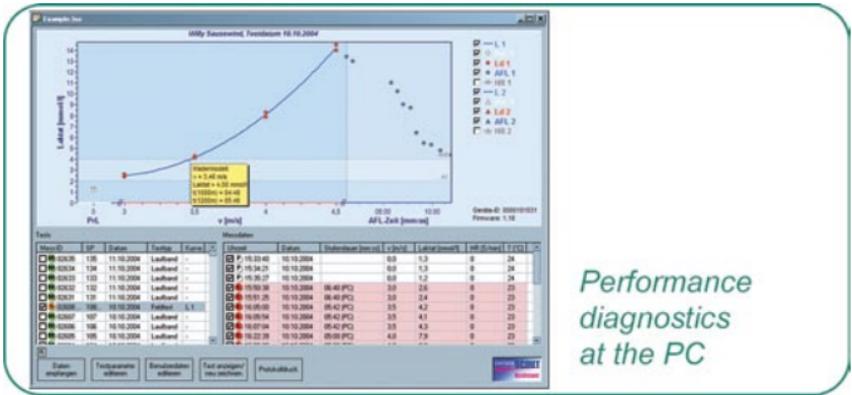
In difference to pocket devices with disposable test strips, lab analyzers are featured with re-usable chipsensors for long-term use (e.g. to replace after 6.000 measurements or 50 days). The better this capacity can be used, the lower are the costs per test. The return of investment for lab devices, compared to test strip devices, can be calculated easily by the average frequency of tests per month. Typically, the chipsensors were inserted once only and remain into the device during their full lifetime. They must be activated after insert, and supported continually by a special system solution. This means operating by “wet” chemistry, in contrast to “dry” reagents of test strips. By this reason, lab devices shall not be switched off or removed repeatedly. For best functionality it is also recommended to clean and to disinfect the tubes and fluidic systems all six months. BIOSEN devices are designed for low material consumption and continual readiness. For save and comfort use, all BIOSEN devices are featured additionally with automatic control functions, to display required customer actions in time. All consumables, disposable items and maintenance parts are well accessible, quickly and convenient to handle. E.g., to change a chip sensor of BIOSEN devices is very similar to change a SIM card from a mobile phone - it is done in a few seconds!



### 4. Calibration and quality control

Another advantage of wet chemistry analyzers is the option for continual calibration. Regardless of the typical influences from sensor age or frequency of measurements, it is possible (and recommended) to adjust the accuracy everytime. Therefore, most manufacturers support their devices with special calibration solutions (“standards” for lactate, glucose or all-in-one “Multi-Standard”). EKF BIOSEN devices are featured with selectable calibration frequencies (each measurement, every hour, time schedule settings) to fit all customer needs herein. Additionally, control measurements can be carried out by liquids with defined concentrations. There’s a wide range of different control materials, depending on the specific application and the typical range of readings. By controls with different concentrations (e.g. with 2, 7 and 18 mmol/l lactate) it is

possible to check the linearity of a system, what's very important for meaningful results at all.



## ANALYSIS CONDITIONS AND SOLUTIONS

### 1. Basic principles

1.1. The main application of lactate diagnostic is sports-medical training control. A professionally scheduled training arranges different effort units at the aerobic level (for endurance and basic performance) and at the anaerobic level (for stimulation and power increase) in different time frames for specific targets. Depending on the level and on the kind of effort (running, cycling, swimming), the heart rate can vary significantly herein. To figure out the suitable heart rate in the different training steps, lactate values are very helpful caused by their direct relation to individuals metabolism, to get accurate information of personal changes and limits.

1.2. By the same reason, a "lactate curve" is never standing separately, but always related to the kind, the duration and the intensity of effort. These data must be noted and have to be respect in any calculation and interpretation for a meaningful training analysis.

1.3. To calculate the effort units easily and precisely, software solutions get more and more popular. Instead of typing all data manually, settings and readings of training devices can also be imported directly by PC-link, e.g. from Polar heart rate monitors, bike ergometers, treadmills and lactate analyzers. The most established professional software solution is Winlactat from Mesics, scanning data from h/p/cosmos, Ergoline, Lactate SCOUT, BIOSEN and other equipment. For small budgets are also offered limited solutions as Lactate Express (Polar and Lactate SCOUT only) or Lactate Assistant (Lactate SCOUT and BIOSEN only). Trial versions can be download in the Internet.

1.4. The Lactate SCOUT as well as the EKF BIOSEN devices are generally featured by serial PC interface, to connect by special cable or wireless Bluetooth-adaptor. Data can be transmitted from memory (up to 250 readings stored in the Lactate SCOUT, up to 500 in the BIOSEN) and after each measurement. Additionally to the named products, the Lactate SCOUT is supported by many other software solutions as a "quasi standard".

## 2. Analysis methods

2.1. The 4 mmol/l-model of Mader is a popular method to define the average lactate steady state. In the past years, sport scientists have developed manifold alternate models to determine the individual anaerobic threshold. These formulas are based on complex studies, but hardly to adapt by amateurs in their regular training. The most common models are (named by the scientists) Dickhuth, Keul, Simon, Stegmann or Kindermann. E.g., the Kindermann method respects the elimination rate of lactate instead of its increase, to deduce training recommendations from.

2.2. The growing experiences of lactate diagnostics in new application fields will expand the demand and the Know-How of suitable and usable interpretation models herein. Currently, the analysis of the total shape of a lactate curve (the "lactate kinetic") seems to be a promising way to get a proper impression of individuals metabolism conditions even for amateurs or for therapeutic use. Caused by new scientific studies and by the continual use in coaching practice, further results and progresses can be expected very soon.

Please ask for further information, available as download or printed brochures for free:



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Select a device and click to the "VisiGuide" button!



VisiGuide Hemo\_Control



VisiGuide Lactate SCOUT



VisiGuide BIOSEN

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