SCUBAPRO DEEP DOWN YOU WANT THE BEST

HEARTRATE MEASUREMENT FOR BETTER WORKLOAD ASSESSMENT

scubapro.com

SCUBAPRO

TABLE OF CONTENTS

HEART RATE MEASUREMENT DURING DIVING

The heart rate is an important indicator for arising stress. This has been known for a long time. The sports industry has reacted to this and is offering an array of products for ambitious athletes to analyze and evaluate their training. Whether a passionate recreational athlete, a professional marathon runner or a health-conscious retiree – today a heart rate meter is almost a standard piece of equipment. So why not use this technology in diving as well? With the aid of a heart rate monitor you can keep an eye on the heartbeat underwater as well and are thereby able to make your dives even safer. By monitoring the heart rate, the workload can be better assessed and the diver can react to heightened stress in a timely manner. Furthermore, by measuring the heart rate you can specifically train to increase your endurance in advance.

Since increased exertion while diving in deep water increases circulation and this in turn increases the nitrogen uptake, the heart rate can also be used to calculate decompression times even more accurately and make diving even safer. That's why the SCUBAPRO computers don't just show depth, no-stop times and the decompression schedule but also continuously inform the underwater athlete about his or her own heart rate, i.e. his or her personal stress, which in turn is factored in when calculating other dive parameters.

However, there are several factors to consider when using the heart rate while diving. This booklet will help you to better understand the background and thereby draw the right conclusions from the heart rate behaviors measured. That way, you'll be able to make optimal use of this innovative technology integrated in most SCUBAPRO computers.

To make this fitness booklet easy and quick to use and to make the contents as readily understandable as possible, the table of contents consists of frequently asked questions with regard to heart rate, fitness and diving. This way, any interested diver only needs to take a quick glance at the table of contents in order to find the chapter that contains the answer to his or her question.

Listen to your heart!
Written by:
Dr. Uwe Hoffmann
Dr. Tobias Dräger and
Jörn Kießler (editor)

SCUBAPRO

HOW THE HEART RATE IS MEASURED

There are many ways to measure the heart rate. As an amateur, you can feel the heart rate on the lower arm artery or on the carotid artery, for example, and count it for a set amount of time – usually 15 seconds. You can also hear a heartbeat when putting your ear to another person's chest. In medical practice the heart rate is usually captured by a electrocardiogram (ECG). Every heartbeat produces a measurable electrical signal. Using at least two electrodes, one on each side of the heart, this signal can be measured from the exterior of the body.

Many heart rate monitors used in sports apply this technique and incorporate such electrodes into chest straps. The electronic devices inside the chest strap search for the electrical impulse every heartbeat produces. The registered impulse is transmitted as a signal to the receiver, e.g. a heart rate monitor, and then analyzed. For this application it is essential that the two electrodes remain in contact with the chest at all times.

WHILE DIVING

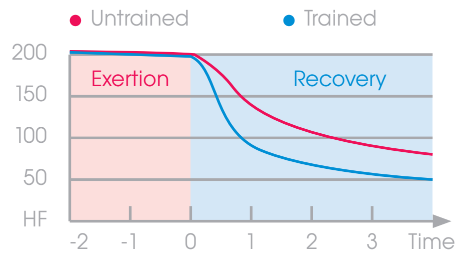
And that's exactly the measuring principles used by SCUBAPRO computers as well. With a waterproof chest strap featuring two electrodes, the electrical impulse of the heartbeat can also be captured underwater.
However, the data is not sent to a simple heart rate monitor but to the dive computer. And the computer does exactly the same thing a heart rate monitor does, for example, while someone is jogging: it shows the heart rate the diver is experiencing a that moment. Of course, it also stores the data, so that after the dive it is possible to reconstruct exactly at what point the workload was especially high or especially low. One special feature of SCUBAPRO computers with which no regular heart rate monitor or traditional dive computer can compete, is that the diver's heart rate is factored into the calculation of the no-stop, decompression and ascent times. Instead of relying on a single algorithm, current personal data is utilized.

To this end, SCUBAPRO computers display the median heart rate over a set period of time, e.g. every four seconds. Using this technique, it is possible to capture the heart rate at rest and during physical exertion easily and without much disruption to the person concerned.

Heart rate measurement under water using the chest strap

RESTING HEART RATE - HOW IS IT INFLUENCED?

What exactly is the resting heart rate and how is it influenced? The resting heart rate is the heart rate a person has when he or she is not exerting himself or herself. To determine its reliably, the resting heart rate should always be measured under comparable conditions. Important factors are timing – usually it is determined in the morning five minutes after waking up – and body position. Ideally, the person should remain lying down in bed during the measurement. The most reliable results are delivered by a heart rate monitor in this case as well. If none is available, you can also count the heartbeats for 20 seconds and then extrapolate this to one minute, i.e. multiply the number by three. However, if you count the heart rate yourself you should keep in mind that even counting will influence the heart rate. The important thing is that the method of measurement should always be the same.
On the one hand, the resting heart rate measured provides you with a value to easily compare yourself to others. However, the role of the resting heart rate as an indicator for the overall workload is much more important. For exertion both underwater and on the surface, the resting heart rate serves as a point of reference in order to assess and classify acute stress.
Of course, not everyone has the same heart rate since every person is different. And it's exactly these differences that influence the respective heart rates. For example, age, body height (not just body position) and the size of the heart are just three characteristics that explain the differences between the values of different individuals. For example, past exertions on the previous day, diet, fluid intake, time of day, ambient conditions (temperature, humidity, altitude), and body position are all factors that influence the heart rate. But also acute changes have an impact on the resting heart rate. For example, breathing always plays a role with regard to the level of the resting heart rate. It influences the heart rate through its impact on the blood supply and drainage to and from the heart.
Among other things, an elevated respiratory rate – due to excitement for example – also increases the heart rate. After an exertion, the heart rate of an endurance-trained person drops back down to its base level more quickly than the heart rate of an untrained person.



Return to base heart rate dependent on training status

WHILE DIVING

The resting heart rate indicates "the lowest limit" that a diver could reach. Certainly, no dive is started at the "true" resting heart rate, since putting on the gear alone is often strenuous enough to boost it.

In combination with the maximum heart rate, you can at least define the range within which the heart rate fluctuates. This way, just one glance at a SCUBAPRO computer will tell you how high your level of exertion currently is, based on completely objective criteria. Keep in mind however that, particularly while in the water, it is conceivable that a heart rate below the actual resting heart rate can temporarily occur. Why? Simply because basic environmental variables change and affect the body when you plunge into the water. The sum of the effects described below makes the heart rate slow down underwater.
This slowdown needs to be considered when interpreting the changes in heart rate.

CARDIAC OUTPUT, BLOOD PRESSURE AND WORKLOAD

The heart is embedded between the two lungs and works like a displacement pump: blood is valve-controlled and sucked in through the superior and inferior caval vein via the right heart side , loaded with new oxygen via the lung, and discharged again through the large body artery (aorta) via the left side of the heart.
For the body, the heart rate is really a secondary factor. There is no place for the body to capture the heart rate directly. Similar to a gas pedal in a car, the optimal heart rate at any given time is determined by other factors. For example, you would never drive full speed at rush hour in the city. Nor would a driver ever crawl along an empty highway at 20 miles per hour. So, just like the traffic conditions determine the speed of a car, supplying the tissue – in particular with oxygen – is central to the organism. If the tissue is using up a lot of oxygen, the heart steps on the gas to pump a certain amount of blood per unit of time through the tissue. Therefore, the critical factor is the cardiac output, that is to say the amount of blood that is pumped through the body within one minute of time, for example.
A second factor is the distribution of blood within the body. This is measured by the blood pressure, which can be determined by the organism based on how much the vessels are stretched.
The way the system works couldn't be easier. As soon as there are signs of insufficient circulation, compensation mechanisms are put into action. The body reacts to the imminent undersupply.

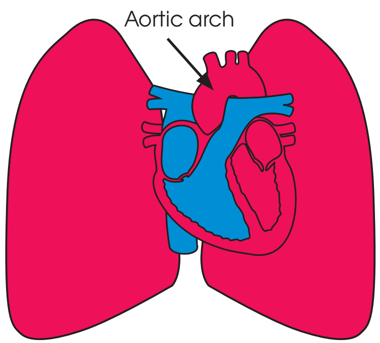


Diagram: Cardiopulmonary System

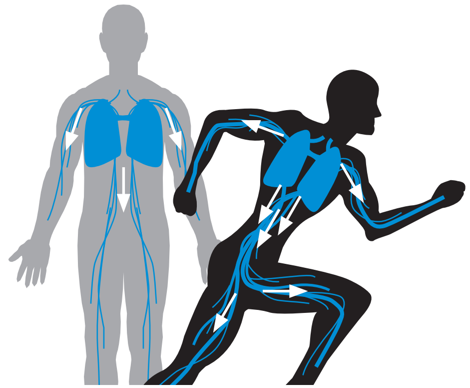
An Emergency situation is communicated to the body by sensors and the central nervous system. In particular, information from the central organs, like the brain itself, is processed. Two compensation mechanisms are possible:

- Locally, better circulation can be achieved by opening the arterial vessels, i.e. the body provides the blood with supply channels that are as large as possible. To use the car metaphor again: the body clears the highway for the blood. This way, it can get to the undersupplied areas quickly.
- Centrally, cardiac output can be ramped up by increasing the stroke volume and/ or heart rate: the body steps on the gas.

A special measure for the interaction between local circulation and cardiac output is the arterial blood pressure. It determines how fast the blood flows and therefore how fast substances are transported back and forth. If the arterial vessels are dilated and offer less flow resistance, the cardiac output needs to be raised to maintain the blood pressure – the heart rate increases.
If the blood pressure is high, that is if the vessels are constricted, it's the other way around. In this case, the heart rate is lowered. Keeping these facts in mind, it is worthwhile to take a closer look at how the cardiovascular system reacts to increased muscle activity. Because here, a special case comes into effect.

MUSCLE ACTIVITY

When muscles are flexed they depress the nearby vessels, which increases the vessel resistance. This should lead to an excessive increase in blood pressure, so the heart rate should actually slow down as a result. However, just the opposite happens because the physical activity triggers complex processes in the brain, which lead to changes in blood pressure. The metabolic process caused by the contraction, the metabolites produced and the heightened impact of the sympathetic nervous system lead to further changes that cause the heart rate to increase. Because when the performance level increases the active muscles must be supplied with more blood. Nutrients and especially oxygen have to be delivered in larger quantities, metabolites, especially lactic acid and carbon dioxide, as well as heat have to be removed. This requires an increased cardiac output.
As the stroke volume (meaning the amount of blood that is pumped through the heart by a heartbeat) limits the ability to increase the cardiac output, the greater need is mainly met by the heart rate. The rule of thumb is: the heart rate rises proportionally to the metabolism.



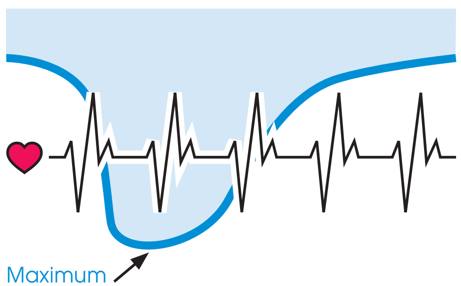
If the workload is high, more oxygen needs to be transported to the muscles, so the vessels are dilated

Let's use the car metaphor again. In a car (blood) certain passengers (oxygen and metabolites) are to be quickly transported to the requested location (muscles). Because the car can only be enlarged to a limited extent (limited stroke volume) and therefore can only accommodate a limited number of passengers, the pilot (heart) has to drive more often and therefore steps on the gas (heart rate). Responsible for the reaction to such changes –(that cannot only be caused by strong temporary exertion but also by a change in position) are special stretch receptors on the aortic arch and at the bifurcation of the carotid artery. They deliver the necessary information that is processed by the central nervous system to quickly adapt the blood pressure to the new situation. However, it is also crucial whether it is static work done over a longer period of time or dynamic work that allows for a continuous blood supply to the muscles. This type of muscle activity occurs with all types of locomotion, so with finswimming in particular as well. Here, the performance level is the decisive factor for the heart rate setting: if a person swims faster or has to fight strong currents he or she needs more oxygen in the muscles used than somebody who calmly glides over a coral reef with an occasional fin stroke.
This greater need for oxygen does not mean that the breathing rate needs to be increased immediately to raise the oxygen uptake, but rather that more oxygen needs to be transported to the muscles used.

WHILE DIVING

On the previous two pages we've explained what means the body uses to adapt to certain situations. Of course, these mechanisms are also effective in diving, both before the dive and later underwater. Carrying and putting on heavy equipment is usually already the first physical strain, which does not only exercise the muscles but also the cardiovascular system.

Even more strenuous is when you are in the water with the equipment, which gives a strong water drag (much stronger than the air resistance during jogging or bicycling) and you are moving along by finning, your muscles and heart are being exercised. Obviously, the faster you swim the more physical effort is required. But this relationship is also heavily dependent on the diving equipment worn and the movement technique employed. A diver who has a refined, economic finning technique needs to exert himself a lot less to achieve the same velocity than a swimmer with less training. However, in this context the heart rate can't be used as an indicator for the absolute metabolic value. Heart rate is a useful tool to measure and prove changes in one's physical fitness, but it is not the best and only one.



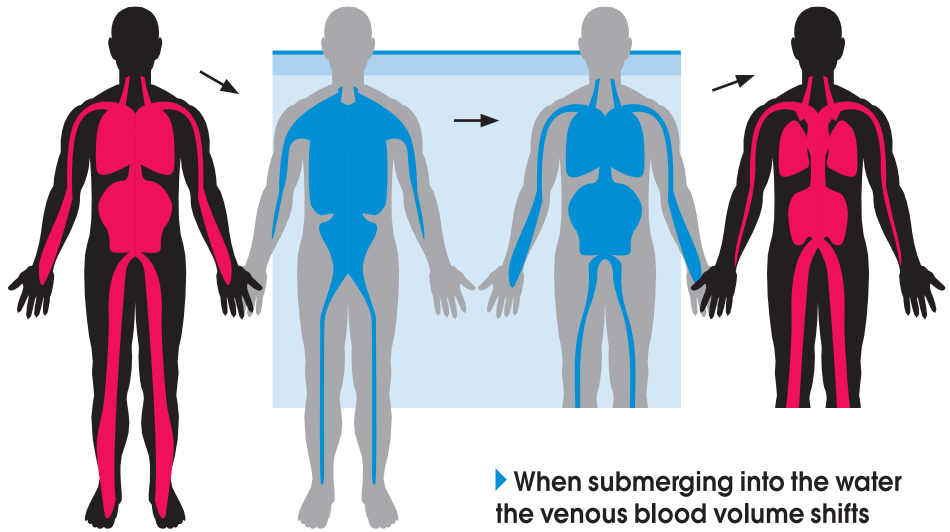
▸ The heart rate behaves independently from the depth

INFLUENCE OF BODY POSITION ON THE HEART RATE

The body position also influences the heartbeat. In particular it determines the venous return to the heart: in a horizontal position for example, when the body lies more or less on an even level, more blood can flow to the heart. Why? The answer is very simple: when standing up the blood moves to the lower extremities. The blood has to flow against the hydrostatic pressure gradient – meaning virtually against the force of gravity – back up to the heart. But if you are lying down and thus move your legs, torso and head at the same level, the blood volume shifts: blood from the legs moves to the heart whereby initially the stroke volume increases and the heart rate decreases. The reason for this is the increased blood supply to the right heart chamber (ventricle, atrium), which the body interprets as a signal for a higher fluid balance –, since this is exactly what also happens when you drink a lot and the blood volume rises as a result. In both cases, another compensation mechanism takes effect: more urine is produced. This increased urine production and the resulting blood volume reduction will over time compensate for at least part of this effect. When you stand up again the exact opposite happens: the stroke volume decreases and the heart rate increases. The blood volume increased once again through fluid supply.

WHILE DIVING

As just described, this effect arises from the influence gravity has on the body. If the body moves to a horizontal position it neutralizes gravitation to a certain extent.
And exactly the same thing happens when the body is submerged in water up to the neck, because the water pressure



▸ When submerging into the water the venous blood volume shifts

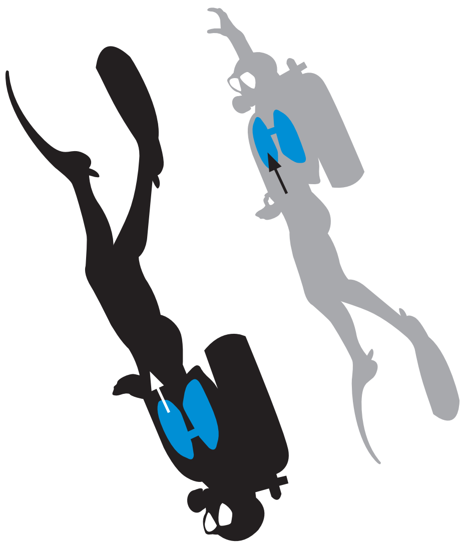
neutralizes the pressure gradient effective outside the water.
When submerging into the water, the venous blood volume shifts: outside the water (left red) a large portion of the volume is found in the leg veins. After submerging (right blue) the volume shifts towards the chest/heart. This affects the cardiac output and leads to an increased urine production. Thus, the blood volume is significantly reduced after diving.

However, as already explained in the previous chapter, the position within the water also affects the heart rate, though no longer because the blood shifts, but rather because the position within the water affects the breathing (see figure on page 9).

CHANGE OF HEART RATE THROUGH BREATHING

Previously, we've explained how physical exertion and body position affect the heart rate. But there are other factors that influence the heartbeat as well. One of which is breathing. Of course, a person's breathing and in particular the breathing volume is often times impacted by physical exertion. When muscles and tissue need a lot of oxygen, the vessels are dilated and the heart pumps quickly, the necessary amount of oxygen needs to get into the system via the lungs, i.e. through breathing. The breathing rate and breathing volume increase. You inhale more air into the lungs more often. But even when you are not puffing like a grampus, heart and lung function are closely interconnected. This is due to the way the human body is constructed: namely that the heart is embedded between the two lungs (see figure on page 6). Therefore, any negative or positive pressure in the lungs also affects the activity of the heart.
During inhalation the lung develops a negative pressure, which causes air to be sucked in through the pharynx.
This negative pressure provides for a better venous return flow, but simultaneously also for a light decline in arterial blood pressure.

The cardiopulmonary system shifts according to the body position



During exhalation it's exactly the opposite. Especially during exhaling on exertion, for example during pressure equalization using the Valsalva maneuver, the venous return flow is impeded, but the blood pressure, at least temporarily, increased. For these two blood pressure fluctuations, the body has a compensation mechanism at hand as well: the so-called autonomous regulation. It limits the increase or decline in blood pressure through corresponding heart rate reactions. As a result, more or less distinct heart rate fluctuations occur, particularly while resting.

WHILE DIVING

The water pressure that impacts the submerged body leads to a greater pressure difference between the gas-filled and the fluid-filled part of the lung, because unlike the fluid-filled part the gas-filled part can be compressed, i.e. squeezed. The rule is: in an upright position the difference is greater than in a horizontal position. So, if you are floating under water in an upright position, for example during a short break in order to look at something more closely on a steep face, the blood pressure fluctuations of the body are more extreme as well. But this effect can also occur while swimming in a horizontal position, namely while snorkeling. A snorkel can increase the pressure difference as well. It too directly impacts the return flow to the heart and therefore influences the heart activity and the heart rate.

HEART RATE WHEN IN APNEA

So, breathing influences the heart rate. But what happens when you are not breathing? Particularly while diving? Of course, you can also hold your breath above water, but during a dive it can be absolutely necessary – for example while buddy breathing. And there are different «levels» of holding your breath , the diving reflex and apnea diving, that is to say intentionally diving without a compressed air tank, just using the air in your lungs.

THE DIVING REFLEX

The diving reflex is a natural reflex that allows mammals to stay under water for extended periods of time. It is especially pronounced in aquatic animals, but also detectable in humans. The trigger signal is a facial cold stimulus, so water as well, which is designed to extend survival. This cold stimulus, which can be triggered by an ice pack pressed to the face for example, also triggers an easily measurable reaction while resting: the heart rate slows down (bradycardia).
This is due to receptors around the nose, eyes and mouth. The slowdown of the heart rate can reach more than 10 heartbeats per minute in humans, in animals a slowdown of over 50% has been shown.
This bradycardia is accompanied by other reactions used by the body to adapt to the new situation. The blood vessels in the tissue, which can function without oxygen for a short period of time, constrict (vasoconstriction).
This way, oxygen is conserved for vital organs (for example the central nervous system or the heart) and simultaneously an increase in blood pressure is prevented.

The more pronounced the vasoconstriction, the greater the slowdown in heart rate. This virtually means that the diving reflex leads to the exact opposite reaction physical exertion brings about. While the body increases the heart rate during exertion in order to be able to supply the entire tissue and therefore dilates the vessels so the blood pressure doesn't go through the roof, under apnea all systems are geared towards conservation.

APNEA DIVING

During apnea diving, exactly the same effects occur since the face comes into contact with water in this case as well. However, apart from the aforementioned reactions additional compensation mechanisms of the body come into effect, some of which have already been described. For example, the blood volume also shifts towards the heart when diving without a compressed air tank (see «Influence of body position on the heart rate»). During apnea diving this effect is even more pronounced, because the air-filled lungs are being compressed more and more the deeper the diver goes, which leaves more space for the blood flowing into the chest area.
This doesn't have any additional impact on the heart rate however, since this shift in blood volume prevents the build-up of negative pressure in the chest area and thus a barotrauma of the lungs. But another factor (which hasn't been mentioned before and which only exists during apnea diving) further slows down the heart rate: the rise of the carbon dioxide ratio. The longer an apnea diver is under water, the higher the CO_2 ratio in his blood gets. This leads to an additional slowdown of the heart rate. Physical exertion during the apnea time, like dynamic apnea, further intensifies this effect.

FLUID BALANCE AND HEART RATE

The question of how the fluid balance impacts the heart rate can be easily answered by applying what we've learned in chapter five. That's because severe fluid loss or excessive fluid intake has the same effect as a change in body position or getting out of or into the water, however for different reasons (see figure on page 9). If the body is supplied with fluid by drinking, the amount of blood available to the heart also changes: the stroke volume increases and the heart rate slows down. The opposite case, too little fluid, has the same effect as getting into an upright position or leaving the water: the stroke volume decreases, and the heart rate speeds up.

WHILE DIVING

Regarding the fluid balance a peculiarity needs to be pointed out as well. On a diving vacation in particular, several factors combine that can have a strong impact on the heart rate. As described earlier, during the dive the blood volume shifts towards the heart. This signals the body that there is a perceived fluid surplus and the body begins to produce urine in order to release fluid (diver's diuresis). After the dive, the blood volume doesn't only shift back towards the lower extremities and away from the heart (see chart on page 9), but two additional factors come into play: a low fluid balance and high heat. At many popular diving destinations, like the Mediterranean, the Red Sea and the Indian Ocean, temperatures are very high. Here, an adequate fluid intake after the dive is essential as the blood volume will otherwise drop so severely that even an increased heart rate can't prevent an undersupply of the tissue. A circulatory collapse might result. And another, diver-specific risk increases as well: namely, to fall victim to a decompression accident during the dive. Because the lower blood volume makes the blood thicker, the viscosity rises and thus the risk that nitrogen bubbles won't dissolve in the blood and therefore cause an embolism.

HEARTBEAT - HEAT AND COLD

When the ambient temperature changes, the body exhibits a similar reaction as when fluid is supplied or withdrawn. If you go outside on the balcony in the middle of the winter just wearing a t-shirt you will sooner or later feel cold. The body counteracts the loss in temperature by constricting the vessels on the body's surface, i.e. in those places where the heat escapes. The constriction causes the pressure on the vascular walls to rise and the cardiovascular system reacts like it does to a fluid surplus: the heart rate is slowed down. Subsequently, when the body tries to stabilize its temperature by producing its own heat through an increased metabolism, the heart rate rises again. Later on, continued cold exposure leads to further adjustments, which we won't discuss here.
Heat has exactly the opposite effect. The heart rate rises because the vessels on the body's surface are dilated. As a result, blood volume is shifted to this tissue and thus missing in the venous return flow. Furthermore, the cardiac output and blood pressure need to be increased. Later on, influencing factors might follow that are caused by perspiration, i.e. fluid loss.

WHILE DIVING

Of course, the same effects occurring on the surface also occur under water. The only difference is that under water you start feeling cold much faster. The reason for this is water's higher thermal conductivity. While air is a poor heat conductor and has an almost insulating effect, water «sucks» the heat from our body, figuratively speaking. While we perceive a day with an air temperature of 25 °C (77 °F) as pleasantly warm, without cold protection and at rest the body already starts to increasingly release heat at water temperatures of below 32 °C (90 °F). The body starts to become hypothermic and tries to counteract this by constricting the vessels that are close to the body's surface.

WHY DOES EXCITEMENT MAKE THE HEART RACE

Finally, we want to discuss a change in heart rate that though it is also brought about by external influences can't be explained by temperature, water pressure or fluid amounts: emotional excitement.
During human evolution the body has learned a lot, including the concept that emotional excitement is usually related to a certain danger, which requires high performance or at least the willingness to physically react. Accordingly, stress hormones cause a change in blood pressure and heart rate. The organism is put on alert. In this sense, the heart rate is no longer an expression of physical exertion, but it prepares the body for increased requirements.
Emotional excitement also differs from person to person. A dive instructor who has been working in the Indian Ocean for many years will be less excited when sighting a whale shark than a diver who has never before come across one of these giants.
Though no matter why you are excited, whether its because you got caught up in a net or because you just spotted a tiger shark for the first time ,it is important to take emotions into account when assessing a change in heart rate!

HEART RATE TRAINING INDICATOR

As already mentioned in the introduction, the heart rate is a good indicator for arising stress. And just one glance at a SCUABPRO dive computer will immediately tell you how high the exertion under water is, based on completely objective criteria. Of course, other parameters could also be used to assess the intensity of stress such as swimming or running speed, but these can't illustrate the individual exertion in a meaningful way.

To give you an example: the heart rate of a recreational athlete would likely go through the roof if he completed his usual Sunday jogging route of 8 kilometers (5 miles) in less than 30 minutes. For a professional marathon runner however, such training sessions are part of his regular training program and his heart rate wouldn't even come close to the maximum value possible.
This example shows how important it is to know your own individual performance limits and to use them to orient yourself in order to experience a meaningful endurance training. Personal limits can be easily but effectively established by using the resting and maximum heart rates.
However, in reality these parameters are just auxiliary values, because what's key for the right training is the muscle metabolism or, more specifically, the ratio of aerobic metabolism to anaerobic metabolism. That is to say the metabolism that takes place with sufficient oxygen and the metabolism for which insufficient oxygen is available.
But since this is only measurable using elaborate technical equipment the heart rate is the easiest parameter to assess the intensity of stress. And the readily determinable resting heart rate offers an additional advantage. It makes it relatively easy to evaluate your own fitness level. One reference point is the resting heart rate, which is about 50 beats per minute for an endurance-trained person and about 75 beats per minute for an untrained person. Another reference point is the maximum heart rate, which is assumed to be about five times the resting heart rate for a trained athlete, while an untrained person can only increase it to three times the resting heart rate. The reason for this difference is the efficiency of the «athlete's heart» that offers a better transport performance. But it's not just the training status that's important ,this leads us back to the before mentioned background knowledge: the maximum heart rate is significantly restricted by a person's age. This means that older divers – even if they are well trained – can't reach the same maximum heart rate as 20 year-old divers.

A simple rule of thumb has been established for mass sports:

- Average maximum heart rate: 220 – years of age=beats per minute
- Example: a 75 year-old man has an average maximum heart rate of 145 beats per minute. 220 – 75 years=145 beats per minute
- According to this rule of thumb, the heart of a 20 year-old however could beat 200 times per minute under maximum stress. 220 – 20 years = 200 beats per minute.

But it's actually much more interesting to look at the resting heart rate described earlier. The heart rate differs greatly from person to person for a number of reasons: the point of time at which the resting heart rate is reached again after an exertion has to be compared subjectively and objectively. After an exertion, an endurance-trained person will be back at his or her resting heart rate much faster than an untrained person.

FITNESS TRAINING AND TRAINING TIPS

Based on this knowledge, it's actually quite easy to design a targeted fitness and endurance training , because you now know how to use the heart rate to assess your own stress level and thus keep your training within the right range of intensity.
There is another rule of thumb with which to calculate the average heart rate you should maintain while training.

- Training heart rate: 180 – years of age = beats per minute
  If we take our 75 year-old athlete and his 20 year-old training partner as an example once again, we can give them the following training advise:

- 180 – 75 years = 105 beats per minute
  This means that our older diver should train

at an average heart rate of 105 beats per minute if he wants to improve his endurance.

- 180 – 20 = 160 beats per minute His 20 year-old counterpart probably needs to step on the gas a bit more to reach an average heart rate of 160 beats per minute.

But there are a few basic tips that apply to both of them and that they should keep in mind when using the heart rate to control their training:

- The ambient conditions, in particular the temperature, should stay the same.
- The body position should not be changed during the exertion.
- Ensure fluid intake at regular intervals.
- Pay attention to regular breathing.
- Avoid exhaling on exertion!

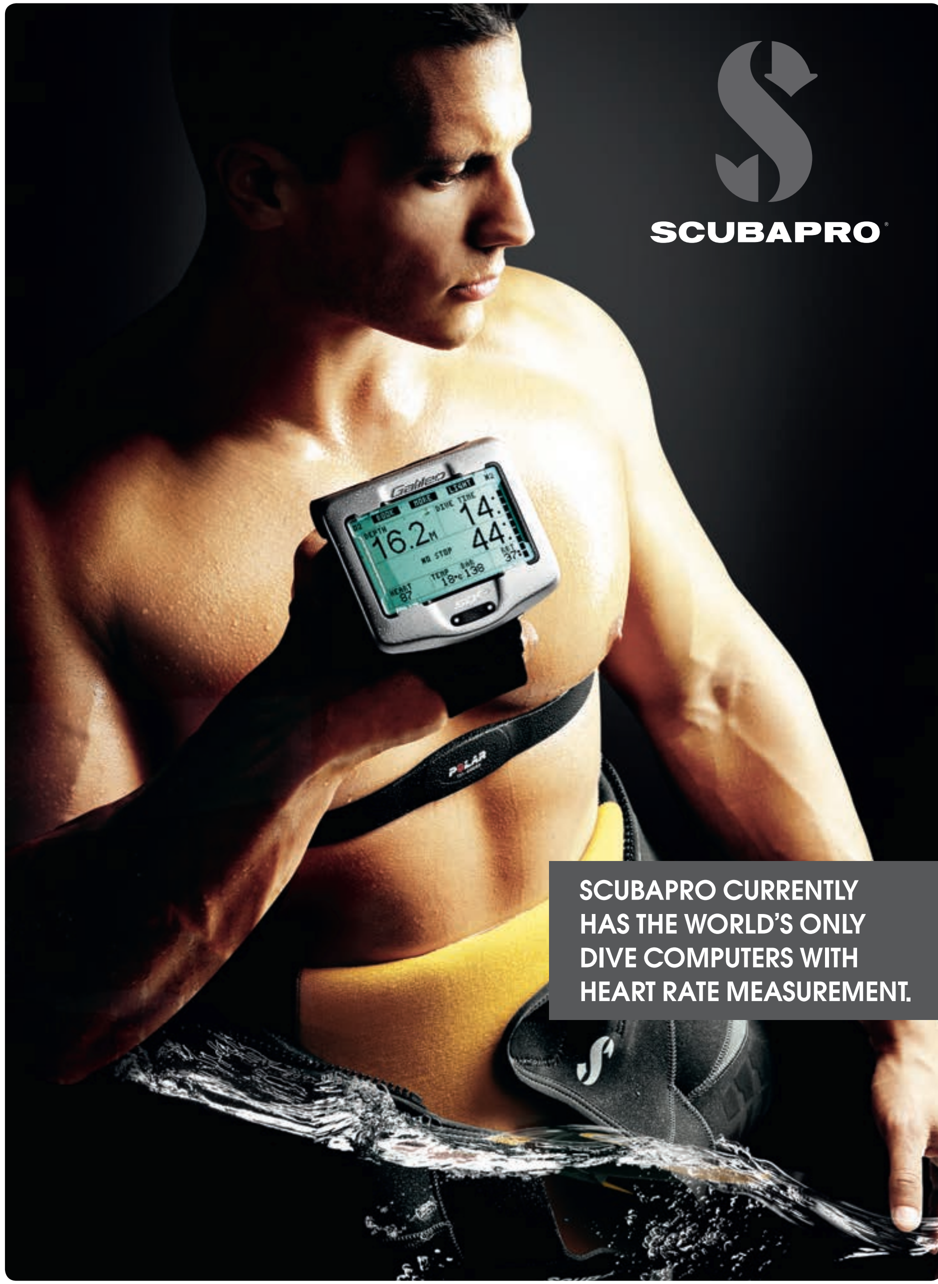
Despite all the rules described herein, the maximum heart rate, which declines the older you get, always differs from person to person. Therefore, it should ideally be determined through a physical workout. Anybody can do this with the aid of a heart rate watch by exerting himself or herself exhaustively for a short period of time. In particular for beginners, it is recommended to have a physician do an ergometry test.

WHILE DIVING

Comparing the resting heart rate before the dive to the heart rate during the dive helps to assess the physical and mental strain. A beginning diver will certainly experience a much greater difference than an advanced diver. This difference can also be used as an indicator for the physical state of the day. If an experienced diver detects a greater difference than usual he should analyze the underlying cause and adjust his dive accordingly (shallower dive, less exertion before ending the dive). A beginner can track his progress with regard to physical and mental strain as the difference gets smaller and smaller. Performing an analysis shortly after the dive on the basis of the recorded heart rate will help to determine the cause for the increase, as it could be brought about by physical strain (unusual exertion due to currents, buddy breathing, excessive weights, unusually long dive...) or mental strain (depth, excessive weights, problems with the equipment or with the buddy, joy or fear when sighting a large fish...). By recognizing the root causes, the diver can target his training to improve. For apnea diving as well, performing an analysis after the session helps to design a training program and to evaluate the diver's progress. The alarm function for an insufficient heart rate is a security aspect that is not to be underestimated.

SCUBAPRO is always striving to improve your diving experiences through innovative technologies. Measuring your heart rate while diving is one of the milestones we are especially proud of. Now and in the future, we stand behind our motto:

DEEP DOWN YOU WANT THE BEST



SCUBAPRO CURRENTLY HAS THE WORLD'S ONLY DIVE COMPUTERS WITH HEART RATE MEASUREMENT.

Adiposity - Obesity, fatness: excessive proliferation or build-up of fatty tissue.

Aerobic energy metabolism - Energy-supplying processes, which only take place when sufficient oxygen is present. (Complete burning of fat and carbohydrates to CO2 and water. Very efficient, allows for several hours of exertion at low to medium levels of intensity.)

Anaerobic energy metabolism - Energy-supplying processes, which take place without the use of oxygen. (Incomplete burning, therefore very inefficient, but allow for very high performance over a short period of time. Burning of carbohydrates, produces lactate.)

Active musculoskeletal system - Comprises the entire skeleton, musculature and the associated tendons and ligaments.

Anaerobic threshold - Stress intensity at the transition between purely aerobic and partially anaerobic energy generation. Marks the highest possible intensity at which lactate production and lactate removal are in balance (max. lactate steady state). It differs from person to person and isn't subject to any rigid law, so it should be re-determined on a regular basis.

Arteriosclerosis - Most common morbid arterial change, characterized by hardening, thickening and loss of elasticity. At an advanced state acutely life-threatening. Counter measures include moderate endurance training and dietary change.

Arthrosis - Degenerative joint disease that mainly develops due to an imbalance between the strain and the condition or performance of the individual joint parts or tissue. Regular customized exercise can prevent or ease arthrotic problems.

Blood pressure - The pressure in the blood vessels and heart chambers that causes the blood circulation and depends on the cardiac output and the vascular resistance (e.g. elasticity of the vascular wall).

Body mass index - Abbreviated BMI, calculated by dividing the body weight (measured in kg or lb) by the square of the body height (measured in m or ft). Index for evaluating the body weight.

Cardio training - Refers to the training of the cardiovascular system, mainly through endurance sports, also in a sports club or fitness studio.

Cholesterol - Is both generated by the body itself and ingested through food (primarily animal fat) and is an important and essential component for the production of many hormones. In high concentrations (permanently > 220 mg/dl), cholesterol is considered to be a risk factor for cardiovascular diseases, taking into account the ratio of «good cholesterol» or HDL (high density lipoprotein) to LDL (low density lipoprotein), the main cause for vascular diseases.

Dehydration - Decrease of body water caused by increase of water discharge (e.g. excessive sweating) without sufficient replenishment. This worsens the blood's flow characteristics in a performance-reducing manner. Severe dehydration (also dehydrogenation) can lead to circulatory failure.

Ergometry - Measuring physical performance under controlled levels of stress using an ergometer and establishing various parameters of cardiovascular function.

Fluid balance - Refers to the water intake, water distribution and water discharge processes of the human body.

Glycogen - A form of sugar (polysaccharide) that represents the stored form of carbohydrates. It is mainly found in the liver and muscles. Under intensive endurance stress with a carbohydrate utilization of close to 100% the stored reserves of an averagely trained athlete last for a maximum of 60-90 minutes of stress.

Heart rate variability - Measurement of time lag between two consecutive heartbeats in milliseconds. Based on the extent of time changes, conclusions regarding the individual training status can be drawn.

Hypertension - Elevated blood pressure

Coronary heart disease - The result of circulatory disorders in the coronary vessels. Main cause of heart attack. Can be influenced through exercise and moderate endurance training.

Lactate - Salt of lactic acid; lactate is the end product of the glycolysis and is generated when glucose isn't completely burned. This is the case when insufficient oxygen is available to the musculature during physical exertion. For example, the lactate concentration rises significantly during intensive muscle activity (see «Anaerobic energy metabolism»).

Maximum oxygen uptake - Maximum amount of oxygen the body can take up and transform during an exertion.

Metabolites - Substances that are generated as intermediate stages or decomposition products during metabolic processes within the body.

Metabolism - Entirety of metabolic processes, composition, decomposition and transformation of nutrients.

Mitochondria - The «power plants» of the cell. This is where the body's aerobic energy generation takes place.

Muscle ache - Microscopic tears in the muscle tissue caused by excessive stress, which lead to inflammation and pain. Muscle ache is a precursor to strains or torn muscle fibers and therefore should be regarded as a sports injury. Subsequent regeneration by resting the affected muscle, measures stimulating the blood flow, rehab training and the intake of fluids should lead to a complete «recovery».

Respiratory quotient - Abbreviated RQ. Describes the ratio between the CO2 exhaled and the O2 inhaled. The RQ plays a role when determining the amount and ratio of fat and carbohydrates burned.

Spiroergometry - Measuring physical performance under controlled levels of stress using an ergometer and establishing various parameters of cardiovascular function and respiration.

Side stitch (side ache) - Possible causes include reduced circulation of the diaphragm, training with a full stomach, excessive strain and irregular breathing. Increased blood flow in the body can cause pain in the spleen and liver as well.

Dr. Tobias Dräger

Studied biology, sports science, and sports economics, with a PhD. from the Deutsche Sporthochschule Köln (DSHS) in Performance Physiology. Head of Business Development at the diver emergency call center qua ed. CMAS dive instructor.

Dr. Uwe Hoffmann

Studied mathematics and sports science, with a PhD. from the Deutsche Sporthochschule Köln (DSHS) in Performance Physiology. Research associate at the Institute for Physiology and Anatomy and Head of the Sports Department of «Recreational Diving» at the DSHS. CMAS dive instructor.

SCUBAPRO®

Our Authorized Dealers will be happy to give you additional information.
You can find our retailers at scubapro.com or use our SCUBAPRO app.

Version I - March 2012