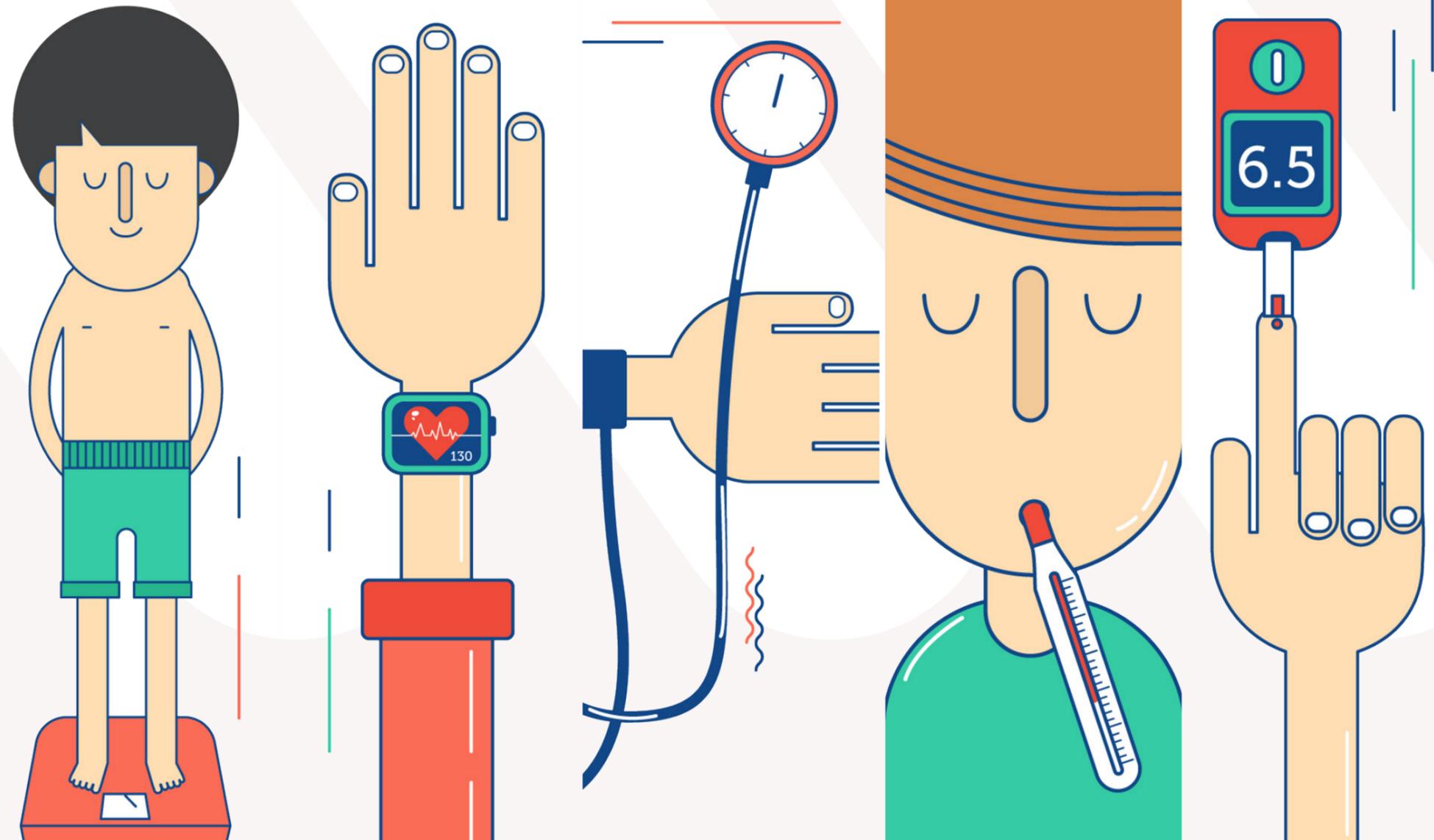


***OXIMETRY,
YES PLEASE!***

Everyone, not just doctors, knows how important it is to be aware of her or his body weight, temperature, heart rate, arterial pressure and respiratory rate. These are all vitals which supply a simple number to measure our state of health. However few people are aware of their blood oxygen level.

The vitals that everybody knows and which measure our state of health

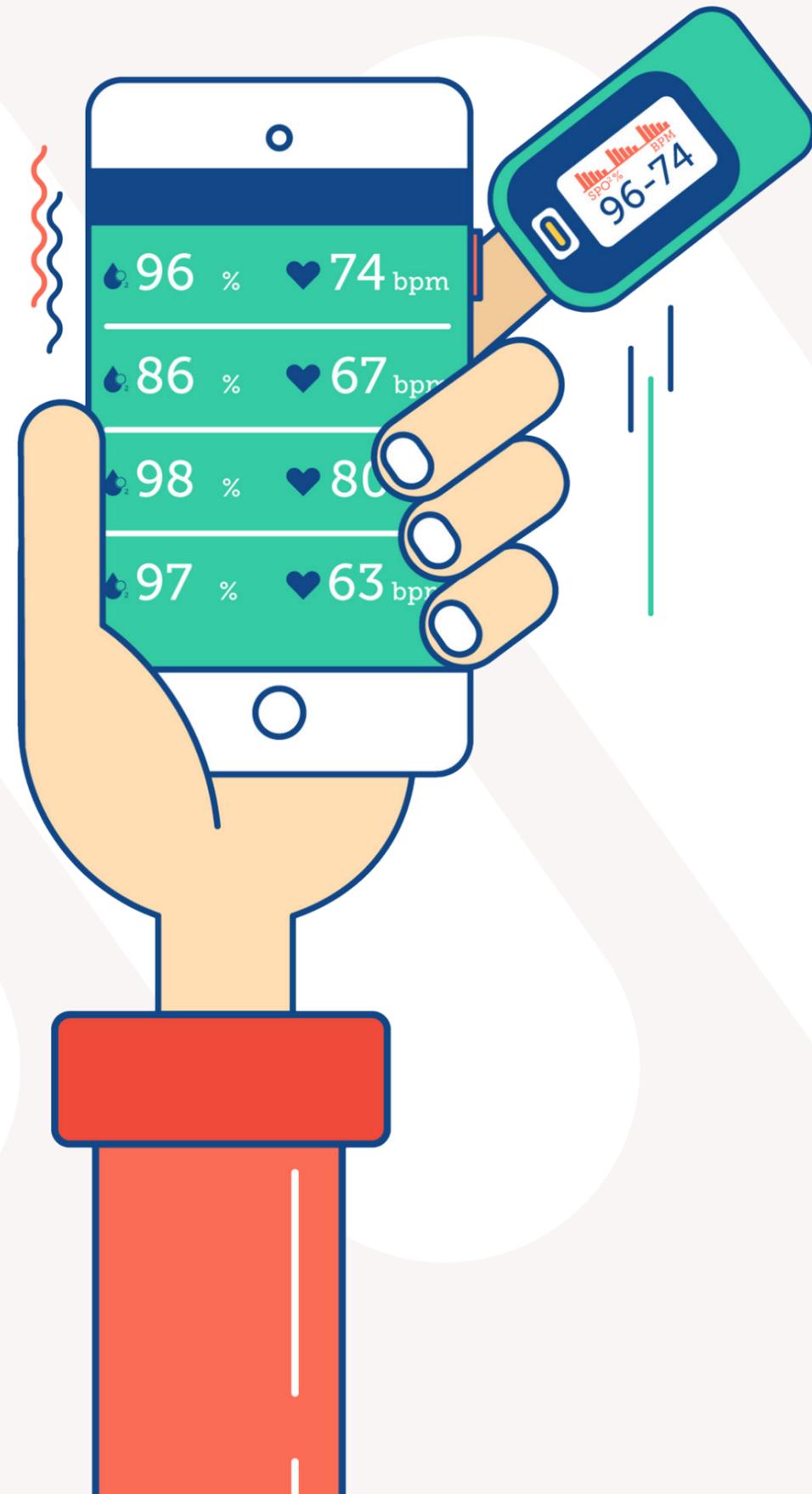
Someone perhaps has heard of Oximetry, without knowing that this is another vital sign expressed by a single number, known as SpO₂. This is a percentage measurement of haemoglobin linked to oxygen and for this reason is usually denoted using the symbol SpO₂.



Measuring another vital sign: oximetry

Oxygen is largely transported by the haemoglobin molecules present in the red blood cells. It can be said without exaggeration that when the haemoglobin is very low, as in acute anaemia, a risk of instant death exists!

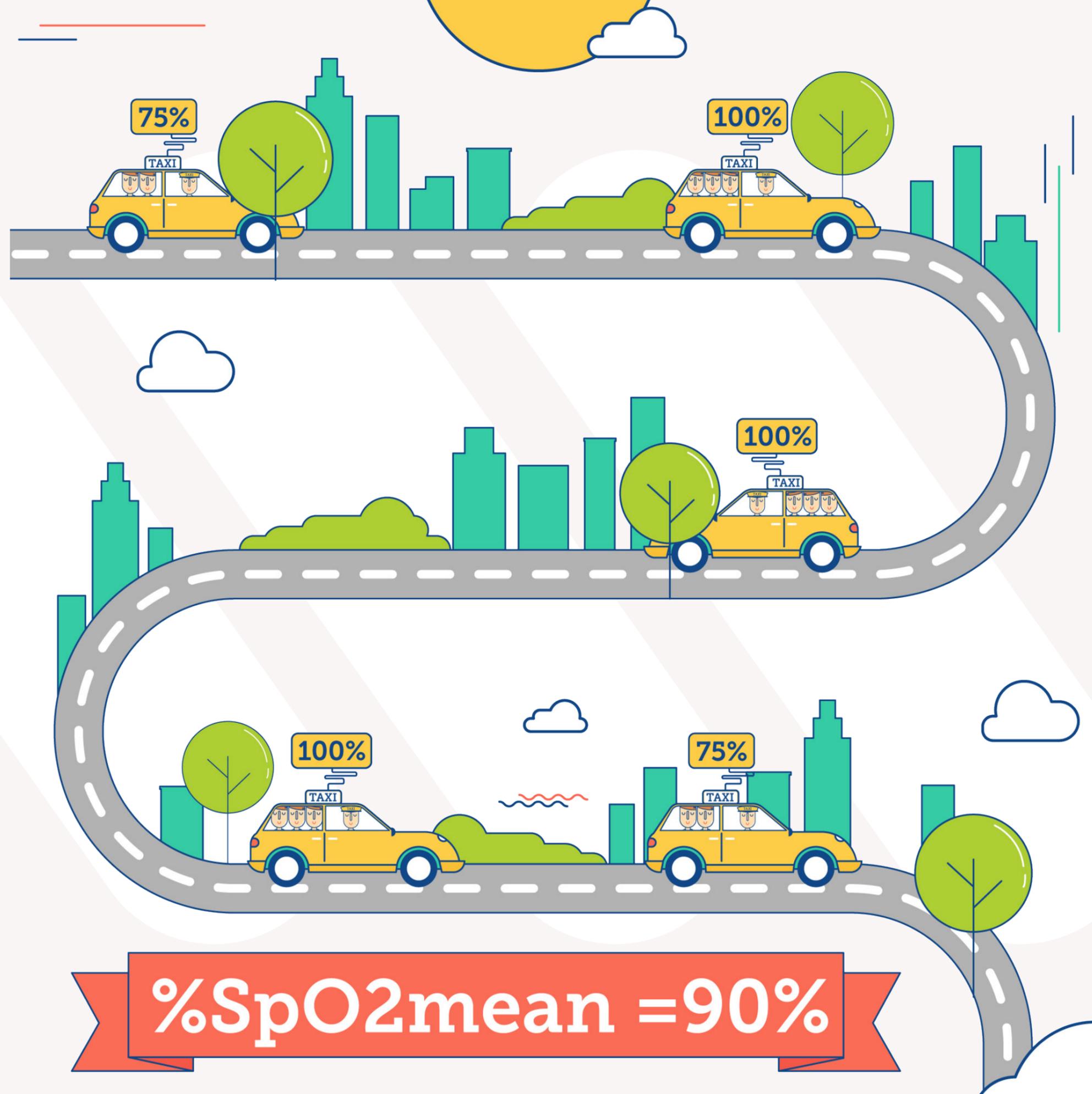
In the reality of our organism, haemoglobin molecules cannot always transport their maximum load. On the basis of our state of health, SpO₂ is at best 99%.



Haemoglobin and its ability to bond to blood oxygen

Each haemoglobin molecule is like an automobile with a load capacity of 4 passengers, represented by the molecules of oxygen entering the lung at each breath. If all the haemoglobin molecules could manage to load 4 oxygen molecules, they would be at maximum capacity: i.e. the SpO₂ would be 100%.

Normal SpO₂ values are comprised between 95–99%. When an individual has respiratory problems due to lung, cardiac or neurological pathologies, this percentage falls, with values of < 95%: the entity of the reduction will indicate the gravity of the deficit.

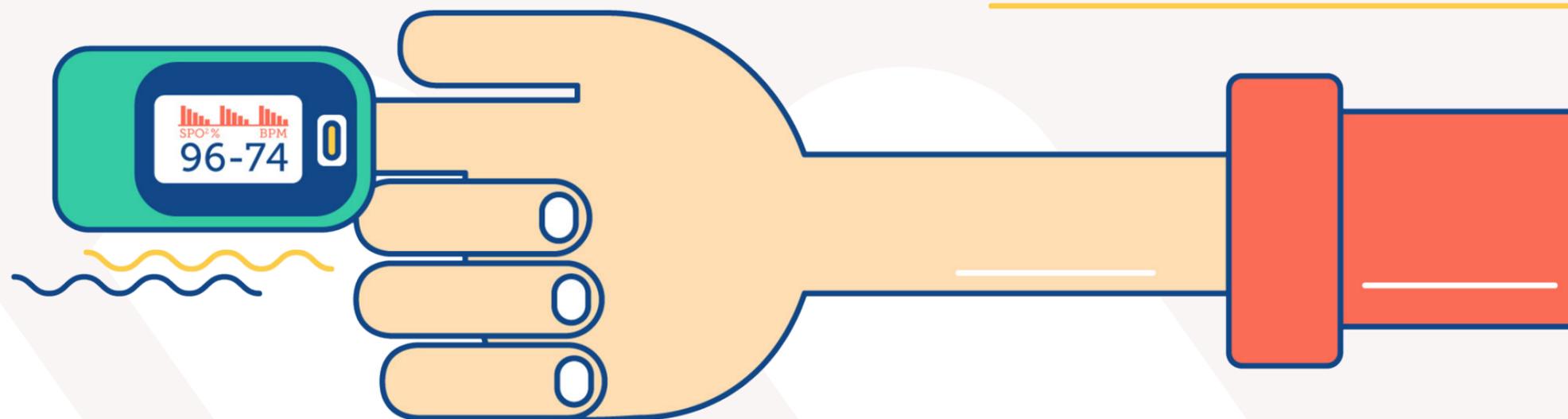


A little bit of history

The Oximeter is an instrument that measures SpO₂ in a simple and non-invasive way. Generally this instrument provides a measurement of the pulse frequency too, and is therefore also known as a Pulse Oximeter.

The first prototype was devised in 1935 by the German physician Matthes, though the actual name "Oximeter" was coined by the American Physiologist Milikan. Following on from developments made during the Second World War, in 1974 Japanese engineer Takuo Aoyagi invented the first computerised Oximeter.

How the Oximeter functions



The Oximeter calculates the percentage of oxygenated haemoglobin (SpO₂) by measuring the variations signalled in a two-wavelength light beam (red and infrared) crossing a part of the body characterised by a good arterial flow (such as the fingers or toes and the earlobes).

While it goes without saying that the Oximeter should be used with patients having respiratory symptoms such as, for example, shortness of breath, its use is less obvious, especially, in apparently-asymptomatic individuals when a respiratory, cardiac or neurological

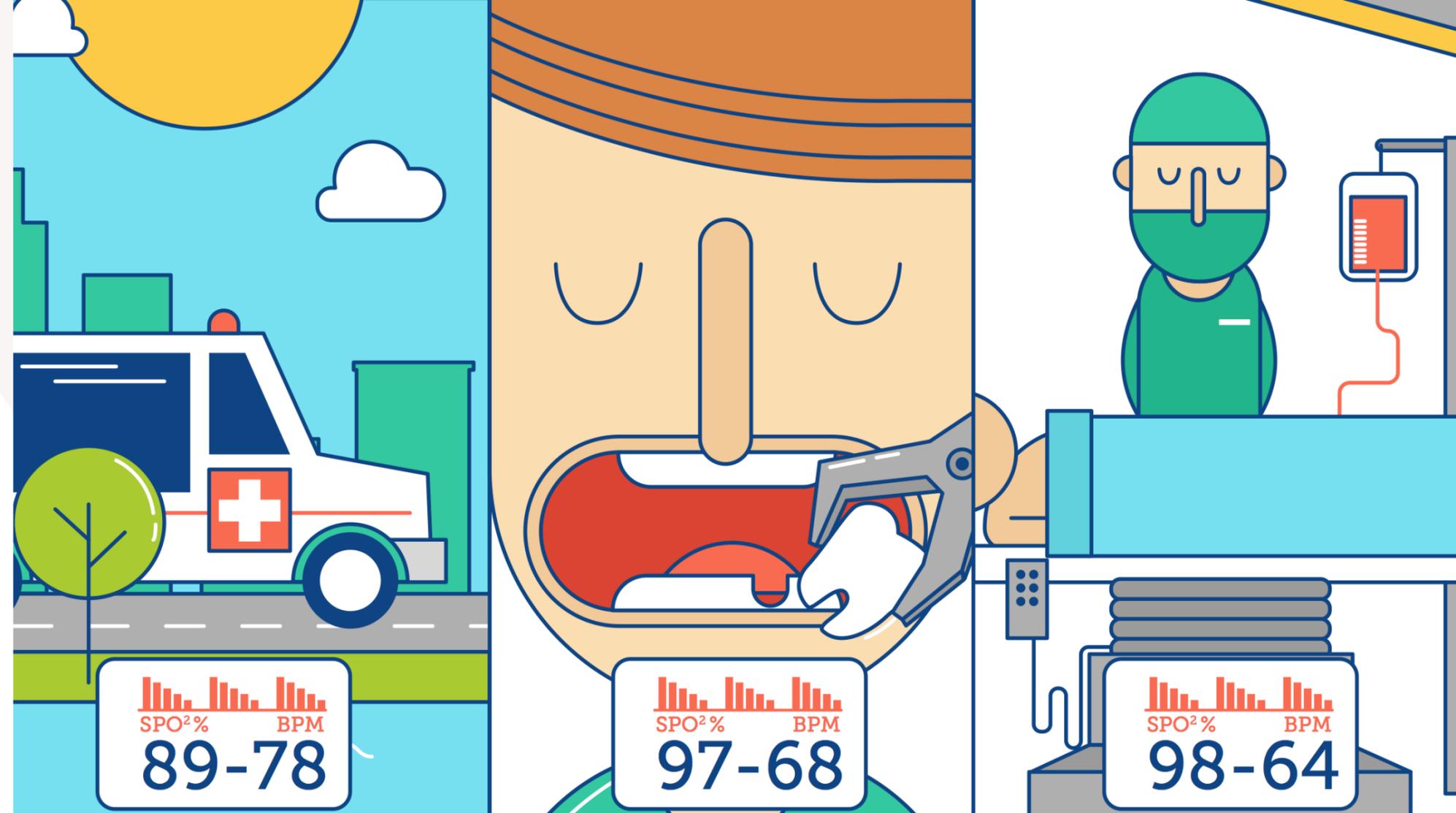
pathology is suspected.

The Oximeter does not require any type of training, so even a patient can easily use it at home to monitor his or her state of health, the progress of treatment and the process of weaning from some procedures such as for example oxygen therapy.

Non-pneumological fields of application of Oximetry

Oximetry is by now indispensable in numerous "non-pneumological" medical procedures, such as endoscopic examinations, invasive procedures, ambulance transport and transfers within a hospital environment, emergency departments or first aid. Indeed, in anaesthesiological procedures, or deep sedation in surgical operations, Oximetry is a safety standard, and since its introduction there has been a 90% reduction in fatal accidents related to anaesthesia!

When an individual has respiratory problems, SpO2 diminishes.

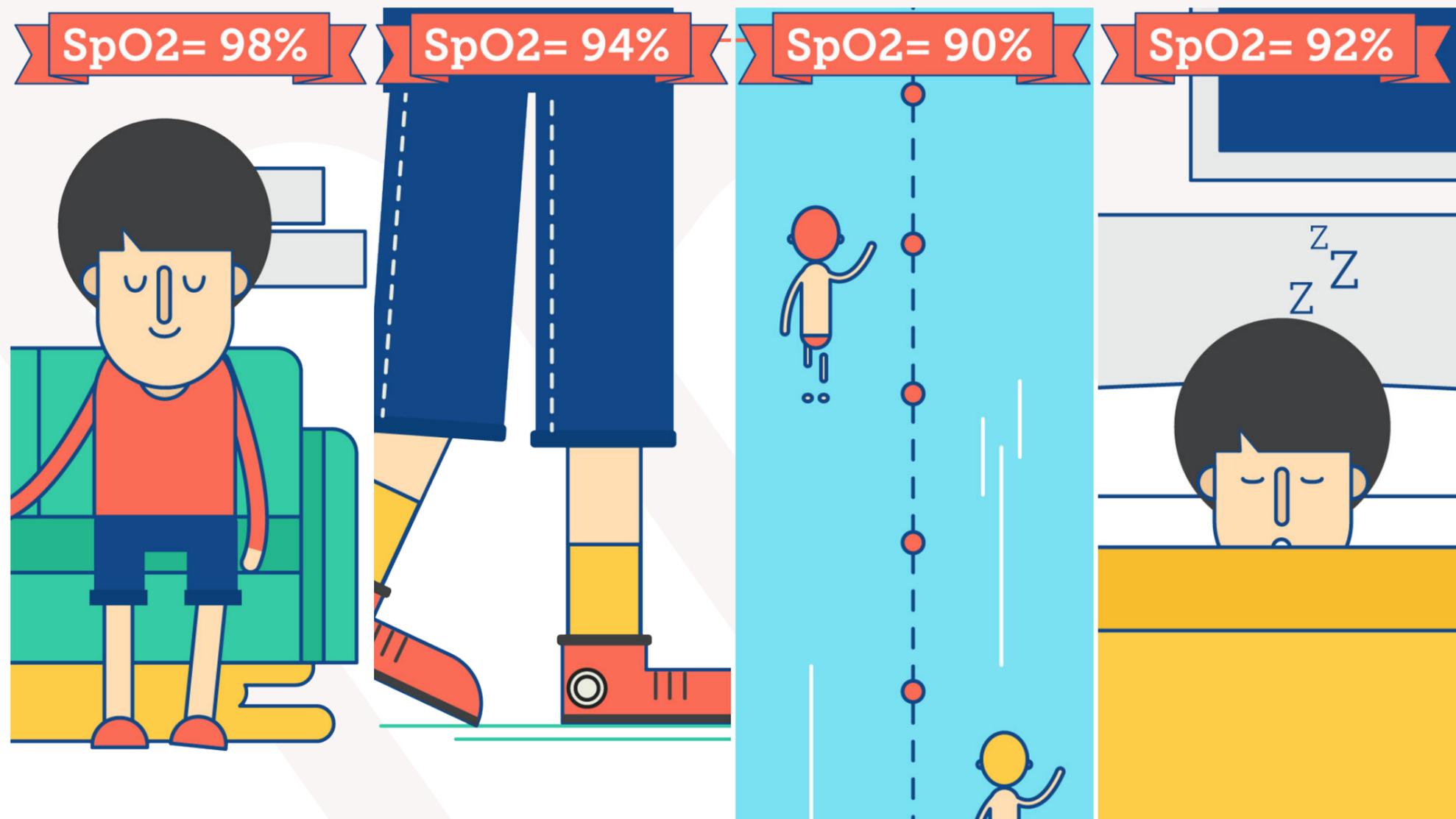


This phenomenon is called Desaturation and its entity indicates the gravity of the oxygen deficit and therefore of the respiratory failure too. It is known that at values of $SpO_2 \leq 85\%$, even the patient's healthy brain endures cognitive, visual and electroencephalographic alterations.

**Oximetry at rest;
Oximetry during
light exertion;
Oximetry during
intensive exertion;
Oximetry while sleeping**

During exertion and/or in his/her sleep, an individual having cardio-respiratory pathologies presents increased desaturation with respect to the rest condition. Indeed, in the initial steps of respiratory failure, SpO₂ at rest is often still normal, while it falls during exertion and/or while sleeping. In this case the term transient hypoxia is used to distinguish it from the continuous or persistent form typical of the more advanced stages of the disease.

If desaturation occurs only during exertion, this indicates that the lung areas still unaffected are able to provide



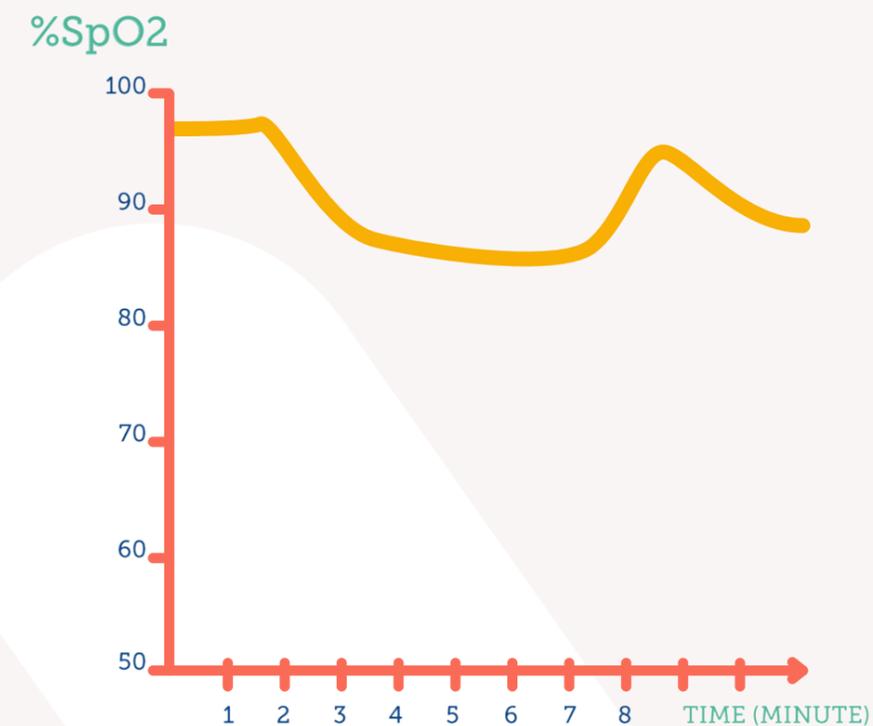
a sufficient quantity of oxygen at rest, but not during physical activity: the respiratory reserve is lowered and the individual often complains of a breathless feeling when performing activity.

Prolonged desaturation typical of BPCO. Rapid desaturation typical of sleep apnoea.

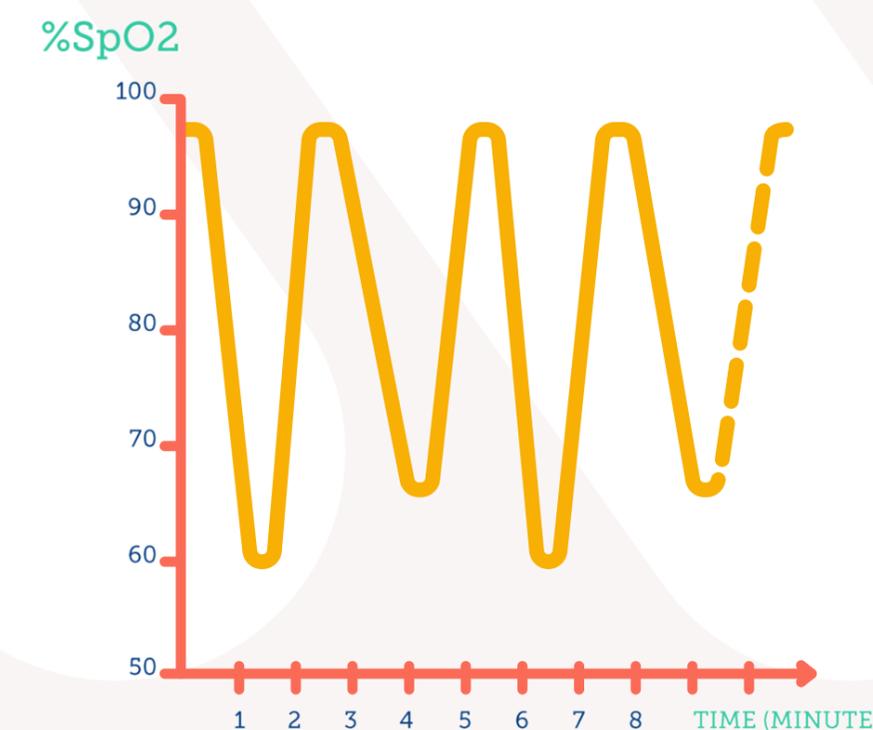
During the sleep phase, respiratory pathologies cause a reduction in lung ventilation with the appearance of prolonged nocturnal desaturation lasting at least 5 minutes: in the most serious cases oxygen therapy is required. Prolonged desaturation can also be encountered in non-pulmonary pathologies, as occurs in obese individuals at rest and/or while sleeping.

Desaturation can also be rapid, typical in individuals affected by sleep apnoea. Generally they last for less than 2-3 minutes but can be profound and numerous.

Though it may seem strange, in patients with a low oxygen level, sleep is a more critical phase than the rest condition. In practice, these patients will have an oxygenation deficit which will be at a maximum during physical exertion, intermediate during sleep and minimum during waking periods at rest.



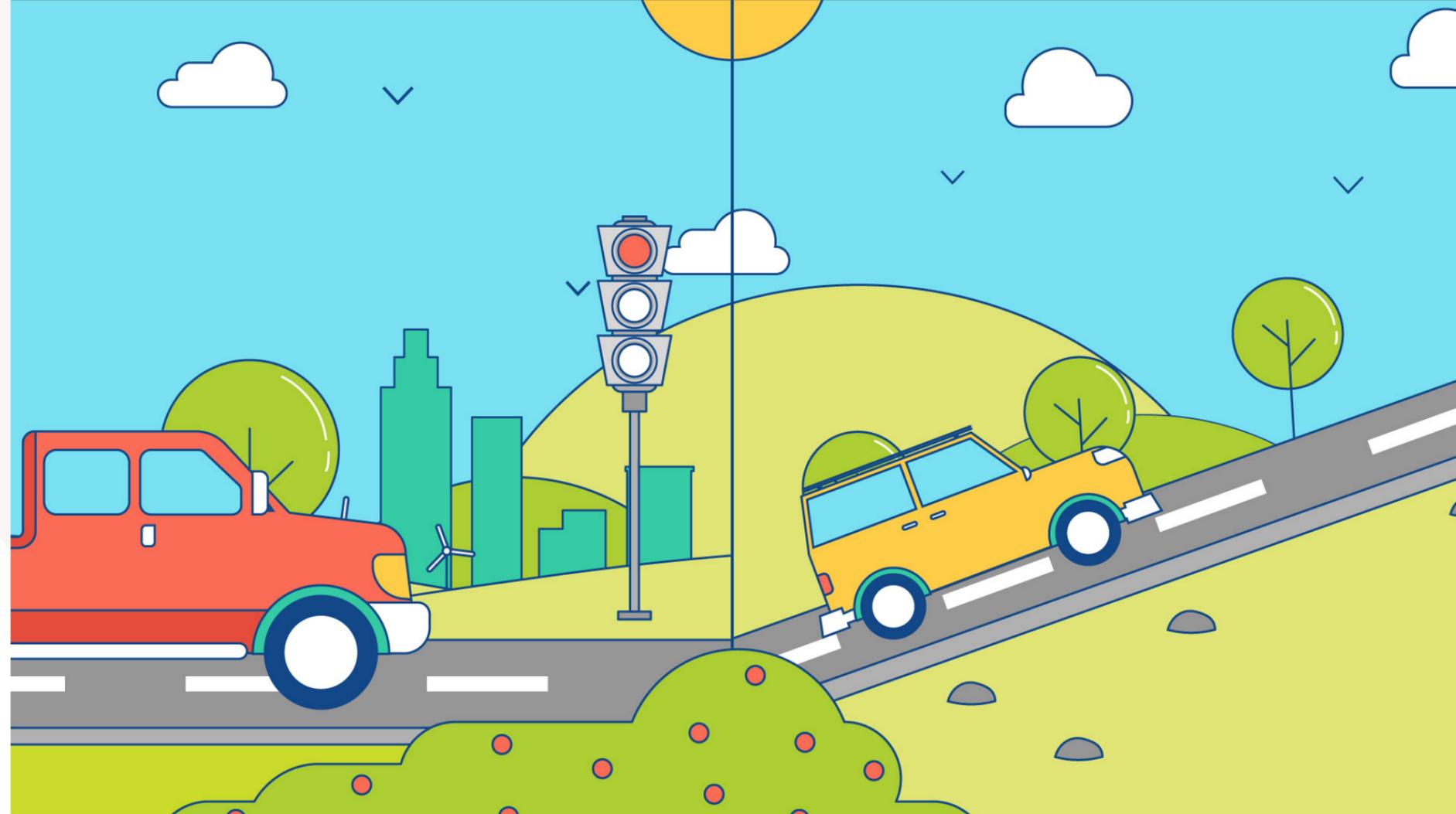
PROLONGED DESATURATION >5 minutes



RAPID DESATURATION <2.5 minutes

Intermediate oxygen requirement. Maximum oxygen requirement.

To stray into metaphorical comparison, we might say that, like a motor car having engine trouble when waiting at a traffic light with rpm at minimum level and risking cutting out, and when at high levels of stress on a mountain road, in the same way a patient having a low oxygen level "suffers" when sleeping and - in particular - when at a high exertion level. Therefore, to identify persistent hypoxia it is sufficient to take a brief measurement at rest with any type of Oximeter. On the other hand, to identify a transient hypoxia during sleep, or due to exertion, an Oximeter with a memory is needed, as well as an accelerometer that can carry



out prolonged measurements with the aim of detecting the pose of the body during sleep.

In the same way as for arterial pressure and the ECG, dynamic tests have been developed for Oximetry that are able to measure SpO₂ in the various conditions: exertion (6MWT, i.e. a 6-minute walking test), during sleep, or over a whole 24h spectrum.

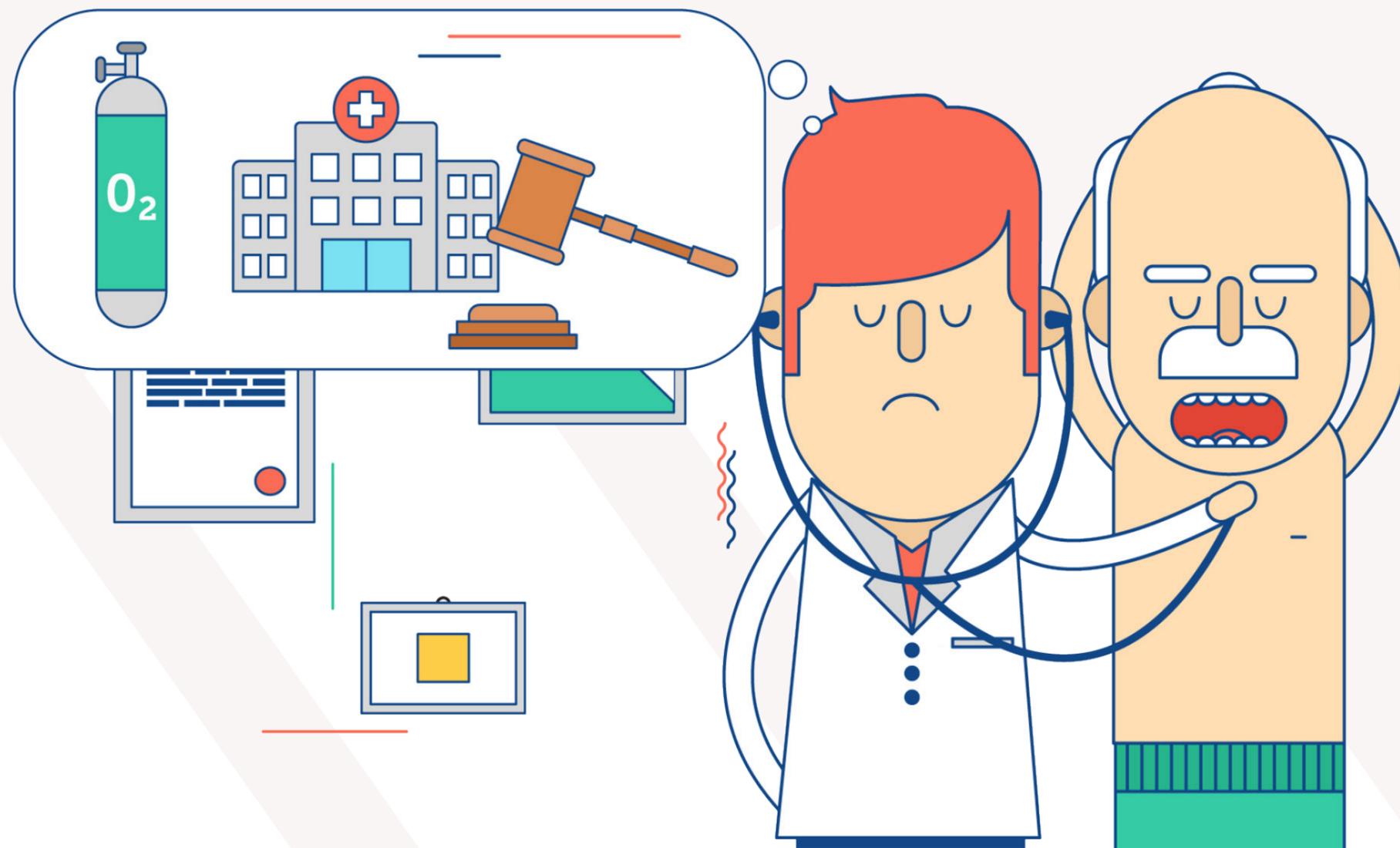
Oximetry: a simple number that everyone should know. Both doctor and patient.

Oximetry at rest should be an element of a standard medical examination. When values of lower than the SpO₂ 95% threshold are encountered, checks need to be made for a possible cardio-respiratory disease, by performing the appropriate diagnostic tests such as systemic arterial blood gas analysis, 6-minute walking test, sleep Oximetry, 24 hour dynamic Oximetry, Chest X-ray and heart examination. It follows that a simple number, obtained by inserting a finger into a small sensor ... can change our lives.

SpO₂ < 92% values during an acute disease can indicate a need for admission to hospital: for example during an asthma attack or pneumonia.

Even in chronic diseases such as BPCO and heart failure, where the base values are in a state of alteration, a SpO₂ < 90%

often indicates the need for long-term oxygen therapy or, in any case, a specialist pneumological evaluation. It should not be forgotten that the role of the Oximeter is also important in pointing to heart arrhythmia such as bradycardia, tachycardia or, more seriously, Atrial Fibrillation.



The 6-minute walking test

The 6-minute walking test (6MWT) is a standardised examination, easily carried out in a corridor where the patient, by walking for 6 minutes at the quickest possible speed, attempts to cover the maximum possible distance.

The aim of the test is to verify, with an entirely natural movement, i.e. walking, the state of efficiency of the cardio-respiratory and neuromuscular system. This enables an evaluation of the capacity for physical exercise in order to carry out normal daily activities, or a possible degree of functional limitation.

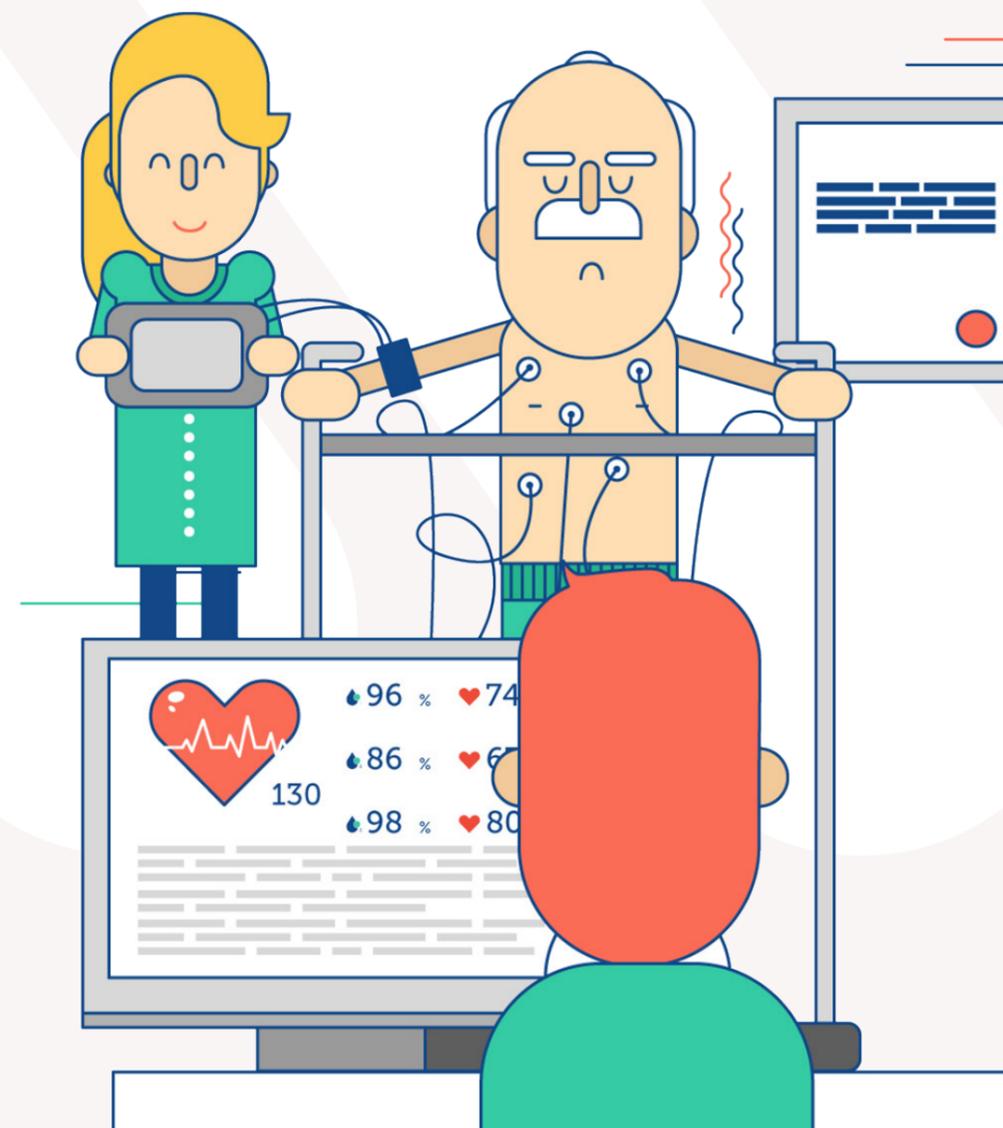
In 6 minutes, a healthy individual covers a distance of between 400 and 700 metres, which in the case of heart and/or lung pathologies is reduced. The theoretical value is based on age, weight, height, gender and ethnic group. As well as measuring the capacity for physical exertion, the information relating to the distance covered is useful in calculating the response to treatment and the lowering in the quality of life.

Oximetry: a simple and economical method for revealing cardio-respiratory disturbances

The 6MWT, though rapid and cheap, has an excellent diagnostic and prognostic worth, throughout the entire paediatric to geriatric range, and is well correlated with the most complex heart stress-tests carried out using cycle-ergometry or the treadmill. The main datum supplied by the test is represented by the total distance covered, to which is added the degree of fatigue and breathlessness reported by the individual following the test.



Multi-parameter Stress Test: an excellent but complex and expensive method for revealing cardio-respiratory disturbances



Further, in the case of some diseases, it has a prognostic value and is a predictor of mortality. For example, in individuals affected by lung hypertension a distance covered of less than 332 metres indicates a life expectancy of less than 20 months!

In medical practice, the distance is not the only factor used in analysis; other very useful indices also have a strong clinical relevance deriving from Oximetry carried out before, during and following the walking test. In particular, not only are the average SpO₂ values and pulse frequency of great use, so are their minimum and maximum values and the recovery time, as they enable ascertainment of any desaturation and/or heart arrhythmia resulting from exertion and - in the case of patients having respiratory failure - verification of the effectiveness of oxygen therapy.

If the Oximeter is provided with an accelerometer, some auxiliary "compound" parameters such as the area

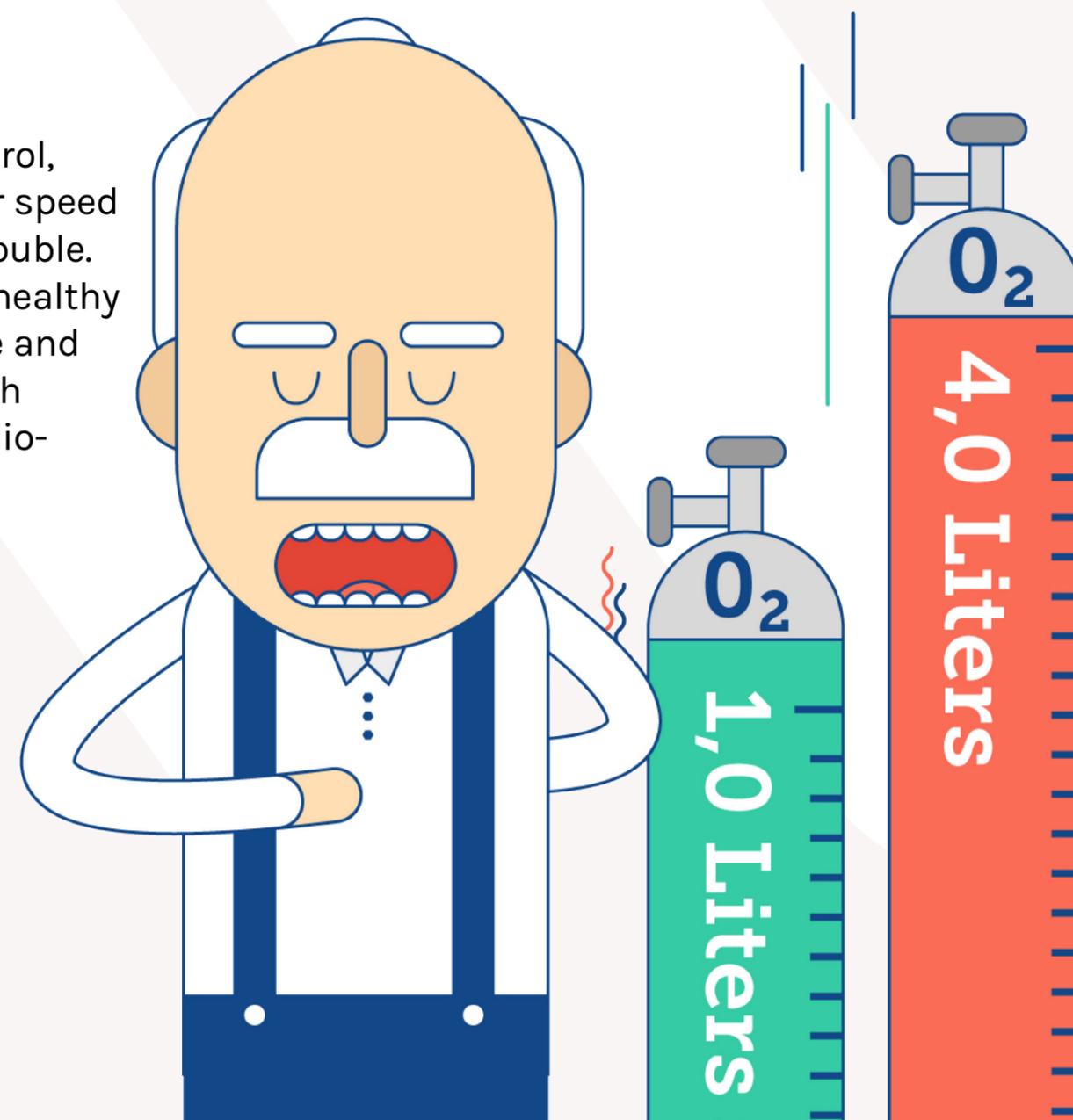
of desaturation can be automatically measured - contained within the SpO₂ curve and indicative of the descent due to exertion - with respect to the distance covered.

O₂-Gap a simple and rapid method for calculating the Oxygen deficit

Another parameter is the O₂Gap index which represents the estimation of the quantity of oxygen (L/min) to be administered to the individual in order to prevent a high level of desaturation during the walking test¹.

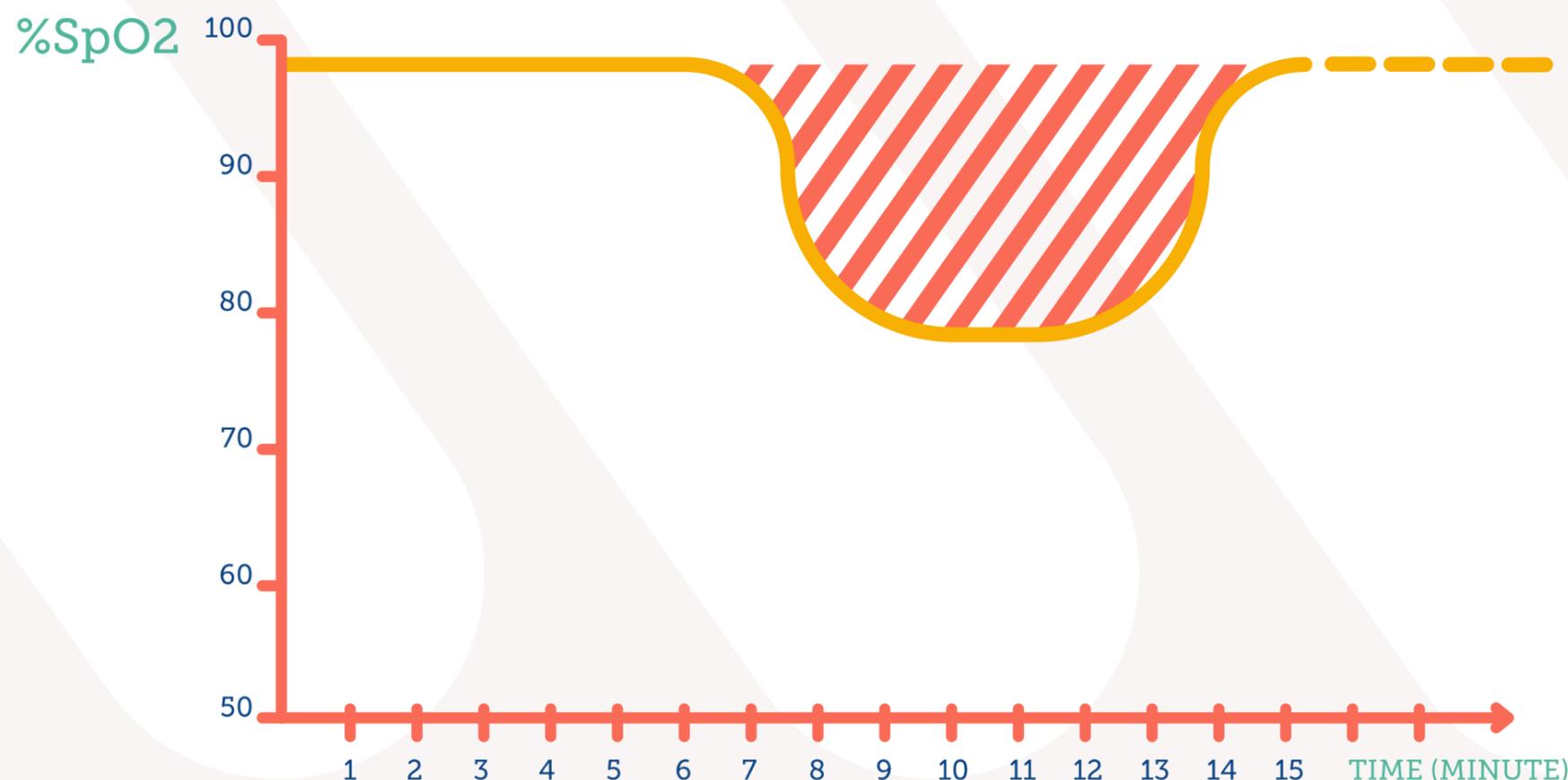
Considering that the parameters supplied by the test are numerous and of varying nature, how do we behave with an individual - for example after a period of treatment - who repeats the test and, with a shorter distance covered - manifests a greater or smaller area of desaturation? To facilitate the response, we might consider an automobile in perfect running

conditions that, with one litre of petrol, covers a greater distance at a faster speed than another vehicle with engine trouble. Likewise, during the walking test a healthy individual covers a greater distance and has a smaller desaturation area with respect to a person affected by cardio-respiratory pathologies.



The area below the curve due to desaturation during the walk

From this point of departure it is simple to understand the meaning of the compound index known as DDR (Desaturation Distance Ratio) which relates the desaturation area to the distance covered. The lower the index (the ideal value is zero!), the greater the distance the individual has covered without relevant desaturation. On the contrary, a high value indicates that there has been a desaturation and/or that the individual has covered a shorter distance. If the individual repeats the test (for example during respiratory rehabilitation), the DDR index is useful for verifying the effectiveness of the therapy.



SIX MINUTE WALK TEST

Oximetry during sleep

Oximetry during sleep is a dynamic test because it includes SpO₂ measurement and pulse frequency throughout the sleep phase. It is a simple test and easy to implement, even at home. The start and end of the recording can be automatically set. For the purposes of the analysis, waking periods in which the individual under examination records (in the clinical diary, similar to the ECG-Holter diary) the main activities carried out and the manifestation of any symptoms, are to be excluded.

The main aim of the test is to verify, in various pathologies - such as BPCO, heart failure, obesity, neurological pathologies - whether prolonged nocturnal desaturation (NOD) occurs during sleep, which would indicate the presence of transient hypoxia. In the most serious cases, a desaturation condition will persist for the whole recording period, and this indicates an advanced state of respiratory failure. When, during sleep,

an individual is undergoing oxygen therapy and/or mechanical ventilation, this examination enables a verification of its effectiveness. In addition to the average and minimum SpO₂ values, the NOD results are particularly useful, as is the percentage of time passed below a determine SpO₂ threshold. For example, T90 is the time lapse in which the individual manifested SpO₂ < 90%.

An Oximeter provided with a recording memory and processing software is able to isolate the desaturation episodes and classify them as prolonged episodes (with a duration of longer than 5 minutes) and rapid episodes (with a duration of less than 2.5 minutes). This latter type of desaturation is caused by obstructive sleep apnoea (OSA), or of a central type. In particular the central types appear in various neuropathies but also during the advanced stages of heart disease where they may accompany the known "Cheyne Stokes respiration" pathology, which is characterised

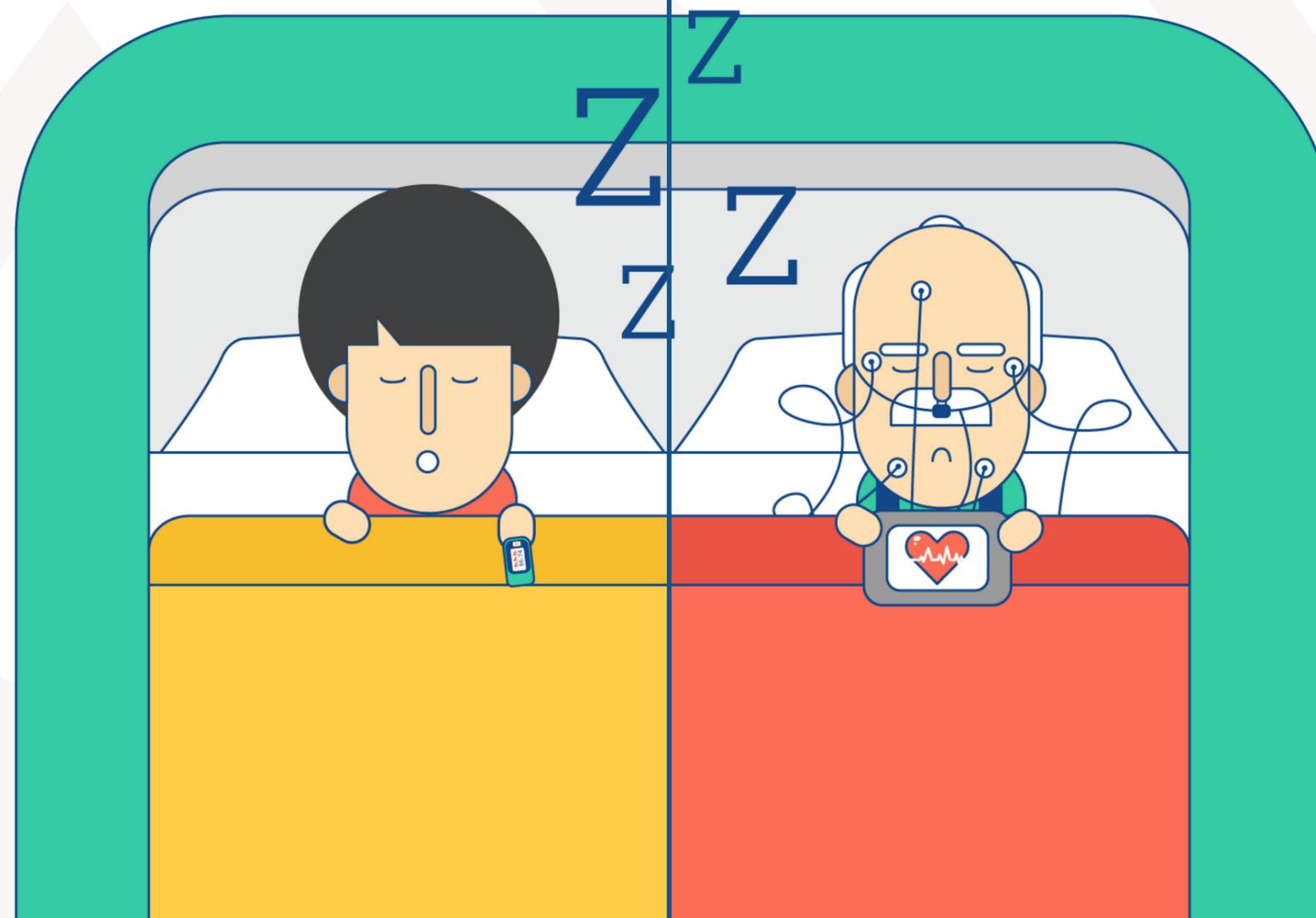
by cyclic alternation of periods of apnoea, interruption in breathing and hyperpnoea.

The number of events per hour of sleep (ODI - Oxygen Desaturation Index), the average duration and the average of the minimum values of SpO₂ during the desaturation stages, signal the gravity of the apnoeic situation, while also suggesting the degree of urgency with which the individual should follow the diagnostic and therapeutic course of treatment.

In a recent 2015 publication, it has been claimed that the diagnostic accuracy of ODI measured using modern Oximeters is akin to that of RDI (Respiratory disturbance index) measured using portable polysomnography for OSA diagnosis. Therefore it is valid, practical and economical to carry out screening for respiratory disturbances during sleep using the Oximeter.

Oximetry: a simple and economical method for revealing cardio-respiratory disturbances during sleep

Polysomnography: an excellent but complex and expensive method for revealing respiratory disturbances during sleep



If the Oximeter is provided with an accelerometer, it affords not only a more accurate exclusion of waking times from the analysis, but also makes possible an analysis of the poses assumed during sleep and the identification of a special type of OSA, termed positional since it is linked to the supine position, a circumstance indicating that dental and ear, nose and throat examinations are required.

As for the number-heavy nature and complexity of the measured indices, to improve the effectiveness of the respiratory distress screening during sleep, over the last 20 years the Delta Index has been used to represent the average SpO₂ fluctuations. In healthy individuals SpO₂ has minimal variations during sleep, so the Delta Index is close to zero. On the other hand, with individuals presenting sleep apnoea, SpO₂ has a greater fluctuation and a Delta Index which, in the gravest cases, can reach a level of 6-7. When the Delta Index > 0.7, it

is always advised to follow the diagnostic pathway (for example polysomnography). The usefulness of this parameter is huge: in practice, a single number indicates the presence and level of desaturation caused by sleep apnoea!

SpO2 almost constant: Delta Index=0.3

SpO2 with fluctuations: Delta Index=1.7

The analysis of the specific indices such as NOD, Delta Index, ODI and average Desaturation improves the diagnostic accuracy of the test, in particular when there are several causes of sleep hypoxia as in cases where BPCO and OSA co-exist (overlap syndrome).

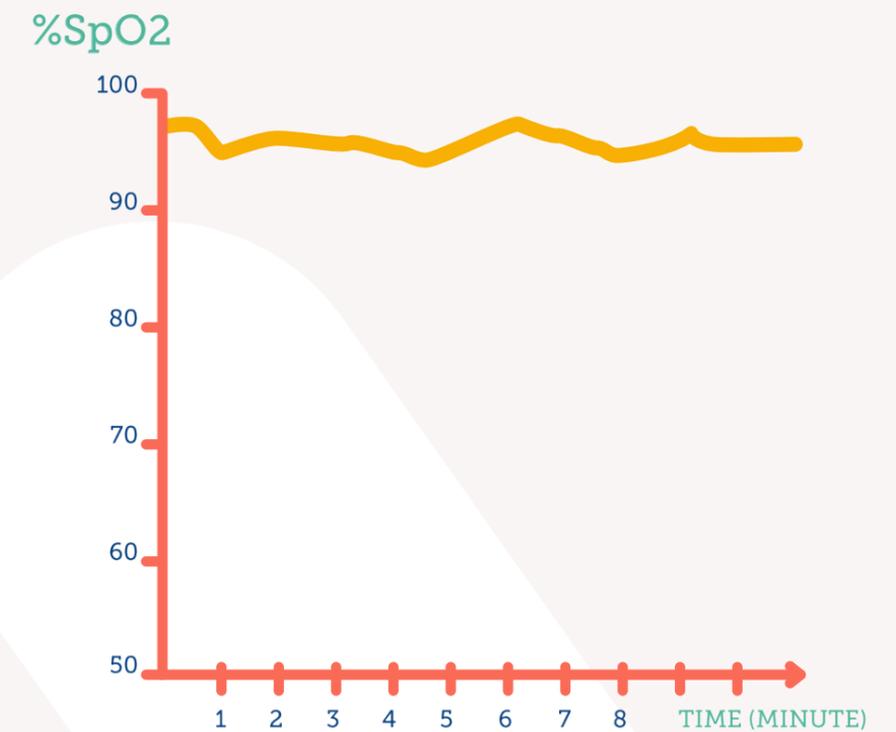
Moreover, pulse frequency analysis during sleep can suggest a greater risk of arrhythmia or sudden death even in the absence of relevant desaturation. When pulse frequency presents anomalies, an ECG Holter is recommended.

Lastly, Oximetry during sleep has a more significant role in the paediatric field,

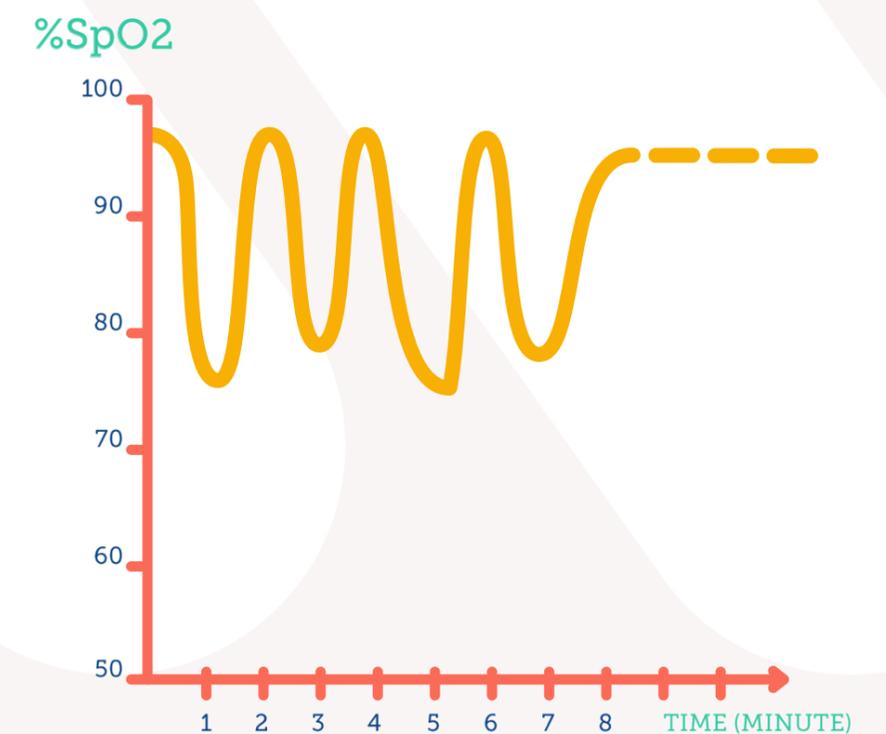
where respiratory disturbances during sleep are very frequent and the more sophisticated lines of investigation, such as polysomnography, are difficult to perform.

24-hour dynamic Oximetry or the SpO2 Holter

24-hour Oximetry consists in continuous measuring carried out during the normal daily activities of the patient. The analysis provides a general evaluation of the cardio-respiratory conditions over the whole day, by determining the average values and the eventual exceeding of some SpO2 (T90, T88) and pulse frequency (T40, T120) risk thresholds.



%SpO2 mean= 94,2 - Δ INDEX = 0,3



%SpO2 mean= 89,8 - Δ INDEX = 1,7

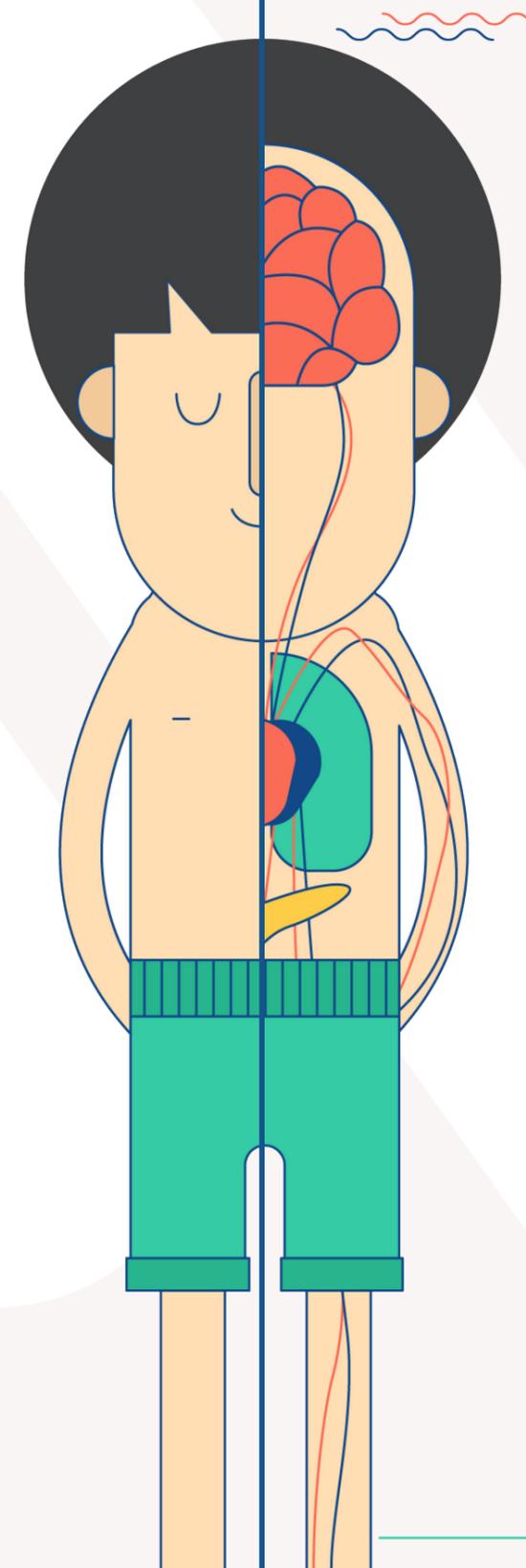
Oximetry: one simple number for so much data on the health of our organs

Furthermore, on the basis of the individual's diary and the data provided by the accelerometer, detailed analysis can be performed, diversified for the three conditions: rest, exercise and sleep.

This type of examination enables highlighting a persistent or transient hypoxia (from exertion and/or during sleep) and carrying out a prescription of oxygen therapy in a way that is better matched to real need (titration of the oxygen therapy) in the various conditions: rest, exertion, sleep). This is in compliance with the main guidelines and insurance policies (among which

Medicare in the USA) and is also compliant with the existing demand for diagnostic and therapeutic suitability.

In conclusion, 24 hour Oximetry is an excellent and complete screening test for breathing difficulties, including sleep apnoea, for verifying the effectiveness and correct use of the therapeutic devices and the compliance of the patient.



Every doctor should have an Oximeter in her or his bag

Everybody knows that life cannot exist without oxygen: determining the need for oxygen in a patient is of vital importance. From this point of view the Oximeter must be considered a true "life-saver" both for the patient - in all possible conditions of "hypoxia" - and for the doctor who, in a few moments, can make a correct and timely diagnosis. Each doctor should keep an Oximeter in her or his bag together with the phonendoscope and the blood pressure meter!



Conclusions

The potentialities of the Oximeter are multiple. By giving a number that is easy and rapid to obtain, it expresses the need for oxygen in any place it is used: from the general practitioner's surgery to the emergency department, from the paediatrician's ward to the operating theatre, from the private dwelling to the pilot's cockpit in an aeroplane, from a check on a mountaineer to the monitoring of high-stress athletes.

The Oximeter is fundamental not only in individuals suffering from established pneumological, cardiological and neurological pathologies, but is also

of especially key diagnostic importance in those who have not yet complained of respiratory symptoms but who have a pathology that already involves respiratory issues, as sometimes happens in the early stages of BPCO.

The Oximeter is of fundamental use in the screening and follow-up of primitive respiratory disturbances during sleep - such as OSA and Obesity Hypoventilation Syndrome - or secondary to lung pathologies - such as BPCO, Bronchial Asthma and Cystic Fibrosis - or extra-pulmonary - such as chronic heart failure, Stroke, Parkinson's Disease, SLA, Multiple

Sclerosis and deformity of the thoracic cage.

Only one watch-word echoes from this presentation: "Oximetry for all."



**OXIMETRY
FOR ALL!**

