9. Physical Preparation

Technique, strategy and state of mind are fundamental aspects of fighting. However, without good physical preparation, these factors may be ineffective. In karate (as in all combat sports), it is important to develop an athletic muscle mass that is capable of explosive moves and movements, all against a background of variable levels of endurance depending on the discipline and objective.

In this section we will analyse some physiological principles and concepts that are useful for physical preparation.

This section largely summarises two popular works: an anonymous text found on the web (*http://mapage.noos.fr/nicoach1/download/basesphysio.pdf*) and the guide *Muscle et fitness du HIIT*. Muscle & Fitness, 2010.

For anyone wishing to extend their understanding of the issues raised in this section, we recommend the books by J. Ferré and D. Reiss that you will find in the references.

9.1 Physiological Principles

9.1.1 Sources of Energy

Muscles use different sources of energy depending on the intensity and duration of an exercise.

At the cellular level, the energy source is adenosine triphosphate (ATP). ATP is a molecule consisting of adenine and ribose attached to three phosphate groups. Energy is released when a phosphate group is detached from the ATP molecule:

ATP → ADP + Pi + Energy (ADP: adenosine diphosphate, Pi: phosphate).

ATP is present in the muscle in small quantities. As these reserves cannot maintain a contraction for more than three seconds, other sources of energy must recharge the ATP.

ATP cellular synthesis

1. The anaerobic pathway does not make use of oxygen (O_2). It is used for short, intense efforts.

a. For efforts of a few seconds at maximum intensity, ATP is renewed through the ***creatine phosphate*** (CP) cell reserve. This is an ***anaerobic alactic*** process. Beyond seven seconds, the muscles must use other resources.

b. For intense efforts of longer duration (30 seconds to two minutes), ***glucose*** produces the energy required for ATP synthesis. This is a ***lactic anaerobic*** process, i.e. it releases a significant amount of lactic acid (associated with muscle pain).

2. The aerobic pathway involves O_2. It is used for long-lasting efforts and efforts of moderate intensity.

This system utilises the oxidation of ***carbohydrates, lipids and proteins***. The presence of O_2 allows functioning of moderate intensity but for a long time. This path produces “residues” that have little influence on fatigue: ***water*** (H_2O) eliminated through sweating and ***carbon dioxide*** (CO_2) eliminated by expiration.

When the duration of the effort increases, the proportion of glucose used decreases in favour of lipids.

Capacity and Power

Capacity is the total amount of energy available.

Power is the maximum amount of energy used per unit of time.

Each energy path has capacity and power.

The energy pathways in summary:

1) Anaerobic alactic: creatine phosphate — in the muscle — without oxygen (O_2) — without producing lactic acid — Maximum capacity 20’’ — E.g. 60-100 m run.
2) Lactic anaerobic: glycolysis — No (or little) O_2 — Production of lactic acid — Capacity of 30 seconds to 2 minutes — E.g. 200-800 m run.
3) Aerobics: oxidising carbohydrates, lipids and proteins — With O2 — H_2O and CO_2 produced — “Unlimited” capacity. E.g. 1500m - marathon

The three energy pathways are not involved in succession; they overlap gradually.

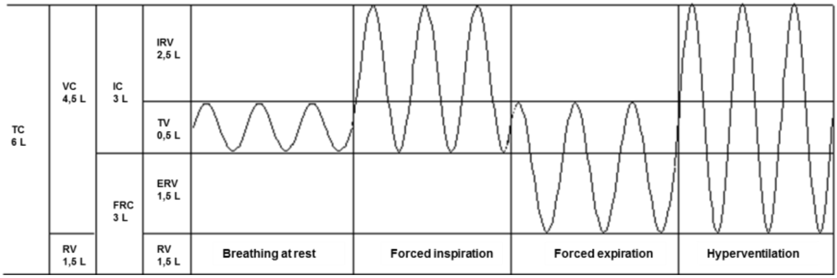
Intense, short-duration efforts are often used in karate, from a handful of seconds to several minutes. It is important, therefore, to prioritise working on and developing the anaerobic pathways.
However, developing endurance and the aerobic pathway is useful if you want to make the most of a lesson of one or two hours or if you want to undertake one or more protracted fights.

9.1.2 Breathing

Inspiration and expiration renew the air in the lungs (supplying O_2 and eliminating CO_2). The respiratory rate is between 10 and 12 cycles/min at rest. This rate increases with physical activity and emotions.

Respiratory volume and capacity measurable by spirometry:

1. The tidal volume (TV) is 0.5 l and corresponds to the volume of air exchanged during calm breathing.
2. The inspiratory reserve volume (IRV) is 2.5 l and corresponds to the volume of additional air inhaled during forced inspiration.
3. The expiratory reserve volume (ERV) is 1.5 l and corresponds to the volume of air evacuated during forced expiration.
4. The residual volume (RV) is 1.5 l and corresponds to the volume of non-expelled air that remains permanently in the lungs during normal breathing.
5. Vital capacity (VC) is the set of volumes, i.e. between 4 and 5 l.
6. Total capacity (TC) is the sum of all the lung volumes, i.e. about 6 l.



Adapted from http://www.chigot.fr/TheoN2/RESPIR.htm

Adaptation to exercise

Physical exercise increases the rate and amplitude of pulmonary ventilation. At rest, the volume of air exchanged is +/- 6 litres a minute (12 movements x 0.5 litre of tidal volume). The increase in the amplitude and frequency of respiratory movements grows with the intensity of the muscular exercise.

If this intensity is moderate, the respiratory and circulatory rates stabilise: there is a balance between consumption and O_2 input. This stable state is the notion of “second wind”, when effort seems easy (e.g. jogging).

If an intense effort is maintained, the respiratory rate increases (the tidal volume can reach 3.5 litres and the frequency increase to 45-70 movements/minute i.e. a rate of 120 to 200 litres of O_2 a minute).

When all the available oxygen has been used in the muscles, we say that the **maximal aerobic power** (**MAP**) has been reached.

MAP is expressed in watts and equates to the athlete's maximum potential for delivering oxygen to his or her muscles (**maximum oxygen flow: VO2 max**).

VO2 max

VO2 is the maximum volume of oxygen (or dioxygen) that an individual can consume per unit of time during maximum aerobic exercise. There should be a dot over the "V" as it is a volume rate. VO2 max is also often used as an abbreviation for "maximum oxygen consumption".

VO2 max is expressed in litres of oxygen per minute.
"Specific" VO2 max is expressed in ml/min.kg. The observed value is related to the body mass unit in order to take different constitutions into account. This value reflects an athlete's endurance.

VO2 max is measured accurately using a treadmill (ergometer) or on a bike (cycle ergometer) during an exercise where the intensity increases incrementally until exhaustion. In parallel, the inspired and expired flow rates at each respiratory cycle are measured using a full-face mask, together with the partial pressures of oxygen and carbon dioxide.

These measurements depend on temperature, atmospheric pressure and ambient humidity. As a result, the apparatus normalises the figures obtained by calculation for STPD conditions (Standard Temperature and Pressure, Dry: 0 °C, 1013 hPa, 0 % humidity). This method makes it possible to overcome the conditions in which the test is carried out.

The athlete reaches his or her VO2 max between 6 and 7 minutes at maximal aerobic speed (MAS). The norm is 40-50 ml/min.kg, but can go beyond 80 ml/min.kg in high-level athletes.

MAS

Maximal aerobic speed (MAS) is the running speed at which an individual reaches his or her VO2 max. An athlete can generally continue at MAS for 4 to 8 minutes. At this speed, 85 % of the energy is produced by the aerobic system and 15 % by the lactic anaerobic. Below this, oxygen consumption grows with the intensity of effort, and most of the energy comes from the aerobic system. Above this, oxygen consumption remains constant and the additional power is provided by the anaerobic lactic system.

Coaches use several tests to assess the MAS. These tests are performed on a track marked with studs positioned at equal distances. On each signal, the runner must be level with a stud. The time between two signals gradually decreases, meaning that the running speed gradually increases. At a certain speed, the runner is no longer able to keep up. The MAS is the speed of the last level that was completed in full. It is better if the test lasts no more than 20 to 25 minutes. Consequently, the speed of the first level should be adjusted to suit the ability of the runners.

Léger and Mercier's formula links the VO2 max and MAS of a runner on the assumption of an ideal running technique: MAS = VO2 max / 3.5. MAS is expressed in km/h and VO2 max in ml/min.kg.

The MAS is an indication of the performance levels of an athlete who can undertake tests in the order of 5 to 10 minutes.

Anaerobic threshold is the point at which the lactic anaerobic system begins to produce energy. It is linked to MAS (approx. 85 % of it).

Oxygen debt

In addition to VO2 max, athletes can further increase their effort by drawing on the lactic anaerobic process. After an effort of this intensity, breathlessness is observed when the exercise stops. During recovery, the energy demand is reduced but oxygen consumption (VO2) remains high. The O_2 debt is defined as the quantity of excess O_2 consumed during the recovery period compared to the rest period.

O_2 debt is a function of the intensity and duration of the effort that resulted in the deficit. The “excess” O_2 consumed during the recovery phase serves to:

1. Replenish ATP-CP reserves (~ 85 % of the creatine is synthesised in two minutes);
2. Replenish muscle glycogen (lactic debt: produced during intense exercise— long recovery: 10 to 48 hours, or five days) — 88 % of the lactic acid is eliminated in 75 minutes;
3. Regain normal body temperature;
4. Meet the O_2 needs of the respiratory muscles.

It is important to assess the O_2 debt to determine the recovery times.

For alactic anaerobic exercises (e.g. 100 m), a recovery time of three to five minutes is needed between series if you want to rework the ATP-CP path.

For lactic anaerobic exercises (200-400 m), the recovery must be longer (10 to 48 hours). In addition, it is advisable to undertake active recovery (jogging for 15 to 20 minutes).

For longer lactic anaerobic exercises (400-800 m), it is possible to train in a state of "lactic fatigue" with a shorter recovery as a way of accustoming the body to sessions with a high concentration of lactates. This calls for motivation (and should be avoided by young people).

Recovery periods following maximum exercise

1. Restoration of ATP-CP reserves: from 3 to 5 minutes
2. Re-synthesis of muscle glycogen: from 10 to 48 hours; if interval work: 5 to 24 hours
3. Elimination of lactic acid: active recovery from 30 to 60 min; passive from 1 to 2 hours

Adaptation to effort

The time for mobilising the aerobic pathway is about two minutes. An athlete's **VO2 max** level will only begin operating after this period. VO2 max is limited by the functioning of the respiratory, cardiovascular and enzyme system of the muscle fibres. Its capacity depends on genetic factors and training (especially under 25 years of age).

The ability to last during an exercise using the aerobic system depends on the percentage of VO2 max used and the level of training. At maximal aerobic power (MAP), an untrained individual will be exhausted after four to six minutes, whilst a trained individual will be exhausted after seven to 15 minutes.

Aerobic and anaerobic thresholds

1. Basic endurance recovery: up to 60 % of VO2 max (aerobic threshold), lactate level remain low. Training the aerobic pathway below this threshold has no effect.
2. Aerobic capacity work (aerobic-anaerobic transitional zone): at 60 % to 80 % of VO2 max, lactate is accumulated but the exercise can be continued for 30 to 60 minutes depending on the level of training. This work can be done in sections of 20 minutes or more.
3. Anaerobic threshold: about 85 % of VO2 max. An increase in effort causes a sudden rise in lactate and reduces the continuation of the effort.

4. Development of aerobic power: above 85 % of VO2 max, the work must be split by active recovery periods.

9.1.2 Cardiovascular system

Cardiac output and heart rate

Systole and diastole correspond to the contraction and relaxation phases of the cardiac muscle.
Cardiac output (Co) equals the heart rate (HR) multiplied by the stroke volume (SV), i.e. the volume of blood ejected during the contraction of the heart. The rate is expressed in litres or millilitres a minute (**Co = HR x SV**). At rest, cardiac output is about 5 l/min.

The heart contracts autonomously. However, heart rate is influenced by:
— The **autonomic nervous system:** the sympathetic nervous system causes an increase in the heart rate. The parasympathetic system slows down the heart;
—Exercise, **certain hormones** (such as adrenaline) and increased body **temperature** cause the heart rate to rise.

At rest, the normal heart rate varies between 60 and 100 beats a minute. Below and above these rates, we use the terms bradycardia and tachycardia respectively.

Maximum heart rate depends on age and can be measured using an exercise test. During the test, the intensity of effort gradually increases. In parallel, the heart rate accelerates then stabilises. The maximum heart rate is sometimes estimated using the following formulae:

Astrand formula:

Max HR = 220 – age in years (for an individual aged 40 years: 220-40 = 180 of Max HR).

Other "more precise" formulae:

For men: Max HR = 214 - (0.8 x age)

For women: Max HR = 209 - (0.7 x age)

The heart and exercise

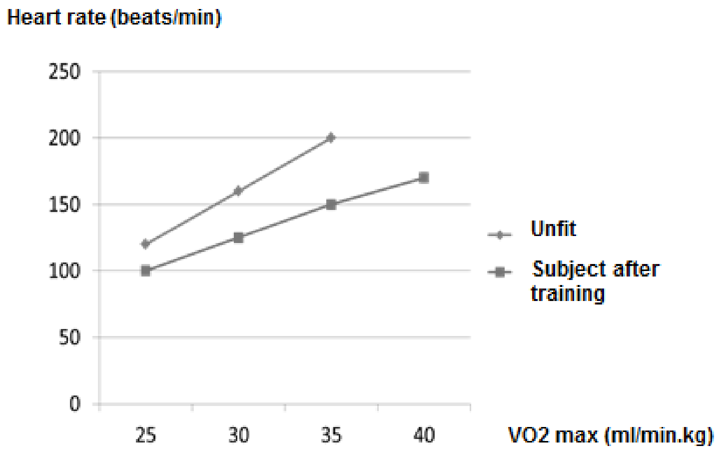
The heart rate increases before exercise through stimulation of the sympathetic nervous system (secondary to the emotion before a test). It increases further during the exercise due to hormone secretion and muscle contractions, which massage the peripheral veins and thereby increase the volume of blood returning to the heart. The heart reacts by increasing its

frequency and cardiac output in response to the increased needs of the muscles.
The heart rate then stabilises depending on the intensity of the effort. If MAP is reached, the rate is at its maximum and remains there.

When the exercise stops, the HR decreases:
— rapidly at first = “disengaging” phase
— then more slowly. This is the “paying the O_2 debt” phase.

Relationship between heart rate and VO2 max

As shown in the graph below, there is a parallelism between HR and VO2 max. This is particularly useful to know because the heart rate is the only indicator that can be easily used in the field to measure intensity of effort.



Understanding the relationship between HR and VO2 max

VO2 max reflects the endurance of the cardiorespiratory system (the capacity to undertake prolonged continuous or intermittent exercise at low or moderate intensity).

VO2 depends not just on cardiac output but also on the oxygenation capacity of venous blood by the lungs.

VO2 = Cardiac output x the difference in oxygen concentration between venous blood and arterial blood.

$VO2\ max = Max\ HR \times SV \times (Ca0_2\text{-}Cv0_2)$

Max HR: maximum heart rate

SV: stroke volume (heart)

$Ca0_2$-$Cv0_2$: difference in oxygen concentration of arterial blood and oxygen concentration of mixed venous blood.

Effects of training on the heart

Stroke volume increases with aerobic training. This increase is secondary to hypertrophy of the heart muscle. The rise in a fit individual's SV is accompanied by a high maximum cardiac output and a high VO2 max. To achieve the cardiac output required to perform an exercise, the heart rate will be lower in a fit individual. This fact underlines the importance of preparing physically through aerobic work to ensure there is a basic physical condition before embarking on more intense work.

Heart rate and O_2 consumption

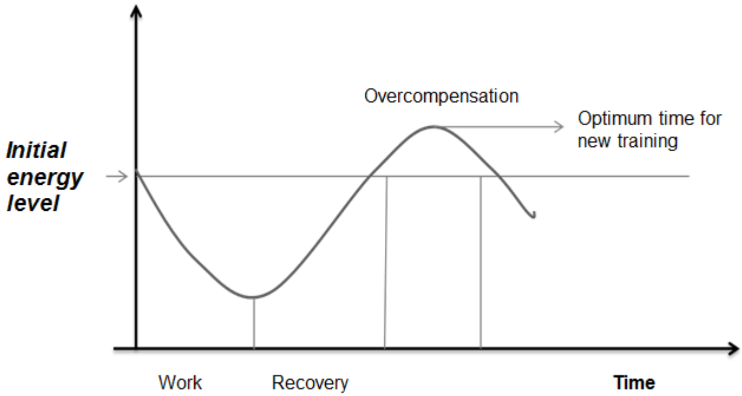
1. At about 40-50 % of VO2 max, the stroke volume reaches its maximum value. At this intensity, the heart rate is about 120 beats/min for an average person.
2. The SV is subsequently maintained at the same level.
3. If the intensity of the effort grows, the heart rate increases. An individual at maximum heart rate reaches his or her maximum volume of oxygen (VO2 max).

To develop aerobic capacity efficiently, it is necessary to train at a rate of at least 150 beats/min.

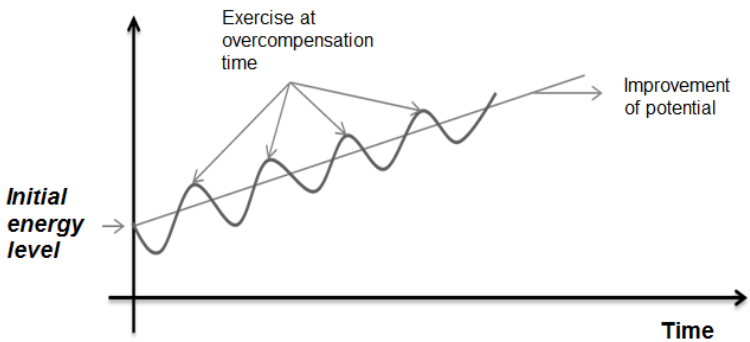
9.1.3 Recovery and overcompensation

Anaerobic glycolysis results in the production of lactic acid.
The acid part is neutralised by buffer substances in the blood to prevent acidosis (decreased blood pH). The lactate part (with a molecular structure similar to sugar) serves as fuel. It is stored as glycogen in the liver with O_2 and is used for ATP synthesis.
The degradation and recovery processes are triggered as soon as physical activity starts.

When the effort stops, the synthesis processes predominate. Energy reserves are replenished at a level that is higher than the original level: this phenomenon is known as overcompensation. The more an effort depletes the energy reserves, the greater the overcompensation will be, provided that there is sufficient recovery.

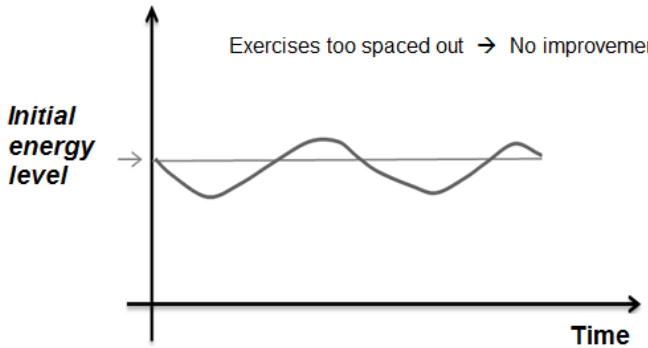


To optimise this principle, it is in the athlete's interest to re-start a new effort when he or she is in the overcompensation phase, because the subject will then have higher energy reserves than at the start.

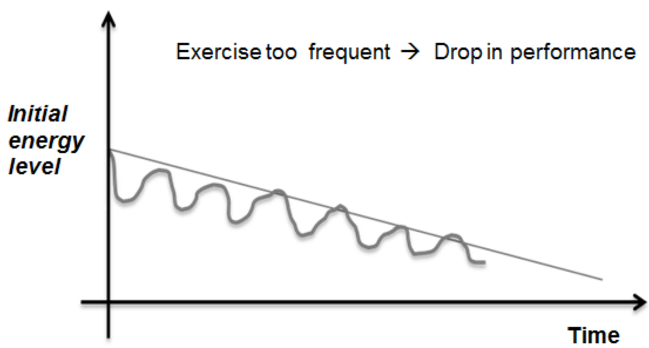


Proper planning of exercise and recovery times is essential, therefore, during the session, week, month and year. Where this is not the case, there is a risk of under or overtraining:

Undertraining: no improvement because training sessions are spaced out too much.



Overtraining: decrease in potential due to training sessions too close together



Recovery times

Dominant energy system	Recovery times	
	Minimum	Full
Anaerobic alactic (ATP-CP)	2 minutes	5 minutes
Lactic anaerobic Depends of food within 2 hours Decreased lactatemia - Blood concentration - Muscle concentration	48 hours 30 minutes (for active recovery) 1 hour (for active recovery)	72 hours 1 hour (for passive recovery) 2 hours (for passive recovery)
Aerobic Muscle glycogen restoration - Continuous exercise - Intermittent exercise	24 hours 10 hours 5 hours	72 hours 48 to 72 hours 24 to 48 hours

9.2 Performance Evaluation

You are advised to undergo a medical check before embarking on a physical activity and periodically thereafter. Subsequently, it is useful to regularly assess an athlete's performance in order to evaluate progress. In this section, we will look at a handful of tests that evaluate physical performance.

9.2.1 Field tests

Field tests are easy to perform but cannot replace laboratory tests (which are not discussed here). Their primary objective it to assess changes in performance.

ATP-CP system assessment:

These tests analyse explosive efforts. Power is measured using tests that last less than 7 seconds. Capacity is assessed by tests lasting between 15 and 20 seconds.

Vertical jump test (Sargent Test, 1921): the fingers are covered in chalk, the arm is raised vertically and a mark is made on a graduated wall or board. Then, without taking a step, the subject jumps as high as possible with the arm extended and makes a second mark. The difference between the two marks gives the result.

Squat-jump (Abalakov 1931): measures vertical jump height using apparatus. The subject starts with knees slightly bent, back straight and hands on hips before jumping as high as possible with hands remaining on the hips. This test measures the concentric strength of the lower limbs.
Results: < 30 cm = poor/30 to 40 cm = average/50 to 60 cm = good/60 to 70 cm = very good/ >70 cm = excellent.

30 m test for 7-12 year olds and **60 m** for over 12 years. From a standing start, the subject runs at maximum speed. The time taken to cover the distance is recorded and the average speed calculated. This test reflects the capacity of the anaerobic alactic system. The same test is used in swimming over 15-30 m.

Phosphagen system endurance tests: measures the ability to last in the alactic anaerobic pathway. Sprints over 10 to 20 seconds.
E.g. 40 m in 4 seconds → 10 m/s. Then 100 m in 12 seconds → 8.33 m/s. The ratio of the speeds (8.33/10 = 0.83) indicates the alactic endurance. A ratio close to 1 signifies a very good result.

Assessment of the anaerobic glycolytic system

These tests analyse high-intensity efforts. Power is assessed using tests of +/- 30 seconds. Capacity is estimated using tests with a duration of +/- 2 minutes. This type of effort produces lactates and should be avoided by young people and inexperienced athletes.

Lemon Test the individual runs 500 m at maximum speed on an athletics track marked out every 50 m. The second and the last 50 m are timed. The difference is an indicator of lactic anaerobic potential. The test may be performed with other exercises on specific muscle groups.

Evaluation of the aerobic system

These tests analyse efforts of long duration and moderate intensity. This type of effort is limited by maximum oxygen consumption and muscle fatigue.

Cooper Test: Kenneth Cooper, a doctor in the US army, developed this test in 1968. The individual runs as far as possible in twelve minutes. A table then links the distance covered to the level of physical condition.

In addition, the following formula (devised by Dr Howald) evaluates the V02 max as a function of the distance:

VO2 max (ml/mn/kg) = 0.022 x (distance in metres – 10.39)

The running and weather conditions, and the subject, may modify the result of the test and the VO2 max result, which should be interpreted with caution.

Cooper 2,400 m running test: the athlete runs 2,400 m as quickly as possible. The results are evaluated using the table designed by Cooper, which serves as a benchmark.

Multi-stage fitness test (Léger test): this assesses maximum aerobic speed and maximum oxygen consumption. The individual performs shuttles until he or she is exhausted between two lines spaced 20 m apart at an increasing pace of 0.5 km/h in increments of one minute. The rhythm is set using recorded beeps. The individual has to reach the line opposite before the following beep. This test, although it skews the estimated maximum aerobic speed because of multiple bursts of speed, makes it possible to assess the MAS and VO2 max based on the following formulae:

MAS = 1.82 v - 8.18 (for 11 km/h < v < 21 km/h)

VO2 max = 31.025 + 3.238 v - 3.248 a + 0.1536 av (for a < 18 years)

- A: age of the individual (years);
- V: Velocity of the final level achieved (km/h);
- MAS: maximal aerobic speed (km/h);
- VO2 max: maximum oxygen consumption in ml/min.kg.

9.2.2 Observation in a real-life setting

Analysis of the discipline must determine the type of energy expended. A distinction is made between sports that demand continuous efforts and discontinuous efforts. These sports solicit the three energy systems in different ways. For example, against a background of aerobic work, combat sports involve a succession of short, intense efforts interspersed with recovery time.

Of course, physical preparation depends on energy systems, but work must also be done on coordination, technical aspects and the tactics that are specific to different disciplines.

Observation in a real-life setting is highly instructive. To facilitate this analysis, the coach can split the practice into basic situations and possibly create special rules or restrict the practice time.
This helps the coach offer sessions focused on each individual's physical and technical shortcomings.

9.3 Planning workouts

This section is not intended to replace the advice of a qualified and experienced sports instructor. We will, however, review some important aspects of planning that will enable us to analyse a training programme.

9.3.1 Determining goals and motivations

The coach must identify what motivates the practitioner before drawing up a programme where the sessions are **tailored to the individual and his or her objectives.**

Children look for immediate satisfaction. It is helpful, therefore, to work in a short-term perspective, as a child takes pleasure in demonstrating a skill, getting better at something and seeking social approval.

Adults and **adolescents** are motivated by long-term projects. Adults may attribute a variety of meanings to a sporting activity. Swimming, for example, may be seen as a performance sport, a training sport or a means for recovering fitness.

The objective is associated with emotions. Achieving realistic goals builds self-confidence, a sense of competence and motivation.

It is important to undertake work that is varied and rich, and in pleasant surroundings; all this improves motivation.

9.3.2 Notion of workload

It is important to put in place various workloads and recovery periods. A distinction is made between internal and external workloads.

External workload measures what the athlete does. For example, a bike ride at a speed of 40 km/h, which is commonplace for a high-level athlete, is a task close to agony for an amateur (**internal workload**).

Consequently, it is necessary to assess what happens in a given subject: the internal workload (the level of fatigue that is experienced).

Here are some features of workload:

- ✓ The **length** of the workload: i.e. the duration of the exercises;
- ✓ The intensity of the workload: i.e. the level of difficulty of the exercise;

- ✓ **Growth** in the workload: the gradual increase in workload (via duration, intensity, repetitions or recovery time);
- ✓ The workload is said to be **specific** if it solicits the same neuromuscular capacity as the activity performed;
- ✓ **Continuity** of the workload: when there is a stoppage through injury or lack of motivation, performance capacity declines. *The capacity for aerobic efforts (which is acquired slowly) regresses slowly. The capacity for anaerobic efforts (power), which is acquired quickly, disappears quickly. Technical ability is more stable (the actions in volleyball remain but one "loses" one's breath and power);*
- ✓ **Recovery:** any workload demands recovery periods, which have an influence on the way exercises are organised during a session and the frequency of sessions.

9.3.3 Phases of a session

Warm-up

Work capacity increases gradually during the warm-up, which is reflected in improved coordination, energy efficiency and flexibility.

The warm-up may be divided into three parts:

- ✓ General warm-up;
- ✓ Warm-up specific to the activity;
- ✓ Warm-up specific to the session, which stimulates and targets the systems directly affected by the core of the session.

Core of the session

- ✓ The effort invested in a session is the main factor influencing its effectiveness. However, the longer and more intense the effort, the longer the recovery period will be.
- ✓ The sessions will differ according to the goals: recovery, technical work, physical work, etc.;
- ✓ Several sessions a week are required;
- ✓ Sessions must be adapted to the level and age of the athlete;

- ✓ Work capacity is optimal between 10 am and 1 pm, and between 5 pm and 8 pm;
- ✓ You do not practise in the same way or at the same intensity all year round. There are three periods: **the preparatory period, the competition period and the transition period.**

After a session

Active recovery (light jogging) or flexibility exercises can be performed. Massages, warm baths or saunas can be used to enhance the end of sessions.
Do not forget to drink plenty of water and eat some dried fruit or sweet snacks.
Finally, it is worth bearing in mind that children and beginners recover more slowly than adults or experienced athletes.

9.3.4 Planning workouts

Planning takes into account motivation, the initial physical level, the goals to be achieved and material conditions. The key element in planning is the competition **timetable** and **the season's main objective**.

General training improves fitness and increases the capacity of the practitioner. It is essential, therefore, for the coach to include general physical preparation in the planning.

The state of optimal form for an athlete is short-lived. The training plan reflects the temporary priorities chosen by the coach to develop the different lines of work that will attempt to improve performance. The training plan may be subject to adjustments.

Here are a few principles to bear in mind when devising a programme based on the training phase:

Preparation phase:

Dominated by general exercises with a gradual rise in the workload.

Pre-competition phase:

Practice time decreases but the intensity increases.

The proportion of exercises specific to the relevant sport increases.

Competition phase:

The amount of work decreases (the athlete must be brought to a state of psychological and physical freshness).

Recovery time is incorporated.

Participating in competitions helps to maintain the level of form.

Be aware that form comes fast but also disappears quickly with the lactic anaerobic pathway.

For trials of power, one competition a week is possible. In combat tests or trials of strength, longer intervals are required for recovery. For endurance tests, you can participate in three half-marathons or two marathons in a year.

Compensation phase (recovery):

These phases include a reduction in the quantity and intensity of work.

Transition phase:

After the competition phase, there is a recovery phase with a reduction in the intensity and number of sessions. The type of sporting activity can be changed, and spa treatments or massages can be added. During 2 to 4 weeks of holiday, light aerobic work can be undertaken, and flexibility and strength maintained.

9.4 HIIT

9.4.1 Introduction and definition

Traditional cardio sessions are useful for improving endurance and burning fat. Intense and heavy weight-training programmes promote muscle mass.

HIIT (**High Intensity Interval Training**) consists of short but very intensive sequences (with any exercise* leading to a significant increase in heart rate) interspersed with recovery time or low-intensity work.

Basic HIIT example: after warming-up, run at 8 km/h for one minute, then accelerate to 16 km/h for another minute and drop back to 8 km/h and so on until you have done 8 repetitions of the same sequence, i.e. a total of 16 minutes of running.

(*) Examples: running, cycling, swimming, push-ups with jump squats, star jumps and any type of exercise that makes a large number of muscle groups work quickly and which is likely to raise the heart rate.

This type of physical preparation takes into account the requirements of practitioners of combat sports fairly well. Furthermore, some of karate training drills may be similar to those of HIIT.

9.4.2 Principles of HIIT

During intense anaerobic training, lactate accumulates and oxygen debt is produced. This state is associated with a feeling of “burning” muscles caused by the H+ released during ATP degradation. During the recovery phase, the cardiorespiratory system continues to work (the feeling of breathlessness) to supply the oxygen required to break down the lactate accumulated during the anaerobic exercise (oxygen debt).

This type of training forces the body to adapt by increasing its ability to use oxygen (VO2 max) and the buffering systems, and by strengthening the cardiorespiratory muscles and enhancing the elimination of lactate (increased lactate threshold) whilst increasing speed and coordination. Even for high-level athletes, maximum intensity efforts can only be maintained for five to seven minutes (examples: five intervals with a maximum effort of sixty seconds or 15 intervals with 15 seconds at high intensity).

During this kind of effort, the body burns a maximum amount of sugars and generates oxygen debt. After the effort, the body, having exhausted its sugar reserves, will dip into its reserves of fat for several hours, which explains the fat burning.
Finally, the lactate produced during this kind of exercise seems to help boost the concentration of testosterone and growth hormones that aid recovery, muscle performance and growth.

9.4.3 Research examples

Tabata

In 1996, professor Tabata conducted a study on cycling with two groups of high-level athletes. The first group trained for an hour a day for six days out of seven at low intensity (70 % of VO2 max). The second group trained for five minutes a day for six days out of seven with eight intervals of 20 seconds at high intensity (170 % of VO2 max) followed by ten seconds of rest.

The study concluded that there was a significantly greater increase in the VO2 max (endurance) in the HIIT group compared to the low intensity group. Furthermore, the HIIT group also improved its anaerobic capacity (power) in contrast to the low intensity group.

McMaster

McMaster demonstrated that eight to twelve cycles of 60 seconds of intense exercise (at 95 % of VO2 max) followed by 75 seconds of rest obtained results comparable to five hours of training a week at low intensity (between 50 and 70 % of VO2 max).

Macpherson

One group performed four to six sprints of 30 seconds separated by four minutes at low intensity; a second group ran twice the distance at low intensity. The first group lost more than 12 % fat compared to only 6 % for the second group.

Tremblay

This study showed that, in comparison to a group carrying out exercises at moderate intensity, athletes in the HIIT group lost nine times more fat per calorie consumed during the sessions.
Muscle biopsies demonstrated that in the HIIT group there was an elevated concentration of phosphofructokinase (the enzyme

involved in the metabolism of carbohydrates (sugars)) and 3-hydroxyacyl-CoA dehydrogenase (the enzyme involved in the metabolism of lipids (fats)) in contrast to the low intensity group.

Fat oxidation is improved after HIIT sessions in spite of the low fat consumption during HIIT. Moreover, the only way to spare the carbohydrate (extensively consumed during the HIIT) is to burn more lipids.

9.4.4 Advantages of HIIT

— It is the most effective method for burning fat;
— It improves endurance and VO2 max;
— It improves anaerobic and aerobic performance;
— It is not boring (time passes quickly);
— It can be easily incorporated into any training programme.

9.4.5 Precautions

Before undertaking this type of training, it is recommended to take a basic fitness test and undergo a stress test under medial supervision.

Increase the length and intensity of the exercises gradually.

Although the HIIT seems extremely effective, an excessive volume can result in over-training. A recovery period of 48 hours is often advised.

Before this type of session, you are strongly recommended to warm up for at least five minutes. At the end of the session, a cool-down period of roughly two minutes is also suggested. Do not forget to stretch the target muscles.
To avoid hindering the acquisition of muscle mass, it is better to undertake the HIIT (or the cardio) BEFORE a weight-training session.

9.4.6 HIIT and Nutrition

Carbohydrates

If you are aiming to lose fat tissue, a diet containing about 200 grams of carbohydrates (i.e. +/- 40 % of daily intake) seems optimal. Insufficient intake of sugars will impede performance during HIIT. Excessive intake of carbohydrates, on the other hand, will reduce fat burning.

Proteins

An intake of proteins helps to burn fat and has an anabolic effect. Six grams of EAA (essential amino acids) and 15 to 25 grams of milk proteins (whey protein) before a session is more effective than training on a empty stomach.

9.4.7 HIIT in practice

High intensity interval training appears to be a very effect method of physical preparation. It addresses the needs of people practising combat sports and other disciplines that need to develop the anaerobic pathway against a background of endurance.

Practical Tips

- ✓ Take medical advice first.
- ✓ Individuals who have not been in training should only practise HIIT after a period of returning to fitness: cardio exercise, gentle weight-training and pre-stretching are recommended.
- ✓ Children should only practise HIIT sparingly.
- ✓ Maximum two to three sessions a week (between 20 and 60 minutes).
- ✓ Follow the Tabata protocol: five minutes/days – six days out of seven.
- ✓ Always start with a warm-up and stretches before a HIIT session.
- ✓ Always remember to work the agonist and antagonist muscles (e.g. rowing training: high intensity rowing for three minutes – recovery with slow push-ups at low

intensity or burpee up to 70 % of maximum heart rate, i.e. often one to two minutes);

- ✓ Do HIIT (or cardio) BEFORE the weight-training session;
- ✓ To optimise fat burning without losing muscle mass, ensure you have an optimal input of sugars and protein;
- ✓ Studies are still needed to determine the optimum intervals and durations according to the objectives pursued. The table below, however, may be of help.

Aim	Interval at maximum intensity	Recovery time at low intensity	Repetitions	Remarks
Fat burning	15 to 30 seconds	2 to 4 minutes	10 to 15 (i.e. between +/- 22 and 67 min)	Lemon shows that twice as much fat is burned in half the time compared to a similar type of exercise (e.g. cycling or running) + improved V02 max
Aerobic power	10 to 30 seconds	4 minutes	10 to 15 (i.e. between +/- 22 and 67 min)	
Aerobic performance (endurance exercise)	20 seconds	10 seconds	8 (i.e. a total of 5 minutes)	Tabata protocol: cycling for properly-trained athletes: improvement is greater than for a similar exercise performed at low intensity (70 % of VO2 max) for one hour + improved anaerobic capacity

Summary

- The length of the high intensity exercise varies from 10 to 30 seconds: 10 to 15 seconds to develop anaerobic power and 20 to 30 seconds for fat burning and VO2 max (aerobic capacity).
- The length of recovery varies from 10 to 240 seconds: 10 seconds for VO2 max (endurance, aerobic capacity), 2 minutes for fat burning and 4 minutes for aerobic power.

Using this information, simply design your own workouts. Choose your intervals based on your goals: fat burning, endurance or power development. In addition to traditional cardio and weight-training exercises, you can use *kihon*, *kata* or *kumite* sequences to do HIIT work-outs.