Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva / Italian Journal of Health Education, Sports and Inclusive Didactics - ISSN 2532-3296 - Anno 2 n. 2 - aprile - giugno 2018 - ISBN 9788860223562 - CC BY-NC-ND 3.0 IT - doi: https://doi.org/10.32043/gsd.v0i2.72

New Technologies in Swimming Sports

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Abstract

The aim of this research contribution is to bring to the fore the importance that technological progress can play in sports disciplines too, just like what already guaranteed in other sports contexts such as football or formula one.
In this regard, we are going to introduce some of the main technologies useful to support technicians, coaches and experts in the field in optimal training planning and in the increase of performance during competitions.
The proposed research aims to provide a solid basis for future empirical and qualitative research in measuring the effectiveness of technological instruments in water sports.

Keywords

Water Sport; Technology, Match Analysis, Water Polo, Sport Innovation

Introduction[1]

The technological support used in many sports is now well-known, and the wins in Formula one or Motorcycle Grand Prix are a certain and recent testimony. Just like in football, or in American football, technology plays an increasingly fundamental role in determining the entire training planning and the race performances.

However, it is less known that in other sports such as skiing, cycling and even swimming and all related water sports, for example, the technological equipment has been used on a large scale. In fact, in improving the quality of the equipment, also technicians and athletes have had a huge amount of devices available to measure performance and improve it. All this makes the task of the coach difficult, and the training science and scientific research more fascinating.

We are going to start this work by analyzing the evolution of the technologies applied to swimming in order to show the close relationship between technological innovation and sports performance in contemporary sport. In order to better observe, measure and improve every technical gesture, the athletes and their coaches resort more and more to technology, which, in this case, must deal with the presence of water that makes everything more complicated.

Swimming has always been a sport with low technological impact; just think that, in order to achieve a good performance, only three elements are sufficient (1-4):

- A swimcap;
- A swimsuit;
- A pair of goggles.

Even in some water sports, such as water polo, the athlete does not need any goggles, but to be able to train and compete he needs only a swimsuit, a swim cap and a ball.

What has been affirmed shows that, when technology becomes part of this world, it deals with significant cultural barriers.

In this regard, the dual objective of this research is to offer an overview on the use of technology in sports and, at the same time, to analyze, at national and international level, its dissemination and consequent acceptance and adoption.

1. The first technological approach in swimming

In the '80s and' 90s the only options linked to the improvement of swimming performance were related to the development of innovative training methods, and to the use of depilatory practices to reduce body frictions in contact with the water fluid. However, the technological evolution, in the last years, has clearly conditioned the performance. Covering the body with advanced materials has the purpose of significantly reducing friction, by improving floatation and sliding. Scientific research applied to the creation of increasingly performing materials has allowed us phasing out a very high number of world records. The search for greater speed in water has brought innovations in the field of new types of lanes, starting blocks and pools for competitive competitions, designed and built with particularly performing materials: no aspect that could result in significant increases in performance has been overlooked. In swimming, technology has brought a real revolution, up to receiving the approval by the FINA (the International Swimming Federation), in the early months of 2008, of a swimsuit made with inserts of plastic material, which opened up the door to the general use of swimsuits made of "non-woven" material, and therefore of the so-called full body swimsuits, commonly called in Italy "plac-

1 This work is the result of a collective work of the authors, the specific contribution of which is referred to as follows: Davide Di Palma: Paragraphs n. 3, n. 4, n. 5 and n. 6 – Antonio Ascione: Introduction, Paragraphs n. 1, n. 2 and Conclusions

cati" (plated), or "gommoni" (dinghies), depending on whether the swimsuit was made up of plastic material only partially or entirely. Meanwhile, quickly wearable swimsuits become the subject of debate among those who consider them a simple improvement of the dress worn by athletes, and those who instead consider them a technological tool to be banned as it artificially improves athletic performance. The fisrt launched one was the so-called speedo LZR racer, a swuimsuit characterized by the introduction of thin panels of polyurethane material, positioned at strategic points of the athlete's body. By using this swimsuit, the Anglo-Saxon nations most closely linked to the American company get amazing results and records fall to a degree never observed before (5, 13, 18). At this point, a little-known Italian company proposes a swimsuit, which is made entirely of polyurethane. The fabric definitely disappears from the swimsuit to give start to era of the "gommoni" (dinghies). Even other brands are rushing to churn out new swimsuits, both plated and integrally polyurethane-made. In fact, it is clear that, by using the old models, athletes are likely to remain on the sidelines in international competitions. Given the surprising outcomes of many athletes and the high number of records made, perplexity and confusion arise, so much so that we get to talk about technological doping, especially for the high costs of the new swimsuits, which create an objective inequality during the race. The International Swimming Federation, in tune with other national federations, prohibits the use of new generation swimsuits for the Boys category, trying to limit the phenomenon at least among the youngest. At International level, the "Dubai Chart" was signed, in which strict limits were set on the swimsuits features, such as thickness and floatation, and the technical specifications for the swimsuits were defined; it was decided that, since January 1st 2010, only swimsuits made with less than 50% of non-permeable material on the surface would be allowed (16).

The Fastskin Revolution issue offers a wide field of reflection. First of all, it is an example of the correlation in contemporary sport between technological innovation and sports performance. A simple change in size and fiber used for the suit worn in swimming competitions generated an impressive improvement in the athletic performance made. The improvement ceased when the suit previously considered admissible was banned. However, the fastskin issue is also a sign of the indeterminacy of the rules ruling over sports competitions, in the field of performance improvement. In fact, the same provision wasinterpreted in an opposite way; it was first considered as not suitable to limit the size and the fiber of the swimsuits, then as a prohibition: an interpretative change that produced a breakdown in the swimming world, allowing achieving performances that now seem hardly comparable. On the other hand, fastskins are not the only technological innovation that deeply changed the sports performance in a given discipline. We should wonder why some technological innovations generating performance improvements are considered eligible, while others are prohibited (6, 14). The answer, however elementary it may seem, is that, in order to decide whether an improvement is allowed or prohibited, it is important to note other factors than those commonly considered as decisive: these are the reactions of scientific researchers in this discipline, of professionals or amateurs, of the audience and supporters, of the public opinion and, to some extent, also of the market and producers.

2. Technologies in the swimming disciplines for monitoring movement into the water

Monitoring systems are crucial in sports as they provide timely feedback from both coaches and athletes. In fact, athletes need information about their physiological abilities and their past performance during competitions, to develop a personalized training plan aimed at continuous improvement. To this end, the technical collaboration of various professional operators is necessary to meet the needs of each athlete, and to evaluate his development quantitatively. A large number of commercial monitoring systems are available for this purpose.

The systems available on the market focus on direct monitoring (connected equipment for the athlete) and distance (indirect / remote / i.e. equipment disconnected from the athlete) techniques. Both direct and remote (indirect) monitoring tools are widely used in many sports, but it is unusual for them to be used in swimming because of the environment in which the athlete competes.

The most commonly used direct monitoring techniques are the sensors connected to the athlete. Inertial sensors are technologically advanced devices capable of measuring certain movement variables (called kinematic variables) of a body to which they are firmly fixed. The body in question can be an object (a mobile phone, a car, and an airplane) or the human body, or more specifically, one of its body segments. Since the late 1990s inertial sensors have been impacting the recognition of activities, expanding the field of research to scenarios not yet considered. Scenarios, for example, in which a direct implementation of the sensor is requested on the subject's body, for rehabilitation or sports support purposes. There are mainly two categories of inertial sensors: accelerometers and gyroscopes (7-9, 20).

From the accelerometers, as the word itself says, it is possible to derive a (linear) acceleration measure to which the body is subjected. From this, theoretically, through a mathematical operation called numerical integration, a (linear) speed and position estimate could be obtained. Gyroscopes, on the other hand, are sensors capable of measuring the angular velocity to which a body is subjected. To give an explanatory example we can think of a gyroscope as a sensor applied to the pendulum of a clock, and that is able to quantify how fast that pendulum is rotating around the fixing pin and from which an estimate of the angle of the pendulum can be obtained. This estimate is considered more reliable than those derived from accelerometers. In addition, the magnetometers, which can be considered as sophisticated compasses able to indicate the direction of the Earth's magnetic north, belong to the group of inertial sensors. A fundamental distinction between the inertial sensors concerns the number of sensitive axes, i.e. axes in which the measurement is detected. From a minimum of 1 to a maximum of 3, we speak respectively of mono sensors, bi-sensors or tri-axial sensors. If it needs to evaluate the acceleration of a swimmer's progress, a mono-axial accelerometer appropriately fixed along the forward direction will be sufficient. For more "three-dimensional" movements, instead, a tri-axial sensor will be required.

There are different types of inertial sensors with very different functional and mechanical characteristics: for example, the MEMS (micro electro mechanical system), which measure only a few square mm, or laser ring gyroscopes31 that can measure up to 50 cm. The functioning of all these sensors is based on the same basic concept: inertia. Typically, the data collected by the inertial sensors can be transmitted in real time through connections via cable (e.g. USB) or wireless (e.g. bluetooth) to a computer, or stored in internal (or removable) memories appropriately sized. Inertial sensors find many applications in everyday practice (air bags, smartphones, games consoles, tablets, but also helicopters, airplanes, ships, cars, etc. ...) and what has granted them this success was the extreme degree of miniaturization that can be achieved with the so-called MEMS technology, through which the sensors are built, as well as the decrease in costs. Just think that a low-quality accelerometer costs just like a coffee. The first prototypes used in sport date back to the 2000s, while in swimming they date back to 2002.

If we want to describe an inertial accelerometer we can make the example of a MEMS-type one, which consists of a mass-spring system positioned in a vacuum. If acceleration is applied to the accelerometer, the result is a displacement of the mass in the spring system. The mass displacement depends on the mass-spring system, therefore calibration is needed. The reading can be done through a capacitive system. Furthermore, MEMS accelerometers, like most inertial sensors, are available in single-axial, bi-axial, tri-axial versions.

As for the inertial gyroscopes, however, there are different classes. MEMS gyroscopes, for example, have a small vibrating mass that oscillates, suspended in a spring system.

When the gyroscope is rotated, the rotation exerts a Coriolis effect perpendicular to the mass, which is as large as the mass is far from the center of the rotation. The oscillating mass then provides a different reading on each side of the oscillation, referred to the rotation speed. In addition to this cited example, there are more advanced and innovative ones, such as Ring Laser Gyroscopes (RLG) and Fiber Optic Gyroscopes (FOG), which are very reliable but also very expensive. Most inertial sensors are accessible at low cost and have good measurement accuracy. They also have a small dimensions as their strength point, which, together with the advancement of the technology in micro electrical mechanical systems (MEMS), the improvement of wireless communications and the progress of digital electronics, has allowed for great integration in modern commonly used technologies such as tablets and mobile phones, as well as the possibility to organize real sensor networks (WSN, wireless sensor network). The WSNs, in particular, are composed of a set of nodes (called sensors) placed in proximity or inside the phenomenon to be observed. The sensors generally have very small dimensions and weight and, if produced and distributed in bulk, can reach negligible production costs. Every sensor has a limited and non-renewable energy reserve and, once set up, must work independently; for this reason, these devices must constantly keep the consumption very low, in order to have a longer life cycle. Eavery sensor is composed of a processor / memory subsystem through which it can process the data detected by the transducers before transmitting them, a variable number of transducers, and a radio subsystem for communications. Just communication, realized through short-range wireless technology (in the order of hundreds of meters), is usually asymmetric as the sensors send the collected information to one or more special network nodes, called sink nodes, which have the purpose of collecting data and transmitting them typically to a server. Communication can occur autonomously by the node when a given event occurs, or the sink node can induce it by sending a query to the interested nodes. To conclude the description of sensor networks, it needs to add that each node that forms it can include microphones, temperature transducers, humidity transducers, pressure transducers, light transducers, electromagnetic transducers, gyroscopes and accelerometers. All together, they offer a wide variety of uses, from the military up to the scientific, industrial, medical and domestic fields. Finally, among the latest generation technological applications regarding inertial sensors, we can mention the Wiimote, an accessory used with the Nintendo Wii console, equipped with a triaxial accelerometer that reacts to vector forces and orientation with respect to the space; in addition, there are alternatives of technologies wearable by users such as Xsens MVN Inertial Motion Capture. To use an inertial sensor in swimming, in fact, some specific features are required (1, 2, 10-12) :

- Good waterproofing features. Currently there are no inertial sensors, for the analysis of human movement, that are generated as waterproof. The operation must be done with the appropriate precautions by the operators.
- High working autonomy. The battery life must be such as to ensure the measurement of a given performance. It must be taken into account that, once the energy has been exhausted, the work must be interrupted during recharging.
- A full scale of sensors adapted to the speed of the gestures performed. Although gestures in swimming are not particularly fast, the freestyle hand can reach accelerations even higher than 6g. In breaststroke swimming, on the other hand, the highest angular speeds are reached: up to 800 degrees per second. Therefore, full-scale accelerometers ranging from 6g to 18g and full-scale gyroscopes ranging from 1000 to 2500°/s are suggested. Other important parameters are the sampling frequency and the resolution in bit. A minimum sampling frequency of 100 Hz, optimal higher than 250 Hz, is suggested. The resolution in bit must be at least of 12 bit.
- Extended amount of memory to store data. The transmission of real time data in water is currently only guaranteed by mixed radio systems (very bulky for the moment), and even if placing the sensor near the water surface (like on the back) or near the receiver, the transmission may not work, risking an irretrievable data loss. The ideal data buffer (encumbrance size ~ 20g) has a minimum capacity of 1 GB.

To perform the analysis, the positioning of the sensors on the body is chosen according to the movement to be followed (limb, barycentre, head...). In swimming, different sensor locations have been tested, such as on the wrist, on the head, on the lumbar-sacral area (lower-back). This last location is considered ideal because it is very close to the bodily barycentre, and used in many works. The recommendation is to perform an excellent alignment between the axes of the inertial sensors and the bodily ones. The implicit assumption, in fact, is that the measurement of the sensor accelerations and angular speeds are the same of the segment to which it is fixed, which is assumed to be a rigid segment. Making an incorrect alignment of sensor axes-body axes would lead to over and under-estimated measurements, thus incorrect. To date, however, it is not easy for swimming technicians to find a clear application of the information that can be obtained fromthe data collected.

- Measurement of rotation speeds and body orientation

By positioning a gyroscope in the lumbar region, it is possible to monitor the rotation speeds, on the three spatial axes, while the angles assume the names of roll, pitch and yaw respectively. The graphic trend of the different rotations allows identifying the adopted style and the different performance phases. The most studied rotations in freestyle are the rolls (or body-rolls). During the stroke, the athletes accentuate torso rotation to facilitate breathing, reduce the risk of inflammation of the shoulder joint, and better apply the propulsion in the underwater phase. Several studies are being carried out in this sense to observe the Shoulder/Hip coordination in freestyle rotations, testing different athletes monitored by 2 Sensorize gyroscopes (Free Sense), positioned on shoulders and hips. They cause a loss of linearity in the movement and an increase in drag. However, the application where the gyroscopes find their ideal location is in the measuring of the turns. In this field, several articles have already validated the system. With only one sensor, it is possible to identify the different phases that make up the turn, and measure them over time and in the performance speed. Already several technicians use some prototypes of these sensors during training, in order to recognize the slower phases in an athlete’s technique, and decide where to intervene to make him improve.

- *Accelerations measurement*

As explained above, these measurements are still quite complex and the data obtained are not easily interpretable and usable. Among the various problems, there is the difficulty of positioning the sensor correctly aligned with the interested body axis. Several researchers are working in this direction, experimenting with different types of protocols. The main goal is to study the swimming fluctuation. By monitoring the continuous speed changes, it is possible to study parameters such as: infracyclic acceleration, energy dispersion, estimation of the added mass of the drag, and evaluation of forces starting from inverse dynamics procedures, etc. Unfortunately, these data, still under test, are difficult to be interpreted and used by technicians for athlete training purposes. What amazes swimming technicians is the great difficulty in obtaining average speed values from these data. As stated above, the mathematical operation, which allows obtaining speed starting from the acceleration, presents a high level of approximation.

- *Joint angles measurement*

An important qualitative leap in the type of information that can be acquired is the use of inertial sensors, typically referred to by the names of IMU or IMMU, which can be used to measure joint angles. They are tri-axial inertial sensors equipped with accelerometer, gyroscope, magnetometer and temperature sensor, able to provide both “raw” acceleration data, angular speed and magnetic field vector, and accurate information on their spatial orientation, i.e. on how they are “turned”, rotated, within the 3D space. Starting from this information, by means of specific movement analysis protocols, it is possible to measure the swimmer’s joint angles with good accuracy.

This type of measurements is very innovative and allows for the acquisition of data of the entire test required by the swimmer, thus making it possible to study also the modifications of the technique that take place under conditions of fatigue. Nonetheless, its low invasiveness on athletes (small and light sensors) does not involve substantial modifications in the swimming style to be analyzed.

Until now, the unique and complex three-dimensional kinematic analysis exploited underwater cameras, able to resume a few cycles of strokes at a very reduced speed, and it was unthinkable to acquire data on an entire pool, limiting most of the studies of interest for technicians and coaches.

The effects of these new studies made possible by inertial sensors will be of particular interest in the study of swimming technique and its didactics. In particular, it will also be possible to assess changes in variation in the action of the swimmer's shoulder subjected to acute and chronic stress.

3. Technological support to improve the athlete's physiological measurements into the water

The latest fitness devices, designed for swimming, thanks to a combination of GPS andtime monitoring technology, allow improving and measuring speed, technique,and performance, and setting goals to improve the swimmers' performances (1, 15-17).

The swimming devices are designed to be waterproof and range from fitness watches to trackers like pedometers, which are so small that they can be placed under the cap, put on the finger or under the goggles band. Unlike devices for cycling or running, swimming technology is not limited to monitoring distance, pace, heart rate and calories consumed. These devices are able to detect the slightest movements and repetitions, some of them can even automatically recognize the types of strokes and their variations, evaluate the efficiency of each training session and store the data to analize them subsequently. To notify swimmers about distance, lengths or time, they often use vibrations, allowing for uninterrupted monitoring of movement.

Intra-auricular technology and video tracking are also increasingly used aids by coaches to refine the technique during practice, or to evaluate performance at the end of the training. Swimmers must monitor stroke speed, lengths/distance and speed. The most basic devices monitor stroke speed, establish its rhythm or count the lengths by monitoring the repetitions of each arm movement into the water, or, at a more basic level, count leg strokes. However, in large open water areas, it is almost impossible to accurately count strokes and evaluate the performance without a specific device for swimming.

Swimmers can guarantee best results with the minimum effort by extending each stroke. Counting 15-20 strokes in 25 m is not difficult, but in 50, 100 m in open water, it is almost impossible. Therefore, setting goals to improve is complicated. The strokes rhythm (the number of tractions of the arms into the water) per minute is equally difficult to be deciphered without a well-placed assistant who, at the edge of the pool, on the lakeshore or seashore, counts the strokes for the athlete. Even the recent use of GPS technology allows swimmers accurately monitoring distances and speeds in large open water spaces.

- *U-COACH*

U-COACH is an underwater voice radio transmitting system designed to communicate with the swimmer during the training. The system consists of a receiver and a transmitter. The receiver, which is waterproof, can be easily worn under any silicone cap and remains fixed even during the start and turn phases. The transmitter, with three channels and equipped with a special microphone, has a maximum range of 75 m. Each transmitter can connect with a maximum number of 30 receivers, 10 per channel. The sound is perceived by the athlete through a bone conduction technology, which exploits the diffusion of vibrations from the temporal bone to the cochlea. In this way, the ear channel remains free, allowing for the simultaneous perception of the sounds coming from the external environment. Listening is always clear even in environments with loud noises. The trainer, from the pool edge and during the training phases, can: provide technical corrections during the swimming action, communicate to the athlete important references such as number of stroke cycles and chronometric intermediates, give rhythm changes without continuity solutions, modify breathing cycles during the action, provide immediate feedback during or immediately after the turn phase, motivate and exhort the athlete to make greater efforts.

Swimming into open water is one of the U-Coach strengths. Thanks to its range of about 75 m, the coach can communicate the rhythms, the swim cycles and the speed to be held directly from the beach or the boat. In a group workout, he can also suggest slipstreams, breakaways and tactics. It can be used also in synchronized swimming training because, with U-Coach, it will be possible to communicate with the synchronettes up to a maximum depth of 1.5 m. The system, if connected to an MP3 player, can transmit music. By using the three transmission channels, it will be possible to train at the same time, in the same pool, up to three teams with different musical bases. Lastly, it can be used during water polo training sessions too, in which the technician will be able to give indications relating to an attack or defense scheme. In fact, it is possible to equip two teams at the same time by tuning the receiver on two different channels. In this way, the coach will be able to communicate selectively with both teams.

- *X metrics*

X metrics is a wearable device that, placed behind the head and connected to the ears with lightweight and ergonomic headphones, allows receiving real-time audio feedback on the performance obtained during pool training. For example, after a turn, X metrics will give an audio message indicating the number of lengths performed, the time and duration of the workout. Through this device, the technician will be able to assess the number of strokes, breaths, heart rate, blood pressure and oxygenation, and the internal body temperature; it will also be possible to have an automatic and precise chronometer without having to interact with commands of any kind.

X metrics will also allow performing a detailed analysis of the training session data, and easily consulting them on the smartphone, tablet or PC; it will also be possible to program the individual workouts through a software or directly on the device. X metrics is aimed at all athletes and coaches who wish to monitor and improve their pool performance. Moreover, for the coaches, a dedicated software will be available to manage the workouts, monitor and analyze their athletes' data, with a speed and absolute precision.

The idea was born just over a year ago by Andrea Rinaldo, creator, co-founder and CEO of the company, a Telecommunications Engineer, former athlete and former swimming coach. In his experience, first as an athlete and then as a technician, he realized how much technological tools were lacking in the pool to support swimmers and coaches during training, in order to improve what will be expressed during a competitive competition.

- *Instabeat*

Unlike other sports, swimming requires a total detachment from what happens outside the pool, and Instabeat automatically registers the heartbeat, the calories consumed and the lengths performed, saves them in the internal memory to make them being downloaded on the computer via USB. The swimmer can thus study the evolution of his training over time, know about which countermeasures to take to improve it, and have a history of his training sessions. In short, it is like a black box applied to the human body, to which nothing escapes and which is activated automatically when the sensor receives the beating from the temple.

Instabeat is the first all-in-one training monitor designed to adapt to swimming biodynamics. This particular instrument was developed by a start-up founded in 2011 by the professional Hind Hobeika, a swimmer from Lebanon, and is characterized by a patent-pending optical sensor capable of accurately reading the heart rate from the temporal artery. The project was published on Indiegogo, one of the crowdfunding sites, and it managed to raise the funds necessary for its development. The rubber case that contains it was designed to be flat and to be fixed under the goggles rubber bands, thus ensuring that the sensor always remains positioned above the area of the temples on any cranial conformation.

It is thanks to this feature that it is possible to read the heart rate, regardless of the athlete wearing the instrument. This device has multiple built-in sensors, which, in addition to calculating the calories consumed, the flip turns and the breathing rhythm, it also act as a filter to reduce the disturbance created by the head movement, ensuring accuracy in reading the heart rate. The device automatically turns on as it detects a heart rate, monitors it in real time throughout the workout and turns off only once it has been removed from the head.

The information collected by the sensor can be viewed in real time by the swimmer on the goggles lenses, under the form of colored lights, divided by intensity and into three categories (fat burning, fitness, maximum performance).

The swimmer can thus know about the type of training he is making, and the level of intensity with which he is swimming. Furthermore, these data are saved in the internal memory and can be downloaded on the computer via USB for future consultation.

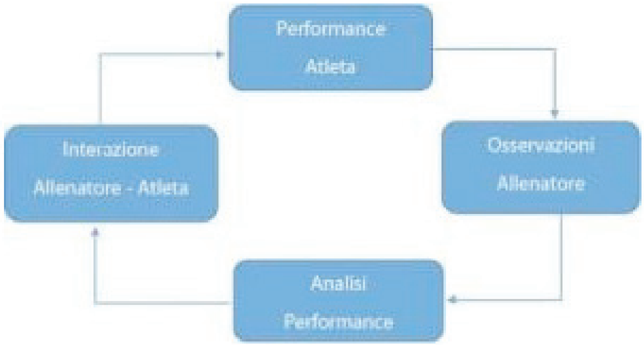
4. Technology in remote monitoring techniques in water sports training

The athlete needs or the coach or instructor, ever since he learns the fundamentals of this sport; he needs a guide to develop skills and to get expert advice on performance.

By schematizing the coaching process, 4 phases can be identified (13, 19, 21):

1. The athlete carries out the technical gesture or the performance;
2. The trainer makes his observations;
3. The performance is analyzed;
4. There is interaction between coach and athlete.

Figure 1: The Coaching Process



Source: our source Processing

The process repeats itself from the beginning each time with the implementation of a skill and the coach's observation, and ends with the provision of recommendations and suggestions. The coach's function is to give clear and concise indications, which are the result of the analysis made after the observation. The final part of the coach's job is to give "feedback" to the athlete with different presentation methods (verbal and visual), in order to facilitate the different learning styles.

However, there is the performance analysis phase before, which is heavily influenced by the coach's experience, and by the training, the courses, the comparison with other colleagues and the planning strategies to improve performance. Given that this is all in the coach's "toolbox" (ability to give feedback, analyze a performance and plan), the weak link in the chain is represented by observation.

The eye is highly unreliable (especially with regard to the submerged part of the technical gesture that undergoes refractive effects, just to name one) and, above all, several scientific studies show that the trainer remembers only a 30% of the competition information.

In the practice and in the most common cases during the coaching process, some coaches look at the performance and give some advice. Other more scrupulous ones, in addition to observing and giving advices, take note of what has been done during the training or during the race, highlighting the salient events. It seems clear that the precision and functionality of this last method is certainly lower than the observation of a video camera, to the note that can be quickly made through notational analysis software, and certainly will never connect images of the technical gesture with the data derived from the performance. The training process, therefore, needs to be updated. Researchers have shown that observation and human memory, however amazing they may be, are not reliable enough to provide accurate and objective information to (especially) high-level athletes. Objective measurement instruments are needed to activate the feedback process. These can be post-event video analysis systems, biomechanical or computerized notation systems or other (real-time) systems activated during the event itself (2, 3, 22).

Manual or computerized notation systems, being part of the same process, provide the same type of data and are used for the same purposes: movement analysis, technical-tactical evaluation and statistics. Recent advances in information and video technologies have changed the approach to the performance analysis and, consequently, their use in the training process.

By employing an objective observation system, the coaches can focus their attention on the analysis of those they consider as critical events in their atheltes' performance. In this way we can hope to improve the athletes' performance by planning practices based on these analyses. Manual and computerized notation systems and all biomechanical analysis systems have showed to positively influence these processes. The simple model of the training process can now be expanded to include some of these advances in information and video technologies. (19, 23-25).

To ensure that the coach collects accurate and reliable data for a useful analysis, a particular training of the operators is needed, in order to make the application of any of these systems specialized. Therefore, without getting caught up in the desire to do everything, also because it is observed that time is always too little, the coach can rely on the video-analyst technician who can provide feedback on the team and on individual technical skills, and integrate fitness data.

5. Monitoring of swimming performance through technological support

At the University of Loughborough, a research project is being carried out to design and develop an integrated monitoring system usable in the swimmers' training environment. Currently, a prototype monitoring system is under development with the aim of providing a distributed, imrpoved and less invasive control system. The system aims to provide both indirect (remote) and direct (continuous) monitoring, which results in the application of the instrumentation on the swimmer during the training phase in the pool. The aim will be that to provide timely feedback on all the swimmer's aspects, whose technique then gets monitored. This type of instrument is crucial for the swimmer who requires accurate information to develop more effective training programs.

Current technology gives the swimmer limited feedback. Monitoring technologies are limited by their accuracy, set-up time and invasive reach on the athlete's body. It is expected that the system under development at the University will provide real-time feedback of athletes' performance to coaches and sports scientists, both during training and during competitions. In this initial phase, the system has been designed to monitor athletes, but it cannot be excluded that it can be used by all the types of swimmers, from simple amateurs to international athlete (4, 21, 23).

Indirect monitoring techniques in swimming seem to be the preferred performance analysis method, as they constitute a non-cumbersome approach. This type of performance monitoring allows collecting data both during the training and during the competition. Generally, video analysis is used for qualitative discussion rather than for quantitative analysis, because it requires some time for data processing. The goal of Loughborough University researchers is to develop a comprehensive monitoring system that integrates video analysis with software data processing. This is because video monitoring is a consolidated and reliable technique. In addition to image processing and video analysis techniques, the goal is to place force and pressure sensors around the pool, such as into the starting blocks

or synchronization touchpads, to obtain a fully integrated system. These devices can be used to provide the swimmers quantitative information about the position and time spent on the wall during the flip turn, and the time taken before their first movement out of the blocks.

6. The Match Analysis technological instrument in Water Polo

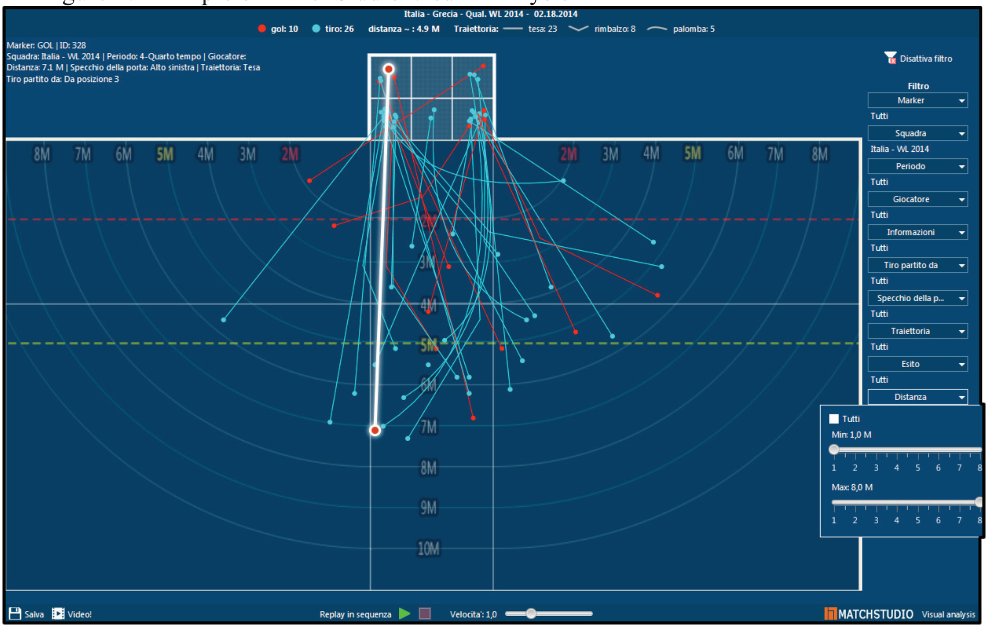
First of all, it is appropriate to state what Match Analysis is and what its scope and usefulness are. The Match analysis is the maximum development of the notational analysis of the sportsman's performance; studying the athletes's behavior, in any discipline, has always been the starting point for improving individual or team performance.

Over time, this instrument has undergone a significant development: in fact, it started with the annotation on thousands of sheets of what happened during a competition, so that it could be analyzed without any emotional influence; subsequently, evaluation sheets were developed, which allowed the operator taking notes of the outcome of various predetermined situations through simple standardized symbols. Afterwards, the use of the first cameras to record the performance offered the opportunity to review the races several times, providing the technicians a more complete picture of the performance. With the advent of the PCs, some software was develped; this software, even in real time during the competitions, provide the parameters necessary for performance analysis, the Match analysis, in order to help the coach in his strategic choices.

In some team sports, such as football, basketball and football, numerous ad hoc software have been developed that can support the study of the game situations of the team and of the opponents both from a collective point of view and from the individual player. In the water disciplines, the only sport that would seem to require (and not just a little) such technological support is certainly water polo, one of the sports disciplines par excellence.

It is no coincidence that, in the last few years, SportDigit's MatchStudio software has been developed, which has focused most of its functions on the analysis of water polo training and matches.

Figure 2: Example of MatchStudio Visual Analysis



Source: Sport Digit website

The data that can be analyzed through the technology of a match analysis software in a sport like water polo allow obtaining useful information concerning (2, 22):

- Managing replacements
- Ability to regulate recovery time both during the match and during the training sessions following the official competition;
- Ability to identify tactical problems and improve one's own game strategy;
- Ability to understand the opposing game strategy;
- Ability to homogenise a team's level of training and the specific roles.

All this contributes to improving both the physical training phase and the technical and tactical one, constituting an excellent support instrument to be integrated into water polo training methods.

Conclusions

The technical innovations and the development of training methods have made possible to witness a wide and rapid evolution of many sports disciplines over the last few years.

The athlete's priority requirement in the era we are living in, dominated by the demands of the international scene, is the improvement of performance beyond human limits, in order not to fall behind in a context in which sports experience is globalized too.

In the scenario of globalization, the athlete's preparation has had to reach levels of professionalism and scientificity never achieved before; and it is precisely in this context that sport has come to increasingly require external aid in trying to overcome barriers and breaking records that, until yesterday, were considered insurmountable.

However, there is a clear difference between swimming disciplines and other sports, as widely emphasized in this work. The technological innovations used in sports training such as swimming, in fact, are more difficult to impose themselves in everyday sports practice as, for the most part, they are not easily employable without adequate training.

However, we conclude by claiming that this specific training is essential to optimize the training methods employed in water sports, increasing the effectiveness of each session and improving the monitoring of any aspect. This, withn reason, allows stating how much technology has become an instrument of enormous importance in these sports, and how much it is appropriate that also scientific research and academic didactis in the sports sciences focus on these issues to guarantee adequate support for future innovations and within the entire sports system.

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