Politecnico di Milano
Design Department
Doctoral Programme in Industrial Design

“S&D”
Integration of Sport and Design for innovative systems.
Application to a Swimmer Wearable Integrated Monitoring System For Innovative Training

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Abstract

The swimsuit project aims to designed innovative textile solutions to create a sensorized and functional swimwear for athletes who engage in amateur swimming or racing. This allows both to optimize the performance and training methods, and to monitor health conditions. Moreover, with some simplifications, the system can be used in different areas: in addition to other sports, telemedicine and safety at work. For example, in a clinical setting it may be useful to monitor cardio-respiratory diseases, which include a wide range of diseases and affect a significant percentage of the population with major impact on health spending. The wearable monitor is offered as a solution to reduce these costs as part of the expansion of telemedicine services. The new generation of sensors costume will monitor in real time during training in water: Hearth rate; Breathing rate; 3-D Accelerations; Stroke number (hands & feet); Poolside timing.

Design was done in four phases: textile electrode performance validation; motion and style detection validation; swimsuit design and experimental validation.
The validation of textile electrode was performed to verify the correspondence in terms of amplitude and shape between signal acquired with textile electrodes and the generated one. Even after varying amplitude and frequency of the generated signal, no differences were encountered (average R2 = 0.9988±0.00041), both in the pattern and in the amplitude of the measured signal. Thus this demonstrates the theoretical reliability of the textile electrodes.

Taking into account the movements of swimmer, for validation of motion and style detection have been selected four positions of the body: on the central axis of the body just below the chest; on the central axis of the body in the middle of the back; on the central axis of the body in the lumbar region of the back; in correspondence with the right or left hip. After analyzing the obtained results was chosen the best locations for placing the accelerometer (in the lumbar region of the back).

Swimsuit was designed for all, in a simple way so that everyone can to use, athletes as well as lovers of swimming. The experimental validation of prototyping product showed the correctness of obtained results.

Part I. Introduction:

Part II. State of art:

Part III. Materials:

Part IV. Experimental validation:

Part V. Conclusion:

[Part I] - Introduction

1. Design

Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanization of technologies and the crucial factor of cultural and economic exchange [1].

It's a fascinating world of products and services that surround us on all sides. Design makes us live more comfortable and smarter: in other words, Design for a better world [2].

Depending on the type of entity being designed, this process can include the following:

- the identification of a set of needs,
- the initial conceptualization of a way to meet those needs,
- the further development of that initial concept,
- the engineering and analysis required to make sure it works,
- the prototyping of its preliminary form,
- the construction of its final form,
- the implementation of various quality control procedures,
- selling its value to the consumer,
- its delivery to the consumer,
- providing for after-service,
- and obtaining feedback regarding its utility and value.

Good design begins with the needs of the user. No design, no matter how beautiful and ingenious, is any good if it doesn't full fill a user need. This may sound obvious but many products and services, such as the Sinclair C5, Warp mobile phone services, and a great many dot com businesses failed because the people behind them didn't grasp this. Finding out what the customer wants is the first stage of what designers do. The designer then builds on the results of that inquiry with a mixture of creativity and commercial insight. Although gut instinct is part of the designer's arsenal, there are more scientific ways of making sure the design hits the mark. Different designers use different methods - combining market research, user testing, prototyping and trend analysis. Any product launch is ultimately a gamble, but these methods help decrease the risk of failure, a fact that often comes as a surprise to clients.

Design hasn't to be new, different or impressive to be successful in the marketplace, as long as it's fulfilling a need, but design methods do lead to innovative products and services. Designers learn that ideas that may seem strange are worth exploring and that the 'common-sense' solution isn't always the right one. Designers often hit on counter-intuitive concepts through methods such as drawing, prototyping, brainstorming and user testing. Watching users in real-world situations especially gives insights into their behavior that lead to ideas that wouldn't have formed had the designer simply thought about the situation, or relied on generalized market research.

Aren't shoes for everyone, but is a design for everyone!

The door to the building too small for a man in a wheelchair, a bottle cannot be opened by people with diseases of the joints, pictograms at the airport confusing for visitors from other cultural areas. There are a lot of these problems. Because even though everything around us has been designed not everything has been designed well. In other words - it isn't always Design for All".

Design for All is a non-negotiable requirement of the built environment, to ensure ACCESSIBILITY health and safety. "Design for All" is based on social and civil right of every citizen to live in a safe and healthy environment, to carry out their activities in an autonomous way, without discrimination. The solutions must be appropriate, commensurate with the performance capabilities of the individual, inclusive of everyone's needs, avoiding as much as possible to specialists.

Design for All is design used of human diversity, promoting social inclusion and equality. Design for All sound design-so as to work served as the largest group of people. Design is for everyone, if:

- is created by the people, for the people and everyone that can use it with the same ease,
- offers an alternative: if you cannot read anything, you should be able to hear,
- is simple to use and easy to learn,
- can be used by a person with a disability or reduced mobility,
- provides choice and gives satisfaction to consumers.

Good for seniors, so good for us!

Among us are more and more seniors. Is an economists and demographers problems. For designers - challenge. If we allow them to work, the world will be friendlier to all of us. If new technologies are too complicated for young people, what have to tell seniors, who were born in the days of black phone with circular shields for dialing numbers? Too much details on the display or too small numbers on the keyboard are a few reasons why many seniors have problems with the mobile phones. Thinking about them special equipment began to appear. Unfortunately, many of them look like children's toys. Some may feel humiliated that they have to use such a "not serious" phone. Recent projects don't duplicate these errors. Business Phone Emporia Elegance plus looks like an ordinary mobile, but has a slightly larger screen, heavily backlit keys and discrete alarm button (Fig. 1). At the same time not deprived of extra features - it has a radio, calculator, Bluetooth system, and LED flashlight.

Figure 1. Business Phone Emporia Elegance plus.

Disability is no obstacle!

In these times we can count on good design. Thanks to the cooperation of designers and engineers, people with disabilities grow the sport today, which previously couldn't even dream.

During the summer Paralympics games they played in 21 sports. Most of them are involved athletes in wheelchairs. Even a contact sport such as rugby can be grown even with paralysis or without legs. The carts are changed largely due in view of war in Vietnam. More than 300 thousand soldiers returned from there wounded, many permanently. Young men, often mutilated by the explosion of mines, they were at the beginning doomed to heavy and bulky carts. Under their pressure began to design increasingly lighter and more manageable models.

Today carts, especially those designed for sports use, don’t resemble ordinary seat on wheels. Derailleurs and brakes are converging them into sport bikes. The materials from which they are made (titanium, lightweight steel), approaching them to space shuttle.

Specializing in wheelchair sports RGK British Company has developed special models to practice basketball, tennis, and even off-road, which allows free from asphalt (Fig. 2). They aren’t only ergonomic, makes it to which they can fully control, but also aesthetically pleasing. Each customer has a choice of several color frames. In this way, the truck goes back to where it belongs - to the world of fashion.

Figure 2. The wheelchair for sports.

The influence of design for sport is far-reaching in all the word where image and aesthetics are involved. Designs can include athletic shoes, bags and clothes such as swimsuits, gym wear and tennis outfits.

Behind every new design is a desire to break new ground, to improve and to enhance consumer experience. Good design makes products easier, more comfortable and safer to use.

In a highly competitive marketplace, design that makes a product more attractive for consumers, plays a critical role in adding commercial value and making the product more marketable. Companies invest large sums of money and expertise in developing winning designs that respond to changing consumer tastes. By registering their designs and obtaining an intellectual property right over them, companies can defend themselves against imitators and counterfeiters.

The good design must:

- improve the performance,
- bring style of technology,
- encourage people to participate,
- help make one brand more successful than another.

2. Sport (swimming)

What is a sport? This is form of activity that can be a real pleasure and a way of life. However, after the turn. Sport is an incredibly important thing in these days. It is a great global industry and an everyday activity. “Sport is a part of every man and woman’s heritage and its absence can never be compensated for” [3]. But this is true?

For many people, sport is a whole life, and we are talking about professional players. It is their way of life, however, is more than a profession. It is an incredible passion that anyone can get "infected". Sport is becoming increasingly popular for children and adolescents as well as adults. Many people attend football clubs, swimming section, dance schools, fitness classes and martial arts, visit the gym or attend classes in tennis, squash and volleyball. Especially young people like to meet in the afternoon to just play football. More people organize weekend trips for kayaking, sailing or mountain climbing or cycling. Enormous interest is for winter sports, such as skiing and snowboarding.

Sport gives us pleasure, can be a form of entertainment. However, it’s a very important aspect of healthy living and physical fitness, is useful in a variety of unexpected situations.

Currently, large funds became allocated to programs and campaigns to promote the sport among children and adolescents. It is important for physical education in schools. It's the smallest instill in children a love for the sport. Many of them will love it, and it will certainly good for their physical development and mental, which among other things develops a healthy sport competition.

Sport is, a kind of interests, hobbies, and almost every person has it. There are sports such as dance, which can be a spectacle as an art form. There are also sports that can be an individual, such as climbing, jogging, yoga or pilates. However, the most interesting are volleyball, basketball and football where the game is in team which help integrated people and are the nice form for spend time with friends. People have different personalities and preferences. However, sports disciplines and fields are so many that everyone will find something to interest him.

Sports are supposed to be good for kids, youth and adults. In theory, a sport should build strong bodies. It should promote sportsmanship, self-discipline, and perseverance. One of the least traumatic and most popular sports in those times is swimming.

The ability to swim is in a human as old as the ability to walk or run. Already in ancient times, when people settled down near bodies of water, they also learned to swim. Depending on the different stages of social development were the reasons why people started learn swimming skills. In primitive peoples need swimming skills was connected with greater efficiency in for example hunting. In ancient Greece, the owners of slaves practiced swimming in the interests of the harmonious development of his body. In the ancient Roman Empire swimming skills associated primarily with the efficiency of fighting legions. At present, the validity of master swimming skills can be reported both to stimulate the physical development of young people, as well as recreation work-weary people, rehabilitation of the disabled, as well as in the creation of gifted youth sports. In addition to improving the health of European citizens, sports have an educational dimension and play a social, cultural and recreational role [4].

Among the most widely practiced sports in Europe there are swimming and running followed by cycling [5]. Just two and a half hours per week of aerobic physical activity, such as swimming, cycling or running can decrease the risk of chronic illnesses. People prefer enjoying water-based exercise more than exercising on land. They can also do exercise longer in water than on land without increased effort or joint or muscle pain. Swimming and other water-related activities are excellent ways to get the physical activity needed for a healthy life and millions of people enjoy oceans, lakes, rivers, pools and spas each year. Swimming targets have also important health benefits in developmental age thanks to a comprehensive and balanced development of the individual muscle groups and the whole organism. All styles of swimming exploit equally right and left side of the body.

In competitive swimming, world-level performances require specific training devoted to improvement determinants of performance like technique and coordination, strength and aerobic capacity. It may be argued that training-time is especially efficient when devoted to the enhancement of those performance factors that are weak links in the performance chain. That is they represent the phase of the process where the performance system first becomes insufficient. These are known as limiting or determining factors, because they are the first to reduce and hence settle on performance. It may make sense to train several factors in a somewhat isolated manner and overloading them maximally without interference from other processes, such that each will improve separately to a greater extent and then contribute more to performance when integrated with the other factors during a race. It seems therefore necessary to identify the relevant performance factors and design the optimal training programs to improve them.

2.1. Demographic aspect

Approximately 60% of European citizens participate in sporting activities on a regular basis. In the group of countries whose citizens treat the sport very seriously, are Ireland, Sweden, Finland and Denmark. 23%. Irish practice sports regularly, means a minimum five times a week - it's the most in the EU. The worst situation is in Bulgaria, Italy and Greece, where only 3% citizens are doing sports regularly. Indeed swimming is the second practiced sport both by boys and girls aged 5-14 years (the first one is soccer for boys and dancing for girls) [6].

The National physical activity guidelines for Australians are the same for women and men and encourage adults to think of movement as an opportunity, not an inconvenience [7]. To gain health benefits, physical activity needs to be done at moderate intensity and it’s recommended that women and men complete at least 30 minutes of moderate-intensity physical activity on most, preferably all, days. Moderate intensity means being physically active to a level where it is possible to talk but not to sing. Fifty four percent of Australian women meet the national guidelines [8].

Currently, 30.9% of Australian women are overweight and an additional 24% of women are obese. Regular physical activity is vital for optimizing the physical and mental health of all women. The proven health benefits of physical activity include the prevention of a range of chronic diseases [9], the promotion of good mental health [10] and the maintenance of a healthy weight [11]. The key chronic diseases that regular physical activity can prevent are type 2 diabetes, cardiovascular disease, osteoporosis and some cancers including bowel and breast cancer [12]. Apart from breast cancer, these chronic conditions have a similar impact on both women and men's health in Australia.

Physical activity encompasses several types of activities including sport and active recreation, active transport and occupational activity 24% of Australian women participate in organized sport or active recreation, which includes 'non sports' such as bush walking and aerobics [13]. The most popular forms of sport and active recreation for Australian women are walking (32.8%), aerobics/fitness (15.7%), swimming (10%), netball (4.8%) and tennis (4.7%) [14]. The top three forms of physical activity for women are non-competitive in nature and this is an element valued by women [15].

And how is situation of swimming in United States? There are 10.4 million residential and 309,000 public swimming pools [16]. During 2009, there were approximately 301 million swimming visits each year by persons over the age of six. Thirty-six percent of children aged 7-17 years, and 15% of adults in the United States, swim at least six times per year [17]. About half (56.8%) of spas are in violation of local environmental health ordinances, and about 1 in 9 spas require immediate closure (11%) [18].

In Italy also some people that participate to swim, but the numbers aren't so high. Only 6% of Italian people practicing the swimming. From 377000 people in Italy only 7% of this people make the official agonistic activities in swim and 6% not official (Fig. 3).

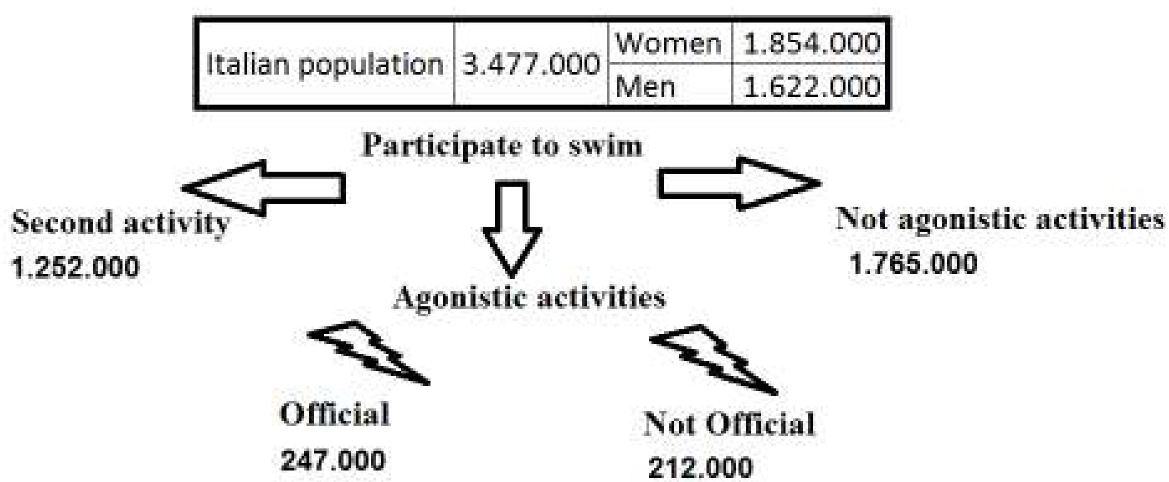

Figure 3. The statistic of Italian people participates to swim.

About 51% of the population of Italy practiced swimming as not agonistic activities and 36% participate like the second activity.

2.2. Social and health relevance of swimming

Physical activity is defined by the World Health Organization as any bodily movement produced by skeletal muscles that require energy expenditure. Perhaps more relevant to the health sector is the fact that physical inactivity is ‘an independent risk factor for chronic diseases, and overall is estimated to cause 1.9 million deaths globally each year’ [19].

Physical activity is a gendered issue because the context of women’s lives can impact on their ability to participate in regular physical activity. Women face numerous barriers to being physically active including caring responsibilities [20], body image [21] and perceptions of safety [22]. Change needs to occur at the societal level to address current gender roles and how they can limit women’s ability to be physically active and maintain health.

The physical health benefits of physical activity are clear. They include lower blood pressure and cholesterol and maintenance of a healthy weight. Some other examples of benefits include improved mental health and wellbeing, social engagement [23], enhanced sleep [24] and reduced risk of fractures [25].

Regular physical activity plays a significant role in improving moods and subsequent mental health has been shown to relieve symptoms of depression. These benefits can be experienced by those with a diagnosed mental illness as well as the general population. The mental health benefits of physical activity frequently motivate those who are already physically active to maintain their routines. The benefits of physical activity on mental health can be achieved even in the absence of fitness gains [26]. This may be due to factors including increased social engagement and increased exposure to sunlight.

Social engagement is another key benefit of physical activity, and for women this often motivates continued participation in physical activity. Regular group exercise is found to be a means of social support, especially for older women [27]. Improved quality of sleep is related to women’s participation in physical activity and it is an important marker of quality of life. People, who are physically fit fall asleep faster, sleep better and are less tired during the day [28]. Women who participate in regular physical activity sleep more and experience a better quality of sleep than women who are sedentary [29].

There are additional benefits for older women who remain physically active. Regular physical activity aids muscle strength, aerobic capacity, reduction of fracture risk and general wellbeing [30]. Strength training can enable older women to maintain their independence and ability to do day-to-day tasks and leisure activities through reducing the risk of developing osteoporosis [31]. Physical activity is associated with maintaining independent function over time, irrespective of increasing age 28.

The healthiest sport is swimming. This water property allows people to do exercises that are difficult on land. The 90% of your body is buoyant when in the water up to neck, so are not hitting the floor as hard as you would on land. There is continual resistance to every move you make. The water offers 12% - 14% more resistance than exercise on land. Resistance doesn't allow for sudden body movements. Water disperses heat more efficiently, so there is less chance of overheating. Exercise in the water is cooler and more comfortable than on land.

Why do people exercise in the water?

- Fitness: For getting or keeping in shape.
- Therapeutic: For helping people recover from accidents and sickness. Combating the aging process.
- Social: For meeting and being with other people. They can talk to others during water exercise or knows new people.
- Stress Release: Gives a chance to just relax and forget about work, problems, and other things.
- Fun: Enjoying the diversion. Water exercises in a playful way and don't need be serious. Water exercise is fun.

Swimming is a lifetime sport that benefits the body and the whole person! It is generally believed that swimming is one of the healthiest sports. This is true but only when people during swim obey the basic rules of safety and hygiene. Movement in the water, with defeating the resistance significantly, harmoniously shaped posture. Swimming and whole water environment give beneficial effects for the human body. It's considered as a useful skill, a form of physical recreation, sport and the exercise therapy. Helps in particular remove excessive curvature of the spine, improve the chest, increasing her mobility and increase lung volume. It's recommended it to all who have any kind of posture, flat feet and suffer from overweight.

Exercises carried out in water, provide relief of the spine, hardening the body, improving overall exercise capacity, strengthening muscle power, improved neuromuscular coordination.

Water environment is beneficial to adopt good posture, because relieves the spine and fosters relaxation of muscles. This form of exercise not only improves physical fitness, but also has beneficial effects on the psyche: relaxing and soothing.

The horizontal position of the body in the water during the swim makes more easy work of the heart. In addition, pressure and water current work massage on the blood vessels and thus improve blood circulation, resulting in more abundant supply to the heart and help to breath. Large system needs oxygen in the water caused by the acceleration of metabolism during swimming. So great means blurs hypoxia body and is under the most favorable, because the air above the water is clean and free of dust and other contaminants.

During swimming are involved almost all the muscles and joints, which can expand the muscular corset that keeps the corrected posture. The aquatic environment No overload of the joints, so any exercises performed in water doesn't cause any contusion or injuries. Activities at the swimming pool especially enjoy great popularity among children, because they are a combination of pleasures offered by playing in the water with the improvement of swimming skills and therapeutic effect - correction of posture that children don't need to see. Those who swim, less get sick, are protective from the influence.

Evaluating usefulness of individual styles in swimming correction on the basis of the development as well as personal experience (working as a swimming instructor at the pool), it is clear that the most useful style is the classic style and backstroke, as shown in the table below (Tab. 1).

Style	The use for
Breaststroke	Posture Correction located in the lumbar spine - concave back, lumbar scoliosis, foot various, flat feet. Most preferred is a phase slip. Should pay attention to keeping hands (hands and forearms) near the water. Elongation of the spine.
Backstroke	Correction of defects located in the lumbar spine - back concave, round back, back concave-round, flat feet. Keeping hands over and under the water give highly beneficial for posture correction. Elongation of the spine.
Freestyle	Posture Correction located in the lumbar spine, flat feet. Conducive the elongation of the spine. The limited usefulness correction - using the leg work.
Butterfly	Correction feet flat, shape of lumbar lordosis (with professional swimmers), pelvic ante version. Very limited usefulness correction, uses only the leg work.

Table 1. The usefulness of individual styles in swimming for correct posture of body.

The ability to swim suggests for practicing exercises in the water. Thanks to these skills we feel safe and we can fully enjoy the pleasures offered by us being on the lake or the sea. Good mastery of swimming is also the best safeguard against drowning.

3. Design for sport

Sport in the cosmic of design technology.

Sport technologies are considered as means developed to help an individual reach certain goals and interests related to a specific type of sport. They are technical means wherein athletes and sportspersons tend to enhance their training alongside with their competitive surroundings to come up with a thoroughly improved athletic performance. It basically speaks of knowledge and the application of utilizing a specialized kind of equipment along with the latest advance technologies needed to execute certain types of sports efficiently.

The recent developments and innovations in sports technologies have made it possible to produce various types of products designed to improve and increase athletic performance. With these technologies, athletic health can also be observed and maintained while injuries are also being treated. These are possible with the help of advanced sporting technologies like monitors for heart rates, monitors for body fat, pedometers, etc.

Because of such advancement in the field of sporting technologies, a profound sense of knowledge is recognized when it comes to the potential of the human body. This allows the athletes to undergo training and join sports competitions even when they are already old. These sporting technologies and equipment have also been developed to enhance the safety of every athlete participating in any sports events. Some of the common sporting tools and equipment which have been developed to enhance safety include helmets and other types of body protection used in the sports such as ice hockey and boxing. All of these are designed to help in the prevention of injuries.

Design for sport is too much important . The new technology give security , comfort and the opportunity to test biomechanical parameters . Design for new technology also gives the opportunity to sport for all , also for the disabled. Think like a person with a disability, how could execute any exercise without special instruments or items ?

The creator of the modern Olympic Games was a French reformer of the school system and education, aristocrat, Baron Piere de Coubertin (1863-1937). The Olympic Games are organize in every four years. At the same time since 1924, also every four years, are held the Winter Games and from the 1960 Paralympic games with disabilities. The organizers of the Games from the beginning of the resume isn't the state, thus formally confirmed is the universal, independent and non-political status. The example of Paralympic disciplines are:

- Goalball (Fig. 4) - this discipline is addressed only to people with damaged eyesight. Goalball was established in 1946 as a form of rehabilitation of visually impaired World War II veterans. For the first time Goalball was introduced to the Paralympic Games in Toronto in 1976. The aim of the game is to throw the ball into the opponent's goal, while opponents try to block the ball with his body. Inside the ball is a special bell that tells disabled athletes at which point the ball is and how it should be set to effectively bar all the way to the goal. Therefore, even though the game is in progress there is complete silence that allows players to maximum concentration. In order to level the playing field, during the game the players are blindfolded special armbands.

Figure 4. The Goal ball - Paralympic disciplines for people with damaged eyesight.

- Horse riding - for many years is used as a form of active rehabilitation and form of recreation disabled (Fig. 5). The issue was the inclusion of riding time for the Olympics. This took place in 1996 during the Paralympic Games in Atlanta. Discipline is adapted to people with different disabilities. The event is one namely dressage competition. We can distinguish two parts of riding, which are amenable to the judges. Players must be able to ride a horse. The governing body is the International Equestrian Federation (FEI).

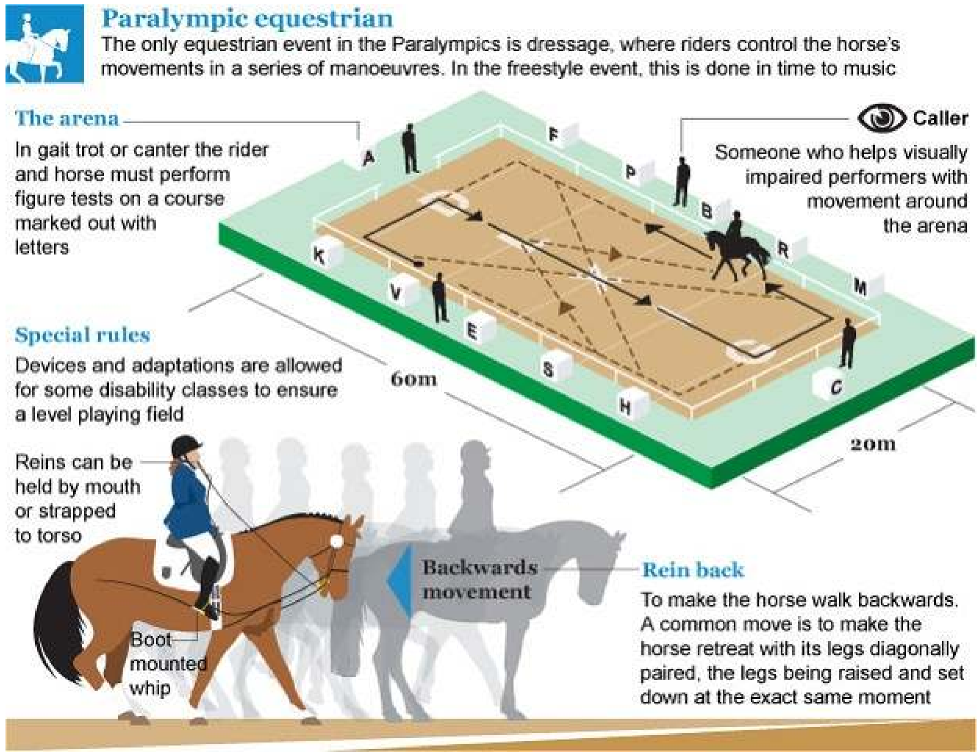

Figure 5. The horse riding for active rehabilitation and recreation of disabled during Paraolimpic Games.

- Cycling - the speed and excitement to cycling are available for players with disabilities relatively recent. For the first time have appeared in the Olympic Games in Seoul in 1988. Discipline is designed for athletes with different disabilities, which result in division into classes (blind and visually impaired, movement dysfunction, cerebral palsy, amputations). Depending on the type of disease, they can use the following types of cycles: "bicycle", "tricycle", "tandem" and "handbike" (Fig. 6). The event includes road and track cycling. Players can compete in endurance distances up to 120 km, the velodrome to 4 km and in the sprint. Can be also stand out blind people with seeing from the pilot.

Figure 6. The hand bike for disabilities used during Olympic Games.

- Wheel Chair Basketball - one of the most popular Paralympic sports (Fig. 7) . It was introduced to the Olympic program already in Rome, in 1960 , and addressed to both women and men . Basic dimensions, such as pitch and height of the basket is the same as able-bodied basketball . Basketball is a team sport so we cann't distinguish the division into classes. He admits , however, the players points because of the level of efficiency from 0.5 to 4.5 where the aggregation number of points of all players on the field cann't exceed 14. An important aspect of the game are special competition carts, having covered spokes and bent wheels. Strictly defined also move around the field. The player who receives the pass can only drive the truck twice not trestle . The objective of each team is to score as many baskets after successful kicks . Wheel Chair Basketball is practiced in over 80 countries around the world.

Figure 7. The basketball chair for disabilities used during Olympic Games.

- Track and field - the program of the Paralympic Games since 1960. Players and athletes compete in all disability groups (Fig. 8). During the Olympics we track athletes competing in wheelchairs, with prosthetic and cooperating with non-disabled blind guide. Modern technologies allow to optimize the player's level of play equipment, and thus improve the results. Currently athletics is grown in more than 100 countries worldwide. Competitions: racing 100m, 200m, 400m, 800m, 1500m, 5000m, 10000m, 4x100m and 4x400m relay, marathon, high jump, long jump, triple jump, shot put, javelin, discus throw, throw a club, pentathlon.

Figure 8. The Track and Field of disability group during Olympic Games.

Without design disabled-person couldn't be involved in the sport....

The world of sport is continually changing over the years, and the use of technology is just one of those areas that have made an impact on many sports in the modern day. The game turned on the sports industry - manufacturers of clothing, equipment and event organizers.

For example Nike is a tycoon in the footwear market. The company controls 53% share in the segment running shoes while her biggest competitor, Adidas, is 4.4%. Such an advantage hasn't also Apple created the tablet market by itself. Both rivals connect a rare ability to expand the areas which are normally associated. Nike has long been not only a manufacturer of shoes, but the seller of a particular lifestyle. Now it's also a technology company.

Shoes seamless, game console or recording motion rings are used to build a community of sports enthusiasts who, in exchange for the ability to analyze data on the tablet of their physical activity, comparison with other service users and even compete with the company hired by the stars, are related to with the brand.

Thanks to the new design Nike in 2012, earned 2.1 billion dollars, an increase of 12% more than a year earlier. Profit of the company in 2011 (compared to 2010) jumped by 28%. These successes sees the industries, and as the eighties began copy invented by Nike to build the image around the sports stars, now focuses on new design technologies.

Race to innovation:

- AlterG - antigravity runway invented in 1992 by NASA helps reduce stress on joints running person. Rapidly gains the fitness clubs (Fig. 9).

Figure 9. The antigravity runway invented by NASA.

- Qcue - the hit among fans is the dynamic management platform ticket prices to match (Fig. 10). For last-minute sales so far are mainly used by the American League baseball clubs (MLB), basketball (NBA).

Figure 10. The dynamic management platform ticket prices to match.

- Babolat - French family company manufactures tennis rackets Play & Connect, which, thanks to the electronic sensors accurately registers the movement and allow analyzing Own, game on tablet (Fig. 11).

Figure 11. Tennis rackets with electronic sensors.

- Music - In the near future, the music in the headphones will be adjusted to the rate or pace at which we move. In this way, we will receive information about the degree of tiredness and - eventually - the motivation to continue the effort.
- Fuel band - Bracelet, which allows in real time monitor calorie burning process (Fig. 12). Recorded information is analyzed in detail using an application on the smart phone, and in every moment the intensity of effort shows us the color of the display.

Figure 12. The bracelet, which monitor the process of calories burning.

- Electronic boots - Located in the outsole chip not only keeps track of movement while person running, but also measure and analyze the way of performed in the movement. Can be thus compare with professionals.
- Smart Cycling Helmet - in turn link a mandatory element of the rider-biker with the latest technologies, similar to those used in advanced aircraft (Fig. 13). That helmet can keep track athlete of the heart without the use of cumbersome band on the chest. The whole measurement is made "head" person uses SMART technology.

Figure 13. The Cycling Helmet with sensors.

➢ Sensor W/Me of Phyode company - The device that doesn't apply to strictly physical effort, but every daily lives (Fig. 14). The goal is continuous monitoring the mood and parameters that impact on them. W / Me monitors the user's nervous system, determines its current mental state (happiness, anger, indifference, pessimism), and even examine the approximate age of the nervous system. Almost like a personal doctor. The whole interacts with a mobile application for iPhone, which has the "trainer breath" - this is for those who often get angry and have to count to ten, to return to full peace.

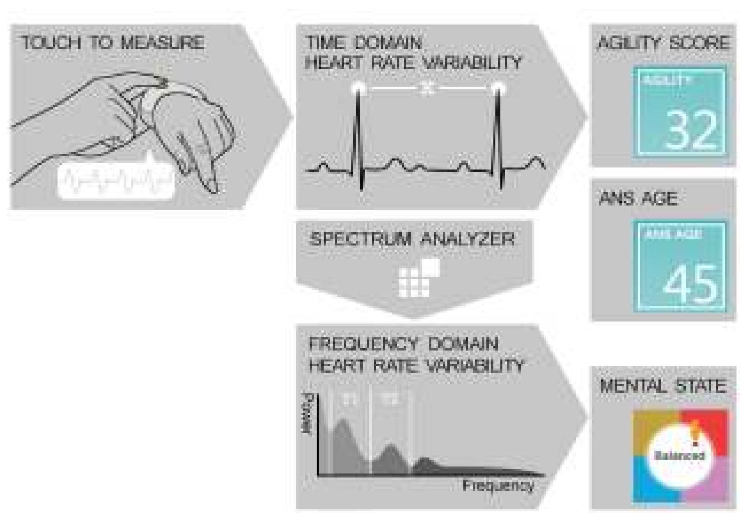

Figure 14. The bracelet with sensors.

There are different types of sports gears like footwear and clothing and each of them has to be user-friendly. They have to be tough, strong, flexible, durable, moisture-resistant and effective cost. Footwear should be comfortable and helps the user avoid injury. In the field of swimming, full body suits are known to rationalize the performance of the swimmers. The use of composite racket for tennis was created to enhance ball speed and reduce to vibration which is known to cause tennis elbow, a kind of condition which entails the damage of capillaries of the ligaments and muscles surrounding the joint of the elbow. As for the modern golf clubs, their overall mass was reduced for more achievable distance coverage and a more accurate shot. Bicycles have also come up with the latest sporting innovations like pneumatic tires, specialist wheels, pedals, and brake levers which improve rigidity and stability of the bicycle.

4. New technology in sport and medicine

For help to people make a healthy sport we can use the new technology for the monitoring of vital physiologic parameters. A lot of designer try find some machine for use during sport. Is important that this type of new design has to be for all – for normal people that like participate to some sport and see their result, coach for see immediately physical performance managing to provide for all time of training session a full description of the athletes situation, the athletes that can see their self alone for change and improve their skills as also the doctor during patient rehabilitation.

4.1. Top of 10 design products that have changed sport forever

In this time we have a lot of possibility for make sport. During the years a lot of people designed the new technology. How we can see, here are the top of 10 products that have changed sport forever:

- Hawkeye 2001 (Fig. 15)

Developed from a spin off from military research Hawkeye has enhanced the enjoyment of cricket, tennis and snooker and enabled viewers and commentators to gain insight into the technical aspects of the game. Used by the umpires at Wimbledon for the first time in 2007 Hawkeye has gained recognition from many authorities as a way of officiating.

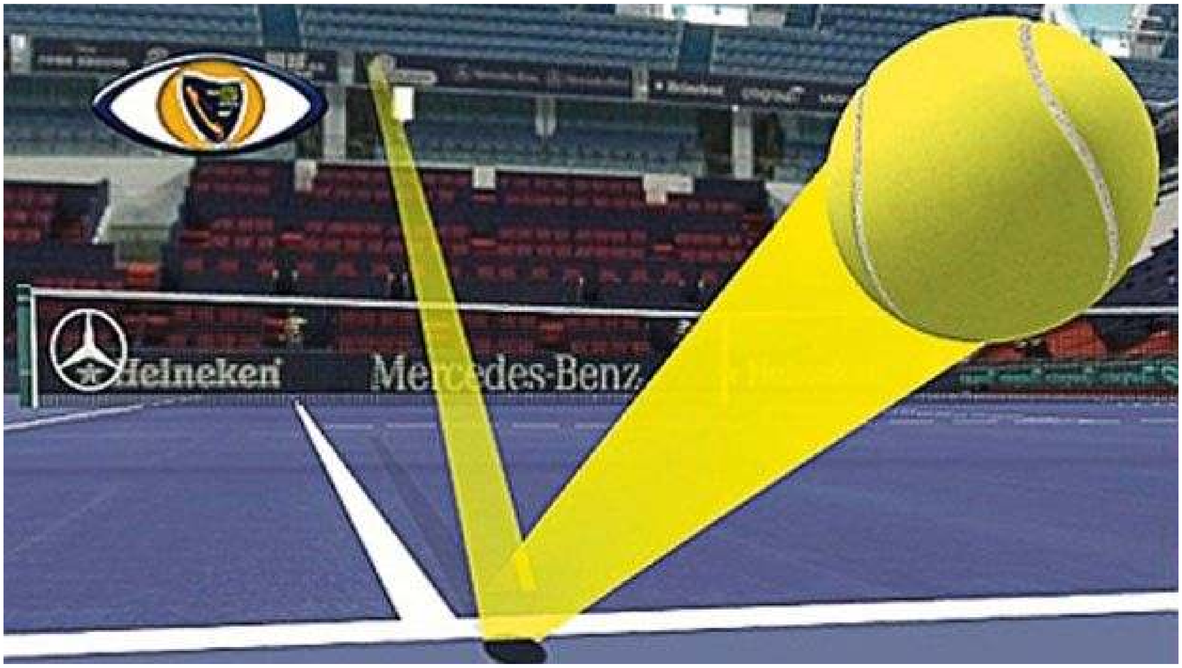

Figure 15. The cameras around the stadium to track the trajectory of a ball and judges it's most likely destination.

Undoubtedly technology's biggest gift to modern sport, the British-born innovation, which uses cameras around the stadium to track the trajectory of a ball and judges it's most likely destination, was initially used as a means of analyzing umpiring decisions during TV coverage. Tennis and cricket adopted the tech as a means of adjudication, immediately clearing up contentious decisions and removing excuses for losers.

- Oversized tennis racquet 1976 (Fig. 16)

In 1976 Howard Head struggles with off centre hits and lack of control, motivating him to invent the first patented Prince oversized racquet, the Prince Classic. At 110 square inches, it's revolutionary design changed the game and became the most successful racquet of this time. Fundamentally changes the appearance of tennis and makes the game more accessible for beginners.

Howard Head with Prince tennis rackets, n.d.
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Figure 16. The first tennis rackets.

- Predator football boot 1994 (Fig. 17)

A determination for a genuine improvement in playability from football boots encouraged Craig Johnston to create prototypes from existing boots with various ribbed and textured materials glued to them. Finally selling the idea to Adidas the result was Predator. Combined with blade type studs instead of the usual round form the boot provides a visible and performance differential from existing designs.

Figure 17. The first football boots.

The boots were debuted and released for the 1994 USA World Cup and became an instant hit. 60% of the players in the WC were wearing Adidas, and some of the World's most influential players were wearing the Craig Johnston Adidas Predator. Since their release in 1994 the Adidas Predator Range has evolved and changed, but it's humble table tennis beginnings signify the most advanced and revolutionary pair of football boots ever seen – and changed the world forever.

- Carving Skis 1998 (Fig. 18)

Although there is plenty of dispute the successful commercial exploitation of the carving skis originated from two Slovenian scientists, Jurij Franko and Pavel Skofic. Carving skis (sometimes called parabolic skis, which were originally used for beginners) are between 10 to 25 centimeters shorter than traditional skis. This makes them lighter and more maneuverable, but the key innovations are the dramatic side cuts in the middle or "waist" of the skis and the wider tips and tails. The deeper the side cut, the sharper and easier the turning becomes.

Figure 18. The first carving skis.

- Big Bertha driver 1991 (Fig. 19)

Golf Company Callaway introduced the Big Bertha into its range in a search for performance. The head size was larger than existing drivers and its construction was from aluminum rather than the more usual persimmon wood. In recent years Calloway has grown the head size near to the largest permitted (460cm3).

Figure 19. The first product for golf.

The performance of the driver has enabled players to hit longer and more accurately with the same effort, effectively reducing the length and difficulty of golf courses around the world. The development of the Big Bertha Driver (below) was a watershed moment both in the history of the company and in golf. This oversized steel driver was hugely popular both with professionals and amateurs, especially after Mark Brooks won the Greater Greensborough Open using the Big Bertha from the tee. The extra distance and accuracy afforded by the metal club saw golfers switching to the new technology in their droves and slowly woods were disappearing from golfing bags across the world.

- Air Jordan basketball shoes 1984 (Fig. 20)

Nike took a chance with a relatively unknown basketball player by developing a range of shoes specifically based around his ability around a court. Through a combination of notoriety (the shoes were black and red – and constantly banned by the American NBA) and performance the brand began to gain market share. When Michael Jordan won the Slam Dunk competition in 1986-87 Nike incorporated the flying man logo and the rest is history.

Figure 20. The first basketball shoes.

Jordan became more involved in the design collaboration process and in 1997 Nike launched the Air Jordan marquee as a standalone brand (Fig. 21).

Figure 21. The first shoes for basketball – Jordan.

- Astroturf 1964 (Fig. 22)

Astroturf was invented in 1964 by employees of Monsanto and originally sold under the name "Chemgrass". It was renamed AstroTurf after its first well-publicized use at the Houston Astrodome stadium. The ability to play, practice and perform on the artificial surface without the expense of constant maintenance has transformed many sports – notably field hockey, five a side football and club tennis.

Figure 22. The first AstroTurf for the sport stadium.

- Performance enhancing drugs – Nandrolone 1983 (Fig. 23)

Passed for medical use by the American FDA, the effects of the drug include muscle growth, appetite stimulation, increased red blood cell production and bone density. Banned for competitive athletic use Nadrolone was repeatedly detected in athletes in many sports categories, leading to speculation that use was widespread. A more rigorous testing procedure is now in place but doubts remain about the numbers of performance enhancing drugs in sport.

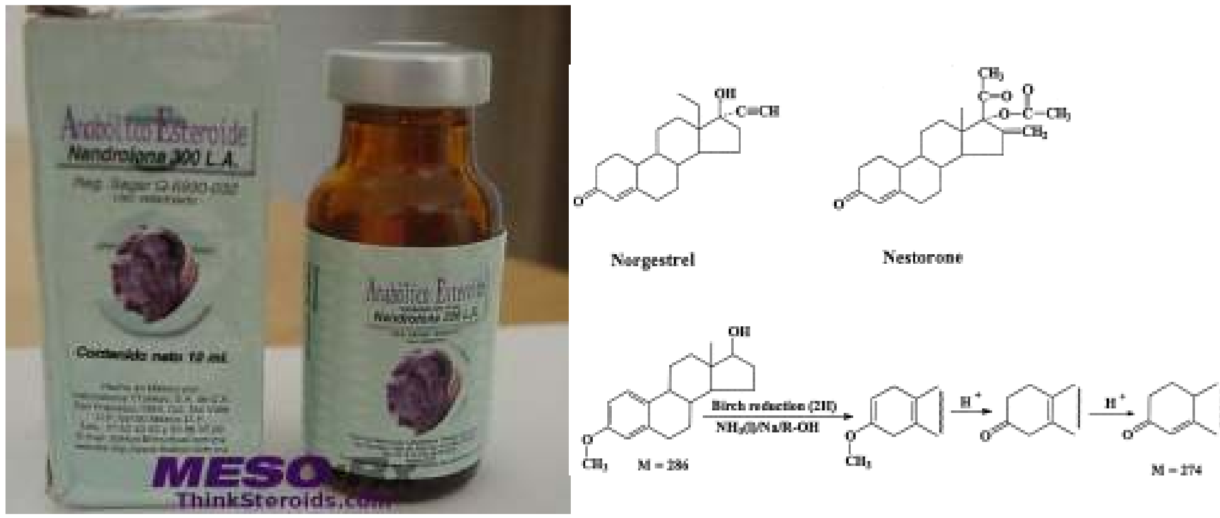


Figure 23. The first medical drugs for the muscle growth, appetite stimulation, increased red blood cell production and bone density.

- Carbon fiber resin process 1980's (Fig. 24)

The use of carbon fiber filaments, woven into sheets and resin bonded under pressure and heat has transformed the performance of many sports products, from the high technology of Formula One through yachting to tennis and a myriad of other sports. Carbon composite parts can be built so they exhibit high strength in the direction of load, so they can be designed to be as light as possible for the application. Combined with sophisticated CAD/CAM technology and analysis parts are routinely many times lighter than their predecessors whilst being stronger and more resilient.

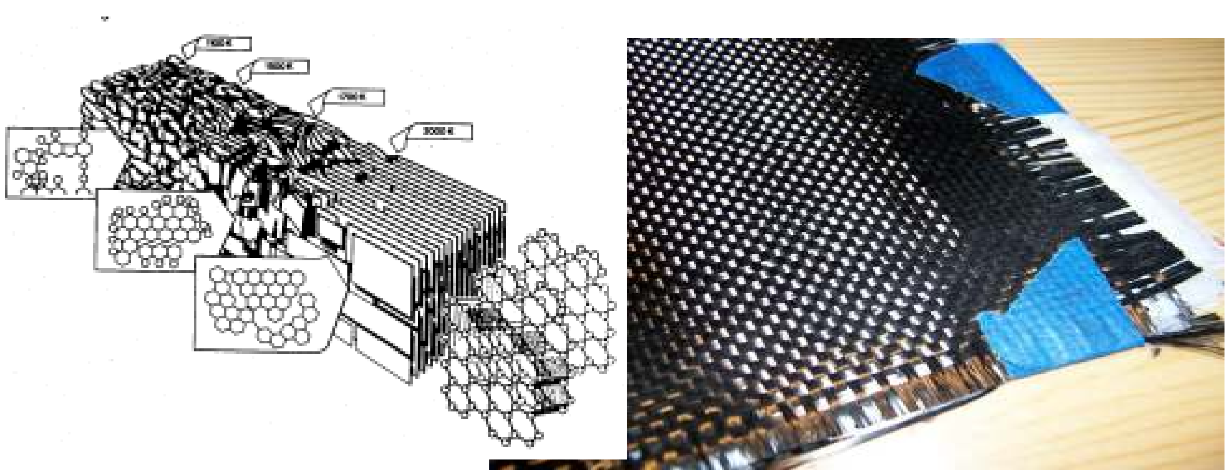


Figure 24. The first Carbon Fiber.

- Snowboards 1965 (Fig. 25)

Sherman Poppen is most often credited with inventing the snowboard in 1965. Poppen fixed two skis together for his daughter to "surf" down the snowy hill outside their Michigan home. Combining the words "snow" and "surf", the new invention became the Snurfer, and went into production the following year.

Figure 25. The first snowboard.

Over the next decade, early pioneers like Jake Burton, Demetrije Milovich and Tom Sims created more specialized and refined board designs. The founder of Burton Snowboards Jake Burton started making snowboard from fiber glass in 1979. He also added snowboard bindings for better control. But the real breakthrough came from Dimitrije Milovich, an east coast surfer. Dimitrije had the idea of sliding on cafeteria trays upstate New York. He then developed his idea and started developing snowboards designs and in 1972 he started a company called the Winterstick (Fig. 26).

Figure 26. The snowboard design in the start.

By the early 80's a handful of snowboard brands were on the market, including Burton, Winterstick, Sims, Barefoot, Avalanche and Gnu.

- Lycra 1959 (Fig. 27)

Lycra fiber was invented in 1959 by a team of scientists, originally as a replacement for rubber in corsetry. Before lycra fiber was invented, consumers endured saggy, baggy, stretched and bunched clothes. But when the DuPont scientist Joe Shiver perfected a revolutionary new fiber – code named K, that all changed. In the 1960s, lycra fiber revolutionized the way in which fabrics could be used. In beachwear it replaced thick and heavy swimsuits with light, quick-drying garments like the bikini. In 1968, the medal-winning French Olympic ski team became the first high-profile sports personalities to wear ski suits with lycra – a trend that soon spread to other sports. By 1972 Olympic swimmers swore by the sleek, lightweight suits with lycra.

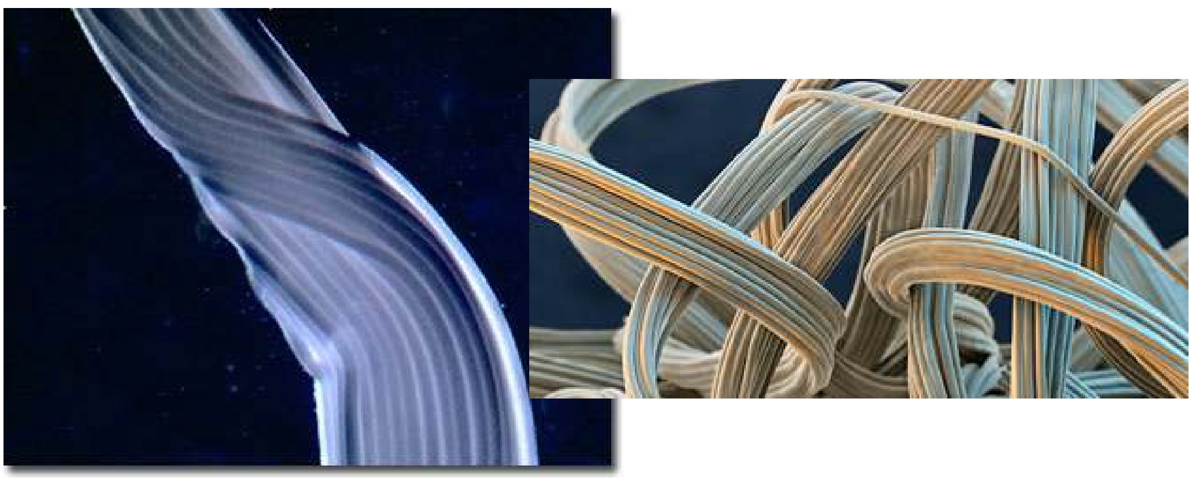


Figure 27. The first Lycra Fiber.

4.2. The new technology in sport and medicine

The important things during sport, which we have to remember is take care of our body, means of our heart, muscular, joints and breathe. In the past, monitoring of biomechanical and physiological parameters was very complicated: the large machine standing in one place, not disposable, expensive, uncomfortable to use. In recent years, has become a very popular method of recording and the use electronic accelerometers located at various sites on the swimmers body. The use of accelerometers in athletic performance monitoring has been validated by numerous studies covering a range of disciplines including: ambulatory measurements [32], physical activity [33], gait analysis [34], orientation and movement [35] and to improve athlete performance [36].

The use of technologies in sports can enter several advantages in evaluating and improving the efficiency of physical training for the whole time. Evaluation in the same time cardiac and biomechanical parameters it is need for a trainer, to assess his level of physical state, a potential overload or the need to increase the working load. When is need of prepare a training session or competition it's necessary to clearly know the targets what we want to attain and the physical abilities of those with will be submitted to physical exertion (exercises during training should be stimulated, modified, depending on the athlete's predisposition).

In this moment we have a lot of products that can help us make a measurement during the sport, for example:

- Nike+ system, with especially designed shoes, a motion sensor fitted in the insole and support with the Apple iPod/iPhone (Fig. 28). With this arrangement, information during a training run is transmitted wirelessly from the Nike+ sensor to the runner's iPod/iPhone. The information is displayed on the device screen and real time audio feedback is provided through the headphones.

After the run, the runner simply connects the iPod/iPhone to his/her computer and workout data in the form of a customized work-out log is stored on the computer. Using a graphical user interface, the runner can view and evaluate personal training goals and review distance travelled, time elapsed and pace and calories burned on a particular run.

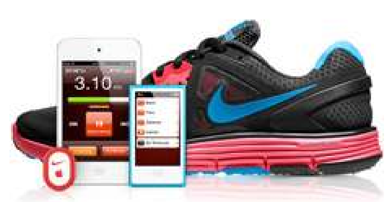


Figure 28. The Nike shoes with sensor.

➢ The XFT-2001 Foot Drop System is a single channel, tilt sensor switch controlled neuromuscular stimulator designed to correct dropped foot. Self-adhesive skin electrodes are placed on the side of the leg over a nerve called the common personal. Stimulation causes the foot to lift (dorsiflexion) and tilt slightly (eversion). Electrode positions can also be chosen that produces a reflex action, adding knee and hip flexion. Stimulation is timed to walking by using a pressure switch placed in the shoe under the heel. Stimulation begins when the heel is lifted from the ground and ends just after heel strike. Stimulation causes the foot to lift and stabilizes the ankle when the foot is returned to the ground. XFT-2001 Foot Drop System employs FES to:

- improved ground clearance,
- reduced tripping and falls,
- reduced compensatory movements such as hip hitching or swing the leg out sideways,
- reduced effort of walking,
- reduced spasticity in the calf and quadriceps muscle,
- increased walking speed,
- heel strike with aversion,
- improves the position of the foot in weight bearing resulting in greater stability in stance.

Figure 29. The sensor switch for control neuromuscular stimulator designed to correct dropped foot.

➢ Vesper - Biomimicry and NASA’s cooling technologies are the new frontier in sports rehabilitation (Fig. 30).

Combining cooling and compression pads that hold blood in the upper arms and thighs, his (short for vascular performance) fitness system fools the brain into thinking it has been working flat-out for several hours, when in fact it has only been exercising for 20 minutes. It sounds like an infomercial for an abs machine that promises the Earth for little effort, but Wasowski's team has been getting startling results - as have high-profile test subjects such as US Olympic athlete Erica Ashley McLain, who used the system to recover from a serious ankle injury.

Once humans reach puberty, the body, being much bigger, can no longer concentrate lactic acid at previous levels. At the same time, metabolic rate slows along with the growth process. So every ten years after puberty, they lose 14% of what they call endogenous growth hormone release. According to Wasowski, a 16-year-old athlete is already running at 86% of growth hormone, not 100 - and this slows recovery. By contrast, a footballer with an injured knee given six to ten weeks to recover completely can, supposedly, hit the Vesper machines and be match-fit in two weeks.

Along with this bio-mimicry, Vesper relies on cooling technology designed on Nasa spacesuits to aid healing and performance. Wasowski explains: "If you were to take a bowl of water and heat it over a flame, you would see it starting to warm up and oxygen coming out of it. The same thing happens to the bloodstream. As the body temperature goes up, the blood temperature increases and starts releasing blood oxygen. The less of oxygen people have on board, then more start gasping for air.

Wasowski says that in swimming, as blood has much higher blood-oxygen volumes because the temperature is cooler, this type of exercise burns 45 percent more fat as the body is giving maximum fuel to the muscles and running at a much higher efficiency.

Figure 30. The cooling technologies for the new frontier in sports rehabilitation

- The Forerunner 910XT is the perfect training partner and is the only all-in-one, GPS-enabled device that provides detailed swim metrics and tracks distance, pace, elevation and heart rate for running and cycling.

It sports a sleek profile, comfy wristband and an easy-to-read display. The 910XT Tri Bundle is compatible with ANT+™ sensors, including the speed/cadence sensor (for cycling), and the premium heart rate monitor (both included). Can be pair the 910XT with an existing ANT+ heart rate monitor or purchase as an accessory.

Whether during training or racing, every second counts, so the 910XT makes it easy and seamless to transition between sports. The auto multisport feature lets switch sport modes with just 1 button press, so is impossible lose precious seconds in transition. The quick release mount (supplied) allows moving the 910XT easily from wrist to bike.

Designed for open water and swimming pool, Forerunner 910XT is water resistant to 50m (164ft) (Fig. 31). It's Garmin's first multisport watch to offer extensive swim metrics, including swim distance, stroke identification, stroke count and pool lengths. It also computes swolf score to help gauge the swimming efficiency. (Swolf is a combination of the words 'swim' and 'golf' and it is a way of calculating a swimmer's efficiency. To find Swolf score lap time is added to the number of strokes have taken. Eg. if it takes 20 seconds to swim a lap and took 15 strokes score would be 35.) The 910XT's robust design and easy operation make it suited for other water sports, including paddle boarding.

Figure 31. The watch with sensors for sport.

- The Polar H7 heart rate monitor Bluetooth sensor provides live heart rate on mobile training application (Fig. 32). In addition to low energy Bluetooth smart technology, the H7 heart rate monitor uses coded 5 kHz transmission to connect with the majority of Polar training computers on the market and with compatible gym equipment. The soft fabric chest strap seamlessly adapts a body shape, bringing full freedom of movement to training.

Figure 32. The heart rate monitor with sensors.

- Nike Pro Turbo Speed suit designed the new product developments from both small companies and large brands alike, not only make garments look and fit better, they also help athletes perform better (Fig. 33). Many of these require uses of new design technology within the manufacture of the garments, not just the materials they were made from.

The market leaders present these specialist technologies at Texprocess, the leading international trade fair for processing textile and flexible materials from June 10 – 13, 2013 in Frankfurt, Germany in co-location with Techtextil, International Trade Fair for technical textiles and non-woven’s from June 11 – 13, 2013.

Figure 33. The new textile materials of Nike.

- Smart Soccer - a virtual performance gauge with real-time data on each of the player out on the field (Fig. 34). The Adidas miCoach Elite System was included within Adidas’s Olympic Performance Sports

Figure 34. The t-shirt of Adidas with sensors.

Bra. It has also been introduced to football to help with coaching and game monitoring. Connected by a series of electrodes and sensors woven into the fabric of the base layer, the cell wirelessly transmits more than 200 data records per second from each player to a central computer which is instantaneously displayed in a series of simplified insights and results on the coach's tablet or iPod enabling the coach to monitor the work load of an individual player by measuring every move, heart rate, speed, acceleration, intensity, distance, and the new power output measurement, compare one athlete with another, or view the whole team, to gain a complete picture of the game both physically and physiologically.

➢ FASTSKIN Racing system - For the Olympics, Speedo introduced its FASTSKIN Racing System which designed the swimsuit, cap and goggles into a unified system, which Speedo claim enhances both comfort and hydrodynamic efficiency, with a full body passive drag reduction of up to 16.6%, an 11% improvement in swimmers' oxygen economy enabling them to swim stronger for longer, and a 5.2% reduction in body active drag (Fig. 35).

Figure 35. The new design of swimsuit, cap and goggles for the Olympics.

Accurate three dimensional head mapping data is used to ensure the cap and goggles are made to fit head and face contours of each swimmer exactly, delivering optimum comfort, improved hydrodynamic performance and ease of use'. Different fabric construction, surface structures, fibers and finishes on the body suit combine to help reduce skin friction drag, water absorption and create graduated compression across different body zones, whilst the seam framework provides a flatter, more efficient profile and gives greater stability.

4.3. The new technology in swimming

The most difficult sport for measure physiological parameters is swimming. In this case is changing the environment, in which is water. For this reason a lot of people designed some special instruments.

The user should not accept the technology but technology should adapt to the user and his/her needs: this is crucial for identifying new killer applications and devices to a market success. From the Design point of view main attention will be paid to comfort and end-user compliance. As a highly technical product the final system must be comfortable during use and with easy-fit. To enhance the feeling of comfort of the swimmer during the sport activity, the specific movements of the muscles during the individual styles of swimming will be studied, in order to create the design of the garment and accordingly differently elastic yarns will be embedded in those areas where the muscle movement of the swimmer must find release from part of the fabric. This flexibility, however, should not affect the hydrodynamics of the garment. For this purpose was consider studying technical solutions that allow for proper matching between woven zones and knitted ones. This solution is highly innovative on the production side and can be very useful for the creation of products devoted to extreme sports and then “downgraded” into everyday applications. Great attention will be given to the aesthetic importance and therefore to fashion. First, the modeling, as well as the decorative component of the costume will be addressed, not so much to hide, but to enhance the non intrusive or transparent presence of the electronics to make it a fundamental part of the aesthetic impact. Even in this case it will be crucial to study the individual styles of swimming, to visually enhance the muscular movements involved. Secondly, the fashion aspect known as "feeling" will lead to dictate first and to marry then a fashion trend; it must be an integral part of the garment. This is crucial because the athlete lives with fashion a strong relationship of integration: he/she creates fashion on one side and the other he/she has to be fashionable.

Many authors used new design techniques to research on swimming. To investigate the flow parameters, very important is to use the smallest and lightest technology as not to disturb the sensor speed, technology and comfort of the swimmer.

Pansiot J. et al. [37] used head-worn inertial sensor to Inter certain bio motion details of specific swimming techniques. Important is also place of mounting. Sirlota P. [38] compared two different sensor placements (wrist and Upper back) during swimming exercise. Tracking is done by recognizing the swimming style, the intensity of swimming and the number of turns and strokes. The information can then be used to define the swimming speed, swim distance and to estimate the energy expenditure. It is shown that an upper back-worm sensor is more accurate than a wrist-worn one when the swimming style is recognized, but when the number of strokes is counted and intensity estimated, the sensors give approximately equally accurate results.

Callaway et all. [39] designed the multiple sensor-based measurements of swimmers acceleration profile have the potential to offer significant advances in coaching technique over the traditional video based approach. As Troup [40] recognizes, capture of reliable performance data can provide greater insight into the dynamics of swimming and has the potential to enable swimmers to perform to their highest potential.

Each of the four competition swimming strokes has been investigated, where swimmers instrumented with a portable sensor were asked to perform their normal swimming strokes. During each swimming trial, sensor and video data were recorded. Preliminary testing has shown that accelerometer data can be useful in the determination of simple stroke characteristics, for example stroke rate and duration, and those differences in profiles can be attributed to a certain stroke or swimmer.

The research outlined in paper of Slawson S.E. et all [41] had explored the relationship between stroke characteristics and how they are represented by accelerometer data. Each of the four competition swimming strokes has been investigated, where swimmers instrumented with a portable sensor were asked to perform their normal swimming strokes. Preliminary testing has shown that accelerometer data can be useful in the determination of simple stroke characteristics, for example stroke rate and duration, and those differences in profiles can be attributed to a certain stroke or swimmer.

Bahtiyar et al [42] used accelerometer for to investigate the effect of leg kicking on different styles of swimming. He compared normal swimming with swimming with arms only in the context of two biomechanical parameters, namely velocity and arm stroke index. Each category was timed in seconds and the number of strokes was counted and recorded. The swimming velocity was calculated by dividing the total distance swum in meters by the swimming time measured in seconds. The arm stroke index was defined as the arm stroke rate over the swimming velocity, or equivalently as the number of strokes necessary to cover a certain distance. The result shown that the velocity while swimming the full stroke (arms and legs) was significantly higher than swimming with arms only. In crawl and backstroke swimming, results suggest that the contribution of leg kicking to swimming velocity was approximately 10% and to swimming economy it was approximately 25%. The effect of leg kicking on breaststroke swimming was much more pronounced: its contribution to swimming velocity was approximately 25% and to swimming economy it was more than 100%. Of the three styles studied, the highest impact of leg kicking was on the breaststroke.

Several studies reported that the arms contributed more to propulsion than the legs in different swimming styles [43]. It was reported by Holmen [44] that the efficiency of swimming with arms only at a constant sub maximal velocity was higher than in that with leg kicking. On the other hand, Ogita et al [45] showed that the total energy production during swimming with whole body was lower than that during swimming with arms only.

5. Objective of work

I started my university in Warsaw in Josef Pilsudski University, where I obtained the university degree in physical education. After I decided to start the PHD in biomechanics of sport for analyze the performance during sport. I found an interesting connection in design study so I changed my specialization for create a connection between biomechanics and design studies for create the perfect exploitation.

5.1. Rationale of the study

This project aimed to create a connection between sport and design to find the best product for analyze the performances for athletes. The most specific and difficult sport for analyze is swim for this aimed to find a technical system useful for sport, rehabilitation and day use. The most important things for monitoring in swim are:

- performance;
- recovery;
- health.

Monitoring the physical parameters during sport is too much important. Design for new technology in sports can introduce several vantages in the evaluation of physical performance managing to provide, for all the time of a training session, a full description of the athlete situation. The most difficult a real-time monitoring system is in water.

At the market are many companies that offer a lot of products for analyze performance also for the swimmer. Every these products are good, but isn't no one that can give us all the necessary parameters at the same time.

Taking this into account, was attempted to design a swimsuit in which aims to developing a sportswear able to monitor performance and health in swimming, in real conditions giving in the same time comfort and aesthetics, focusing on innovative textiles and electronics.

5.2. The research pathway

The design and implementation are managed by means of some work packages, which are: "Analysis of user requirements" is aimed at defining the functional and aesthetic specifications of the system that will result from the convergence of different lines of the study. The research started by analyzing the characteristics of the gestures and the design of a proper swimwear, different for gender and for swimming styles; this identified the position of the sensors that were used and their integration in a swimsuit privileging aspects of fitting, robustness, ease of use aiming at wide dissemination of the system not only for amateurs but also in the competitions.

Through Design Workshops and code sign methodology, was defined solutions for the following strategic issues:

- the needs of the coach and athlete,
- the physical limits imposed by the water: the electronics must be designed and built so as not to be affected by the release into water, fabrics and yarns chosen to serve the technological needs of the system (hearth and respiration signal detection),
- the fit and ease of use: modeling of the textiles components had to ensure maximum comfort, the embedding of sensors, the connection with the recording devices while the complete system was designed to allow easy wearing up of the swimsuit while maintaining the correct sensor positioning (which ensures the quality of signals in all conditions) and the non intrusively of the electronic case (no influence on movements and hydrodynamics),
- aesthetical and design preferences of the users to develop an innovative appealing swimwear also for these features; new ultra technical textiles facilitated this activity by embedding sensual, tactile, communication and cultural properties. Data recorded and then transferred from the body-worn

swimsuit device to a computer system (PC or PDA) transparently to the user to facilitate the immediacy of the measure and its interpretation.

The overall S&T objectives of this research were:

- the development of a suitable acquisition and processing system for monitoring of biomechanical and physiological parameters in the water to support training and healthcare;
- the design and selection of adequate textiles and materials able to cope with the technical needs on one side and the sport needs on the other;
- the integration of the system above in an appropriate swimming suit, with main emphasis on innovative textiles research;
- the design of the final instrumented swimming suit according to a human-centered, need-driven, design-led approach, i.e. an adequate matching of technology, fashion and sport.

5.3. Research goals

The swimsuit project aims to designed innovative textile solutions to create a sensorized and functional swimwear for athletes who engage in amateur swimming or racing. This allows both to optimize the performance and training methods, and to monitor health conditions. Moreover, with some simplifications, the system can be used in different areas: in addition to other sports, telemedicine and safety at work.

The project aims at the creation of an ergonomic performance monitoring system based on a sensorized swimwear embedding sensors and supporting the device in a waterproof pocket; the device would be able both to record and to real-time transmitting data to a receiving station/system out of the pool.

This project proposes the development up to the industrialization of an innovative wearable system, embedded in the swimsuit textiles, for swimmer's monitoring including:

- ✓ a wearable device with hydrodynamic performances measuring and recording data of motion, temperature, HR and, possibly, breathing;

- ✓ a sensorized swimsuit with special design for textile electrode positioning and waterproof area onto the skin, with a textile/non textile but hydrodynamic ISM band antenna for transmitting data;
- ✓ a side-pool device for data real-time processing and visualization.

Swimsuit has to monitor in real time during training in water: Hearth rate; Breathing rate; 3-D Accelerations; Stroke number (hands & feet) and Poolside timing.

Part II. State of art:

6. Swimming

What is the swimming? Swimming is the method of movement in the water used by humans, animals and machines. It is a popular recreational activity, particularly in countries with warmer climates and natural water bodies. Swimming is a sport.

Swimming is recommended for everyone, regardless of age or ability. Swimming is good for everybody and is effective in helping to keep the health and physical condition.

For the babies - small children love the water. The child which start go to swimming pool from early years , is developing proportionately, is more healthier and more physically efficient and in the same time is immunized to be sick. Additionally, water is a great opportunity to have fun with their parents and has a positive effect on the emotional development of their little person.

For the young people going to the swimming pool is a good way to spend free time, thus combining business with pleasure. Swimming is one of the most important factors in the physical education of children and youth. For youth activities at the pool are a great exercise that develops all muscle groups. It also prevents faulty posture and generally increases mobility. It's also a fun way and at the same time combating overweight. Swimming also shapes the motor characteristics such as speed, coordination, endurance and strength. It also influences for psychological aspect of a young man, as is used for making the personality characteristics as regularity, discipline, self-reliance, courage and strength of will. Modern pools are like kind of sports resorts that are also different types of slides, whips and massage well as other variety, which means that no young person will be boring.

For the older and sick persons the pool is a good place for people after heart attacks, knee or spine operations. It is the water that makes patients recuperates faster.

6.1. Styles

At the moment are four basic techniques in swimming sports: Freestyle, Backstroke, Breaststroke and dolphin. In the professional race is also the combination of these techniques in the style of a variable.

Each technique has its own characteristics and advantages. Are different in the arrangement of the body in the water, the character of the movement's propulsion of arms and legs, an angle of attack and angle of rotation.

The freestyle method of swimming is the easiest style of swimming to learn. It's the most basic form of swimming used at a swimming competition. The freestyle stroke involves lying on stomach in the water, and looping the arms overhead in a continuous circular motion. At the same time, legs alternately kick in a scissor-like motion. For the breathe, head turn away from the water, while executing stroke.

The back stroke is similar to the freestyle form of swimming. The difference is actually lying on back as opposed to stomach in the water. The arms loop overhead out of the water in a circular motion. Kick of leg is more of a flutter as opposed to the power kick used in the freestyle form. Breathing is much easier when performing the back stroke because face is up, as opposed to being face down in the water.

The breast stroke is a complicated stroke. To execute the breast stroke, person should be on stomach in the water. The arms move in a continuous semi-circle motion in front of body. The head bobs in and out of the water as legs perform a rhythmic, frog kick. Breathe can be catch when head bobs out of the water.

The Butterfly is the most difficult swimming style. The arms simultaneously emerge from the water in a huge overhead, looping motion. As arms enter the water, legs move together at the same time in a fluttering motion. This is known as a dolphin kick. When swimming is competitively, people can't swim the butterfly underwater.

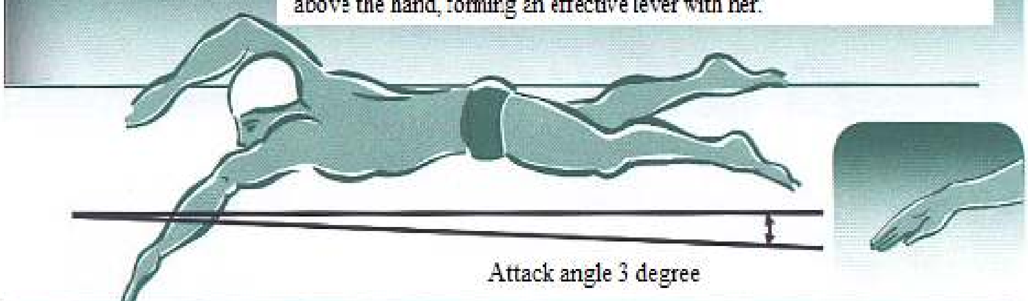
6.1.1. The freestyle

Freestyle swimming technique is the fastest and most efficient way to swim. The characteristic feature of this technique is the continuity of swimming drive resulting from alternately movements of arms and legs (Fig. 36, 37, 38, and 39).

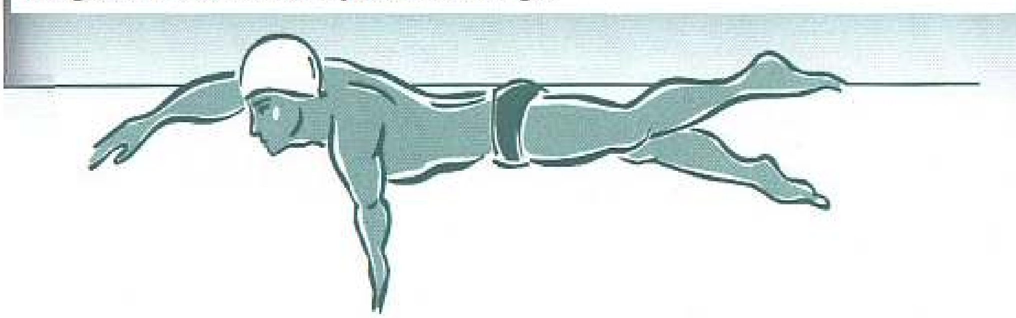
FREE STYLE

The body of swimmer is under water with the exception of the shoulders and head, as well as arms (at the time of of transfer on water). Swimmer lies straight on the chest with a small angle. This angle, called angle of attack , is slight fluctuations depending on the swimmer speed.

1 Left arm is located in the phase of pull on - the most forced in the whole movement cycle. Right hand enters to the water before the head with the speed as the speed of swimmer. Right elbow is above the hand, forming an effective lever with her.



2 Right hand in the full immersion (phase gripping of water) going down and outside of the shoulder line and starts to move back. Left arm goes phase of push back, the deflection at the elbow reaching 90 degrees. Left arm moves clearly faster than the right.



3 In the final phase of push back of the left arm , swimmer turns head slightly to the left and breathes. Left foot hits down. Left arm now produces a large strength of propulsion. Right arm goes to phase of pull increasing the speed of movement. Too fast entrance hand in the the phase of movement, reduces the effectiveness of the second arm movement. The rotation of trumk in the right direction of engages large muscle and gives the the swimmer body streamlined form.

Figure 36. The free style techniques.

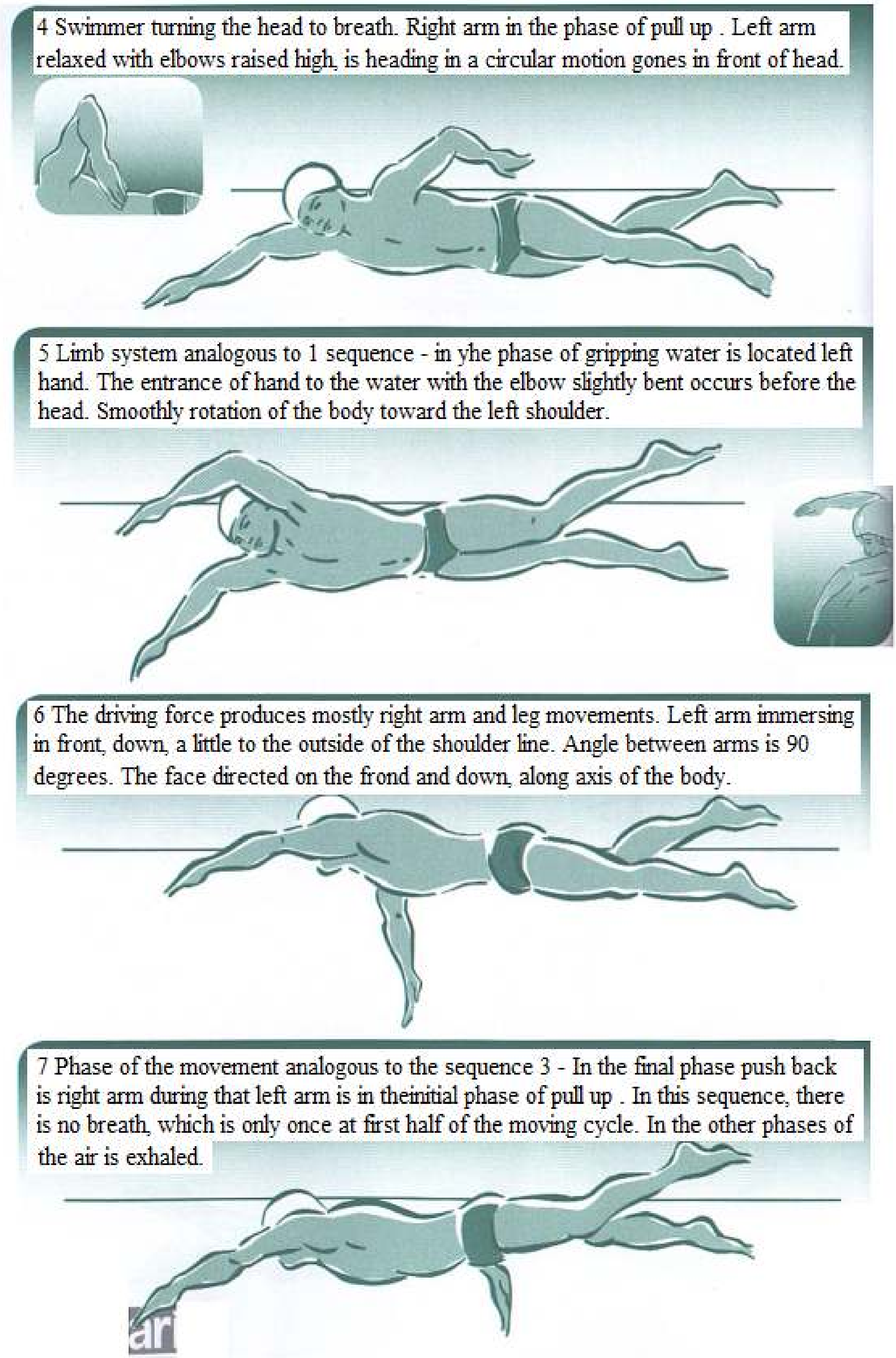


Figure 37. The free style techniques.

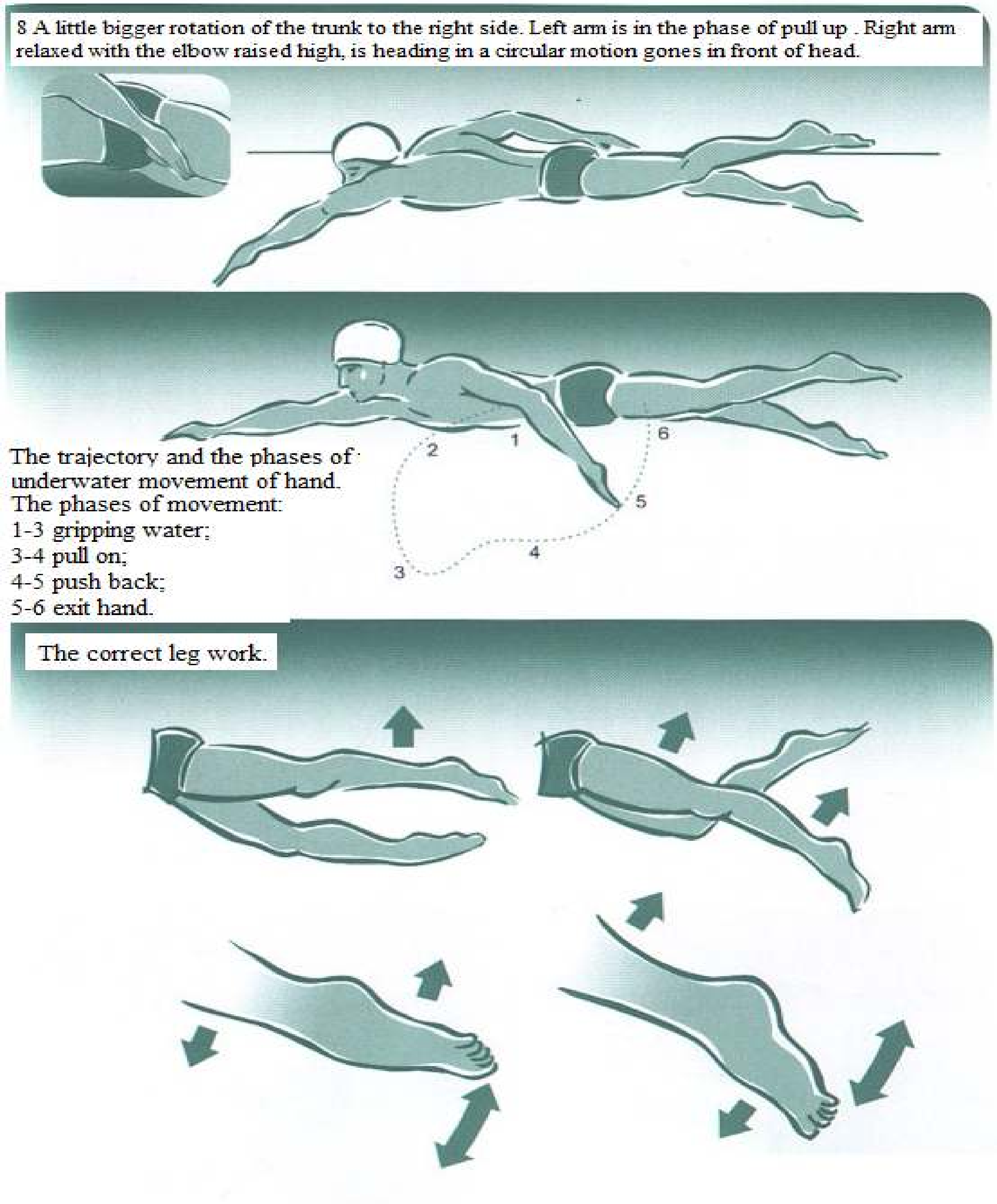


Figure 38. The free style techniques.

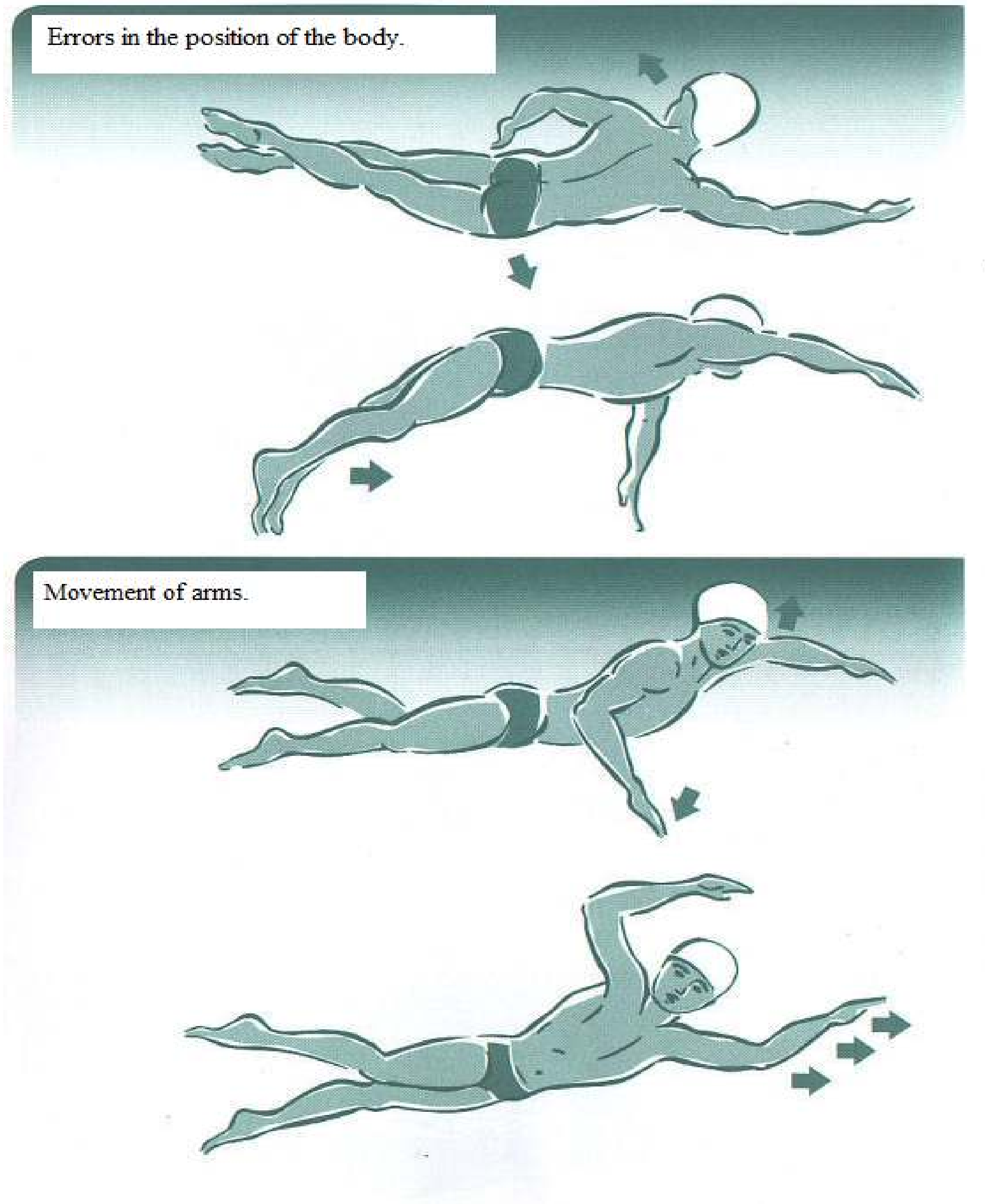


Figure 39. The free style techniques and mistakes.

The Fig. 40 show the stroke from the side. The relative positions of the both arms are close to being correct.

A VIEW FROM THE FRONT (Fig. 40)

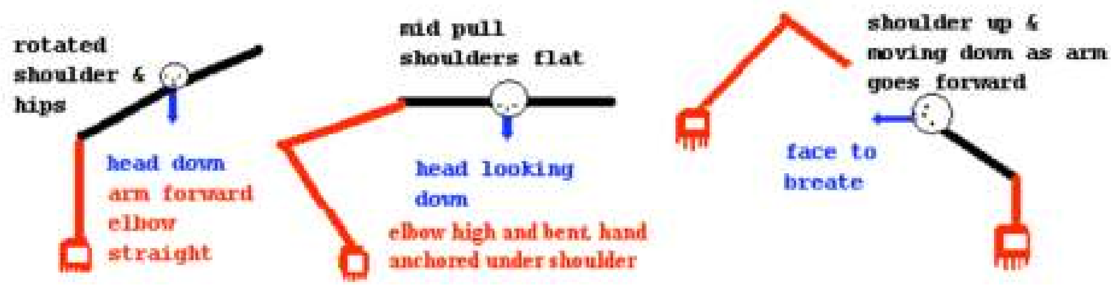


Figure 40. The view of free style techniques from the front.

The amount of overlap (both hands in the water) varies among swimmers. The variance is greater between successful sprinters and distance swimmers than it is within either group. As the forearm pasts pointing at the pool bottom, the release takes place. This is where the hand stops holding on to the water and the recovery begins. It is also the point where stroke gets an extra push from the core body rolling up to the surface. Some points to remember:

- Hand enters before the elbow. Then it moves down while the elbow anchors near the surface.
- At the catch point, the hand anchors and the body moves past the hand.
- After hips pass the anchored hand, the hand releases and prepares to recover.
- Fingers point at the bottom from catch to recovery.
- Legs must roll along with the hips. This means the feet will kick on an angle. They will not point down towards the bottom at the maximum point of the hip roll.

The angle formed by the upper and lower arm at the elbow joint during recovery varies among swimmers. The sharper the angle the more the shoulder may be strained. A wider angle can relieve this. It is important to get this part of the stroke right. Too sharp an angle places extra stress on the rotator cuff. Too wide an angle interferes with hand entry and shoulder extension prior to the catch.

A VIEW FROM THE SIDE (Fig. 41)

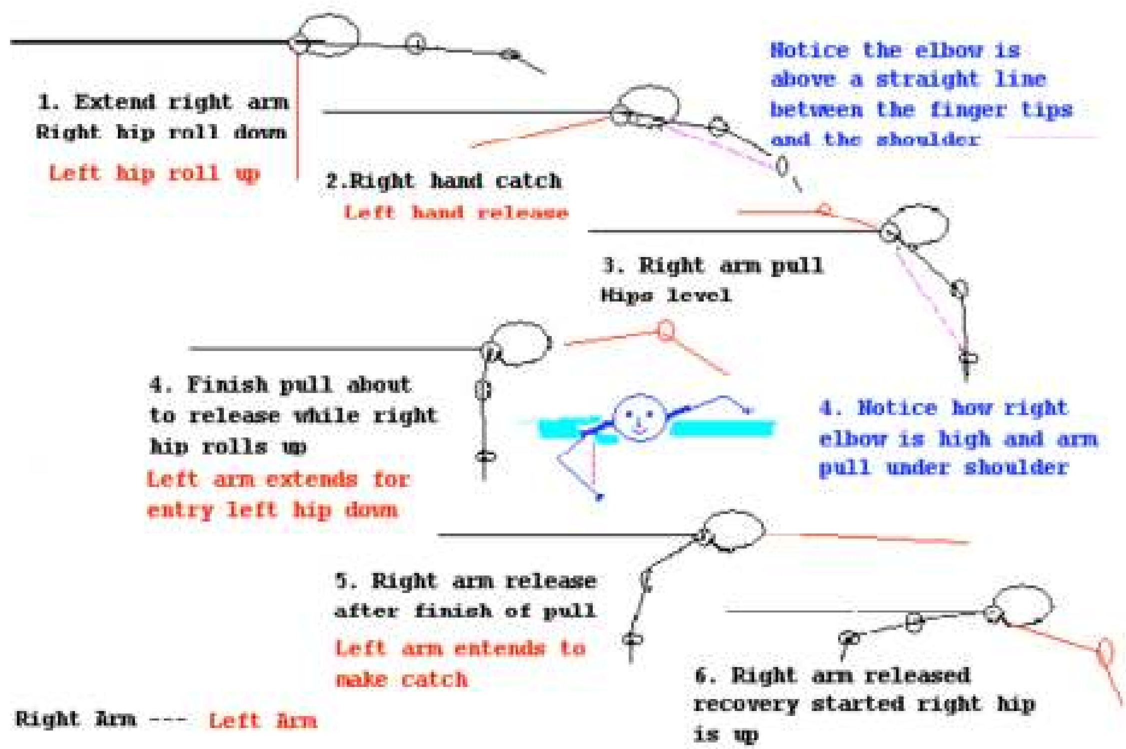


Figure 41. The view of free style techniques from the side.

The body roll is in the hips through to the shoulders (Fig. 41). The arms before entry thrust straight forward like a sword. They do not chop across as an axe would into a tree. After entry, the hand makes the catch. The catch anchors the hand in the water to pull the body forward. Right shoulder above roll to level with the surface after the catch and then up in the air for the recovery. As the shoulder lifts the pulling arm moves faster past the hip. The elbow bends, forearm rotates and begins the recovery motion. The hand skims just above the water surface. The elbow is higher than the hand. Breathe when the hand is in line with the shoulder and make sure the face is down before the hand enters the water. Must be remembering to exhale through the mouth and nose when the face is in the water. Need be careful of too much body roll. When is kicking, if legs fly apart like a cheerleader's arms and legs the cause is likely must be too much roll.

The most popular mistakes made in FREE STYLE are:

- Incorrect body position in the water. The body should be straight,
- Too big or too small (stiff leg) bend in the knee joints during movement,

- Footwork horizontal (left-right),
- Irregular, no rhythmic footwork,
- An ascent feet of water,
- Too big head tilt in the back or too large attracting beard to chest,
- Too much deviation to the side of the body during breathe,
- Lack of coordination while working arms with breathing. For early or late breath,
- Stopping the one hand near the other over the head,
- Lack rhythmic and continuous work of the limbs (hands stop near hip or the head, irregular movement of legs),
- Insert the elbow into the water after the hand,
- Continuous movement of straight hands,
- Lack straighten arm near the hip,
- No rhythmic and irregular movement of hands (one hand in one rhythm second in the other).

6.1.2. The back stroke

The backstroke is not fast as the crawl or dolphin, but it is the easiest to learn and the fastest way to move on his back. During swim should be maintained streamline body shape with deflected shoulders, making it easy to move alternately sided of legs. Shoulder restraint is a little higher than the lap belt. A deeper immersion of the hip stems from the need to create the most favorable conditions for work of the lower limbs (Fig. 42, 43, 44, 45).

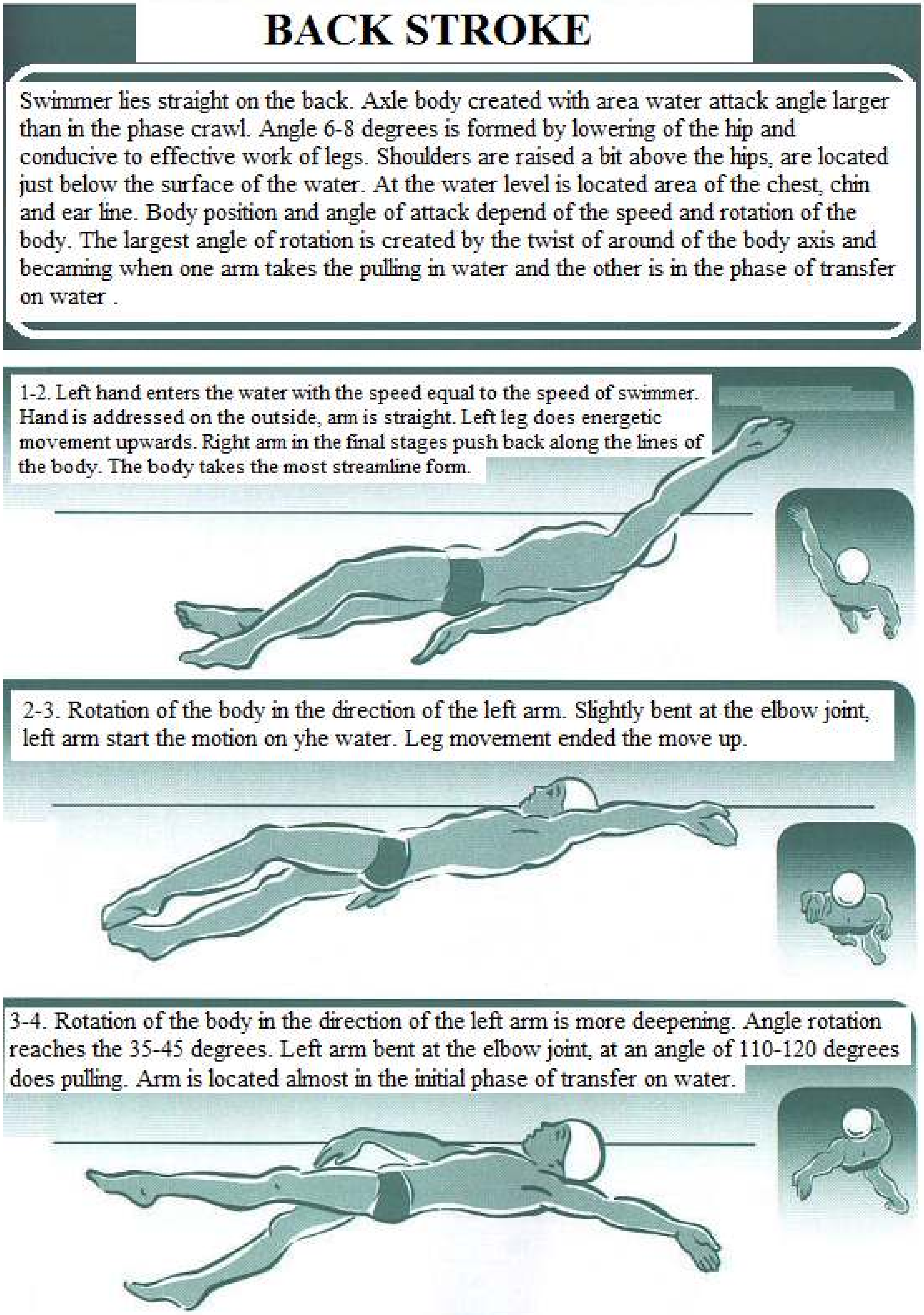


Figure 42. The back stroke techniques.

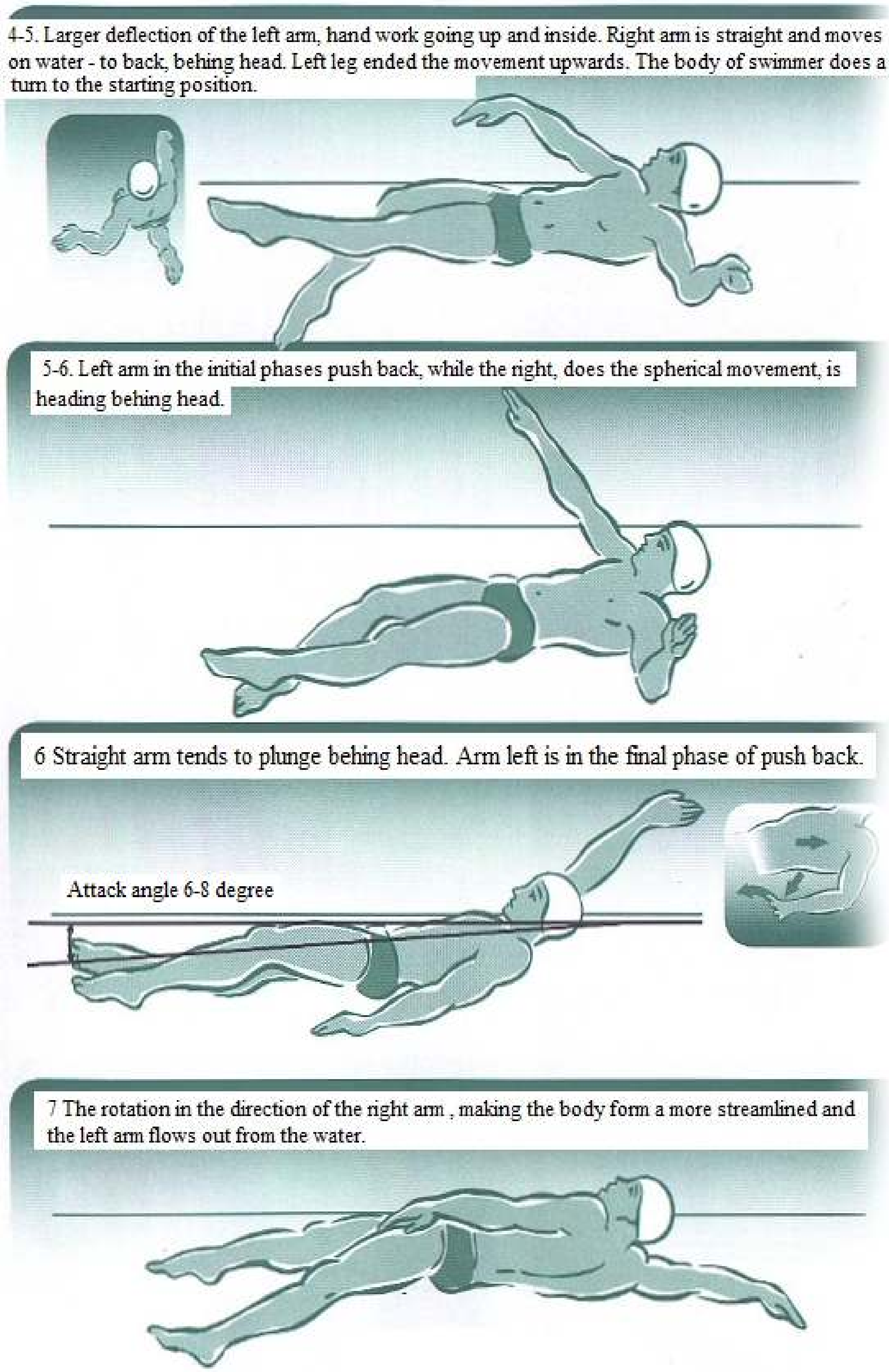


Figure 43. The back stroke techniques.

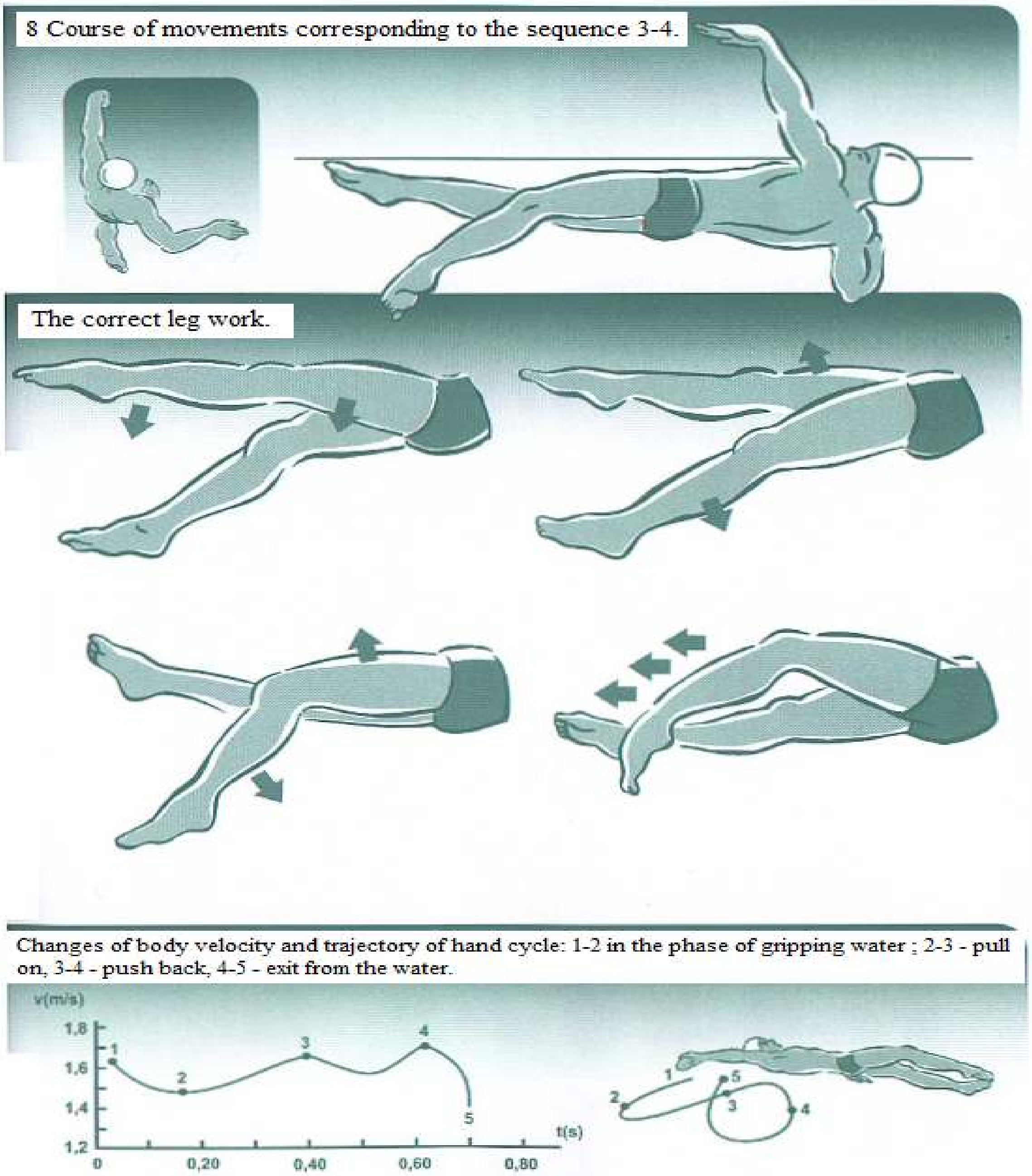


Figure 44. The back stroke techniques.

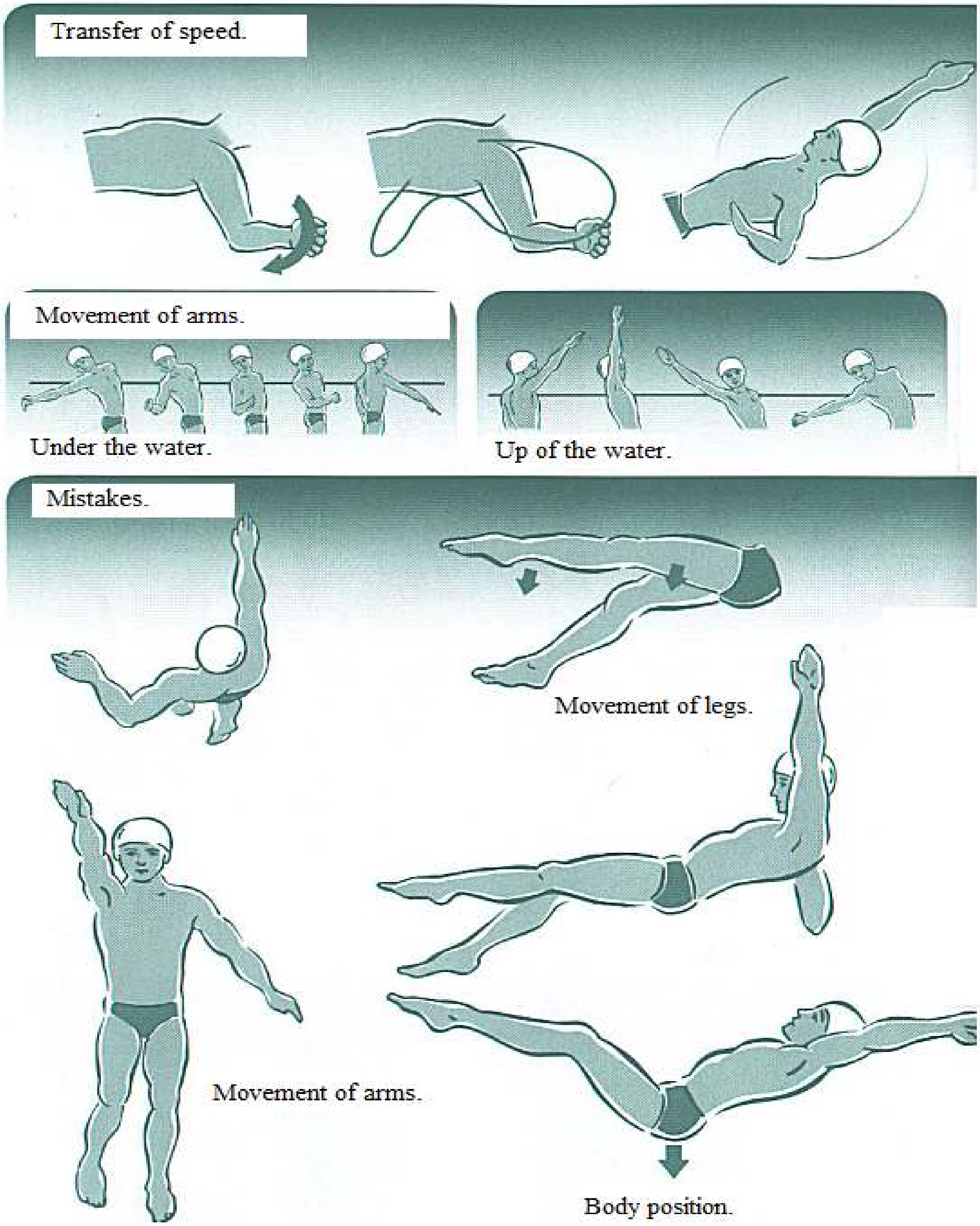


Figure 45. The back stroke techniques.

Figure 45. The back stroke techniques and mistakes.

Backstroke is a little different. The joints in arms and legs can't be bending in all the ways when people would like to swim on backs. The trick to going fast in the backstroke is roll on side to pull. The arm goes straight back just like in the freestyle. The little finger enters the water first. Then shoulder dips down and people scoop a big handful of water. Scoop deep into the water because that is where the best water to pull is. As body rolls back to where the shoulders are level, the hand moves up towards the surface and throws the scoop of water past of feet. Need to remember to keep the hand under the water and avoid making bubbles. Then as the hand passes by the hip, rotate the hip up and lift the arm out of the water for a recovery (Fig. 46).

A VISUAL REVEIEW OF BACK STROKE (Fig. 46)

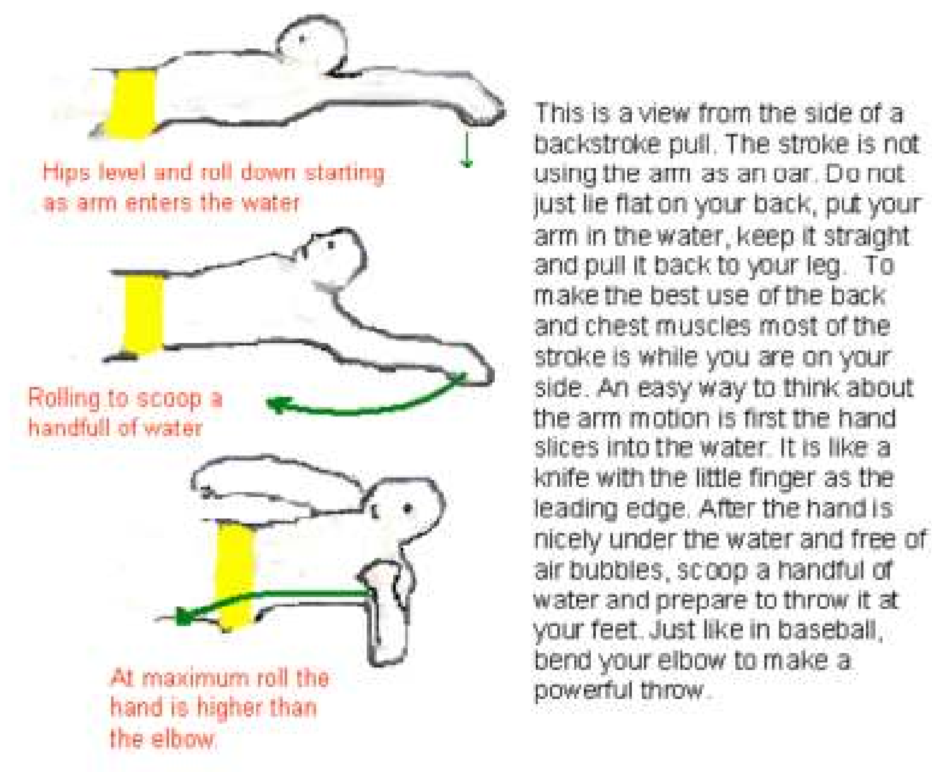


Figure 46. The visual review of back stroke.

The most popular mistakes made in BACK STROKE STYLE:

- Incorrect body position in the water. The body should be straight - deflection in the hips is a serious mistake,
- Too much deflection in the knee joints during movement,

- Lack deflection and stiffening of the legs,
- An ascent knees from water,
- Too big head tilt to the back or too high (too high attracting beard to the chest),
- Working both hands at the same time,
- Stopping the one hand near the other near waist or over the head,
- Lack rhythmic and continuous work of the limbs (hands stop near hip or the head, irregular movement of legs),
- Bent arm during transfer hand up, straight during movement proper to the back.

6.1.3. The breast stroke

The breast stroke is slowest one style of swimming. The characteristic feature of this technique is to perform legs and arms at the same time in the same levels, with breath during lifting head up above water and downloading arms under her chest. Depending on the size of the angle of attack of the body and scope of the changes within each cycle of the locomotive, there are two variants of the breaststroke swimming technique. The first is characterized by a flatness position where the change in the angle of attack of the swimmer is minimal, while in the second with a wavy character of changes within each cycle motor (Fig. 47, 48, 49, 50).

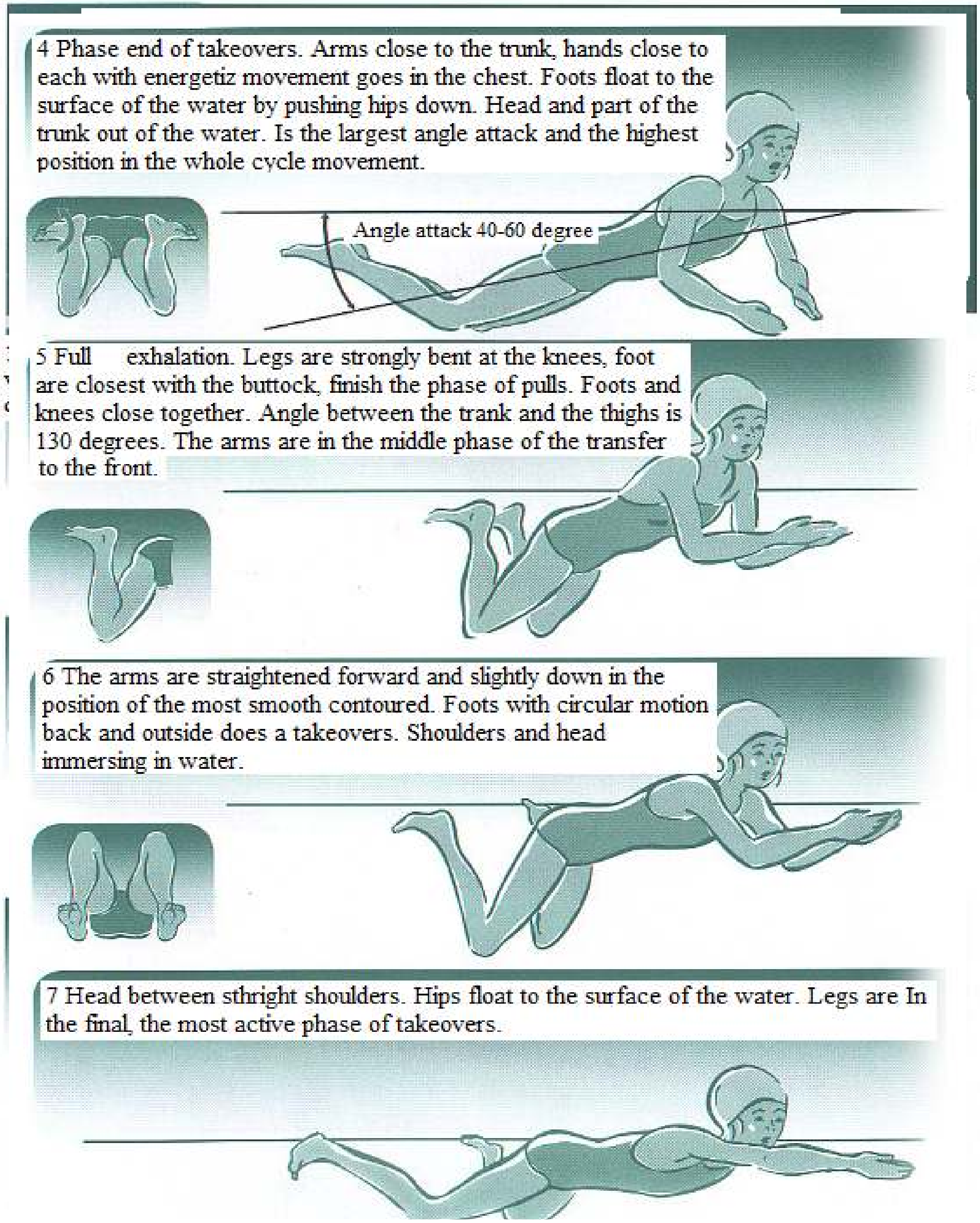


Figure 47. The breast stroke techniques.

Figure 48. The breast stroke techniques.

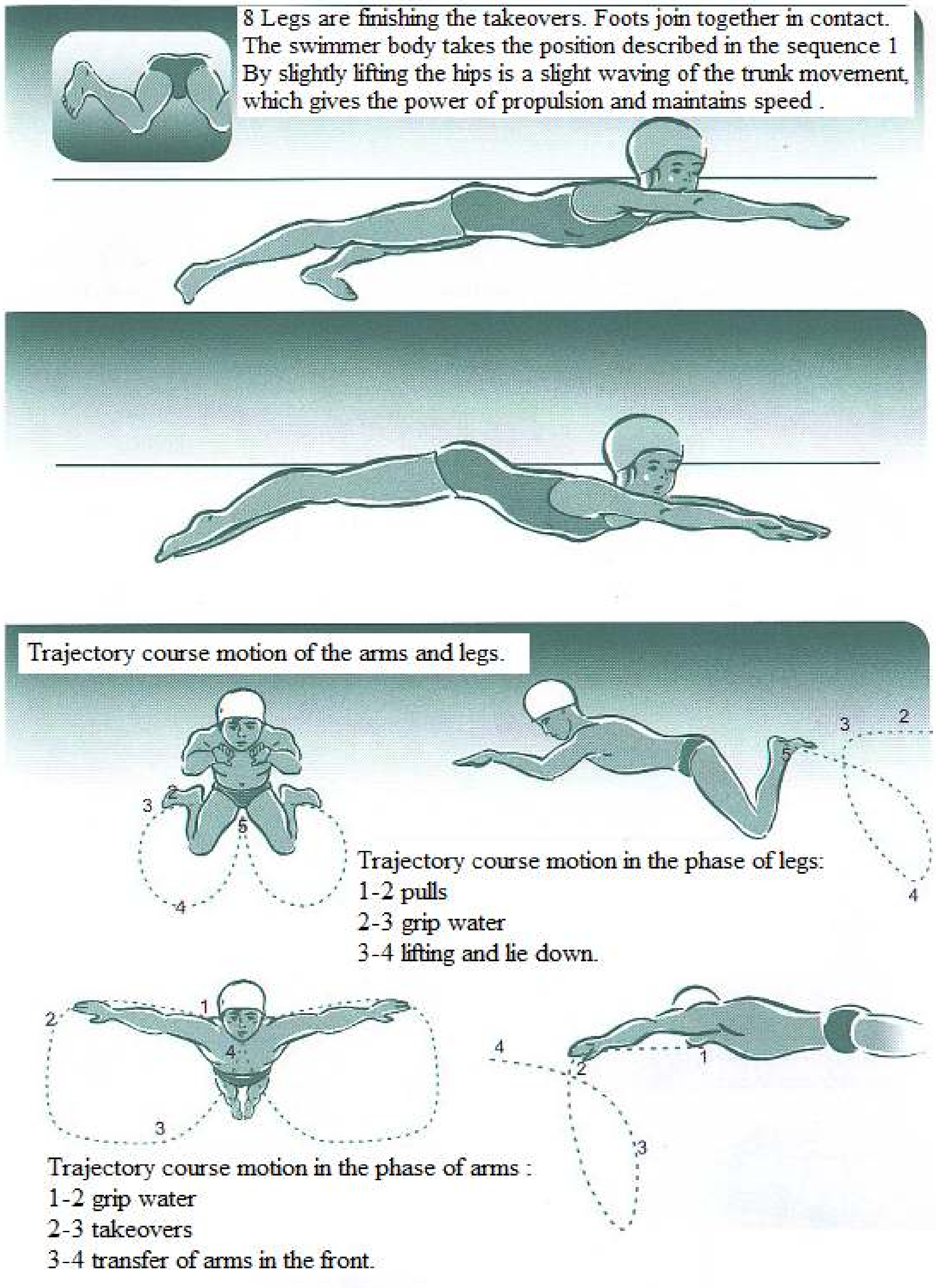


Figure 49. The breast stroke techniques.

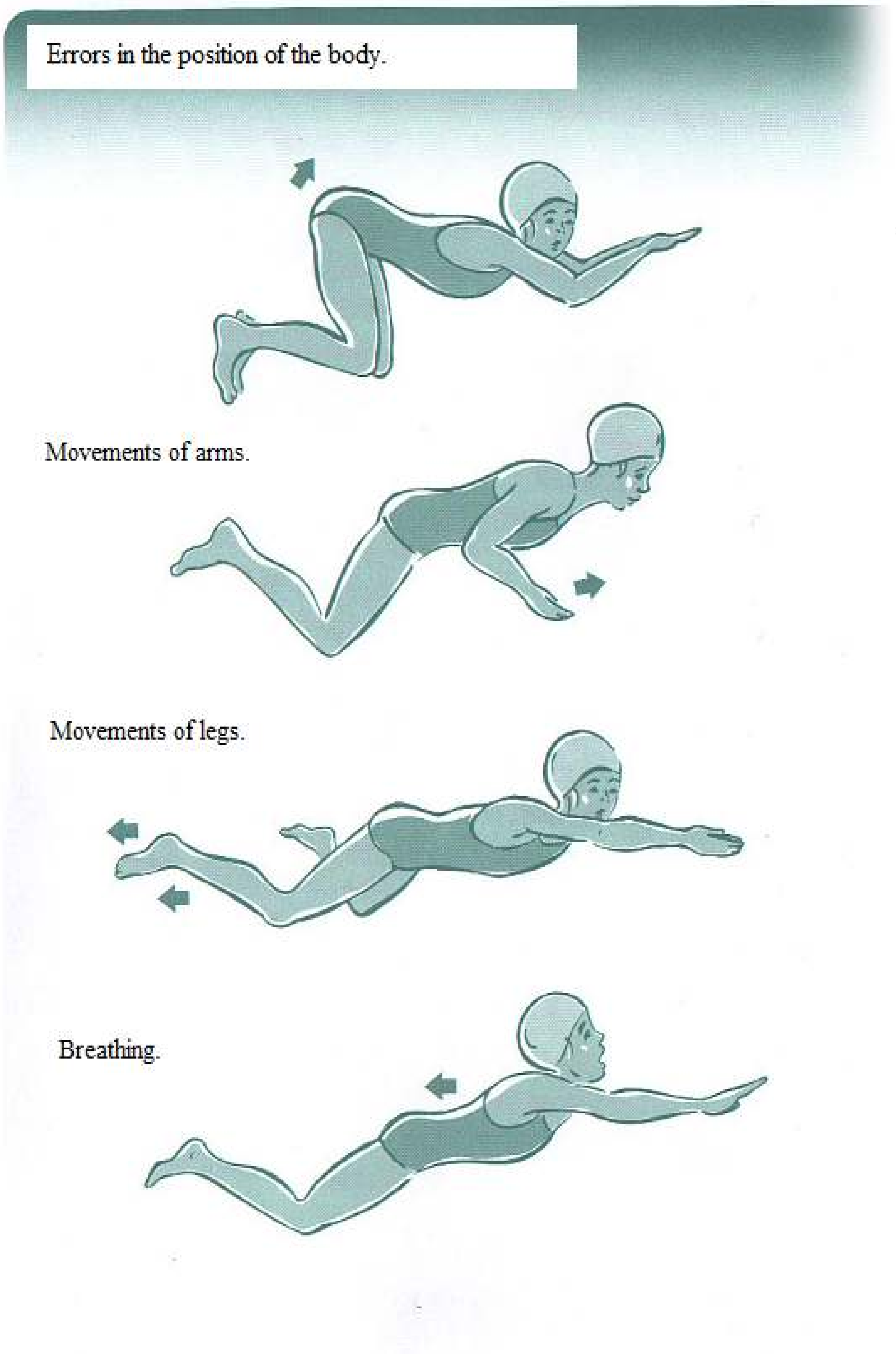


Figure 50. The breast stroke techniques and mistakes.

In breaststroke, need look to the frog for inspiration. The kick is slightly different but the principles are identical. They have those big flippers to push the water. People do that with the bottoms of feet. Frogs have a short body that cannot bend. When frogs kick all the force goes through the body and moves them forward. Need do that when thrust arms into the streamline position during the kick. Frogs keep their knees out when they kick. People are in. People can run. Frogs cannot so we do it a little differently. After getting the heels up to backside, push back and slightly out with the bottoms of the feet. Then squeeze the legs together as the legs fully extend. The kick finishes when the legs are straight and insteps touch.

Breaststroke has a special form of the stroke done on starts and turns. This is the pullout. The pullout consists of a pull where the arms go back to where the hands touch the legs, a dolphin kick while finishing this long pull and finally a proper breaststroke kick into a streamline again. A standard pull follows the pullout kick and the head must break the surface (Fig. 51).

A VIRTUAL REVIEW OF BREAST STROKE (Fig. 51)

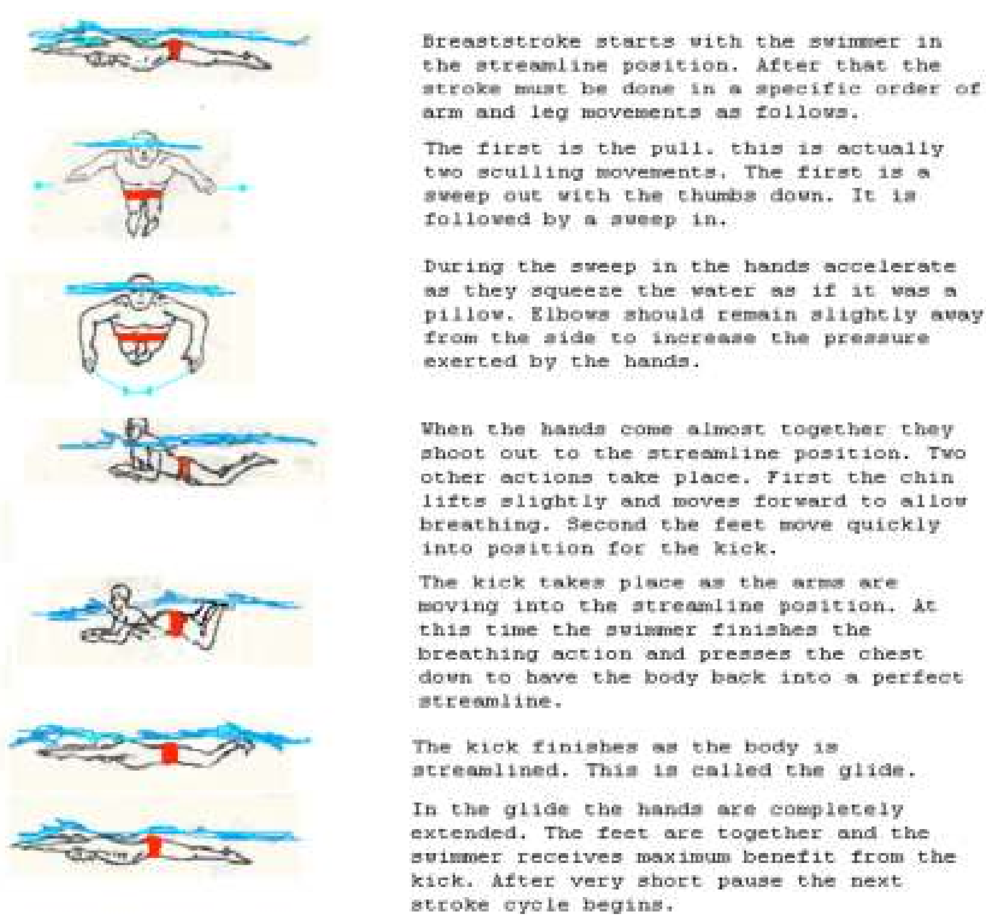


Figure 51. The virtual review of breast stroke.

The most popular mistakes made in BREAST STROKE STYLE:

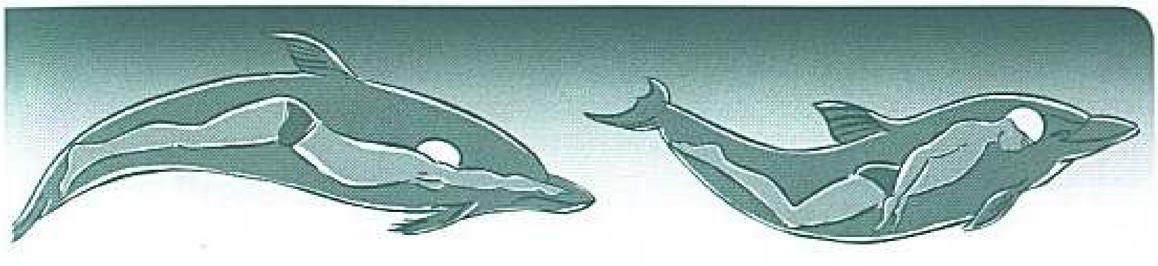
- Asymmetrical arrangement of legs at any stage the legs movement,
- Too small or too large deflection of legs in the hip joints,
- Lack deflection of the foot outside during the phase the proper,
- Lack unbend during the unbend and no deflection of the foot at the end of adduction heel to the buttock (starting of the phase the proper),
- Too big or too small opening knees during the finish preparatory movement,
- Too broad or narrow footwork during the push back phase,
- Too narrow or wide hands work hands during push back phase,
- Not valid hands work of hands in the proper phase (no movement slightly outside aside and after under the thorax),
- Lack head work during the movement of hands and trunk,
- No proper coordination of hands, breath and legs. (Correct - hands - breath - legs),
- Lack slip after each mobility. (The full cycle is - push hands with the breath, the beginning of the preparatory phase of the legs - move hands in front phase push back legs, exhale into the water - slip).

6.1.4. The butterfly

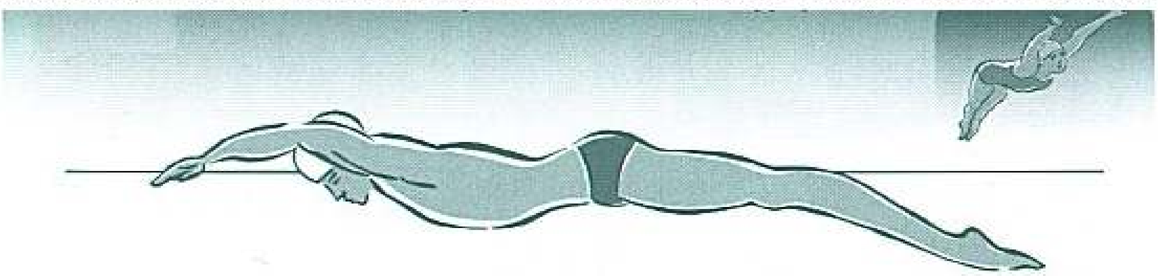
Butterfly is the most recent developed stroke of the four strokes. Swimming the butterfly became a recognized stroke in 1953. It is the second fastest stroke of all the strokes. It is mainly used for competitions rather than a recreational stroke. It is swum the least and taught the least. Swimming the butterfly can be very physically demanding doing the full stroke but learning and some practices can be done without too much physical exertion. What makes this stroke more difficult in comparison to the other strokes is that the recovery of the arms has to clear the surface of the water at the same time (Fig. 52, 53, 54,).

BUTTERFLY STYLE

The body of swimmer during the dolphin swim change the body position always changing. This occurs as a result of vertical movements of the trunk collaborative with leg and arm moving over the water and lifting head to breathe. The value account of every phases of the attack in moving cycle ranges from 20 to -30 degrees.



1 Arms slightly bent at elbows, placed over the water begin with a phase of water grip. Located hands slightly wider than shoulder width apart goes downwards and to the outside.



2 The hips right under surface of the water. Legs performs hit in the lower. The impact is too much importante in maintaining speed.

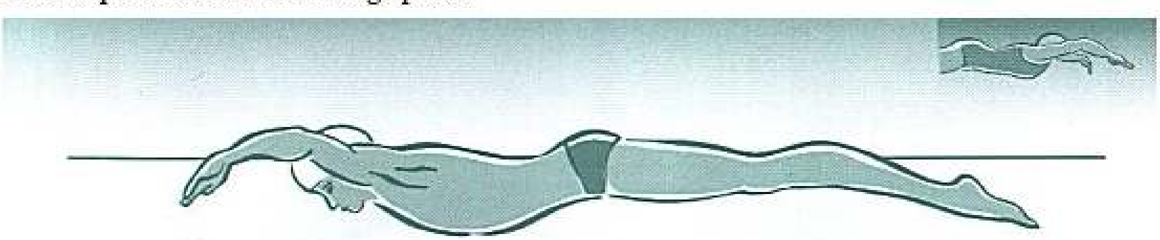


Figure 52. The butterfly style techniques.

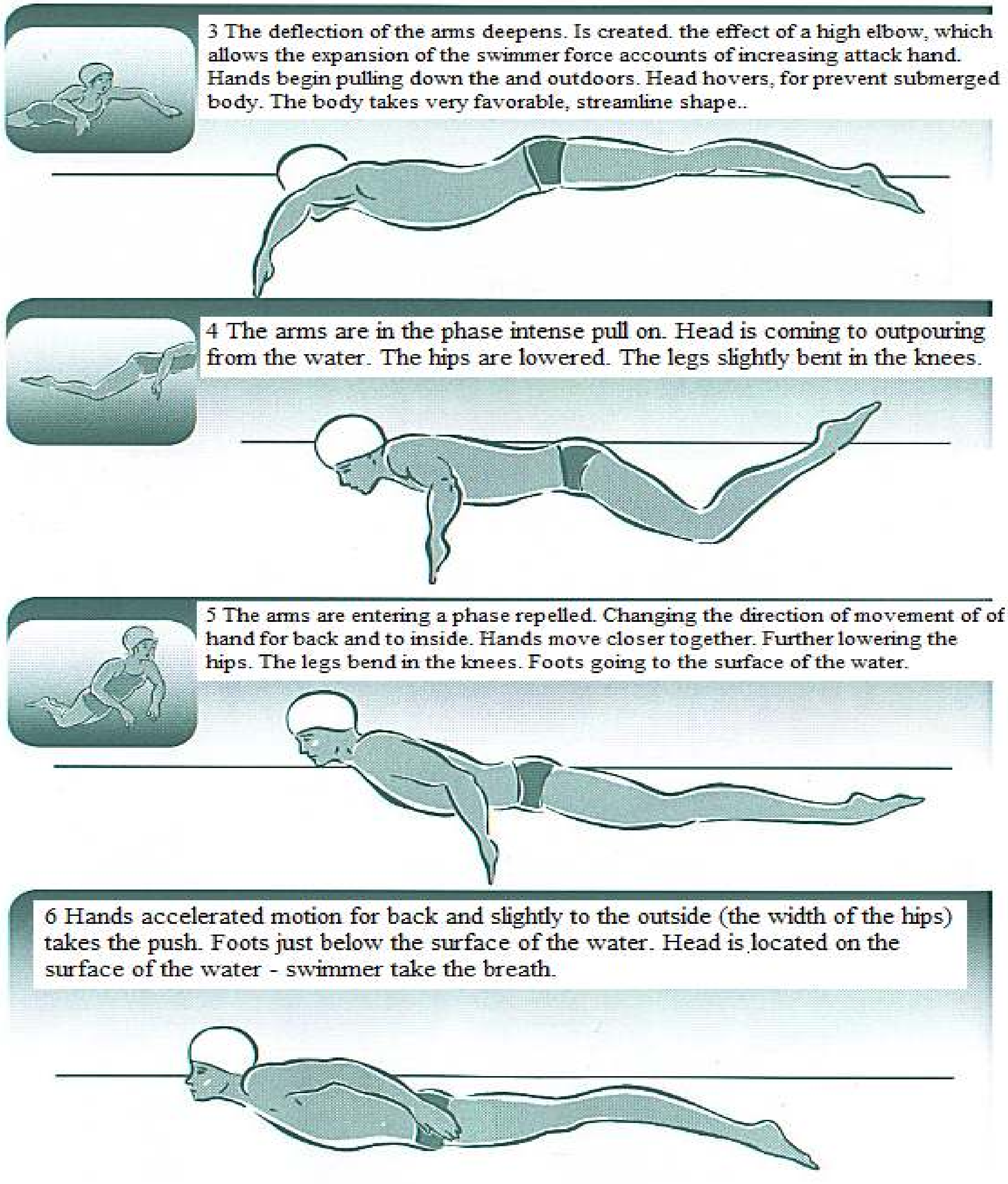


Figure 53. The butterfly style techniques.

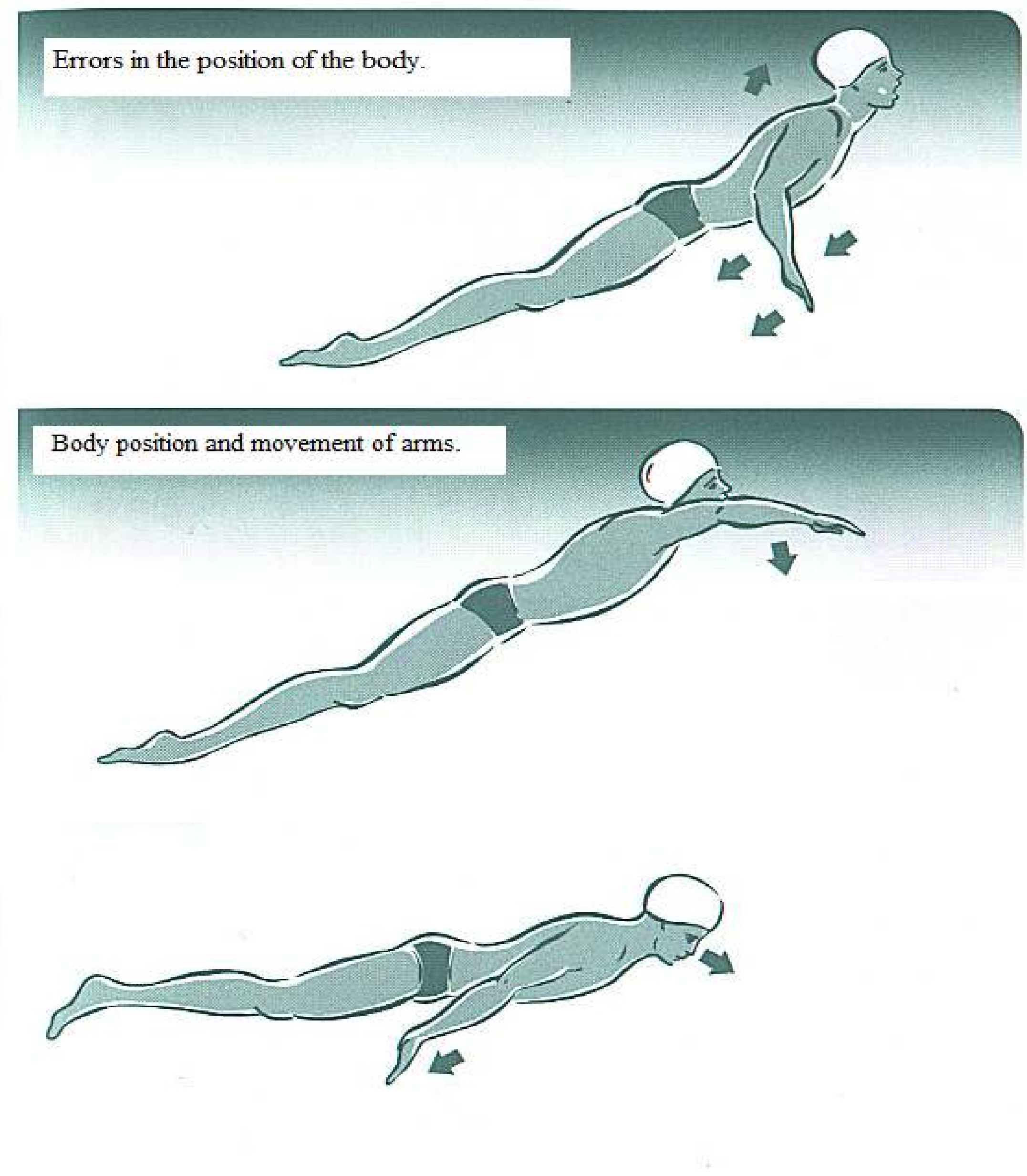


Figure 54. The butterfly style techniques and mistakes.

The most popular mistakes made in BUTTERFLY STYLE (Fig. 55):

1. The most common errors of legs:

- Alternating-sided leg movements (lack of symmetry),
- Too strong deflection of legs at the knees, drawing out leg from the water,

- Too small amplitude movements of the hips (lack deflection of the hip).

A VISUAL REVIEW OF BATTERFLY STROKE (Fig. 55)

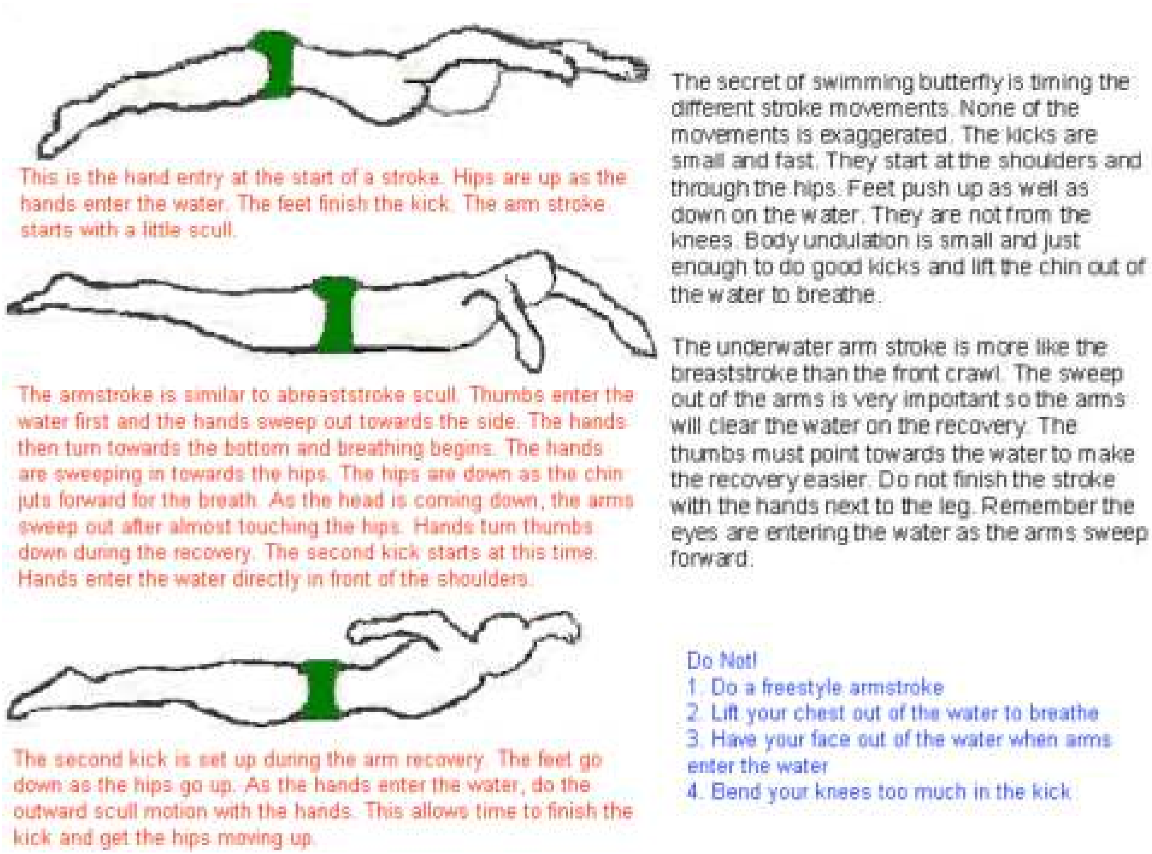


Figure 55. The visual review of butterfly stroke.

2. Errors of arms:

- Too early removal of arms from the water (lack push back phase),
- Transfer the arms with straightened arms elbows joint,
- The high output of the trunk from the water during breath,
- Too broad arms work in water (movement of the hand on the outside).

3. Errors that occur in swimming dolphin (full coordination):

- Incomplete breathe into the water causing the disturbances in the rhythm of swimming,
- Too early work of arms (during the one movement of legs).

4. Errors that occur during reversing:

- No simultaneous placement hands on the wall of the swimming pool,
- Too deep immersion while slipping under the water,
- Too shallow immersion, slip on the water surface.

6.2. Training and performance monitoring

Multi-sports training it is specially structured process in which the athletes dominates the technique and tactics of their discipline, shaped by the physical efficiency, volitional and personality traits, acquires knowledge about its business of sports. Implementation of training tends to produce a number of changes in the body to enhance physical performance and fitness specialist. Its purpose is to exercise such mastery of the skills that will enable the player to achieve the best results in their discipline.

One of the many disciplines of sport is swimming. The purpose of swimming training is comprehensive and balanced development of the individual muscle groups, and the whole organism. All styles of swimming exploits are equally right and left side of the body. The main functionality in swimming is the generation of the driving forces, through the activity of the body in the water and balancing the forces of resistance acting on the body as a whole. There are four styles of swimming: crawl, breaststroke, backstroke and butterfly.

6.2.1. Training

The general structure means the decomposition of content and the purpose of training in the long-term high-quality training swimmers, regardless of their gender and specialization consists of the three criteria:

- age of the starting regular activities training,
- time taken to achieve the highest scores,
- time maintaining a high level of sports (Tab. 2).

Distance	Age				Period prior to getting high results		Period to maintain a high level	
	Start training		Achieve a high level					
	Men	Woman	Men	Woman	men	Woman	Men	Woman
50, 100 m	8-9	8-9	22-24	21-23	14-15	13-14	4-5	4-5
200, 400 m	8-9	8-9	21-23	20-22	13-14	12-13	4-5	4-5
800, 1500 m	8-9	7-8	20-22	19-21	12-13	12-13	3-4	3-4

Table 2. The general structure means the decomposition of content and the purpose of training in the long-term high-quality training swimmers.

Age of starting regular activities training was based on data which correspond to most of the best swimmers in the world [46, 47]. Analyses careers and development of sports results, which made specialized [48, 49] disproved once widespread thesis of "rejuvenating swim." Average age, in which swimmers can reach the "sports championship," in the last XX years has increased quite significantly [50, 51].

I. In training of swimmers are seven stages, which start when people start participates to this type of sport, until the sport championship. Can be distinguish: Initial training (primary stage) usually covers the first two years the care of sports and aims to produce a positive connection with the swim. Children should enjoy the satisfaction and happiness of the sport, know the rules swimming techniques and promote an interest in swimming [52, 53].

II. Preliminary basic training - generally includes children aged 10-14 years. This need to covers general development.

III. Pre-training stage specialty training - usually involves swimmers aged 13 - 18 years. Technical training program at that time assumed - after a thorough diagnosis of morph-physiological and mental faculties of the displacer - choice specialization of the style and distance (Tab. 3).

Parameters of training	Men		Woman	
	Distance [m]			
	50, 100, 200	400, 1500	50, 100, 200	400, 800
The total volume of work (h)	400-700	450-800	400-700	450-800
Volume of work on land (h)	150-200	150-200	150-200	150-200
Volume of work in water (h)	300-500	350-700	300-500	350-700
Volume of swim (km)	800-1800	1200-2000	1000-1800	1300-2000
Number of lessons training	300-450	300-450	300-450	350-500
Number of start in tournament	30-60	30-40	30-60	30-40

Table 3. Amount of training workload and the number of a start in tournament in the annual training cycle - an initial stage.

IV. Next step - training swimmers for higher achievements - in the case relates to athletes in men aged 17-20, while women between the ages of 15-19. During this period, the most important goal is to acquire the highest level of sport. It is necessary to use different forms, and training methods that help to liberate the maximum capabilities of the organism displacer (Tab. 4).

Parameters	Men		Woman	
	in a week	in a year	in a week	in a year
The total volume of work (h)	35-38	1400-1550	36-40	1400-1600
Volume of work on land (h)	8-10	300-350	8-10	300-350
Volume of work in water (h)	100-120	2900-3200	100-110	2800-3000
Volume of strength preparation (h)	6—8	180-200	5-7	150-170
Number of training days	6-7	290-310	6-7	290-310
Number of lessons	15-18	550-600	15-18	550-600
Number of start in tournament and test with the speed of tournament	6-7	120-150	6-7	120-150

Table 4. The values of work training and the number of tournament in stages of preparation for higher achievements and maximize individual capabilities.

V. Step of maximum use the capabilities - lasts from one year to several years, depending on the specialization and individual athletes available, as well as terms of their training and existence. Is needed to improve technical training to the highest possible level "technical mastery" displacer.

Work should be directed to:

- Length Swim step, the rhythm of movement
- Improving competitive swimming elements
- Maintaining high effectiveness techniques at the various options in distance
- Improving techniques in different starting conditions and training; physical tiredness, mental tension, etc.

VI. Step of keep sport championship - depending on the individual characteristics of specialization and can last from one to 15 years. Corrections placed on the training program include: working training aspect of varying orientation and size and character loads connected to the macro-and micro-cycle training. They have to reduce the burden of the swimmer body and maintain his physical performance (Tab. 5).

Specialization [m]	**Step of max realization of the capabilities**		**Step of maintain a high level**	
	Men	**woman**	**Men**	**Woman**
50	1880-2000	1600-1800	1500-1700	1400-1600
50, 100	1900-2100	1800-2000	1600-1800	1500-1700
100, 200	2200-2400	2000-2200	1700-1900	1600-1800
400, 800, 1500	2900-3200	2800-3000	2100-2300	2000-2200

Table 5. Typical of the best swimmers the annual volume (km) in steps of maximize individual the capabilities and maintain sport championship.

VII. Step - gradual reduction of achievements - does not appear at all the athletes, because many of them finish career when are in the "peak". In those who still remain in the sport is the introduction of extended periods of leisure activities as well as the duration of the transitional period in the macro - cycles.

6.2.2. Performance monitoring

For make a good training and correct performance of swimmer is need control the physical and physiological parameters.

A real-time monitoring system in water assists in an absolutely innovative and extraordinary way, training, race and fitness practices. This asks for a wearable system, effective in measurement and process, but also easy to wear, robust, fashionable. Up to now specific efforts in developing wearable monitoring equipments were carried out through a technology-driven approach rather than a user-driven methodology. Indeed design is of particular importance in this context. Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanization of technologies and the crucial factor of cultural and economic exchange (International Council of Societies of Industrial Design). Sport and HealthCare Product Design is usually very complex because it concerns many different disciplines (e.g. Sport Medicine, Electronics, Computer Science, Product Design, etc.). Moreover wearable devices for monitoring are also targeted to different actors, labelling them as multidisciplinary products. This implies great difficulties during the design and development because it is necessary to consider many different points of view. Technology expertise and User Centred Design methodology will contribute to elicit user requirements and produce the concept generation. Design empowers Technology and vice-versa Technology empowers Design in a mutual benefit. Through a joint approach creativity can exploit really usable and appealing product. This mix of technology and fashion is the best arena for growing creative industries aiming at the design and development of break through products.

As competitive swimming increases in popularity, coaches, physical educators, and researchers are becoming more diligently involved in the search for various qualities, abilities, and techniques which might help a swimmer move through the water at a faster rate of speed than his contemporaries. In pursuit of factors responsible for increased swimming speed, is need find out whether faster swimmers seem to possess certain physical characteristics not commonly found in their slower competitors. Selecting, therefore, those physical qualities which experiencc has shown to exist most often with swimming speed, an investigation v/as conducted to determine the degree to v/hich swimming speed might be found to exist together with buoyancy, strength, height, weight, forearm length, and arm span. Coaches and swimming instructors might find it desirable to improvise new stroke techniques for certain individuals in an effort to compensate for an insufficiency of one or more of these factors. Since arm strength and body weight are variables which can be increased or decreased with some control, coaches and swimmers might produce some improvement by changing one or both of these factors. Whether buoyancy, strength, height, weight, forearm length, and arm span were or were not found to contribute to a swimmer's speed, knowledge of the situation should have been helpful to the coach or instructor in understanding the problems which he encounters. If any or all of these items were found to influence distance swimming speed to a greater or lesser degree than they were found to affect sprint swimming speed, coaches might have found a measure of them helpful in predicting whether swimmers should specialize their trajning for distance or sprint events.

Legs are the biggest driving force in swimming. Allows for a high position on the water. It is also the most efficient way to swim under water, especially after the start and bounce from the wall after turning in order to maintain high speed. On the other hand, it is also the largest muscle groups of about 70% of the total muscle mass, which for the implementation of an intensive effort to require far more energy than the muscles used for swimming in the same arms. Therefore, to improve swimming speed, we should concentrate on leg muscle strength; this parameter may be helpful in getting us better results while swimming.

Swimming is classified as group sports, where in athletics there is a broad spectrum of competition. In connection with this, the players cultivating various disciplines tend to develop different motor skills. Swimming for short distances (50m), the characteristics of the effort is similar to athletic sprints (100m). In the body's energy system is dominated by the ATP-CP assisted by the lactate energy system, where the main source of energy for working muscle is intramuscular ATP and creatine phosphate resources. During the 200-400m distances, as in the 800m heats on the essential role played by well-developed strength endurance and speed endurance, the ability of movement characterized by resistance to fatigue when working under predominantly anaerobic capacity and maximal and sub maximal stimuli intensity. From the viewpoint of work physiology, it is called. Strength of the short and medium time. The main energy substrate used during this period effort is muscle glycogen. Re-synthesis of ATP in the process of anaerobic glycolysis is connected with the production of lactic acid. The highest concentration of this component is observed at short distances, while declining reserve alkalinity (approx. 45%), and there is a large oxygen debt. Particularly high oxygen debt occurs in swimming over a distance of 400m, where the alkaline reserves are reduced by as much as 60%. As the lengthening of the working muscle, as is the case during long journeys (400-800m) increases aerobic processes involved in meeting the metabolic needs of working muscles (aerobic power). Much of the pyruvate formed during glycolysis is oxidized in the mitochondria, and the level of lactate in the next few minutes of effort is reduced. The main source of energy used to work inside the political system of muscle glycogen. Further lengthening of the muscle work (distance 800-

1500m), as in long races in athletics, leads to increased aerobic transformation of glycogen (aerobic endurance).

Many factors that affect swimming performance have been studied extensively in adults [54, 55,56]. Performance in swimming has been related to different anthropometrical, physiological, and biomechanical parameters [57, 58]. Specifically, maximal performance in swimming depends on the amount of metabolic energy (Cs) spent in transporting the body mass of the athlete and on the economy of locomotion over the unit of swimming distance [59]. It has been reported that Cs varies largely from one swimmer to another, mainly depending on the specific anthropometrical [60] and technical [61] characteristics of the athlete.

Cs increases as a function of speed [62, 63] and has usually been assessed from the ratio of oxygen consumption (VO2) to the corresponding speed (v) in adult athletes swimming within the aerobic range of intensities [64]. In a few studies, Cs has also been estimated at maximal speeds wherein the anaerobic-energy contribution had to be considered in the calculation of the overall energy balance of the exercise [65, 66]. Oxygen-consumption values measured during recovery have been used to extrapolate backward to determine the VO2peak during a maximal swimming bout [67]. This method of determining VO2peak during maximal swimming has been reported to be valid in adult swimmers, offering a specific in-water assessment of the oxygen consumption during swimming. To our knowledge, however, no studies have been conducted to assess the suitability of this methodology in young children.

Besides the anthropometrical and physiological parameters mentioned earlier, biomechanical aspects should also be considered as determinants of the best swimming performance [68]. Most of the biomechanical studies have been concerned with the relationship between stroke rate, stroke length (SL), and swimming performance [69, 70, 71, 72]. In addition, Costill et al. [63] used stroke index (SI) as an indicator of swimming economy because it describes the ability to move at a given velocity with the fewest number of strokes. It can be speculated that, as in highly trained adult swimmers, SI could be the major indicator of swimming economy in pre-pubertal and pubertal children.

Very few studies have investigated the importance of different anthropometrical, physiological, and technical parameters to determine swimming performance in children. Poujade et al. [73] and Zamparo et al. [74] used children older than 12 years of age and determined the Cs during maximal 400-m front-crawl swimming. To our knowledge, no studies have investigated Cs in prepubertal swimmers. Furthermore, the changes from prepuberty to puberty are important and include different anthropometrical, physiological, and mechanical parameters. Poujade et al. [73] have suggested that morphological characteristics in children are still of the utmost importance when it comes to predicting adult swimming performance.

Accordingly, the purposes of the present investigation were to (a) assess and compare the Cs in prepubertal and pubertal boys, (b) compare indirect in-water measurement of VO2peak with laboratory-based measurement of VO2peak, and (c) examine the influence of Cs, anthropometrical, body composition, and technical parameters on swimming performance in prepubertal and pubertal boys.

The most important parameters that use the coach are:

- Speed,
- Acceleration,
- Arm and legs stroke,
- Heartbeat.

The use of technology in sports performance analysis is a rapidly increasing practice. Tools for analysis aim to provide useful information to supplement coach knowledge and improve feedback in the development of athletes.

Measurement of speed and acceleration during every style of swim is too much important. When we know the parameters, is possible anticipate the result during tournament. The measurement of these parameters, when we do some days in a month, also gives message of better or worse efficiency of swimmer. When is worse result, in this point suggested that needs make a different training. If the results of the day are better means the swimmer is in better shape.

The oldest and most traditional instrument for measuring the speed of the swim is a stopwatch (fig. 56). Is for example stopwatch for swimming "Chronometer Professional Stop" which is used by trainers to keep track the swimming performance. The stopwatch has the function of storing up to 80 lap times. Shows with an accuracy of a swimming result.

Figure 56. The traditional stopwatch.

For healthy swimming sport, is very important to measure heart rate. The oldest method is - the measurement of heart rate before the start and immediately after the end point. This measure was making without machine. To calculate heart rate, needs feel the pulse with two fingers of the radial artery (near the wrist) or carotid. After just count the 'stroke' over equal 60 seconds. Their number is the heart rate. In adult person properly should be from 60 to 80, while the child's heart rate is between 90 and 140 beats per minute.

In the table we can see the recommended frequency of heart rate during exercise, depending on the age (Tab. 6).

Age [years]	Heart rate/min	Max heart rate/min
20-30	107-175	195
31-40	101-166	185
41-50	96-157	175
51-60	91-148	165
61+	85-139	155

Table 6. The recommended frequency of heart rate during exercise, depending on the age.

The most important is to remember that people:

- aged 50 - 70 years should not apply to physical exercise, during which heart rate rises above 110 - 120 beats per minute,
- after 70 years of age are not allowed to lead to a situation in which the body during exercise heart rate exceeds 100 beats per minute.

6.3. Wearable systems

In this time are a lot designed wearable systems for does a performance monitoring that help to trainers and also swimmer makes a good and healthy training. In recent years accelerometers have become an attractive tool for use in wearable computer systems for detecting and measuring aspects of human movement. Such devices are typically very small, even with the requisite processor and power units, one can fit the device into housing considerably smaller than a matchbox, or for surface mount units, the size of a coin.

For the child or old people, or also people that don't know so much swim, is the "Seal", wearable swimming monitor and drowning detection system (Fig. 57). Most pool alarms out there signal when people fall into the water, the goal is to keep people safe but they restrict a person's access to the pool. The SEAL is the first portable swim monitoring and drowning detection system does. The Seal delivers accurate warning alarms to lifeguards or parents – so that either of them can help you when need arises. Employing the Swim Safe Technology, the Seal connects the swimmer with lifeguards or parents wirelessly with use of a wearable device and a monitoring hub.

Figure 57. The wearable swimming monitoring of hub.

Unlike other monitoring systems, the comfortable wireless swim band – the Seal allows a wearer to jump, dive and even hold the breath yet remain safe in the water. The band worn by the swimmer continuously provides a swimmer's status to the central hub and the parent or guard's band. Each band contains unique electronic signal so many swimmers can be monitored at the same time.

When the Seal detects a swimmer in problem, it delivers a warning as – audio, visual and vibrating alarm. The Seal also has a warning alarm to signal a power failure, out-of-range signal or if the swimmer band has opened. Being highly portable and powered by rechargeable batteries, the Seal can even be carried outdoors to beaches etc.

For the measure swimming kinematics we can use the micro sensor data capture dramatically reduces volume while providing detailed 3D analysis capabilities. In essence, this technology is a viable method for capturing human movement measures (Fig. 58). Options of choosing single or multiple sensors for data capture offer dynamic assessment possibilities.

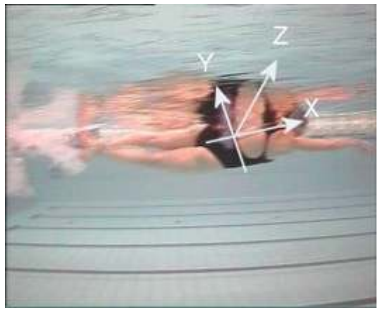


Figure 58. The three detection in 3-D analysis capabilities during swim.

Using a small wearable device a swimmer can now train in their own pool and on their own but gather performance data like they were supported by coach and timekeeper and in an instrumented pool with video analysis. In general the measurement of sport specific performance characteristics is an important part of an athlete's training and preparation for competition. Thus automated measurement, extraction and analysis of performance measures is desired and addressed in this paper. A tri-axial accelerometer based system was located on the lower back of swimmers to record acceleration profiles (Fig. 59). The accelerometer system contained two ADXL202 bi-axial accelerometers positioned perpendicular to one another, the system could collect several hours worth of data. Simultaneous video and electronic touch pad timing was recorded for validation. Algorithms have been developed to derive lap times and stroke counts from the accelerometer data. Comparison against electronic touch pad timing against accelerometer lap times has produced results with a typical error of better than ±0.1 seconds. Video comparison of stroke count algorithm for freestyle also produced results with an average error of less than a single stroke.

Figure 59. A tri-axial accelerometer.

For the measurement of heart rite the FINIS find AquaPulse, which uses an accurate infrared sensor that clips to the earlobe in order to pick up the swimmer's heart rate (Fig. 60). By measuring the light pulses due to capillary blood flow in the skin, the sensors calculate the number of beats/minute (b/m) that the body is working. The internal computer within the AquaPulse then audibly communicates this heart rate to the user using the revolutionary Bone-Conduction Technology, a unique sound transfer technology that communicates sound vibrations through the temple bone to the inner ear. Humans normally hear through air conduction, but because there is no air underneath the water, bone conduction provides the clearest sound quality possible. By simply turning the unit on, the user's heart rate can be sensed and automatically

Figure 60. The sensor for measurement heart rate.

communicated. All functions are integrated into one small unit that the user clips on to their goggle strap and rests on their temple. The AquaPulse heart rate monitor consistently communicates the heart rate every pre-set time period. The user can program this time period from as little as 20 seconds up to 5 minutes, allowing for continuous feedback during training. It also features an instantaneous heart rate function. The user can simply press a button at any time and their most current b/m will be communicated.

6.4. Design requirements for a new concept

For design the new technology of swimsuit with electrodes and accelerometer, is need to take into account of many factors, is need to analyze the following criteria:

- what is need for the help of swimmer and coach;
- which parameter biomechanical they use for measurement during swim for improve the speed swimming;
- analyze the market of methods which are using;
- analyze position that is the most stabilization during swim for put on electrodes and data will be without glitch;
- analyze brand of swimsuits, brand of fibers, etc.

In those years is a lot companies which are producing the swimwear. Each of them, of course, has its own logo, their colors, as well as their shape. The example of the most popular brand for the sports swimwear are:

- Speedo (Fig. 61)

Figure 61. The example of swimwear for men and woman made by Speedo.

- Adidas (Fig. 62)

Figure 62. The example of swimwear for men and woman made by Adidas.

- Arena (Fig. 63)

Figure 63. The example of swimwear for men and woman made by Arena.

- Jaked (Fig. 64)

Figure 64. The example of swimwear for men and woman made by Jaked.

- Head (Fig. 65)

Figure 65. The example of swimwear for men and woman made by Head.

To design a sports swimsuit, it is important to choice of material and shape. Constructing SWIMSFIT with "chip" has to keep in mind that needs to be:

- small, with streamlined design so as not to disturb the speed of swim,
- the sensors has to be fixed and stable contact with the skin,
- must be made of good material that has not seemed offensive odors,
- sensors need to be invisible, durable and comfortable,
- the sensors must also be placed in the correct position for a correct detection of signal,
- The sensors must be placed on the body, that they are the least invasive possible
- Sensor must be fixed with swimwear.

For construct the small instrument, which after will can be attached to swimwear we have to make a good selection of textile electrode, to make sure that the signals will be sending with a high-quality.

Part III. Materials

7. Wearable systems

Wearable system are designed to be worn during normal daily activity to continually measure biomechanical and physiological data regardless of subject location and thus are an appropriate alternative for the recognition of daily human activities, especially bodily or physical activities [75]. Bodily activities require repetitive motion of the human body and are constrained, to a large extent, by the structure of the body. Examples are walking, running, scrubbing, and exercising. Wearable sensors are well suited to collecting data on daily physical activity patterns over an extended period of time as they can be integrated into clothing [76,77], jewelry [78,79], or worn as wearable devices. Since they are attached to the subjects they are monitoring and are independent of the infrastructure, wearable sensors can therefore measure physiological parameters which may not be measurable using environmental or video sensors. Moreover, such sensors are low-priced and unlike video sensors they are not considered as a threat to people's privacy. A range of body-attached sensors including electromechanical switches, monometers , accelerometers, gyroscopes, pedometers, and accelerometers, have been used to capture and analyze human movement in free-living subjects, as shown in Fig. 66.

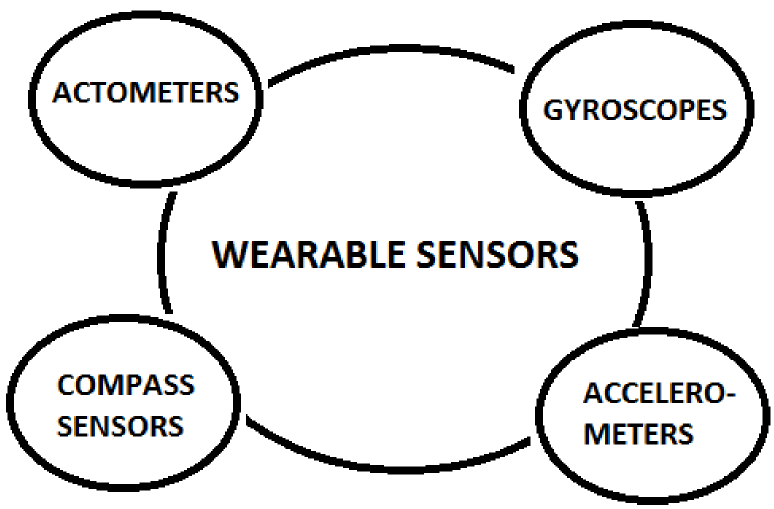


Figure 66. Different wearable sensors used to capture and analyze human movement.

Of these, accelerometers are becoming widely accepted as a useful tool for the assessment of human motion in clinical settings and free-living environments [80]. Accelerometers offer a number of advantages in monitoring of human movement. Their response to both frequency and intensity of movement makes them superior to lactometers or pedometers, which are attenuated by impact or tilt. Some types of accelerometers can measure both tilt and body movement, and thus are superior to motion sensors that are incapable of measuring static characteristics.

In the field of the sports engineering or the sports biomechanics, the video graphical analysis method has been applied for the human motion analysis. However, a wide range or the long term of the motion in the outdoor circumstances prevents us from measuring whole kinematical parameters by using video graphical method. The Ohgi et.al has proposed inertia sensors such as accelerometers or gyroscopes as an alternative to the video graphical motion analysis [81, 82, 83, 84, 85]. Unlike the video methodology, this method using the inertia sensors is characterized by attaching sensors onto the subject body itself. Such accelerometer could not been applied for the sports science, because of the problem of sensor size or its cost. The miniaturization by MEMS technology and the progress of the impact-resistant specification, the inertia sensors enable us to measure human or equipment movement in our sports activities. However, it is to be noted that we must understand the measured acceleration and the angular velocity from the body or object attached inertia sensors indicate the signal based on the local coordinate system not the global coordinate system. Especially, the acceleration from the accelerometer which was originated on the local coordinate system, namely the movement coordinate system, contains four different kinds of acceleration component, such as the gravitational, translational, centrifugal and tangential accelerations. Enhancements in micro electro mechanical systems (MEMS) technology resulted in miniaturized and low cost accelerometers. These features have made possible the development of small, lightweight, portable systems that can be worn by a free-living subject without hindering movement. Thus accelerometer is emerging as a practical, inexpensive, and reliable method for capturing and analyzing daily physical activities [86].

Wearable systems are designed to continually measure biomechanical and physiological data regardless of subject’s location. Based on their data collection methods, wearable systems can be classified as: data processing, data logging, and data forwarding.

Data Processing Wearable Systems: These systems include a processing element such as a PDA or a microcontroller device. These consume more power than other types of wearable systems but they can provide real-time feedback to a user and do not require large amounts of data storage, as the raw data are typically summarized in real-time before storage or transmission. The use of summarized data also reduces costs by lowering the upload time to the server.

Data Logging Wearable Systems: Data logging is those which simply acquire data from the sensors and log these for offline analysis. They have the advantage of being able to monitor the subject regardless of their location. The disadvantage of data logging systems is that the subject's mobility patterns cannot be analyzed between uploads. If an alarming trend occurs between uploads it will not be discovered until that data is uploaded and analyzed on the pc. This problem will become more significant as improving memory technology increases the time between uploads.

Data Forwarding Wearable Systems: Data forwarding systems are those which simply acquire data from the sensors and forward these directly to a local computer for further analysis. These are used when the weight of the wearable system is a key factor, as data storage or a data processing unit can be replaced by a miniature transmitter. However, data forwarding wearable's, which typically use RF, Bluetooth, or WLAN, are range-limited, and therefore the data from the subject is not recorded when the subject is outside the range of the receiver. This makes data forwarding systems suitable for housebound subjects but not necessarily those who are independent and have the ability to move outside of the house.

A range of wearable sensors have been used to assess daily mobility levels in free-living subjects. Of these, accelerometers have emerged as the most useful tool for mobility assessment in both clinical and home environments. The reasons for such a wide acceptance of accelerometers are: Firstly, they can respond to both frequency and intensity of movement. This fact makes them superior to lactometers or pedometers which are attenuated by impact or tilt [87]. Secondly, most of the widely available accelerometers can measure both the movement and the tilt which makes them superior to motion sensors that lack the capabilities of measuring these characteristics. Thirdly, due to enhancements in micro electro mechanical systems (MEMS) technology, today's accelerometers are not only coming in small size and at a low-price but are also capable of demonstrating a high degree of reliability in measurement.

Accelerometers are devices which are capable of measuring the applied acceleration acting along a sensitive axis. Accelerometers use transducers for measuring acceleration. These come in different varieties, such as piezoelectric crystals, piezoresistive sensors, servo force balance transducers, electronic piezoelectric sensors and variable capacitance accelerometers. Some accelerometers require an external power supply whereas others do not. Moreover, some accelerometers are capable of responding to static accelerations (such as the acceleration due to gravity) whereas others do not.

Most physical activity recognition systems have used accelerometers which are capable of responding to acceleration due to gravity as well as acceleration due to movement. At any point in time, the output of such accelerometers is a linear combination of these two components, the acceleration component due to gravity (GA) and the acceleration component due to bodily motion (BA) [88]. Since these two components are linearly combined and overlap both in time and frequency, they cannot be easily separated. However, low pass filtering can be used to make approximation to the two components. Low pass filtering, when applied to an acceleration signal, separates the GA from the actual signal. GA can then be subtracted from the original signal to obtain the BA. Since most human movements occur between 0.3 and 3.5 Hz [89], most investigators have used a filter with a cut off frequency between 0.1 and 0.5 Hz to separate the two components.

7.1. Motion and style detection through MEMS

Three dimensional motion analysis methods [90] has been a major approach to observe a swimmer’s underwater stroke motion [91, 92]. For the three dimensional motion analyses, usually, we need more than two underwater cameras. However, this video graphical method was inappropriate for the swimming research. Because it took long time and work for the digitizing process. Since the swimming stroke motion is performed underwater, we cannot use an optical or magnetic motion capture system, which has been a popular method recent years. So, the researchers could not provide the real time feedback to both the swimmers and coaches on the poolside. Therefore, another alternative has been expected for the swimming stroke analysis and swimming coaching.

The three-axis acceleration sensor made in MEMS technology, based on the readings of the three axes X, Y, Z shows us information about the acceleration vectors ax, ay, az and their angles αx, αy, αz. These

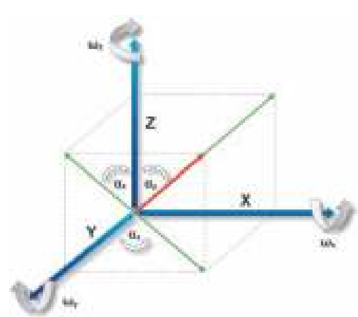


Figure 67. Three axal angular speed sensors enable the determination of the three components of the angular velocity vector: ωx, ωy, ωz.

angles define the orientation of the sensor relative to the direction perpendicular to the ground. It is worth noting that it can be a source of information about the orientation of the component of X and Y coordinates system but does not give information about the orientation of the component Z (Fig. 67). Three axial angular speed sensors allow the designation of the three components of the angular velocity vector: ωx, ωy, ωz.

During the swim when the 3-axial accelerometer is placed on the back the forces are distributed in three directions. The axes X is directed to the right side, slightly to the back. Axes Y is directed to the front. And the axes Z are directed to the left side of body (Fig. 68). Instantaneous velocity is estimated by integrating the forward acceleration signal in the global frame (GF: X, Y, Z). Among the axes of GF the Z is assumed to be vertically upward and Y in parallel with the longitudinal edge of the pool. The acceleration in

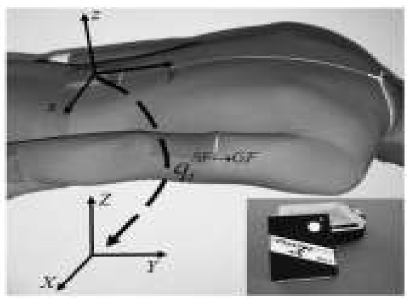


Figure 68. Three directions of axes X, Y, Z on the body.

GF can be calculated from the acceleration measured in sensor frame (SF: x, y, z) by considering the orientation of SF relative to GF at each time sample.

By starting the trials from a relatively motionless posture in water, the initial sacrum acceleration $a_0^{SF}=\left[a_0^x, a_0^y, a_0^z\right]^T$ has a magnitude equal to the gravity. Using quaternion based algebra to represent the orientation, the initial quaternion which aligns the z axis to Z, is given by: $q_I^{SF\rightarrow GF}=\left[\cos\frac{\theta_0}{2}, \frac{u_0}{\|u_0\|}\sin\frac{\theta_0}{2}\right]$ where, I:I represents Euclidian norm, θ0 is the initial inclination and u0 represents the horizontal axis around which the rotation is done. Supposing that azimuth angle at start of trial is null, θ0 and u0 can be calculated respectively as in $\theta_0=\cos^{-1}(-a_0^{SF}.Z^{GF})$ and $u_0=-a_0^{SF}\times Z^{GF}=\left[-a_0^y, a_0^x, 0\right]$ where × represents the normal cross product.

At each time step t, the orientation of SF relative to $q_t^{SF\rightarrow GF}$ is updated using the previous orientation by integrating the angular velocity $\omega_t^{SF}=\left[\omega_t^x, \omega_t^y, \omega_t^z\right]^T$:

$q_t^{SF\rightarrow GF}=\left[\cos\left(\frac{\|\omega_t^{SF}\|}{2f}\right), \frac{\omega_t^{SF}}{\|\omega_t^{SF}\|}\sin\left(\frac{\|\omega_t^{SF}\|}{2f}\right)\right]\otimes q_{t-1}^{SF\rightarrow GF}$ where f is sampling frequency and indicates quaternion multiplication.

The time integration suffers from an accumulative drift [93] due to gyroscopic noise. In order to reduce the effect of this drift we applied a dynamic biomechanical constraint, namely considering the swimmer sacrum rolls in average about forward direction Y. Therefore, for the data samples from cycle k to k + 1 (denoted by Ck and Ck+1 respectively), the principal component of angular velocity in GF (represented by $P\omega_{C_k}^{GF}$ should be aligned to Y. This can be mathematically written as:

$P\omega_{C_k}^{GF}=principle\ component\left(\left(q_t^{SF\rightarrow GF}\right)\otimes\omega_t^{SF}\otimes\left(q_t^{SF\rightarrow GF}\right)^{-1}\right)\cong[0,1,0]\quad\forall t{:}C_k\leq t<C_{k+1}$ Any deviation from the conditions was assumed to be the effect of the orientation drift. The amplitude of the drifted angle is given by: $\Delta\theta_{C_k}=\cos^{-1}\left(\frac{[0,1,0].P\omega_{C_k}^{GF}}{\|P\omega_{C_k}^{GF}\|}\right)$.

Accordingly the rotation axis is presented as in $u_{C_k}=\frac{[0,1,0]\times P\omega_{C_k}^{GF}}{\|P\omega_{C_k}^{GF}\|}$.

So if we suppose that the drift is linearly increased through one cycle with n data points, for the sample we can compute the corrective quaternion as in:

$$\delta q_t=\left[\cos\left(\frac{\Delta\theta_{C_k}}{2(n-1)}(t-1)\right), \frac{u_{C_k}}{\|u_{C_k}\|}\sin\left(\frac{\Delta\theta_{C_k}}{2(n-1)}(t-1)\right)\right]\quad\forall t{:}C_k\leq t<C_{k+1}$$

Therefore, the corrected orientation of SF relative to $q_{t,C_k}^{SF\to GF}$ can be calculated from: $q_{t,C_k}^{SF\to GF} = \left(q_t^{SF\to GF}\right) \otimes \delta q_t$. The instantaneous forward acceleration in global frame can be calculated

$$a_t^Y = \left(\left(q_{t,C_k}^{SF\to GF}\right) \otimes a_t^{SF} \otimes \left(q_{t,C_k}^{SF\to GF}\right)^{-1} - \vec{g}\right) \cdot \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}.$$

where go shows the gravity vector:

Ana S. Silva et al., make the result of the “Wearable Monitoring Unit for Swimming Performance Analysis” (Fig. 69) [94]. They use the accelerometer accelerations on the three axes, the longitudinal rotation of the trunk, as can be seen on fig. The WIMU was located at the dorsal zone of the frontal plane,

Figure 69. The accelerometer use by Silva et all.

within the vertebral region at the inferior scapular section. They make a test for 3 type of swim and after the recorded data was later processed in Matlab applying compensation through cubic interpolation when required, followed by a simple moving average smoother based on window convolution; some results taken at a rate of approximately 7 rpps (Fig. 70).

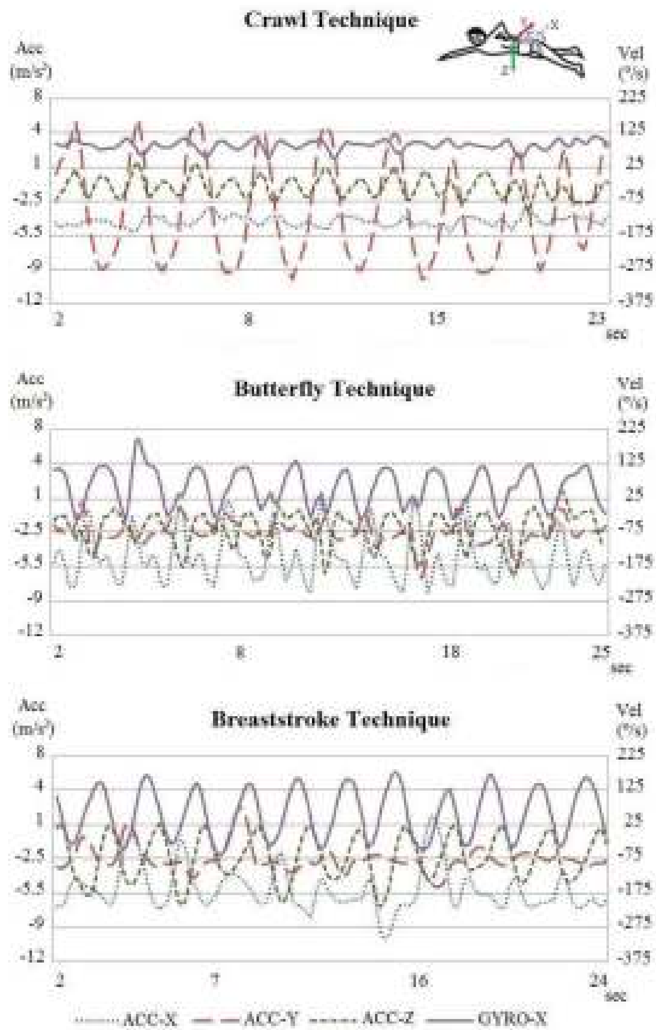


Figure 70. Two laps using crawl technique signals. Gyroscope X-axis is located within the 25 and 125 ◦/s Vel lines.

We can find a few literatures that speak about method of tri-axial accelerometer for analyses performance on swimming. The most popular sensor placements for swimming motion monitoring include the lower and upper back [95], [96], head [97], wrists [98], [99] and ankles [100]. We see also that the picks in every style is a different. Taking this into account this research started with a feasibility analysis with existing IMU systems (Fig. 71).

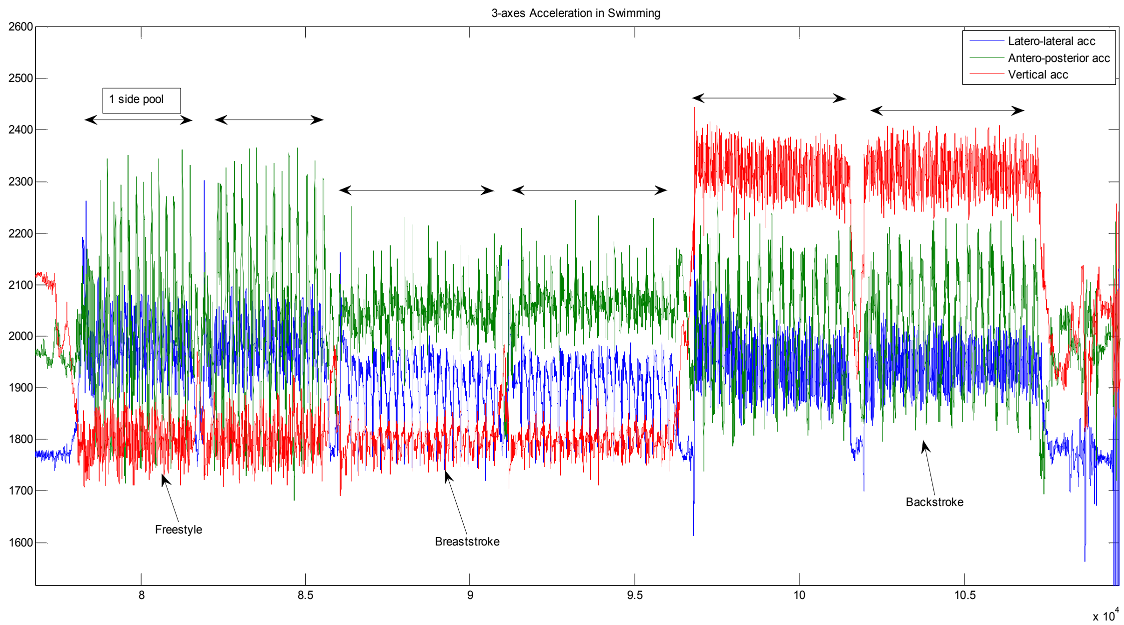


Figure 71. Acceleration patterns in swimming recorded through a wearable acceleration data – logger.

The Fig. 71 below shows the capability of a basic system to identify and measure the accelerations of the body in water through local recording, no wireless transmission is implemented. The first prototype also demonstrated to be reliable in arm and foot stroke detection. Tests in a waterproof suit showed also the capability of monitoring ECG and respiration.

7.2. Cardio respiratory monitoring through sensorized garments

In the medical field, for the cardio respiratory monitoring, are commonly used to allow the reading of the electrode signals generated by muscle or nerve cells. One of the measurements is the electrocardiogram (EKG).

ECG is created from the diagnostic procedure aimed at registration of myocardial function. It can be performed directly on the heart during surgery. However, it is usually performed in the chest area, placing twelve electrodes. Reading is the investigation of the potential difference between the electrodes. Reading values of the amplitudes of the difference signals from the electrodes are very small, which makes them susceptible to all kinds of distortion brought: the change in position of the electrodes placed on the skin terms of heart as a result of heart contractions and diastole from the work of other muscles, and external interference. This makes it necessary use of very high quality electrodes made of silver coated with silver chloride. In addition, all the measuring device must be electrically insulated and protected from the influence of other medical devices, and in particular the high voltage generated by the defibrillator.

Progress in the field of micro sensors increased possibilities of telemedicine, which allows for the provision of medical services at a distance. Information systems used in telemedicine can be divided into:

- support systems in medical diagnosis and treatment,
- systems for remote patient care,
- systems that enable the use of real-time remote support professionals during medical procedures,
- support systems research on emerging diseases,
- prevention systems.

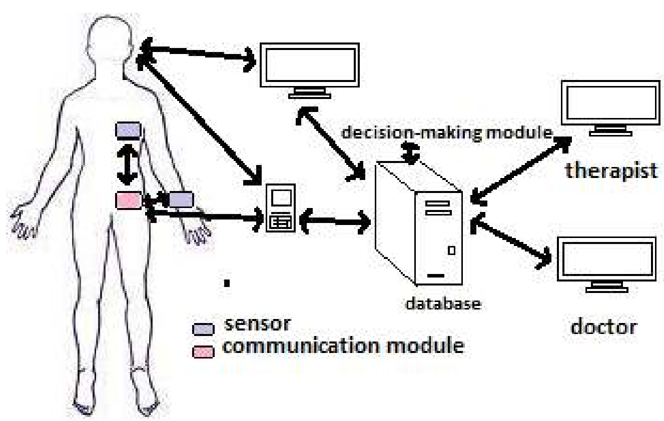


Figure 72. Elements of a remote patient monitoring system.

Fig. 72 shows the main blocks used in telemedicine system patient monitoring. Data on the patient are recorded by the band sensors, which can be divided into three categories: sensors, which the patient is constantly with him, pinned sensors and sensors are periodically contacting with the patient. The most desirable is to place sensors permanently attached to the patient, at any moment of his record data state. They may, however, be cumbersome for the patient, and with prolonged use cause irritation of the places to which they are attached.

The data recorded by the sensors are transmitted to the communication module. As a communication module PDAs are often used because of their small size. Sensors along with a communications module form a network BAN (Body Area Network called). This concept was introduced by IBM. There are several methods to create a BAN. The simplest is to use a wired connection between the sensors and the communication module, wherein each sensor has its own independent connection. The communication module transmits data using wireless transmission technology such as Bluetooth.

The data recorded by the sensors are transmitted to the communication device that can connect to home computer. Recently are more important to transmission over a cellular network. It allows for greater mobility of the patient.

Comfortable and not a disturbing to the patient approach is the use of sensors sewn into clothes that do not require the patient to follow special steps for fitting. Signal Measurement bio field, however, require appropriate clothing design, so that you can move the electrodes to be minimized.

Example sensors sewn into a shirt can be found in Menswear bio monitoring system for remote vital signs monitoring [101]. The system has been named MEMS Wear. Initially MEMS Wear was equipped only with position sensors and acceleration [102]. Later it was expanded to include the ability to measure physiological factors: ECG, blood oxygen, blood pressure and body temperature. Data is collected from the processor module using Bluetooth, the Bluetooth then be sent to the palmtop with GSM.

Another example of placing sensors in the suit is a jacket Smart Vest [103]. The vest is integrated with sensors for monitoring physiological parameters and equipment for the collection, processing and transmission of data. Vest is equipped with a GPS module in the recorded ECG signals without the use of gel-tysmografy fotople (PPG), measured body temperature, blood pressure, heart rate, and galvanic skin response. The vest is made of a mixture of cotton and lycry. In the vest is sewn the cables connecting the sensors with a resistance of 0.3 Ω / m, a thickness of 0.19 mm and a tensile strength of 30 N/mm2 and resistance to temperatures from -65 to +150 ° C.

Thanks to the very rapid development of microcontrollers possible was to create a recording device and transmitting the signals from the acceleration sensors in real time. Miniaturization has allowed placement of acceleration sensors (accelerometers), a microprocessor and a Bluetooth device the size of a box of matches.

How studies have shown of many research groups [104, 105, 106, 107], based on the analysis signals from the three axial acceleration sensors is possible to distinguish several categories of human body movement. In many fields of science and medicine, it is important to have information on the state of activity of the person observed. Analysis of acceleration can automatically distinguish the activities such as: walking, running, getting up from a chair (sit), lying down on the bed (getting up), lifting, and the detection of falls patients.

Adam Kupryjanow et. all [108] in their article describes the classifiers used to identify two types of activities: walking and lifting objects. Described recognition module category of physical activity is part of the monitoring of patients with Parkinson's disease.

Used in the signal recording device (Shimmer) were equipped with triaxial acceleration sensors. These devices allow recording by Bluetooth transmission signals and by recording the signals on MicroSD cards [109].

During the experiments, the signal was recorded using a memory card. This mode allowed the registration of the signal with a frequency of 51.2 Hz, the dynamic range of motion was ± 4 g. This allowed for correct records of typical motor activity. Synchronization sensor was performed by automatically synchronize any device with a clock computer that is running the registration process on the memory card.

Arrangement of sensors was chosen to using the minimum number of units to get the highest recognition rates required traffic categories [110]. The registration process was used five devices arranged as follows: two accelerometers placed on the wrists, two at the ankles and one on the chest. The figure 73 shows the distribution of acceleration sensors on the human body and the return of three-axis acceleration measurement.

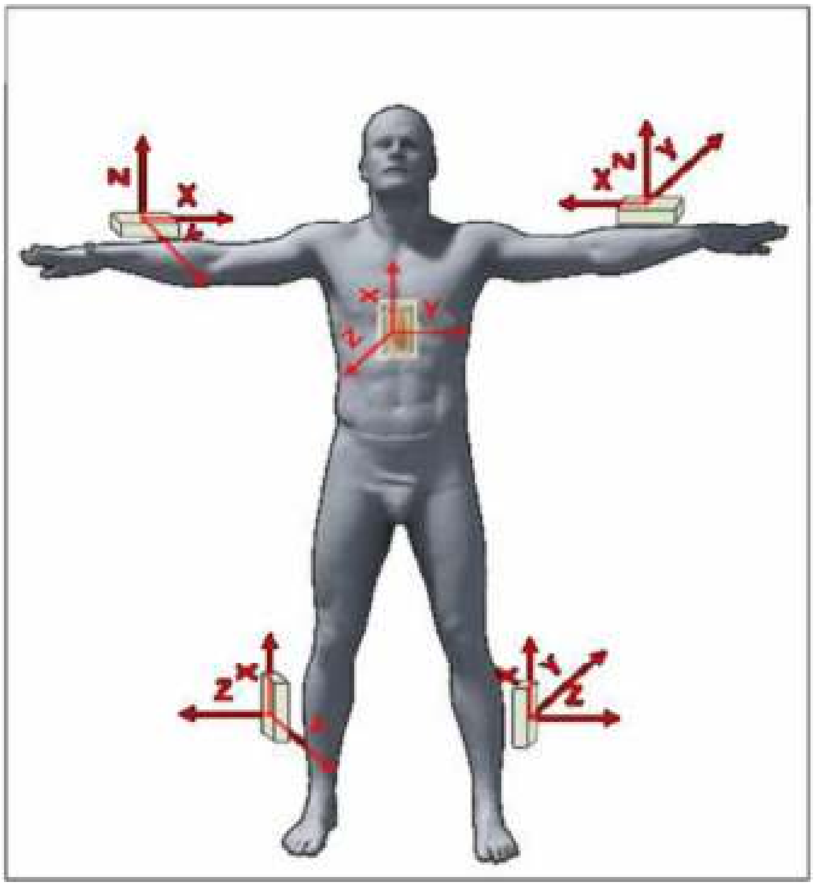


Figure 73. Placement of acceleration sensors.

Registration the signals used for training and test the efficiency of classifiers has been carried out in accordance with a predetermined protocol. Each person participating in the recordings was designed to perform a sequence of specific movements. The sequences include the following categories of movement: sit and get up from a chair, walking, running, walking up stairs, lifting the object with one or both hands, laying on the bed and getting up out of bed. All people have to do a particular sequence of movements three times.

The obtained experimental results allow to conclude that it is possible to classify the acceleration signals in people with Parkinson's disease, because the filter frequencies above 3 Hz does not decrease the effectiveness of gait recognition activity and arm movement.

7.3. Wearable electronics design

In these times, where technology has no limits, is a lot of wearable electronics design. Is very much scientists and engineers who are trying to make life easier for people. They try to design wearable electronics for all:

- ✓ for people, for normal life

DR. AHMED NABIL BELBACHIR designed the project CARE that aims to realize an intelligent monitoring and alarming system for independent living of elderly persons (Fig. 74) [111]. Specifically, this project targets the automated recognition and alarming of critical situations (like fall detection) using a stationary (and non-wearable) technology and real-time processing while preserving the privacy and taking into account system dependability issues, especially ensuring reliability, availability, security, and safety from a holistic point of view. A biologically-inspired dynamic stereo vision sensor from AIT is being integrated into the Everon caring system for seamless analysis and tracking of elderly persons at home. This real-time information is exploited for incident detection (e.g., fall detection, immobilized person), and instantaneous alarming the concerned parties.

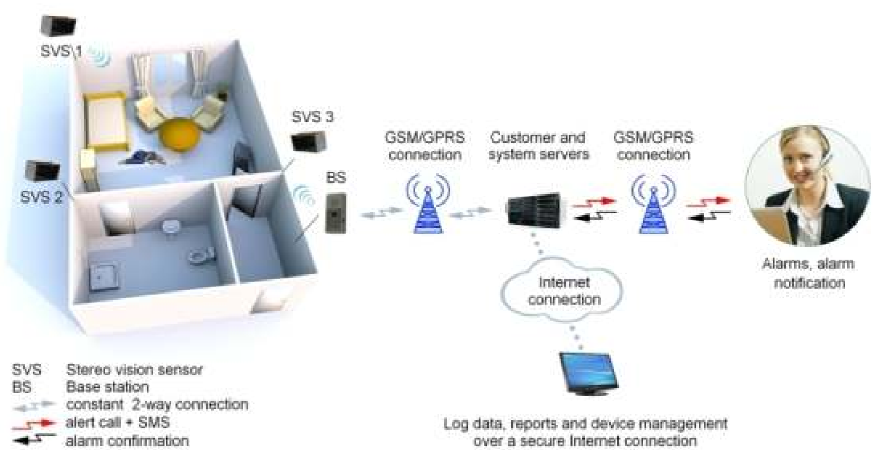


Figure 74. The project CARE to realize an intelligent monitoring and alarming system for independent living of elderly persons.

✓ for medical

A ubiquitous system for continuously monitoring health in patients or during workouts should be lightweight and unobtrusive. It should be possible to conveniently place such a device on the body or even be integrated in the clothing fiber. A number of designed a new technologies are coming up that have made it possible to integrate a wide variety of features with powerful portable computing and real time analysis.

A wearable health monitoring system consists of a set of intelligent physiological wearable sensors, a personal server (Internet enabled PDA or cell phone) and a network of remote health care servers and related services (Fig. 75).

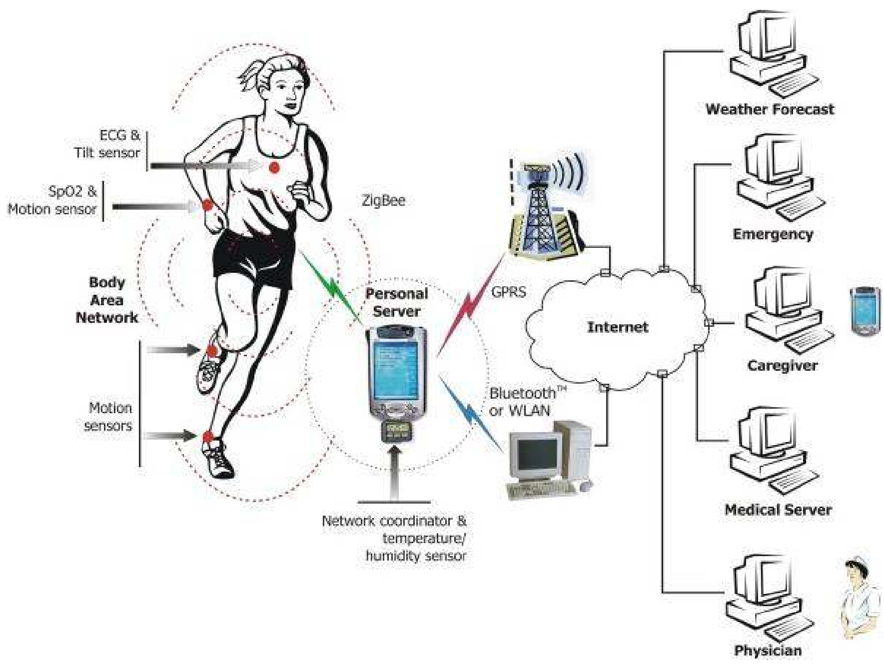


Figure 75. Wireless Body Area Network of Intelligent Sensors for Ambulatory Health Monitoring.

What the technology can do such a system eliminates the need for wires between electrodes and monitoring systems which may limit the patient's activity and level of comfort and thus negatively influence the measured results. A wearable health monitoring device using Personal Area Networking (PAN) and Body Area Networking (BAN) can be integrated into the user's clothing. Recent technology advances in wireless networking, micro-fabrication, and integration of physical sensors, embedded microcontrollers and radio interfaces on a single chip, promise a new generation of wireless sensors suitable for many applications. Moreover, these sensors possess the ability for real time data processing, which eliminates the need for uploading data to be processed off line, and can give immediate results or warnings.

A smart vest with the capability to monitor electrocardiogram (ECG), photo-plethysmogram (PPG), body temperature, blood pressure, galvanic skin response (GSR) and heart rate could be a possibility for sport or medical applications An Italian company called Smartex has been working on a simpler version of this system called WEALTHY, the wearable health care system (Fig. 76). It can sense temperature, respiration and movement, and uses mobile phone signaling to transmit the data or alert emergency services.

Figure 76. The wearable health care system.

✓ for rehabilitation

American Prof. Robert D. Howe, from Harvard Biorobotics Lab, designed inexpensive wearable upper body orthotics system that can be used at home to empower both the patients and physical therapists (Fig. 77). The system is composed of a thin, compliant, lightweight soft orthotic device with an integrated cable actuation system that is worn over the upper body, an embedded limb position sensing system, and an actuator package.

The design goals of the active soft orthotic system for upper body rehabilitation are the following:

1. Generate forces to assist during the rehabilitation process by providing exercises tailored to the user's specific disabilities. This device may also be used as an assistive device to enable near-normal limb use.

2. Assist in diagnosis and in monitoring patient's progress.

3. Affordable for home use.

4. Wearable, lightweight and simple to don and doff.

5. Adaptable to misalignments and anatomical variations.

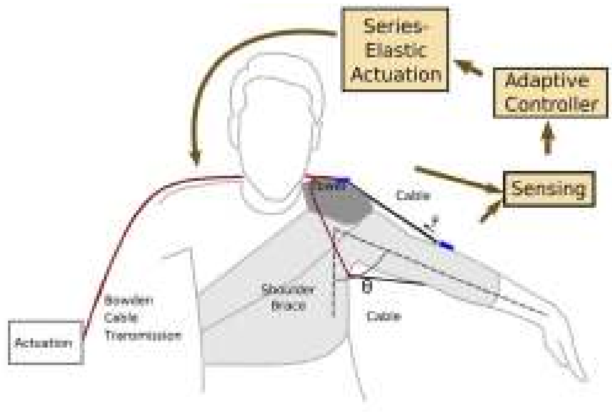


Figure 77. System Design. Actuation Package: Actuator, batteries. Transmission: Bowden Cables to minimize the weight of the wearable system. Sensing: Electromagnetic sensors (testing only), IMUs or Piezo flex sensor technologies will be incorporated. Control: Adaptive control to adjust to anatomical variations and misalignments.

A theoretical model of biologically realistic human arm and actuated brace was designed. This model was used to predict the needed cable tensions to hold the arm still at a specified arm pose for a given set of brace parameters. Brace parameters were chosen based on minimization of required cable tension (energy efficient) and minimization of joint forces (comfort ability) (Fig. 78, 79).

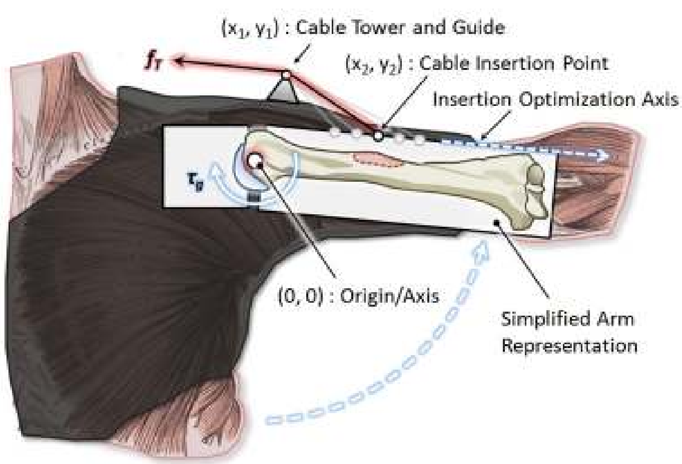


Figure 78. The brace parameters considered to optimize the system.

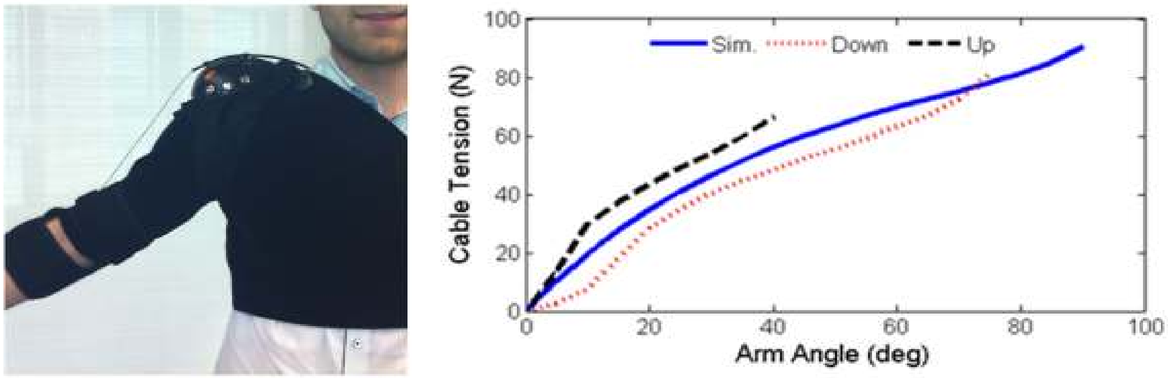


Figure 79. Prototype and simulation model (experiment performed to evaluate the 1 Degree of Freedom (DoF).

✓ for sport

Snowboarding is one of the most popular winter sport activities today. However, it is quite difficult to learn, and often snowboard hobbyists are struggling to improve their boarding skills. Jona Schoch et al. [112] therefore envision a wearable system supporting snowboarders to progress. A system can only help a snowboarder when it is aware of what she is doing on the ski slope. Thus, they have developed SnowPro, a wearable monitoring system for snowboarders (Fig. 80). SnowPro consists of a variety of sensors recording the context of the snowboarder, and a set of algorithms processing the recorded data. SnowPro can detect multiple elements of snowboarding, like turns, the riding edge and turns, with an accuracy of over 90 percent. The functionality of SnowPro was evaluated on different ski slopes in the popular Swiss ski resorts Savognin, Braunwald and Grindelwald with over thirty descents of seven snowboarders.

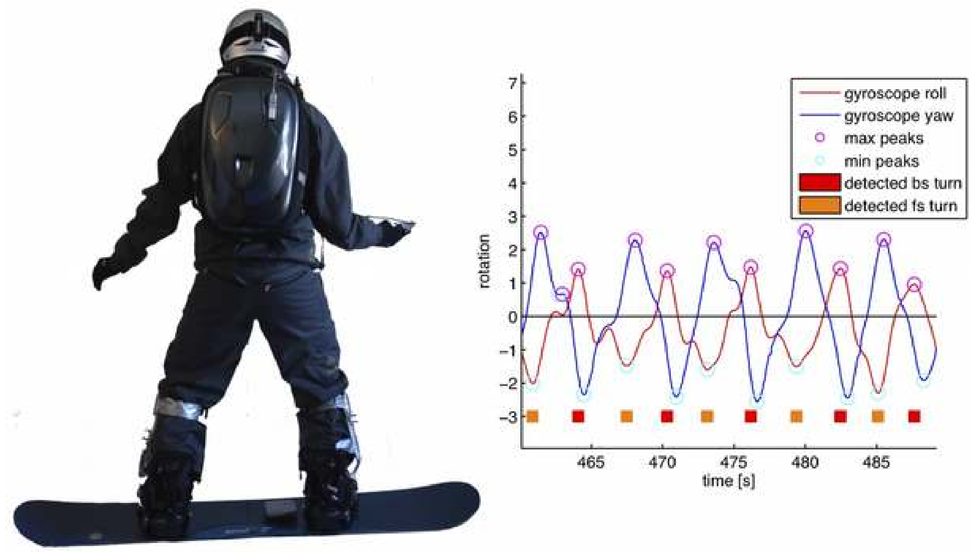


Figure 80. Wearable monitoring system for snowboards.

To create a wearable electronic system, is needed to remember the rules, need to be:

- The adhesion of the electrodes in contact with skin,
- Minimum slippage between fabric and skin,
- Comfort,
- No bed smells,
- Flexible and washable.

7.4. Wear ability issues and studies

Integration of micro-electronic textiles allows the manufacture of products that can find application in health and medicine, safety and rescue, logistics, industrial and sports. Clothing with mounted electronics for monitoring and recording the heart rate, the number of respiratory, skin temperature is designed for athletes. Clothing is also constructed with built-in GPS and electronic compass and altimeter. At Techtextil trade fair in Frankfurt in 2007, presented the Navy with a mobile phone interface mounted in the lid and monitor PDA (Personal Digital Assistant) in sleeve [113].

Of key importance for the integration of microelectronics with textiles had developed the technology to the functioning of the fabrics as electronic interfaces. This means that instead of hard keyboards and switches can be used soft fabric. Fabric interfaces can be implemented into clothing with transferable by coaster electronics. As an example can be given to be prepared in such a fabric called Detect made of conventional and carbon fiber, which is used to manufacture such as a keyboard Qwerty.

The development of smart textiles largely is dependent upon the progress of work on the production of fabrics that can then transfer the data. E-textiles are used in medicine to monitor patients' vital functions, such as infants, bedridden people. An example of the use of electronic textiles in medicine is Life shirt - T-shirt with sensors to enable continuous monitoring heart rate, respiratory rate, temperature during sleep and exercise during the daily days.

Crucial issues related to the placement of micro-electronic power supply on clothing. The most-frequently use is now lithium batteries work is underway to alternative energy sources. Developed material with conductive polymers possessing abilities processing of visible light into electricity. Another way is to use energy during walking: to produce electricity would serve placed in shoes piezoelectric device. Also proposed concepts for miniaturized silicon thermo-generator using the temperature difference between human skin and ambient temperature, in order to generate the electricity that powers the electronic components occurring in clothing. [114].

Electronics is the practical application of the protective clothing, particularly utilized in extreme conditions. Developed clothing designed for emergency services such as fire units, with implemented electronic microchips enable monitoring of physiological parameters, user-level clothing and threats. [115]. The purpose of clothing is to control the physiological state firefighter, in terms of the environment and the level of effort at work (energy expenditure and the resulting load of the body).

The design guidelines below are intended to communicate the considerations and principles necessary for the design of wearable products. According to Francine Gemperle et. All [116] they are listed here in a predictable order from the simple to the more complex, understanding that in development, tradeoffs will exist between them:

I. Placement (where on the body it should go)

Design for dynamic wear ability requires unobtrusive placement. Placement is determined by editing the extensive human surface area with the use of criteria. Criteria for placement can vary with the needs of functionality and accessibility; however, it is important to work within the appropriate areas for the dynamic human body. The criteria we used for determining placement for dynamic wear ability are:

- areas that are relatively the same size across adults,
- areas that have low movement/flexibility even when the body is in motion, and
- areas that is larger in surface area.

Applying these criteria results in the most unobtrusive locations for placement of wearable objects (Fig. 81).

Figure 81. The general areas to be the most unobtrusive for wearable objects.

II. Form Language (defining the shape)

Design for the human body also requires a humanistic form language. This works with the dynamic human form to ensure a comfortable, stable fit. Humanistic form language includes forming a concavity on the inside surface touching the body, to accept human convexities. On the outside surface, convexity will deflect objects in the environment thereby avoiding bumps and snags. Tapering of the form's sides will stabilize the form on the body. Radioing all edges and corners creates a safe, soft and wearable form. These steps are illustrated below, taking a simple block to a wearable form (Fig. 82). The humanistic form language not only makes forms wearable, it adds structural ruggedness which is crucial in an active environment.

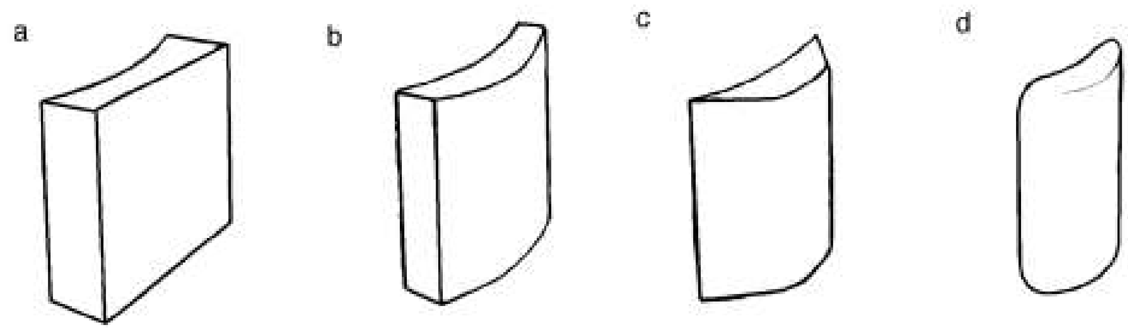


Figure 82. Combining elements of concavity (a) against the body), convexity (b) on the outside surfaces of the form, tapering (c) as the form extends off the body, and radii (d) softening up the edges combine to create a humanistic form language.

III. Human Movement (consider the dynamic structure)

Human movement provides both a constraint and a resource in the design of dynamic wearable forms. Human movement is useful in determining a profile or footprint for wearable forms, as well as to shape the surface of forms. Consider the many elements that make up any single movement. Elements include the mechanics of joints, the shifting of flesh, and the flexing and extending of muscle and tendons beneath the skin. The photographs (Fig. 83) below illustrate how much the form of the body changes with simple motion. Allowing freedom for these movements can be accomplished in one of two ways: by designing around the more active areas of the joints or by creating spaces on the wearable form into which the body can move. For example; the torso is a good place to put a wearable, but the arms need to have full freedom to swing around the side and front of the torso. In addition, the torso needs the full ability to twist and bend. These movements can help sculpt the surface of the form.

Figure 83. Even through simply motions, our bodies change significantly.

IV. Proxemics (human perception of space)

Design for human perception of size (Fig. 84). The brain perceives an aura around the body that should be considered to determine the distance a wearable form projects from the body. The understanding of these layers of perception around the body is referred to as proxemics [117] Forms should stay within the wearer's intimate space, so that perceptually they become a part of the body. The intimate space is illustrated below and can be between 0 and 5 inches off the body. Compromises are often necessary but a general rule of thumb is to minimize thickness as much as possible. This increases safety and comfort, both physical and perceptual.

Figure 84. Aura around the human body that the brain will perceive as part of the body.

V. Sizing (for body size diversity)

Size variation provides an interesting challenge when designing wearable forms. Both the build of a body and the ways in which it will gain and lose weight and muscle are important. Wearables must be designed to fit as many types of users as possible. Allowing for these size variations is achieved in two ways. The first is the use of static anthropometric data, which details point to point distances on different sized bodies [118,119]. The second is consideration of human muscle and fat growth in three dimensions. Fitting these changing circumferences can be achieved through the use of solid rigid areas coupled with flexible areas. The flexible areas should either be located between solid forms as joints or extending from the solid forms as wings (Fig. 85).

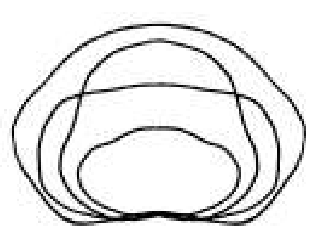


Figure 85. Torso cross sections of various sized bodies show how sizes vary.

VI. Attachment (fixing forms to the body)

Comfortable attachment of forms can be created by wrapping the form around the body, rather than using single point fastening systems such as clips or shoulder straps. As in guideline 5, it is also important to have attachment systems that can accommodate various physical sizes. Design for stable, solid, and comfortable attachment draws on the clothing and outdoor equipment industries. Design for size variations in attachment systems can be obtained in two simple ways. The first is through adjustability; e.g. straps that can be extended as seen on backpacking equipment. The second is through the use of standardized sizing systems from the clothing industry.

VII. Containment (considering what's inside the form)

Designing wearable objects generally requires the object to contain materials such as digital technology, water, food, etc. While some of these things are malleable in form, there are many constraints that these 'insides' bring to the outer form.

VIII. Weight (as its spread across the human body)

The weight of a wearable should not hinder the body's movement or balance. The human body bears its own extra weight on the stomach, waist and hip area. Placing the bulk of the load there, close to the center of gravity, and minimizing as it spreads to the extremities is the rule of thumb.

IX. Accessibility (physical access to the forms)

For any wearable it is important to consider the sort of accessibility necessary to render the product most usable. Extensive research exists in the areas of visual, tactile, auditory, or kinesthetic access on the human body.

X. Sensory Interaction (for passive or active input)

Sensory interaction, both passive and active, is a valuable aspect of any product. It is important to be sensitive to how one interacts with a wearable - something that exists on one's body. This interaction should be kept simple and intuitive.

XI. Thermal(issues of heat next to the body)

There are three thermal aspects of designing objects for the body - functional, biological, and perceptual. The body needs to breathe and is very sensitive to products that create, focus, or trap heat.

XII. Aesthetics (perceptual appropriateness)

An important aspect of the form and function of any wearable object is aesthetics. Culture and context will dictate shapes, materials, textures, and colors that perceptually fit the user and their environment [120].

XIII. Long-term Use (effects on the body and mind)

The long term use of wearable computers has an unknown physiological effect on the human body. As wearable systems become more and more useful and are used for longer periods of time, it will be important to test their effect on the wearer's body.

8. System Validation

Wearable Biomedical Systems (WBS) are a specific category of PHS: in particular, they can be defined as integrated systems on a wearable platform (in the sense of clothing or devices attachable to the human body) and can offer solutions for continuous monitoring by measuring non-invasive biomedical, biochemical and physical parameters. Continuous monitoring with early detection of anomalies has likely the potential to provide patients with an increased level of confidence, which in turn may improve the quality of life. In addition, ambulatory monitoring will allow patients to engage in practicing normal activities of daily life, rather than staying at home or close to specialized medical services. Thus WBS is an ideal platform for multi-parametric non-intrusive monitoring of health status, thus providing a remote primary and secondary prevention. In this way it is possible to obtain the early diagnosis and management of several diseases (in particular cardiovascular and / or respiratory, but also metabolic pathologies and physical rehabilitation), but also to support elderly and disabled people [121].

8.1. Textile electrode performance validation

WBS are used to measure a variety of biological signals, including heart rate (ECG), electrical cerebral activity (EEG), respiration, blood gases saturation, body accelerations, and many others. For example, in case the necessity is to guarantee a general monitoring of physiological parameters, a good balance between system's complexity and user's compliance might be obtained by a wearable device monitoring 1 or 2 ECG leads, breathing parameters (rate but also in/expiration times and volumes), and global motion (through one1 3-axial accelerometer).

Up to now, several studies have been conducted to support new services to monitor physiological parameters of people at home during activities of daily living (ADL) [122, 123, 124, 125]. Despite this wide literature of new methods and services, rarely the performance of sensors have been validated by using a standardize protocol. Even if validation has been conducted for motion sensors like MEMS, used to detect movements and in particular falls [126, 127, 128, 129, 130], we couldn't find any validation study to quantify the performance of wearable sensors.

Nevertheless, textile electrodes to detect ECG signal have been often integrated in wearable systems to have a more complete description of the health status of patients [131]. For these sensors the only validation is generally limited to a qualitative observation of the ECG waveforms to assess a good similarity in terms of shape and temporal patterns with a clinical ECG signal obtained with clinical electrodes and devices.

Standard electrodes for ECG monitoring are a class I medical device and generally are adhesive silver/silver chloride (Ag/AgCl) electrodes because of its ease of manufacturability. Ag/AgCl electrodes are non-polarized electrodes as they allow current to pass across the interface between the electrolyte and the electrode [132]. Non-polarized electrodes are better than polarized electrodes in terms of their rejection of motion artifacts and their response to defibrillation currents.

Instead textile electrodes are built of textile yarns with electrical properties: a) Metal yarns, i.e. yarns containing conductive fibers like stainless steel, copper or silver mixed with natural or synthetic fibers; b) Yarns containing electro-conductive fibers like polymeric or carbon coated threads [133].

Paper of Andreoni [134] et al. presents the structured protocol for textile electrode validation. They compared the performances of ECG textile electrodes with standard Ag/AgCl electrodes not only by looking at the morphological shape of the waveforms of the recorded ECGs, but also by verifying that the diagnostic information is preserved. In order to test their protocol, they employed it on a case study and we assessed the reliability of the textile electrodes under analysis.

8.1.1. Protocol

The validation protocol for textile electrodes consisted in 2 phases:

- a laboratory test for measuring the conductivity and the sensing performances of textile electrodes in a fixed setup using a ECG signal generator;
- a functional set of experiments in real conditions while the subjects performed a standard ADL using a compact and portable clinical electro-cardiograph (ECGraph).

The first step aimed at assessing the “absolute” sensing capability of the textile electrodes, i.e.

without any dependencies on the presence of the subject. The experimental set up consisted in an ECG generator (MiniSim 1000, Netech Corporation, Farmingdale, NY, USA) and a clinical electrocardiograph (Phedra, SXT – Systems for Telemedicine, Lecco, Italy). The MiniSim 1000, Advanced MultiParameter Simulator is a powerful, comprehensive patient simulator in a compact case. It is designed to test the performance of patient monitoring instrumentation quickly and easily. The ECG generator provides full 12 lead ECG simulation with 14 user selectable rates from 30 to 350 BPM and 14 user selectable amplitudes from 0.15 to 5 mV. Firstly, we recorded the signal by directly attaching the ECGgraph clips to the ECG generator (Fig. 85) and by acquiring 10 ECG waveforms, generated using different amplitude and frequency settings; then we repeated the same measures by interfacing a pair of 1x1.5 cm textile electrodes (Comftech s.r.l., Monza, Italy) built with polymeric yarns with a silver-based coating and by mounting the standard ECGraph snaps. To compare the two sets of signals we computed the maximum of the normalized cross-correlation coefficient, the QRS correlation coefficient and the QRS amplitude ratio.

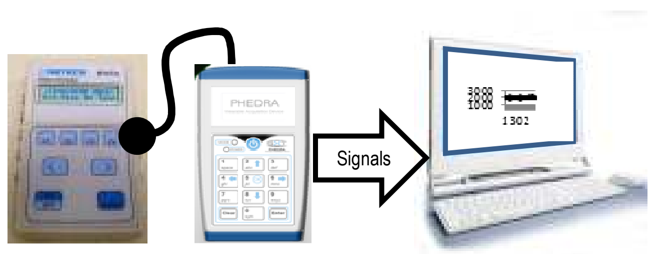


Figure 85. The experimental setup for the validation of the electrodes using an ECG signal generator (on the left) whose output signals are recorder through a clinical ECGraph (in the center) and transmitted to a PC (on the right) for display and further processing.

The second phase consisted in an on-field test in which ECG signals were acquired from subjects performing standard ADL. The study was conducted on 10 healthy adults at the Polytechnic in Milano, Milano, Italy. 7 men and 3 women participated in the research.

During this second phase, the experimental setup consisted of a 5 electrodes configuration to simultaneously record the trunk lead (Fig. 86) - which is the preferred one for wearable monitoring applications - both with standard Ag/AgCl and textile pairs of electrodes.

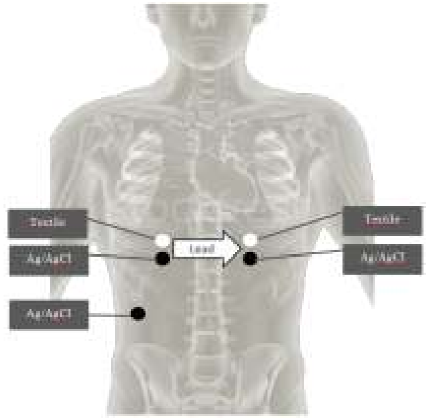


Figure 86. The electrode configurations used in the experimental protocol.

The two pairs of electrodes were mounted as close as possible to each other in order to have the most similar signal as possible. No skin treatment was adopted both for men and women (neither skin preparation with cleaning solution nor shaving the electrode sites). In order to have the same electrode typology (non-polarized class) a small amount of gel for ECG recordings was placed on the textile electrodes before positioning them onto the body. This operation could be questionable for the comparison; in fact one of the main issues for textile electrode is whether to use gel (usually hydro gel pads could be placed in correspondence of the electrodes, as seen in some previous experiences) or leave dry electrodes. In our experience, a small sweat is produced at the skin-electrode interface, and this phenomenon is accelerated by activity, like stepping or stair climbing. Then the condition is nearly stable. Due to the short duration of laboratory test per subject (see next comma for details), we decided to anticipate this "stable" condition with a drop of gel onto the textile electrodes to have comparable results along the trial and among the trial as well.

The clinical ECGraph (Phedra, SXT – Systems for Telemedicine, Lecco, Italy) was used to acquire ECG with 128 Hz sampling rate. The device was attached to the trunk of the subject through an elastic belt adjustable according to the dimension of the chest (Fig. 87). The ECGraph simultaneously records and sends data via Bluetooth to the PC, where the signals are displayed to have a real-time qualitative feedback of the signals quality.

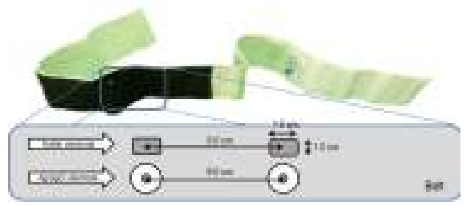


Figure 87. The belt for supporting the 2 pairs of electrodes and their configuration in the experimental tests.

Each trial consisted in a set of ADL epochs to be performed sequentially:

- Standing 30 sec,
- Stand-to-sit (5 sec), stop, sit-to-stand (5 times),
- Standing 30 sec,
- Stepping 30 sec,
- Walking 30 sec,
- Stairs (9 steps), up and down (2 times),
- Walking 30 sec,
- Standing 30 sec,
- Sitting 30 sec.

The duration could seem short but it was previously tested on two subjects that a longer recording during the performance of the same activities lead to constant results. For this reason we focused on 30 seconds recording of steady testing conditions, and we chose to verify repeatability.

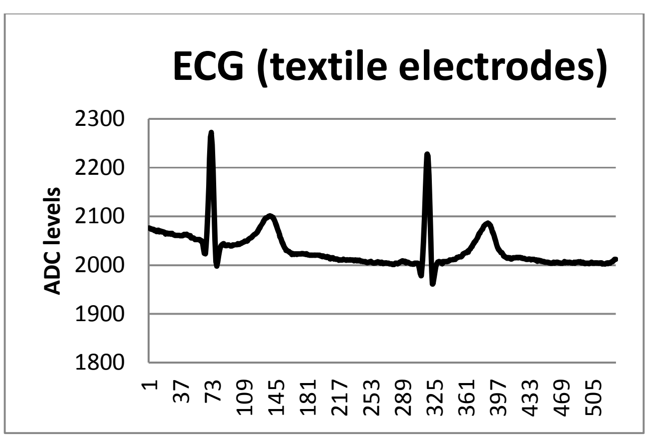


Figure 88. An example of the ECG signal from textile electrodes in the experimental tests with subjects.

Three repetitions of the sequence were carried out and recorded for each subject; each trial was followed by a 5 minutes sitting resting time, before starting a new one. In 3 subjects the positions of the electrodes were exchanged to verify absence of differences due to the positioning of the different kind of electrodes. For more clarity, in these subjects the textile electrodes were mounted upper than the standard electrodes with respect to the configuration shown in Fig. 88.

8.1.2. Subjects

The characteristics of the study group are shown in Tab. 7,8. In the study participated both women and men. Average age of women was 28 years and men 33 years. However average of body height and weight was for men 180 cm, 80 kg and for women - 164 cm, 54 kg.

Subject	Age (years)	Height (cm)	Body Mass (Kg)	BMI
Average	31.8	176	72.4	23.142
SD	7.1	8.8	15.8	3.3

Table 7. Average and standard deviation (± SD) values of age, weight, body mass and BMI for all study group.

SEX (M/W)		AGE	HEIGHT (cm)	BODY MASS (Kg)	BMI
M	**AVG**	33.43	180.86	80.14	24.47
	SD	7.96	4.30	11.81	3.10
W	**AVG**	28.00	164.67	54.33	20.05
	SD	2.00	4.04	2.31	0.91

Table 8. Average and standard deviation (± SD) values of age, weight, body mass and BMI for men and women.

The study group have similar age, men are little older and with bigger standard deviation. Height of men is 180 [±12] and for women – 54 [±2]. The BMI in two groups are similar and is equal about 22.

8.1.3. Results

Results are split in the 2 different set of tests.

a) Validation of the electrodes with the ECG generator.

This test was carried out to verity the reliability of the sensors in providing a signal of an excellent quality, thus suitable for further processing. For this purpose with did not compute derived parameters but we simply verified the correspondence of the acquired signal to the generated one.

The 40 recordings (20 for each electrode configuration) were properly coupled and we computed:

- the average cross-correlation between corresponding signals;
- the average amplitude ratio:

$$AR = \frac{1}{N}\sum_{i=1}^{N} \left. \frac{QRS_{text}}{QRS_{dc}} \right|_i$$

where QRS_{text} is the peak to peak amplitude of the i-QRS of the signal acquired using textile electrodes, QRS_{st} is the peak to peak amplitude of the corresponding QRS in the signal acquired with direct contact between ECG simulator and the clip of the ECGgraph, and N is the total number of QRS in the recording. The average values of cross-correlation and amplitude ratio for each experimental condition are shown in the following table 9 and 10.

Frequency (b/min) **Amplitude (mV)**	**45**	**60**	**90**	**120**	**150**
0.15	0.998	0.999	0.999	0.999	0.999
0.30	0.999	0.999	0.999	0.999	0.998
0.50	0.999	0.999	0.999	0.998	0.999
1.00	0.999	0.999	0.999	0.999	0.998

Table 9. Average signal cross correlation between recordings acquired with direct contact vs. textile electrode in between ECG generator device and ECGraph.

Frequency (b/min) Amplitude (mV)	45	60	90	120	150
0.15	1	1	1	1	1
0.30	1	1	1	1	1
0.50	1	1	1	1	1
1.00	1	1	1	1	1

Table 10. Average signal Amplitude ratio between recordings acquired with direct contact vs. textile electrode in between ECG generator device and ECGraph.

The experiment was performed to verify the correspondence in terms of amplitude and shape between signal acquired with textile electrodes and the generated one. Even after varying amplitude and frequency of the generated signal, no differences were encountered (average R^2 = 0.9988±0.00041), both in the pattern and in the amplitude of the measured signal. The tiny differences could be attributed to measurement noise. Thus this demonstrates the theoretical reliability of the textile electrodes.

b) Validation of textile vs. standard electrodes in real conditions of ADL monitoring.

The 30 recordings (3 for each subject) were processed by separating each protocol epoch and then the parameters were computed according to the previously described methods. The following tables 11 and 12 summarize the result of the test concerning monitoring of real ADL in 10 subjects.

If the same activities are pooled we have the following recapitulating table 13 and 14.

Textile vs. standard electrodes comparison (Average)	QRS detection Error (No.)	QRS Amplitude Ratio (1= std elect.)	QRS Cross Correlation (R^2)	QRS detection delay (samples)
Standing	1.634	0.930	0.926	0.642
stand-to-sit	1.785	1.028	0.806	0.832
Standing	1.595	0.894	0.892	0.566
Stepping	2.026	1.021	0.756	0.661
Walking	2.063	1.116	0.737	0.797
Stairs	2.535	1.040	0.765	1.321
Walking	2.801	1.037	0.763	0.525
Standing	1.557	0.922	0.916	0.731
Sitting	0.525	0.931	0.930	0.563
AVERAGE	1.836	0.991	0.832	0.738
SD	0.652	0.074	0.082	0.243

Table 11. Averages of Reliability Parameters computed in all the recordings and conditions, for all trials (and repetitions) and for all subjects.

Textile vs. standard electrodes comparison (Standard Deviation)	QRS detection Error(No.)	QRS Amplitude Ratio (1= std electrodes)	QRS Cross Correlation (R^2)	QRS detection delay (samples)
Standing	4.734	0.284	0.073	0.496
stand-to-sit	2.532	0.457	0.135	0.788
Standing	4.309	0.238	0.116	0.444
Stepping	3.562	0.315	0.171	0.366
Walking	1.797	0.582	0.124	0.691
Stairs	4.154	0.543	0.137	2.291
Walking	5.133	0.342	0.098	0.378
Standing	3.278	0.292	0.069	0.530
Sitting	0.963	0.270	0.053	0.510

Table 12. Standard deviations of Reliability Parameters computed in all the recordings and conditions, for all trials (and repetitions) and for all subjects.

Textile vs. standard electrodes comparison (Average)	QRS detection Error(No.)	QRS Amplitude Ratio (1= std electrodes)	QRS Cross Correlation (R^2)	QRS detection delay (samples)
Standing	1.595	0.915	0.911	0.646
stand-to-sit	1.785	1.028	0.806	0.832
Stepping	2.026	1.021	0.756	0.661
Walking	2.432	1.076	0.750	0.661
Stairs	2.535	1.040	0.765	1.321
Sitting	0.525	0.931	0.930	0.563
AVERAGE (n=10)	1.816	1.002	0.820	0.781
SD	0.729	0.064	0.081	0.279

Table 13. Averages of Reliability Parameters computed in all the recordings and conditions, for all trials (and repetitions) and for all subjects for pooled activities.

Textile vs. standard electrodes comparison (Standard Deviation)	QRS detection Error(No.)	QRS Amplitude Ratio (1= std electrodes)	QRS Cross Correlation (R^2)	QRS detection delay (samples)
Standing	3.480	0.281	0.148	0.477
stand-to-sit	2.532	0.457	0.135	0.788
Stepping	3.562	0.315	0.171	0.366
Walking	4.651	0.323	0.135	0.373
Stairs	4.154	0.543	0.137	2.291
Sitting	0.963	0.270	0.053	0.510

Table 14. Standard Deviations of Reliability Parameters computed in all the recordings and conditions, for all trials (and repetitions) and for all subjects for pooled activities.

The second set of test aimed at demonstrating the equivalence between textile electrodes and standard Silver/Silver Chloride ones in real conditions. To have a similar behavior of the electrodes a small amount of liquid conductive gel for ECG was used before textile electrodes positioning. A big difference is the presence of an adhesive layer for the Silver/Silver Chloride electrodes with respect to the textile ones that are simply kept in touch with the body through the pressure exerted by an elastic belt to which they are knitted. For this reason a decrease in performance of textile electrodes is expected for the motion artifacts deriving from the not stable body-electrode contact. The performed experimental test could also assess how this effect is relevant and in what conditions (i.e. ADL typologies) this artifact could be significant in real monitoring situations.

Globally, the experiments showed that the acquired signals with the textile electrodes are almost identical to those acquired with the Silver/Silver Chloride ones: the average amplitude ratio is equal to 0.992±0.074 (less than 1% decrease in amplitude, not significant) and the average Cross Correlation coefficient is 0.832±0.082. For this second parameter the best performances are shown while the subject is standing (R^2 = 0,911±0.148) while the most critical condition is encountered when the subject is walking (R^2 = 0,750±0.135). In both cases, the variability of these parameters is very small. After watching the video of the tests, we argued that this was due to the oscillations of the device that was placed just over the electrodes. Because of its not minimal weight and dimensions, even small movement might cause a slight detachment of the belt from the body, so decreasing the applied elastic adherence force. Furthermore the electro-myographic contribution of the pectoralis muscles could be overlapped to the ECG signal. Despite this electrical signal is at higher frequencies, its amplitude is relevant and could affect both baseline and pattern of the ECG signal. This explains why, while standing and sitting, the standard electrodes gave a better signal quality. However, during the movement (stand to sit, stepping, walking, and stairs ascending/descending using also the arms as natural) the best signal amplitude was obtained from textile electrodes that were highly conductive and wet.

However in any condition, the quality of the signals was more than good. To quantify signal quality, we computed the errors in QRS detection and the delay in samples between the times when the R-peak occurred in the signal recorded through the textile electrodes with respect to the time of the same event in the signal acquired with the Silver/Silver Chloride ones. Globally the average number of errors in the detection of QRS was 1.836±0.652 on a set of about 38 beats (about 30 sec acquisition duration for each phase at about 75 beats-per-minute average heart rate for standing/sitting/walking/sit-to-stand activities) that corresponds to a global error of 2.448±0.869%. The delay in the QRS detection was always less than 1 sample except for the stairs ascending and descending; in this case we had the worst results with an average delay of 1.321±2.291 samples. This means that the signals were perfectly synchronized and no pattern modifications were present. Quiet movements or resting situations gave the best and excellent results, as expected. In fact we obtained that, after increasing the intensity of the movement, the error is bigger. For example during stepping, walking and stairs ascending/descending, the number of errors in QRS detection is respectively 2.026, 2.432, and 2.535 ; vice versa when the body is static (standing or sitting) this value decreases at less than 1 (the minimum value is 0.525 while the subject is sitting).

From the methodological point of view a detailed structured protocol for testing wearable sensors, and in particular textile electrodes, have been proposed and applied in monitoring ADL. This scenario represents the next future challenge to be achieved in developing new healthcare services and models. The method and the related experimental activity were easy to be implemented and carried out. Quantitative and effective parameters of reliability were computed to quantify the similarity and correspondence between standard and innovative monitoring solutions.

Also important suggestions were elicited by this work. In fact, the results obtained in this research work suggested that there was no significant difference between the two different typologies of textile and Agl/AgCl electrodes. However specific attention should be taken into account while monitoring movements including arms motion (the EMG activity of the pectoralis muscles could affect the signal in amplitude and in high frequencies) and artifacts due to change in sensors adherence could be noticeable in the signal pattern.

This study was conducted on a single sample of silver-based textile sensors in a given but standard and common configuration (trunk lead and textile electrode with thin layer gel for electrical skin coupling): other materials and other configuration will be now tested for a wider and exhaustive validation of sensors typologies and materials.

8.2. Motion and style detection validation

The performance of swimming is strongly related to the swimmer's technique. Therefore, a swimmer who wants to improve his swim performance has to devote a substantial proportion of the training to his swim style improvement. The two most important physical principles to swim faster and more efficient are:

- Reduction of the resistance through an improved body balance and body rotation.
- Increasing of the propelling force by improving the arm strokes and hence the stroke efficiency.

General consensus nowadays is that both factors must be optimized. The result of an improved streamlined position together with an increased propelling force is synergetic swimming, meaning that both factors have to be improved likewise for fast swimming.

Many recreational swimmers often make training alone and haven't trainer aside at all times, neither they have access to a video analysis system. They aren't professional athletes and haven't experience and sense of self-perception.

Therefore in this research is project - system worn by the swimmer which will help these athletes to keep track of their technique also in the training hours where trainer isn't present. In addition this system will support the trainer during his training hours by providing additional continuous swim performance parameters not available so far.

To create a swimsuit with sensors to monitor the performance of swimmers should be carry out a test for the position of applying the electrodes, where the signals will be the most visible, the purest, strongest.

8.2.1. Protocol

The validation protocol for motion and style detection consisted in 2 phases:

I. A laboratory positioning of the electrodes and accelerometer on the body. Evaluation of possibility position for the object.
II. A functional set of experiments in real conditions using accelerometer.

In the first step was taken the possibility position where we can put the accelerometer. For the all possibility for measure biomechanical parameters during swim is need taking into account that:

- Sensor must be near the body in the place with least mobile,
- Sensor can't disturb swim, must be in place the most comfortable,
- Sensor in future must be on swimsuit.

The general area for put sensor or accelerometer on the body is (Fig. 89):

- ✓ central axis of the body just below the chest;
- ✓ on the central axis of the body in the middle of the back;
- ✓ on the central axis of the body in the lumbar of the back ;
- ✓ in correspondence with the right or left hip ;

✓ on the central axis of the body at shoulder height.

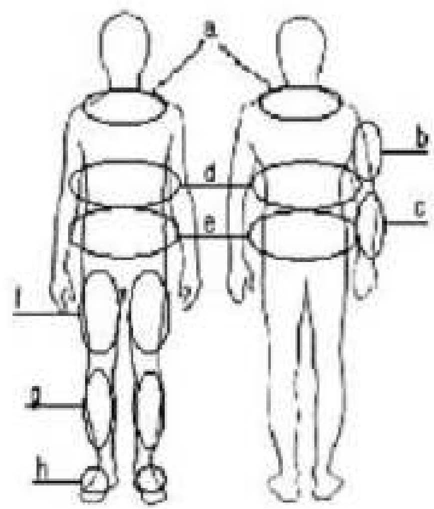


Figure 89. The general areas for the most unobtrusive for wearable objects are: a - collar area, b - rear of the upper arm, c – forearm, d – rear, side and front ribcage, e – waist and hips, f - thigh, g – shin and h – top of the foot.

Taking into account assumptions, that wearable object must be in the position most stationary, sticking as close to the body, and not interfere with the movements of the wearer, cannot be take all options into consideration. As we know, the body of swimmer is in constant motion. The most important parties of the body are the hands and feet. They are responsible for the movement of the body in the water. Head also is in motion. From time to time is needed take the air and resurface head out of the water.

The part of the body's which do the smallest movement is spine. For this reason for validation motion and style detection, was choose 4 positions for analyze:

1. on the central axis of the body just below the chest;
2. on the central axis of the body in the middle of the back;
3. on the central axis of the body in the lumbar region of the back;
4. in correspondence with the right or left hip.

In the second phase was done experiment in the swimming pool using accelerometer, which was inserted into the special container – aqua pack that doesn't get into the water (Fig. 90). A whole was attached to the body with a flexible tape, which has helped to investigate signals while swimming in all possible positions.

Figure 90. Accelerometer used for the experiment.

A tested person had to swim 4 times of 2 swimming pools of 25 meters. For see every data from the start to the end of every style of swim, in the start of pool and in the end swimmer made 3 jumps. The protocol looked this:

I. The first position - on the central axis of the body just below the chest (Fig. 91).

- 3 jumps
- Swim 50 m (2x25m) - freestyle
- 3 jumps
- Swim 50 m (2x25m) - back stroke
- 3 jumps
- Swim 50 m (2x25m) - breast stroke.

Figure 91. Swimmer with accelerometer on the central axis of the body just below the chest.

II. The second position - on the central axis of the body in the middle of the back (Fig. 92).

- 3 jumps
- Swim 50 m (2x25m) - freestyle
- 3 jumps
- Swim 50 m (2x25m) - back stroke
- 3 jumps
- Swim 50 m (2x25m) - breast stroke.

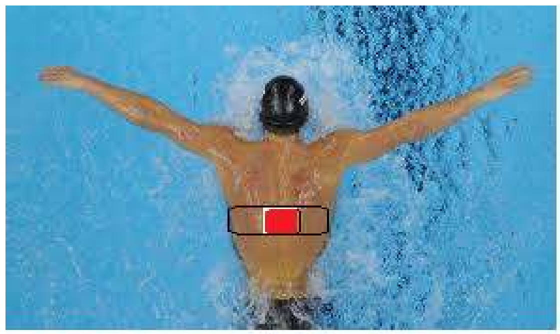


Figure 92. Swimmer with accelerometer on the central axis of the body in the middle of the back.

III. The third position - on the central axis of the body in the lumbar region of the back (Fig. 93).

- 3 jumps
- Swim 50 m (2x25m) - freestyle
- 3 jumps
- Swim 50 m (2x25m) - back stroke
- 3 jumps
- Swim 50 m (2x25m) - breast stroke.

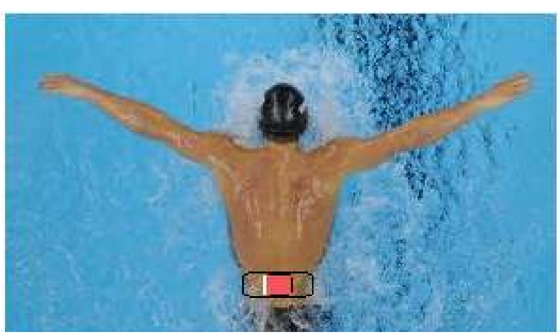


Figure 93. Swimmer with accelerometer on the central axis of the body in the lumber region of the back.

IV. The fourth position - in correspondence with the right or left hip (Fig. 94).

- 3 jumps
- Swim 50 m (2x25m) - freestyle
- 3 jumps
- Swim 50 m (2x25m) - back stroke
- 3 jumps
- Swim 50 m (2x25m) - breast stroke.

Figure 94. Swimmer with accelerometer in correspondence with the right hip.

After transferring the data, it was possible to display the results of tests on a monitor using the program Matlab.

8.2.2. Subjects

Participated in the experiment two people - woman and man. These people swim for recreation, not professional. Female 20 years old, with a body weight of 55 kg and a height of 167 cm. In turn man - 26 years, body weight 55 kg and height 170 cm.

8.2.3. Results

In the figures, we can view the graphs showing the acceleration on the axes x, y and z with the accelerometer in 4 position. The graphs obtained show the time on the abscissa and on the ordinate the acceleration in g. the curves are of three different colors depending on the direction of the acceleration:

- the red represents the acceleration antero-posterior axis (x);
- blue represents the lateral acceleration (y-axis);
- the yellow represents the vertical acceleration (z-axis).

On the charts below we can see the results of the conducted experiment . On first chart are visible results of the three styles of swimming, during which accelerometer was placed in a position on the central axis of the body just below the chest (Fig. 75).

In the case of free style wherever it is placed the accelerometer are clearly visible strokes, represented by the peak of the curve for lateral acceleration. According to the distance between a peak and the other is then possible to derive the time that elapses between a stroke and the other, being able to detect parameters such as the efficiency of the stroke.

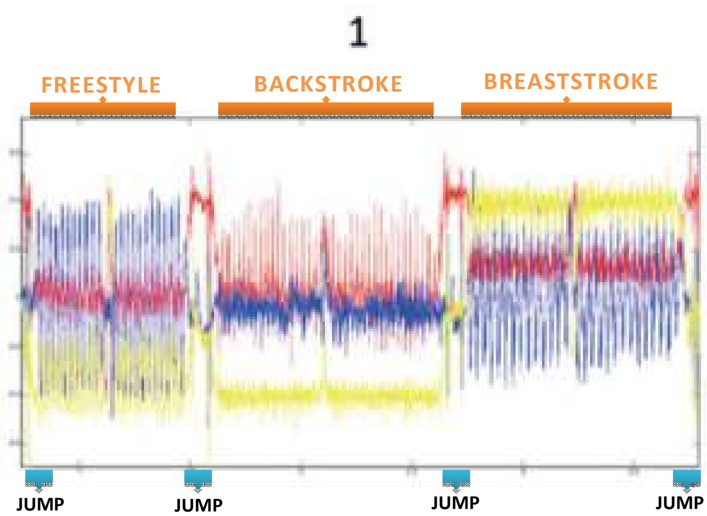


Figure 95. The result from experiment with accelerometer on the central axis of the body just below the chest.

Detecting motion of the legs, however, is more complex when the accelerometer is placed in position 2 (Fig. 96). This result was obtained with accelerometer on the central axis of the body in the middle of the back.

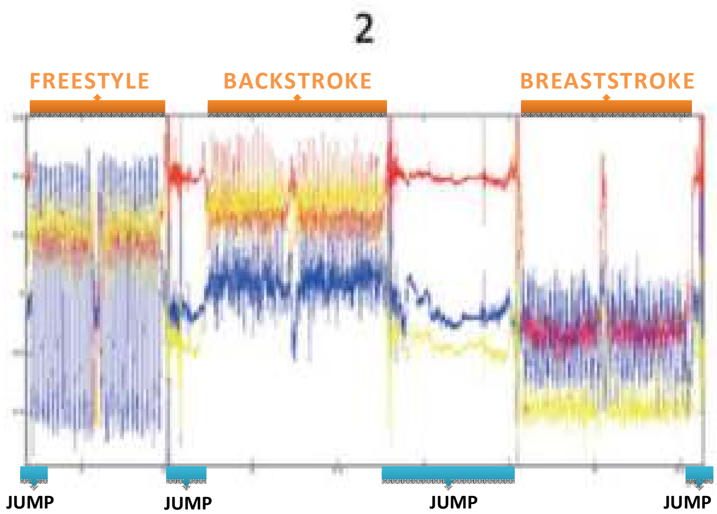


Figure 96. The result from experiment with accelerometer on the central axis of the body in the middle of the back.

In contrast are well recognized when it is placed in the lumbar zone (position 3), where the kicks are well visible in the same curve of strokes: are the peaks of lesser dimension (Fig. 97).

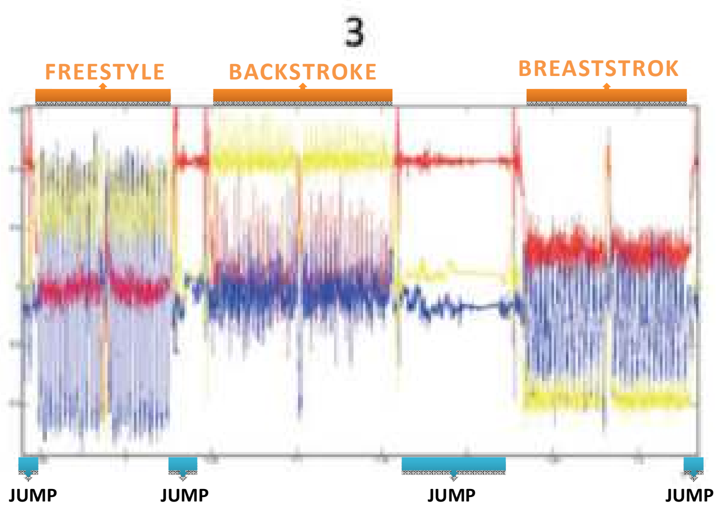


Figure 97. The result from experiment with accelerometer on the central axis of the body in the lumbar region of the back.

The strokes and kicks in breast stroke are recognized very well when the accelerometer is placed on the back (positions 2 and 3) are clearly visible in the red curve, which expresses the anterior - posterior acceleration. Conversely, the movement of arms and feet is not detected properly when the accelerometer is in position 4 - in correspondence with the right hip (Fig. 98).

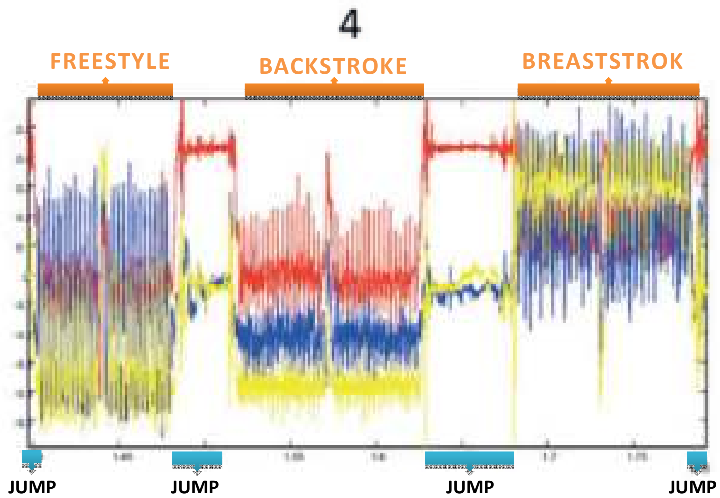


Figure 98. The result from experiment with accelerometer in correspondence with the right hip.

The frog, together with the dolphin, is a style which is very sensitive to the displacement of the body on the vertical axis, however, in the graphs the vertical acceleration, expressed by the yellow curve, is not particularly sensitive: this is an important parameter because a side indicates how the swimmer leaves the water during respiration, on the other hand is an index from which you can understand the degree of coordination of the style.

The backstroke is detected at its best when the accelerometer is placed on the back (both in position 2 that 3), but fail to detect quite well the acceleration of the arms and legs also from the front position.

The curve to be observed is mainly the blue of the lateral accelerations, in which the peaks indicate the greatest stroke, while the smaller ones indicate the reciprocating movement of the legs. In the high-level performance generally should do six kicks each cycle of strokes: This parameter related to the proper coordination arms-legs could be easily detected by the accelerometer.

From this analysis it is clear that the best locations for the detection of the parameters of the styles are the 2 and the 3. But in reality the position 3 is better, in fact placing the accelerometer in the lumbar region of the back allows you to detect kicks the best way to freestyle and for this reason accelerometer in my project will be placed in the position 3 - on the central axis of the body in the lumbar region of the back.

8.3. Swimsuit design

Sports swimwear, although as simple bikini serve for swimming, but have completely different properties. The difference in this case is based on technology and the type of materials used. Athletic swimsuits are in fact made of a material that does not stretch during washing, does not change the color or deformation even during frequent visits to the swimming pool and direct contact with chlorinated water. The material perfectly adapts to the floating body, giving it streamline effect. Athletic swimsuits are not for show, are part of the garment of professions who during swimming must have above all a sense of comfort. This makes it in sporty swimsuit in vain to look for lace, trimmings and badges, order to make the appearance. Athletic swimsuits are characterized by simplicity, having streamlined the movements of swimmer. Women's swimsuits are generally crossed straps on the back, so that will not happen to them slipping. They are mostly one-piece, provide freedom of movement and comfort while swimming.

8.3.1. Human fitting and sensors positions

For make a perfect swimsuit with electrodes is need to remember that the sensors has to be fixed and stable contact with skin, minimaze and comfortable for the swimmers. The sensors must be placed in the correct position for perfect signal detection. Fig. 99 and 100 provides a graphical reference of possible locations for the parameter monitoring sensors according to D.Andre et all [135] and Gemperle [136].

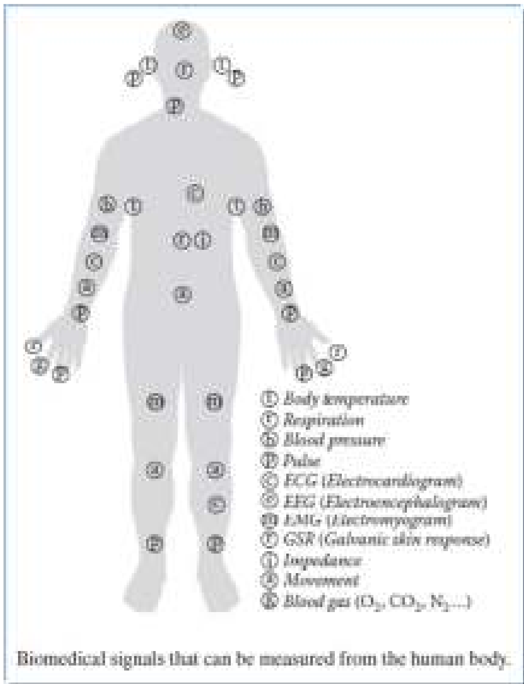


Figure 99. Andre and A. Teller [135].

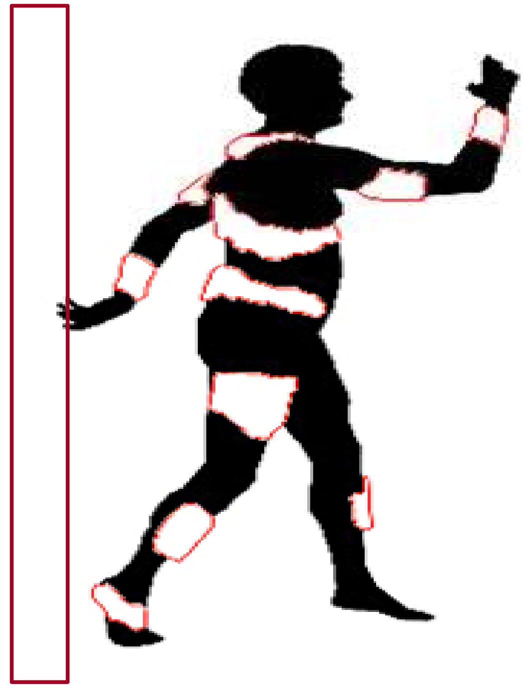


Figure 100. Gemperle et al., 1998 [136].

The general parts that are most suitable are - the area in the neck, the lumbar area, the back part of the arm the wrist, the thigh, shin, and the upper part of the foot. During the swim, legs and arms strokes make so much movement and cons of water generate propulsive forces that can easily move them, better to use the trunk area for wearable devices.

The swimsuit for athletes covers the central part of body how we can see in pictures (Fig. 101).

Figure 101. Examples of swimwear which are use in Olympic Games.

Before analyze the position of sensors is need put objects in every possibility position on swimsuit (on the front and rear part) (Fig. 102). The objects with red color are - accelerometer, and with yellow – sensors.

Figure 102. The possibility area for sensors and accelerometer on swimsuit for men.

The swimsuit for men is smaller than for women and take only down part of the body (Fig. 103). Here also object with red color is accelerometer and with yellow – sensors.

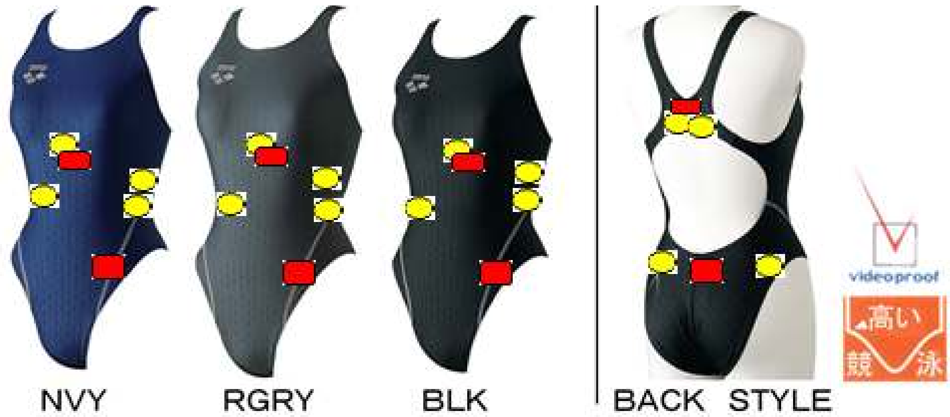


Figure 103. The possibility area for sensors and accelerometer on swimsuit for women.

For the position of electrodes, instead we can take the possibility (Fig. 104):

- 1 - central axis below the chest, 2 - central axis in the middle back;
- 1 - central axis sternum, 2 - central axis in the middle back;
- 1 - under the left pectoral, 2 - central axis at shoulder height;
- 1 & 2 - on the left and right side of the body just below the height of the chest;
- 1 & 2 - in the lumbar fascia to the sides.

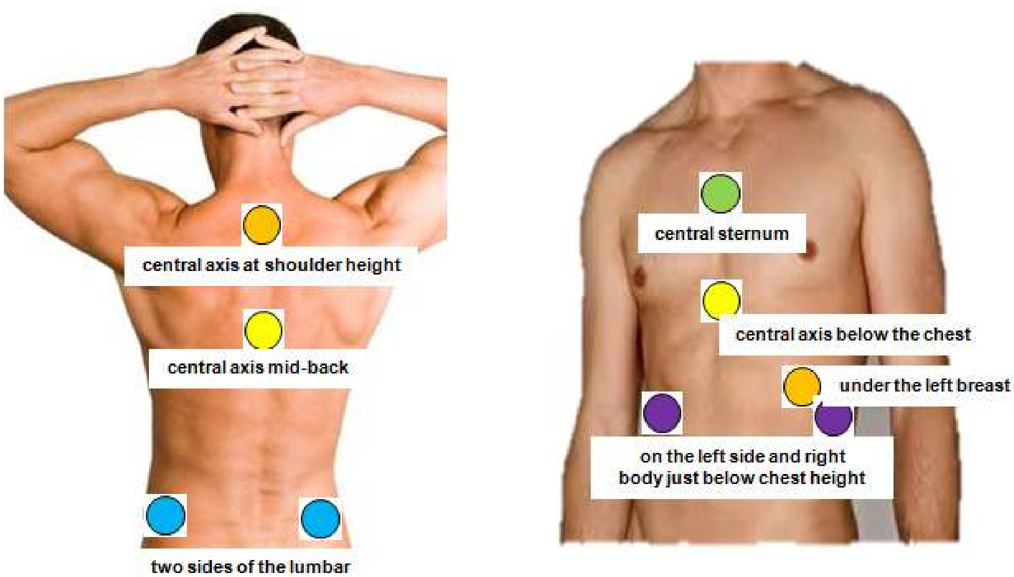


Figure 104. All the possibility position for sensors on the body.

For position of accelerometer we can took into account a 5 possibility (Fig. 105):

- on the central axis of the body just below the chest;
- on the central axis of the body in the middle of the back;
- on the central axis of the body in the lumbar;
- be allocated based the right and left hip;
- on the central axis of the body at shoulder height.

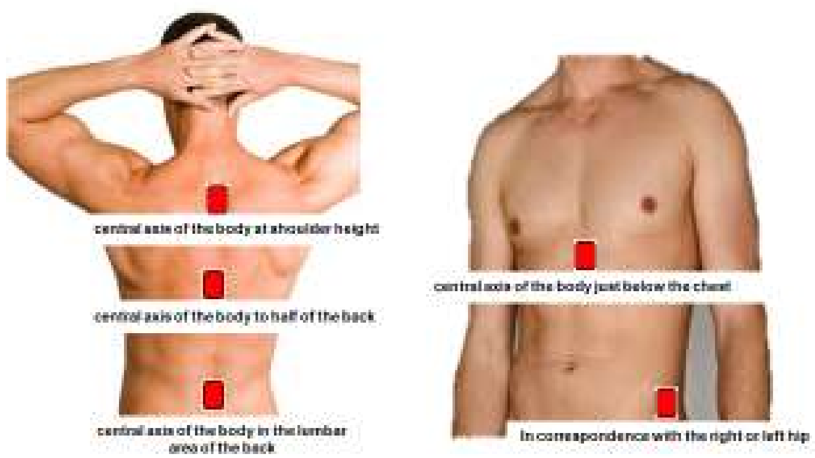


Figure 105. All the possibility areas on the body for accelerometer.

Was carried out test at the pool with accelerometer contained in a waterproof casing, in turn inserted in a pocket sewn on an elastic band that can be moved on the different areas of the body, about which was talking in part before ("motion and style detection validation").

In the experiment taken part two people, which had to swim 18 times a pool of 25 meters with tree styles – freestyle, back stroke and breast stroke. To avoid interfere with the pick, movements of hands and legs , the most taken into account was the position on the wing lower back and lumber part. After analyze every result of experiment, can be propose the best place on the body for put instrument which will give us measures (Fig. 106).

Figure 106. The best position for accelerometer and sensor.

After transferring the data, it was possible to display the results of tests on a monitor using the program Matlab.

In the figures (Fig. 107) is possible to display the graphs showing the acceleration on the axes x, y and z with the accelerometer. The graphs obtained show the time on the abscissa and on the ordinate the accelerations, the curves are three, depending on the direction of the acceleration:

- axis - x represents the acceleration antero-posterior,
- y - axis represents the lateral acceleration,
- z- axis represents the vertical acceleration.

This example is shown from experiment made with accelerometer in the position selected for the project - on the central axis of the body in the lumbar region of the back.

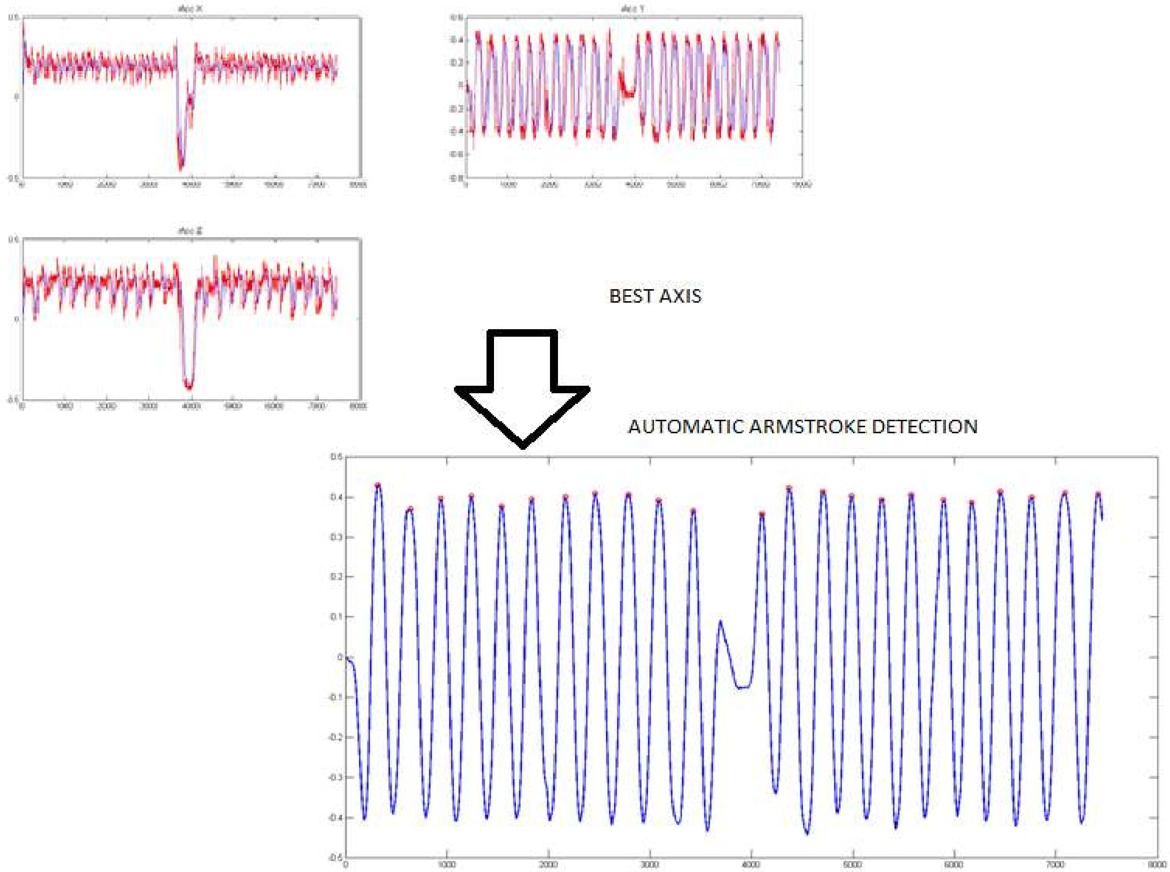


Figure 107. Example of obtained result.

How we can see the pick is clear and is possible work in this direction. After the establishment of special algorithms we have automatically detect arm movements.

8.3.2. Swimming requirements

According to FINA (Rule GR 5 and BL8) the rules apply to swimwear to be used in FINA and Olympic Games pool and open water swimming competitions are:

1. GR 5 SWIMWEAR

- GR 5.1 The swimwear (swimsuit, cap and goggles) of all competitors shall be in good moral taste and suitable for the individual sports disciplines and not to carry any symbol which may be considered offensive.
- GR 5.2 All swimsuits shall be no transparent.
- GR 5.3 The referee of a competition has the authority to exclude any competitor whose swimsuit or body symbols do not comply with this Rule.
- GR 5.4 Before any swimwear of new design, construction or material is used in competition, the manufacturer of such swimwear must submit the swimwear to FINA and obtain approval of FINA.

2. BL 8 SWIMWEAR

- BL 8.1 All swimwear used at Olympic Games and FINA Events (pool and open water competitions) shall be swimwear approved by FINA in accordance with the rules and procedures set forth in the FINA Requirements for Swimwear Approval (FRSA) issued by the FINA bureau and valid on the date of approval. Following an approval process conducted by the Swimwear Approval Commission, a list of approved swimwear is published by FINA (the Approved List) each year. The Approved List is published each year before December 31 and is valid starting from January 1 of the subsequent year.
- BL 8.2 In swimming pool and open water competitions the competitor must wear only one swimsuit in one or two pieces. No additional items, like arm bands or leg bands shall be regarded as parts of a swimsuit.
- BL 8.3 From January 1, 2010 in swimming pool competitions, swimsuit for men shall not extend above the navel or below the knee, and for women, shall not cover the neck, extend past the shoulder, nor shall extend below knee. All swimsuits shall be made from textile material.
- BL 8.4 From June 1, 2010 Open Water swimwear for both men and women shall not cover the neck, extend past the shoulder, nor shall extend below the ankle. All Open Water swimsuits shall comply with the FINA Criteria for Materials and Approval Procedures.
- BL 8.5 From January 15, 2010 in Masters Pool Swimming competitions the rules BL 8.1, BL 8.2 and BL 8.3 apply. From June 1, 2010 the rule BL 8.4 applies also for the Masters Open Water competitions. [Note to BL 8.5: It is clarified that swimsuits which fulfill the shape requirement set forth in BL 8.3, respectively BL 8.4 (for Open Water Swimming) can be accepted even if they do not bear a valid FINA approved label provided they effectively and evidently fulfill the material requirements set forth in the current FINA Requirements for Swimwear Approval. This is the case for swimsuits made of traditional permeable textile (i.e. open mesh material) material (such as cotton, Nylon, Lycra and the like) with no application of surface treatment closing the open mesh

structure. In case of doubt in this respect and when notably such doubt concerns a swimsuit used at the occasion of a World record, an actual check of the swimsuit can be required from the competitor or Certifying Official and the swimsuit is to be forwarded to the FINA Office for submission to an actual control of all or parts of the requirements.]

8.3.3. Material selection

Swimming costumes have been around since the 1800s, but it wasn't until the end of World War II that companies began developing materials designed to increase the swimmer's speed.

At the beginning of the 20th century, most swimming costumes were made of knitted woolen materials - heavy when wet and not exactly a good look! The elite swimmers - including the 1924 British Olympic team - wore outfits made of silk, which was lighter and more comfortable but much more expensive.

Rayon - an artificial version of silk - was introduced in the 1930s, but it wasn't until the 1940s that swimwear technology really took off. Whatever they designed, manufacturers had to bear in mind the Amateur Swimming Association's rules regarding taste and decency - many of which are still in place today.

The dilemma was clear - how to create a costume that was attractive and comfortable without causing offence? The answer arrived in the 1940s and 50s, with the development of man-made fabrics like nylon. They were light, comfortable and cheap to produce.

By the 1960s, swimming was big business and top athletes were getting faster all the time. Realizing that every second counts, in 1962 the ASA commissioned a report into the issue of drag. Swimmers and their costumes create a tiny amount of friction as they move through the water, which means they don't swim with 100% efficiency. Lycra is a lightweight, flexible material used in all sorts of clothing, and nylon/Lycra garments remain the most popular choice for swimmers today.

Speedo's latest innovation - an all-in-one bodysuit designed to mimic the movement of a shark - will be worn by top stars such as Grant Hackett and Michael Phelps in Athens. Of course, modern swimming isn't just about technology. Fashion and marketing play a huge role, as Swimwear Company's battle to get the biggest stars wearing their gear.

In this period we have a lot of companies, which produce the swimwear. Is a lot of concurrency. Every of them would like make the best design and use the best materials.

One of company, which produces professional swimwear is “DIANA”. Diana creates their products using different materials according to the requirements of users, ranging from lightweight hydrodynamic materials for the swimming competition as the chlorine resistant and long stays in the water (for example during training) . Materials which they use are:

- LYCRA: The great advantages of this material are excellent resistance to chlorine, total freedom of movement thanks to its high flexibility and the presence of fiber, excellent adhesion and fit, does not lose its elasticity after long periods of intense activity.
- LINELTEX: Characteristic flexible and soft material for create sports swimsuits particularly comfortable.
- SLICK: Very light material with the highest ratio of speed in the water. Perfectly clings to the body and dries quickly.
- SENSITIVE: Material marked by Meryl Microfiber. Lightly and delicately caresses the skin for ultimate comfort and fit.
- DURABLE: Resistant to longer periods of chlorine materials, retains elasticity for a very long time and very good drying.
- Defensive: Resistant to chlorine and antibacterial materials. Easy to wear and comfortable.
- PLASMA SUPER SLICK: New series of costumes and costume for the tournament - SUBMARINE are made of a new material PLASMA SUPER SLICK. PLASMA SUPER SLICK material is subjected to a cold plasma process, which allows changing the surface properties of the waterproof and more streamlined. The process takes place in an ionized gas atmosphere, in under pressure and at ambient temperature, an electrical radio frequency. The original binding in the material are broken, and a special procedure allows to change the properties of the material arises waterproof. Material PLASMA SUPER SLICK with flat and linear structure also has a minimum thickness and of little weight, comparable to the materials used by other manufacturers. It turns out that extreme compress the material can effectively increase the tension of the material. With the tension of the material, adapted and varied depending on what part of the body that is associated with a given piece suit and smoothing the contours of the body, physical athlete can be maximized.

The next company which is worth observed is “SPEEDO”. Here was designed Fastskin FS-Pro - has been developed in the Speedo Aqualab to equip the most powerful competitive swimmers in the pool with a light dress which are on the market. Outfit is a unique combination of design, shape and materials used, is:

- ✓ LIGHTER - Fast skin FS-Pro has been designed in a very lightweight and water resistant material LZR Pulse (ongoing process his patent claim.)
- ✓ FASTER - Outfit provides reduced surface friction and passive resisted in the water drag. Unique three-dimensional design dress for optimal adhesion to the body.
- ✓ More powerful - Having 15% stronger and more compact ensures greater stability, more efficient energy flow of movement and reduced muscle twitching. These data are for the competitive high-performance costume brand.

Materials that are used for the production of Speedo swimwear are:

- Endurance +: For those who take swimming seriously. New improved Endurance + fabric are 100% chlorine resistant. Demonstrated 20-fold greater resistance to loss of color than just a swimming costume. Maximum strength.
- Sculpture: Only in Speedo. The newly developed material that "sculpts" and controls body, providing additional comfort and confidence in the water and out. It is 40 times more durable than regular Lycra. This collection provides maximum choice for all silhouettes: bust support, tummy control and adjustable straps.
- Fast skin FSII: Designed to help sweep away the competition! FASTSKIN FSII increases the speed by reducing the water resistance of up to 4% compared to other high performance costume. The evolution of the product led to the development of the ordinary Speedo Fast skin suit, introducing 'outfits called. Shark skin 'to reach for the other level, top-class swimmers choose for start in tournament Fast skin FSII around the world.

Seams on clothing FASTSKIN FSII are designed to follow the direction of the water to reduce the resistance. Used strands with increased extensibility, which offer greater comfort and freedom of movement.

The combination of materials to minimize the resistance of water - a combination Flex skin and FASTSKIN FSII adapts to the variable flow rate increases by reducing the water resistance of up to 4% compared to other high performance costume.

Costumes for individual swimming styles - FASTSKIN FSII suits are available in versions for men, women and for different swimming styles. These costumes are better suited to the body, are more comfortable and reduce water resistance.

Swimwear AQUARAPID is sewn only from original materials: Sensitive, Lycra by Du Pont, polyamide Meryl. Combination Sensitive licry by Du Pont and polyamide Meryl creates very soft and pleasant sensorial materials that perfectly adapts to the body while giving maximum comfort and freedom of movement, it does not absorb water and is characterized by high breathability, which is important especially in summer swimsuit piece.

Materials used in this company are:

- CL2RACE is a composition Licry by Du Pont and Meryl polyamide, which has an increased resistance to chlorine. This is a very flexible material that adapts beautifully to the body and does not deform.
- DEFENDER - excellent material, resistant to chlorine because it contains 47% PBT and 53% polyester. It is flexible, easy to care and protects against UV rays.
- CHALLENGE contains polyamide and elasting, and this is a woven material designed for new generation for use on swimming competitions. Its special coating is not absorbing water reduces drag in the water and to improve athletic performance. Is great silhouette providing also high degree of freedom of movement.

As seen each company manufactures swimwear with different materials. The most used materials are:

- ✓ SCALEX-used in high-performance clothing collection Hydro speed gives great compression, feel the water and resistance of soak. The material comprises a densely woven polyester fibers (82%) and Lycra fibers (18%). This composition also influences the greatest of all possible comfortable.
- ✓ Lycra - a sample material composition on the label PA 80% EA 20% (or polyamide / elastane). The composition of the material for maximum comfort and best fit (thanks to elastane fibers) - the best choice for those looking for an interesting design and occasionally swim or using costume to the championship. Durability from Lycra costume is calculated on average for 25 hours in chlorinated water, assuming that the clothes are washed in warm water after each use.
- ✓ ENDURANCE / SPEEDO ENDURANCE - material composition on the label 50% polyester / 50% PBT. Less stretchy material without elastane fibers hence required an exact match costume for size. Extremely durable resistant to chlorine provided rinsing and drying after each workout. Life calculated for 300 h in chlorinated water.
- ✓ DURABLE DIANA - material composition on the label PBT 47% / 53% polyester. Materials in many ways similar to Endurance retain life for about 300 hour’s chlorinated water. Very well suited for training.

- ✓ WATERNITY ARENA - 43% PBT / Polyester 57% - chlorine-resistant materials Arena characterized by a similar life as these two types of media competition (approximately 300 hours). Equally fast drying, soft and pleasant to the touch.
- ✓ XLA / Dura Washable - material composition on the label polyamide 75% / 25% EOL - several times more durable than lycra material, resistant to machine washing at 60 degrees C. Great fit, used by many manufacturers, both in training attire, as and for the tournament. No phenomenon characteristic of long utilized lycra "pull up" material.
- ✓ TopTexDry-component materials polypropylene/14% 86% elastane makes the materials extremely light and absorbs water. Chlorine-resistant, quick drying and very flexible. It felt like teflon materials from which are made, some clothes for championship.

Costumes for championship. - irrespective of the material by the manufacturer's recommended use caution and to a limited extent - means only during tournament. Life of much costume for the tournament does not significantly exceed the life of ordinary from Lycra costume (due to occur in the composition of the fibers of polyamide / elastane). These are special materials often feature such as Teflon coating undergoing rinsing with excessive use. Sample material composition:

- SPEEDO FASTSKIN/FSII – 75% polyester/25% elastan,
- SPEEDO FASTSKIN FS-PRO – 70% poliamid/30% elastan,
- SPEEDO AQUABLADE - 80% polyester/20% elastan,
- DIANA SUBMARINE TF - 66% poliamid/34% elastan.

8.3.4. Swimsuit prototyping

Competitive or fitness swimmers often need advice on selecting, sizing, and fitting swimwear. While appearance may not be as compelling an issue in competitive swimwear as it’s in fashion swimwear, its fit and functionality are still just as important, if not more important.

For start to create swimsuit is need choose the shape. Classic swimsuit must be comfortable and appropriate fit to the body so as to dress does not interfere in sports competition at the pool, while surfing, snorkeling or during team play in the water.

For men the most comfortable shape:

- During training is (Fig. 108, 109):

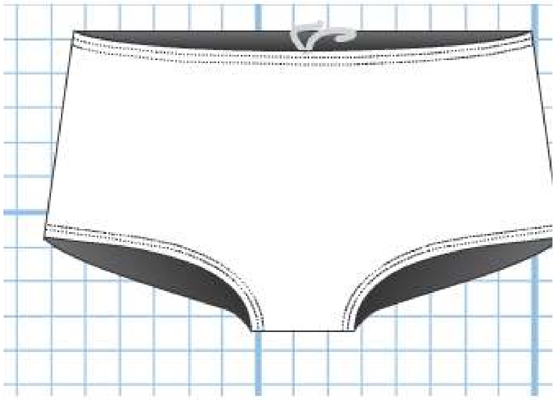


Fig. 108. Front view of swimsuit.

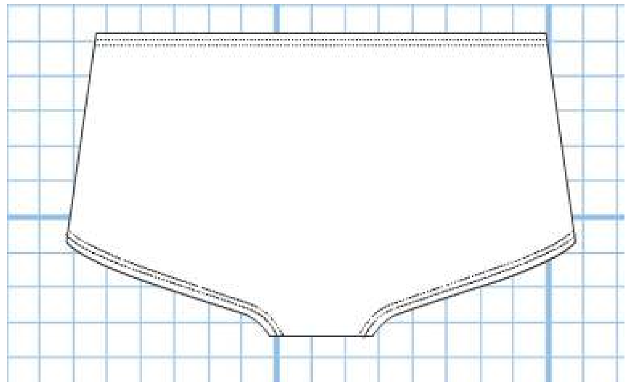


Fig. 109. Back view of swimsuit.

- During swimming competition (Fig. 110, 111):

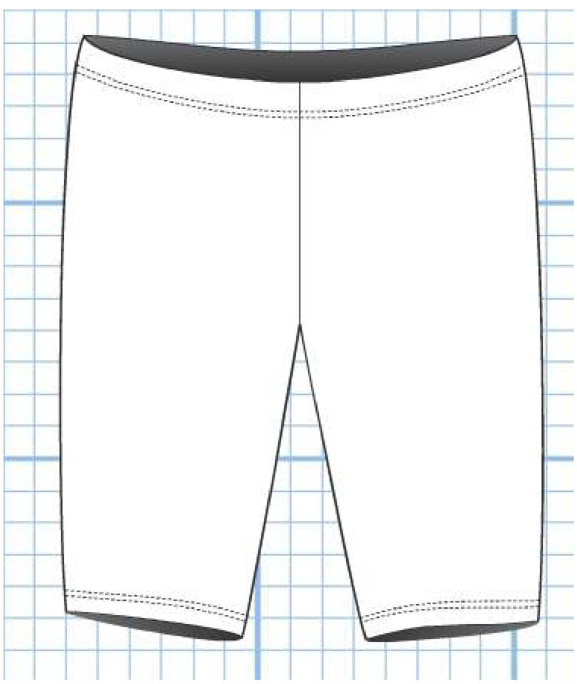


Fig. 110. Front view of swimsuit.

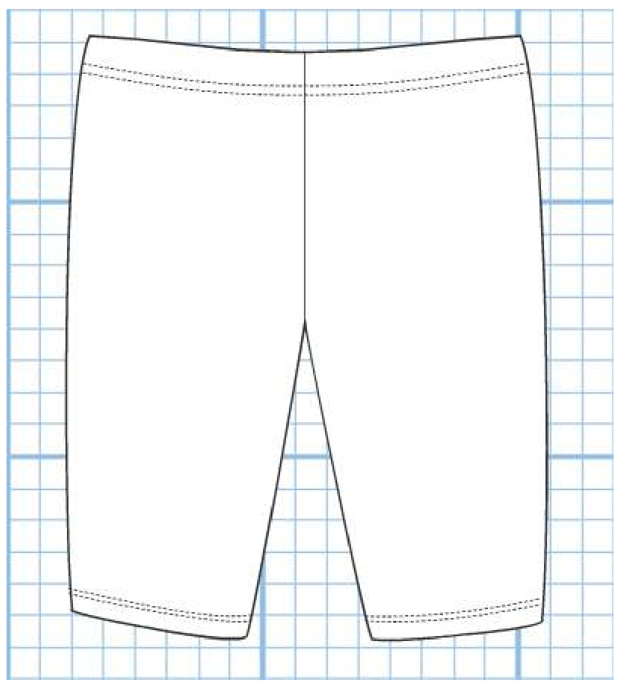


Fig. 111. Back view of swimsuit.

The color is of course optional. The cut should be well matched to the figures, but not too small - is needed to select the appropriate size. The most convenient is inserted, without unnecessary stitching and protruding parts, face out of straps, latches and similar additives, which restricts the freedom and cause too much resistance, especially during competitive swimming.

So for women the most comfortable shape:

- During training is (Fig. 112, 113):

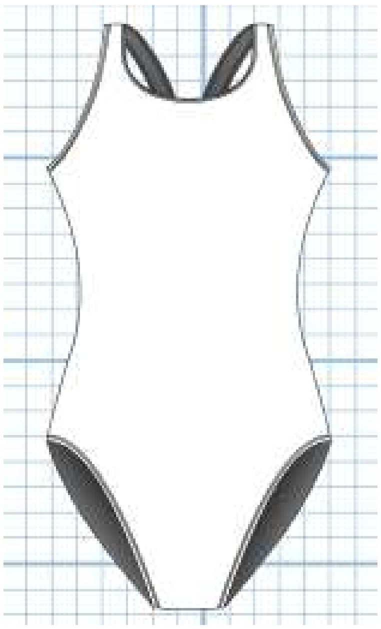


Fig. 112. Front view of swimsuit.

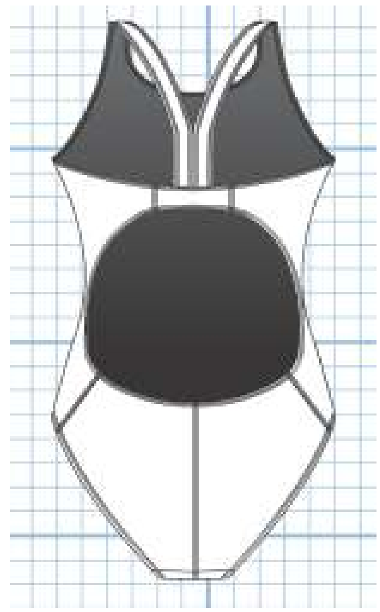


Fig. 113. Back view of swimsuit.

Suit should not crimped the swimmer (which causes an outflow of blood or block of blood in organs and veins), there may be made from random materials. Water and chlorine most often destroy the fiber.

Professional best sports swimsuit should have low moisture absorption and quick drying, and also needs to be more resistant to chlorine and various types of distortion. Worth paying attention to strength and thickness of the material - sometimes it happens that sports swimsuit shines through when the swimmer out of the water. And this may be not comfortable situation that can happen at the pool.

Taking into account all the characteristics swimsuit will be created with the material:

- 75% of polyester,
- 25% of elastin.

These proportions will increase speed of swimmer by reducing drag by up to 4% compared to other high performance costumes. Moreover, the seams of swimsuit will design as the direction of the water supply to reduce its resistance. Will be used the floss with improved stretch ability, which will offer more comfort and freedom movements.

Inside the costume, at the height of lumbar belt, will be sewn the pocket, to which will be insert the accelerometer. According to previous experiments, the selected position for the accelerometer was lumbar part, while for the sensor - right side of the lumber part of body (Fig. 114)

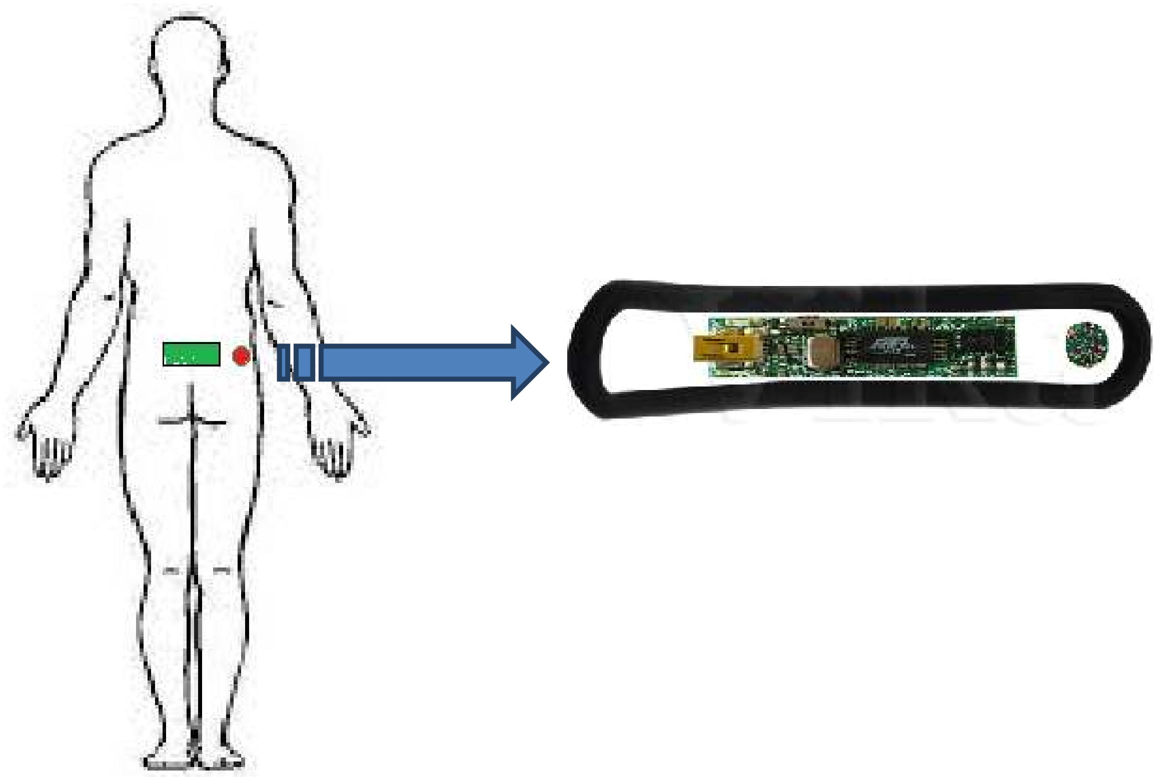


Fig. 114. Position of accelerometer and sensor.

The sensor and accelerometer will be covered by a thin, flexible plastic with three rubber buttons (Fig. 115).

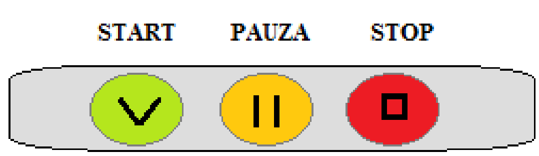


Fig. 115. The object for put inside swimsuit.

These buttons enables the swimmer of control over the device. The unit will be covered with the special water resistant pouch. Aqua pack will be soft and malleable making it even easier to operate of equipment through the material. Will has also strength tensile meaning it's even more difficult to tear or rip apart.

Special belt from elastic and thin material will be very comfortable and waterproof. The sensor includes a 3-axis inertial measurement unit that allows for ongoing and simultaneous monitoring of movement, heart rate, and respiration (Fig. 116).

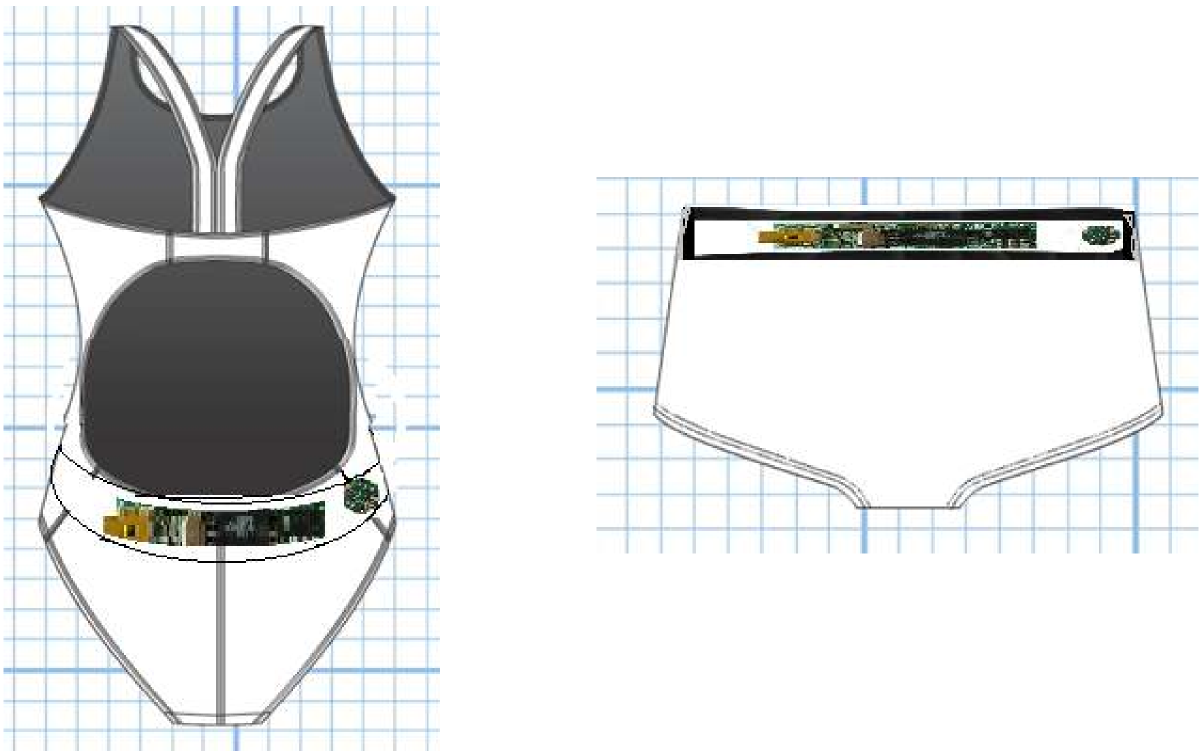


Fig. 116. Prototyping of swimsuit with accelerometer and sensors.

The final project of the swimsuit for women will be:

- For men (Fig. 117):

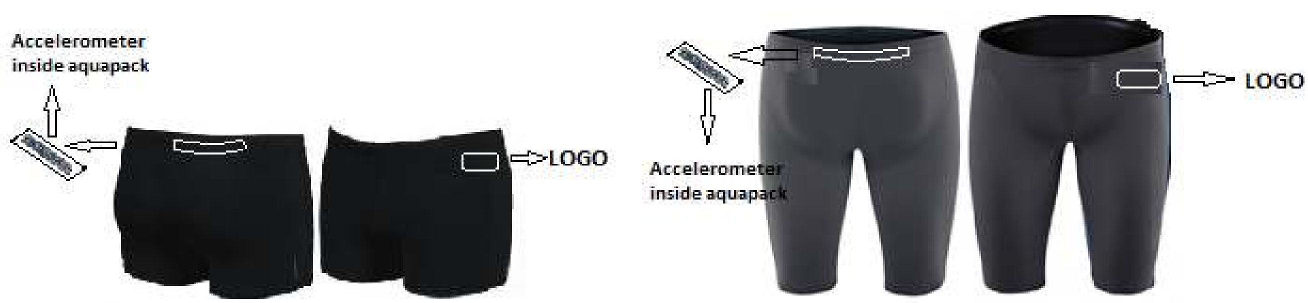


Fig. 117. The final swimsuit.

➢ For women (Fig. 118):

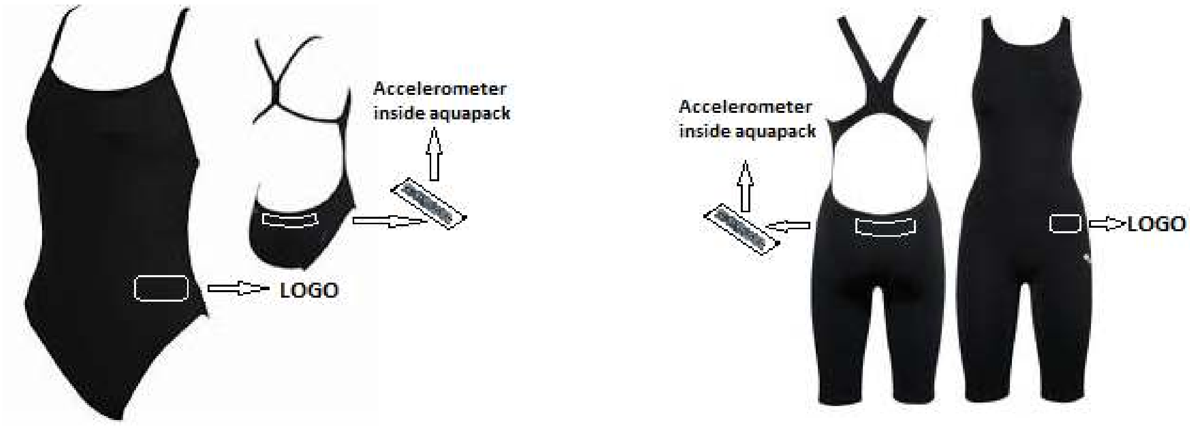


Fig. 118. The final swimsuit.

In the device will be also mounted bluetooth, thanks to which will be sent all information's to iPod or phone (Fig. 119).

Fig. 119. Example of results obtained on iPod and phone.

Part IV. Experimental validation

9. Protocols

For make the validation of swimsuit is need to try it. Before experiment was done the interview with profession coach for ask which parameters is using for measure the performance during training.

9.1. Interviews

For know the reality of needs for the swimmer athletes was carried out the interviews with a trainer of swimming.

Stefania Galdana is a competitive swimmer who competed for many years. She is a graduate degree in physical education with a focus on swimming and is currently a coach. The interview does for learn more about swimming, and in particular how is the training: the role of the coach, what is important to note that equipment is really used. His experience was fundamental to understanding many characteristic of the sport.

During the interview were asked questions:

I. Do you have experience in swim?

Yes I started practicing swimming since childhood seriously at a competitive level and I continued up to about 18 years. I decided to stop because I wanted to attend college, and if people want to seriously practice this sport cannot afford "distractions", because it is very tiring. After a workout is need only rest and sleep.

II. And now, what are you doing?

Now I am teaching. I followed the beginning team of kids between 14/15 years old. But now I am training the beginners (between 7 and 10 years).

III. How does the training?

The training is very different depending on the time of year, if you are more or less close to a big race. It depends on the swimmer of his age and his competitive level. Many factors come into play. The newcomers who I am teaching for example they train five days a week, doing a workout afternoon after school for 1 hour preceded by a half hour of gymnastics heating. On Sunday is usually the day of the races.

Later with age, training is more intensive.

In addition, the swimmer concentrates on short or long distance. Depending on your specialty you will have a different workout. In training on the distance occurs mainly in water in endurance while training on the short distance also provides many training sessions with tools to strengthen your muscles. At very high levels training includes afternoon session and morning.

IV. But a swimmer cannot be good in both the short and long distance?

It is difficult. Typically, a swimmer going strong in 50/100 meters not goes just as well in the 200/400 meters. The characteristics of the swim are different. In the first case it develops the power and strength, in the second case the resistance and the organization of their energies.

V. You said before that the training also changes depending on the time of year.

Yes, there are two greatest periods. The first runs from September to March, and the second from March to August. Each of these is later divided into micro cycles dedicated to the construction or enhancement, but it is a very specific thing.

VI. So at the practical level, what is the task of the coach?

The coach must first organize training sessions, which pools do, how to do them, predict the correct exercises to improve a given parameter. Later the coach is essential during the actual training to correct a swimmer's stroke.

VII. Do you have problem with identification the wrong movements, since the body is underwater?

It depends. I have to keep moving to follow every single person and watch at every point of view. This is very important because in sports in swimming, in particular, make a move in one way rather than another change much performance. I have to observe each swimmer individually can become a problem when you have to follow twenty athletes. This is clearly not happening at high levels, where the individual coach follows five or six.

VIII. And how to talk to the athlete?

We try eye contact or communicate by gestures or screaming. If necessary it comes to the tank bottom. The athlete should look sometimes the coach.

IX. Which parameters are important to detect the swimmer? Means, what makes a better swimmer than another?

The most important parameter is a parameter that cannot be measured. We say that is the way in which the swimmer feels the water. This sensitivity results with particular movements that reproduces the swimmer to move in the water, for example the angles with which the arm comes into water to produce the thrust, but is not so simple. It is not something that can teach: the aquatics are something that you have or not, or still you can learn by spending a lot of time in the water from the child. However, other important parameters are definitely the speed, heart rate and strokes per pool. In particular, the strokes for pool are very important. Less is the number of arm stroke, less will be the energetic consumption.

X. How are measured these parameters?

The speeds and strokes are measured with stopwatches to the frequency that permits to have different options. To measure the strokes in time, generally you count the strokes that are carried out over a 3 or 6 seconds. The heart rate is measured manually by hand from the wrist or jugular.

XI. You don't use specific instruments to measure the pulse?

You can make test out of the water, but aren't very useful. The important thing is to know your heart rate while you are in the pool. The heart belt you can use, but are little time used: are uncomfortable. If you ask the swimmer to wear it he does it's just an issue of discomforts, the performance do not change. At very high levels lactate is taken for the unit of time, which has information on the effort of the muscles and you can get the heartbeat. During the Olympics sometimes you see that the swimmer just out of the bath is done viewing on lactate. It is simply, a very small blood test.

XII. Why is it so important to know the heart rate?

The frequency you can understand the range of metabolic training. In other words you know if you're increasing muscle mass or if you're getting better endurance athlete. For example, I know that if I want to increase the strength, the pulse of the swimmer must be on the 140, and must not exceed 150. If the pulses are not in the desired range for the training session, I do the more challenging exercises or milder to get to the right value.

XIII. There are other instruments that are used to detect the parameters?

If you need to observe very well the movements are used the camera underwater, but you cannot do in public swimming pools. The images are projected onto a screen in real time or more are often used by the coach at the end of the workout.

XIV. With respect to training, how are the performances in the race?

Are generally better. This is especially thanks to swimwear. Those for the training swimwear are "normal", while during race are more rigid and do a compression on the body. This brings the swimmer to make movements more rigid, clean and quickly allowing an increased speed.

XV. So why are not used the swimwear from the race during training?

For the fact that if were used always the body get abituation to this "rigidity", and will not be this benefits that athletes have during race.

XVI. Must be follow the rules for swimwear during the race?

Yes and are very important. The rules are issued by FINA Yes must be followed strictly. After the 2008 Olympics, for men the swimwear must be in bib shorts and may not exceed the knee. For women, the costume must be a whole with the trouser leg that goes up to the knee, the back should remain discovery.

After this interview we know perfect what is need for the athletes and coaches so is does the experiment with use the SWIMSFIT for see if work good.

9.2. Experiments

For see how work the SWIMSUIT was done the experiment in swimming pool. The experiment was attended by five amateur people that know swim and five agonistic swimmers.

Each participant in the experiment had to swim two times along the 25 meter of swimming pool, with three styles – the choose sequence was freestyle, back stroke and breast stroke.

A wearable device on the central axis of the body in the lumbar region of the back (Fig. 120).

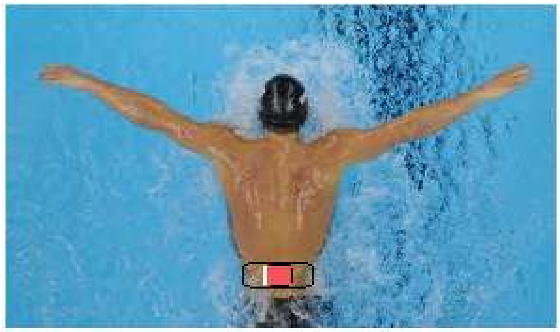


Fig. 120. Swimmer during experiment.

Simultaneously an external observer video recorded the sport task. A synchronizing event (a 5 – hit on the device or a five jump while stopping on the pool side) was used to have a time stamp both in the wearable monitoring data and video images. This the two data set could be compared for validations.

Collected data were analyzed to assess the effectiveness of the prototype system. We developed a swimsuit in Matlab, to compare the times and number of events [arm stroke; foot stroke (if go possible start & stop); start] stop from the acceleration data.

We also adopted the Advene environment that is an open – source platform for importing and compering data from different sources and of different kinds (Fig. 121).

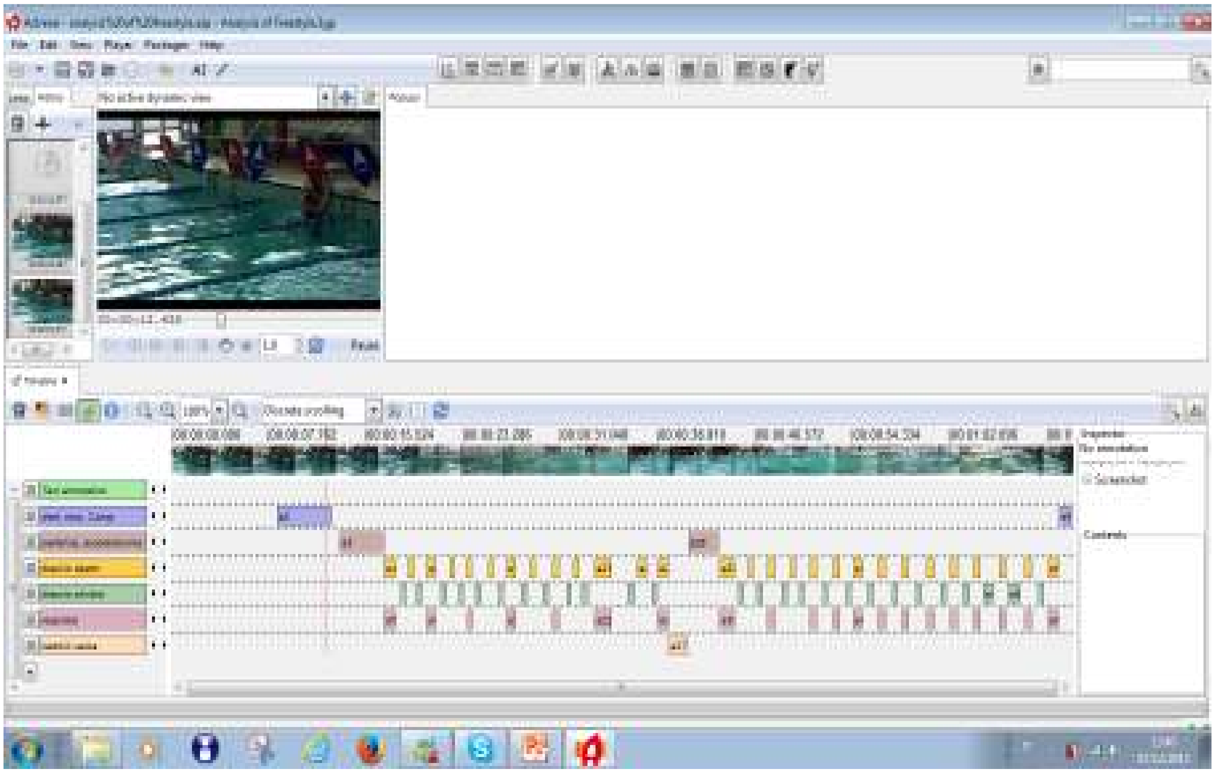


Fig. 121. Example of validation data.

9.3. Result

In this study we confirmed our hypothesis that inertial sensors can be used for automatic temporal phase detection during swimming. Thanks to jumps before and after swim we could see the velocity of swimmer. Comparing the data received from the accelerometer and the film, time, speed and distance of swimmer are in line.

After the application data from accelerometer to Advance we could see which type of pick corresponds to movement during swim. The larger peaks indicate arm stroke while the smaller ones indicate the movement of legs. In the high-level performance generally should do six kicks per cycle of strokes: this parameter is linked to the proper coordination arms-legs could be easily detected by the accelerometer.

In the case of freestyle strokes are clearly visible, represented by the peaks of the curve for lateral acceleration. According to the distance between a peak and the other is then possible to derive the time that elapses between a stroke and the other and managed to detect parameters such as the efficiency of the arm stroke.

Detect the movement of the legs, however, are clearly visible in the same curve of arm strokes: the peaks are smaller dimension.

The arm and foot strokes in breast stroke are recognized very well, are clearly visible, which expresses the antero-posterior acceleration. Conversely, the movement of arms and feet is not detected properly. The frog, together with the dolphin, is a style where the displacement is very sensitive on the vertical axis of the body, however in the graphs the vertical acceleration, is not particularly sensitive: it is an important parameter because on the one hand indicates how the swimmer out of the water during respiration, on the other hand is an index from which you can understand the degree of coordination of the style.

The style back stroke is detected well of lateral accelerations, in which the peaks indicate the largest stroke, while the smaller ones indicate the reciprocating movement of the legs. In the high-level performance generally should do six per cycle of strokes: this parameter is linked to the proper coordination arms-legs could be easily detected by the accelerometer.

The analysis results demonstrate that determining turn events and swimming styles with an accelerometer sensor is possible with high accuracy. This was shown for a cross-validated swimming set and confirmed with a disjoint test set for the three main swimming styles.

A lot of author use accelerometer for research on swim. For example Andy Stamma and all. [137] used the sensor taped to the swimmer’s lower back (Fig. 122).

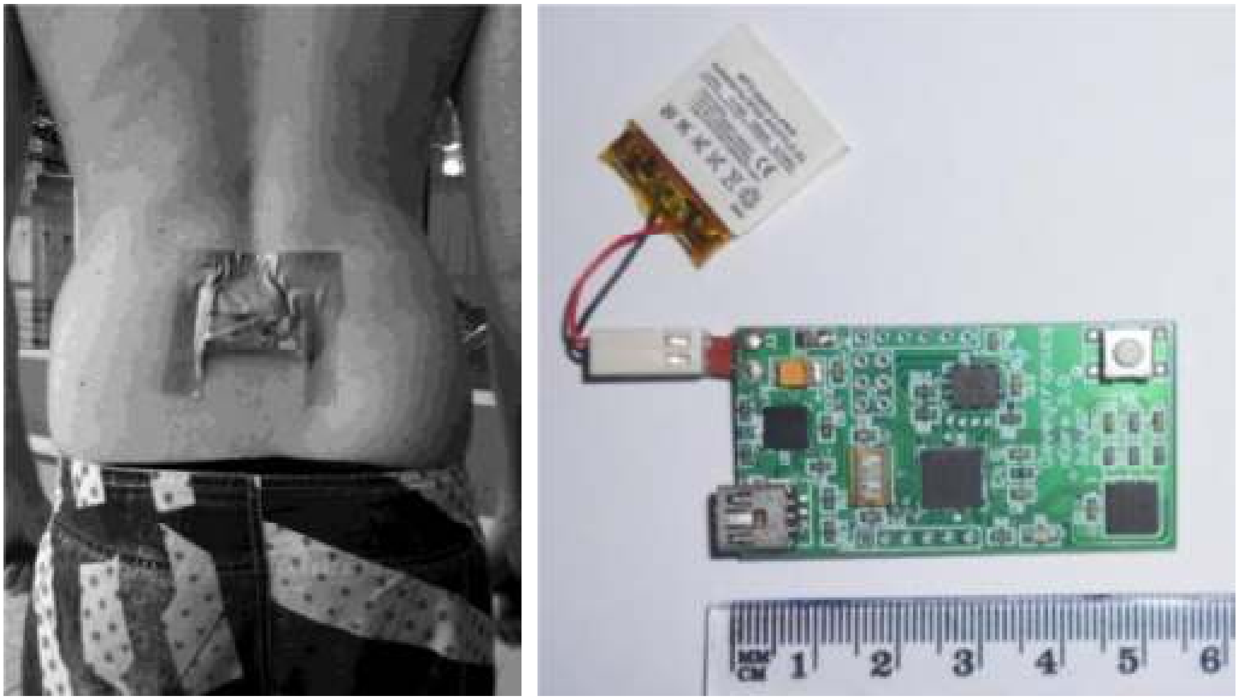


Fig. 122. Taped accelerometer unit at the lower back of the swimmer. The coordinate system shows that the swimmer gliding in the y direction.

Objective of this study was to compare accelerometer derived push-off velocities to a reference measure. As video systems usually capture the video footage with 25 frames per second, the authors decided to use the velocity meter as a reference system as it provides a higher sampling rate and therefore a more precise detection of the maximum push-off velocity.

Seven male swimmers participated in this research. The swimmers were asked to use their feet to push-off, and once in the glide position, to remain in the same relative body position until out of breath or no longer moving forward. Every swimmer performed 12 subsurface wall push-offs at three different effort levels (slow, medium and fast). Due to technical difficulties with two consecutive push-offs, the total number of push-offs (n=84) were reduced by two (n=82).

Regression analysis was used to find the correlation between the maximum sensor velocity and the maximum SP5000 velocity for each individual subject and for the whole data set (Fig. 123).

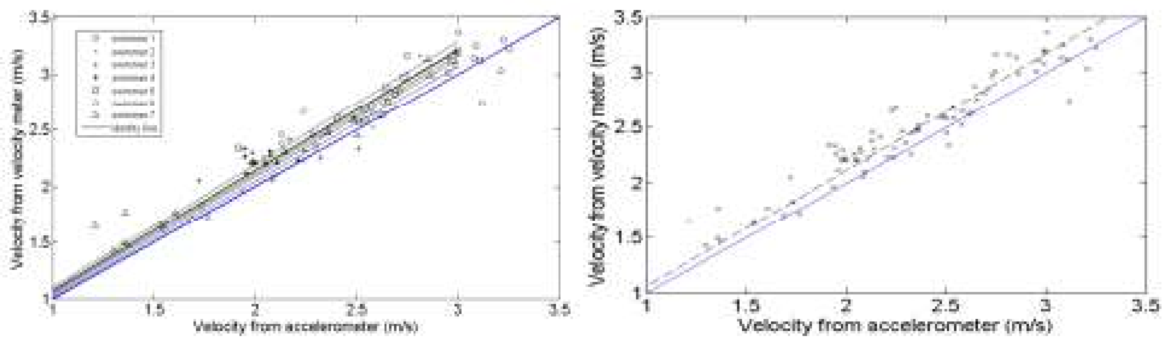


Fig. 123. Results of the regression analysis of Speed Probe 5000 (SP5000) vs. sensor derived velocity of each swimmer individually and all push-offs (n=82) as one data set (r = 0.94, p<0.0001).

As both technologies measure the same parameter, the point (0,0) was included as a data point for each individual swimmers data set. The linear relationship between the measured SP5000 and calculated sensor velocities for all push-offs (n=82) is very strong (r=0.94, p<0.0001), furthermore the average push off velocity ± standard deviation was 2.46 ± 0.50 m/s and 2.31 ± 0.52 m/s for the SP5000 and sensor velocity respectively. The average calculated sensor velocity was therefore 93.1% of the measured SP5000 velocity.

The study was to validate the use of a lower back mounted inertial sensor for the determination of push-off velocities. This method was compared with a velocity meter derived velocity (criterion measure). Nearly perfect correlations (r = 0.94), a slightly lower bias (-0.15) and a low error of estimate (0.15) show that a single inertial sensor is a valid method of measuring a swimmers push-off velocity. Other research has shown that inertial sensors are capable of measuring velocity characteristics [138] and detect stroke phases [139]. This is the first study to our knowledge which has used inertial sensors to calculate push-off velocity. The use of filtered total acceleration data were sufficient to eliminate the change in the tilt of the accelerometer units at the lower back and to reduce the error level allowing an accurate determination of the velocity as a function of time. The maximum push-off velocity can be calculated from acceleration data acquired from the lower back alone.

Yuji OHGI [140] uses the MEMS sensor application for the motion analysis in sport sciences. Three dimensional motion analysis methods [141] has been a major approach to observe a swimmer's underwater stroke motion [142, 143].

The author proposed a new method, which provides us the swimmer's stroke kinematics using their wrist acceleration and the angular velocity by the inertia sensors. The author developed a tri-axial accelerometer data logger (Prototype I) and a tri-axial accelerometer with tri-axial gyroscope data logger (Prototype II) (Tab. 15).

Tab. 15. Specification of the inertia sensor data logger for the swimming stroke analysis.

	Prototype I	Prototype II
Dimension	88 x 21 mm	141.8 x 23.2 mm
Weight	50 g	78 g
Accelerometer	2 x ADXL 210	2 x ADXL 210
Gyroscope	-	3 x ENC -03J
Processor	PICI7LC44	PICI7LC44
A/D	MAXI 147 (12 bit)	MAXI 147 (12 bit)
Sampling rate	128 Hz	128 Hz
Memory	32 Mbit	128 Mbit
Battery	CR1/3N	CR2
Measurement duration	1.45 h	2.9 h

The accelerometer was located on the left hand. In order to examine the sports skill of the athletes, the author has focused on the kinematical data such as the tri-axial accelerations or angular velocities measured by the inertia sensors attached on their body segments or the equipment. The inertia sensor data, which is measured from the critical location on subject's extremities, is sufficient that we can evaluate his sports skill.

Those inertia sensor devices were in practical use already. For example, pedometer within MEMS accelerometer is manufactured recently.

In research of Andy Stamm et all. [137] was used portable inertial sensor platform to investigate the movement of swimmers and was set to record data at 100 Hz. The experiment was undertaken in an indoor pool with the sensor attached to the swimmer's sacrum, a velocity meter (Speed Probe 5000 – SP5000) attached to the swimmers suit with a video camera capturing the swimmer over the whole lap.

The SP5000 measures the velocity directly and provides a synchronized video with the gathered velocity data. This system was used as main reference as it is already proven as a robust method and provides data files which can be directly imported into Matlab. The swimmer was asked to push-off with both feet against the wall and perform one freestyle stroke lap, which was repeated at different speeds. The timing parameters of the lap (i.e. start time, end time, stroke frequency) can be identified from the acceleration data. The acceleration data was then passed through a 0.5 Hz low pass filter to gain the sensor orientation, which was then removed for further processing. The velocity profile was calculated using the acceleration in swimming direction (ay) and the total acceleration (atot). The mean velocity from the SP5000 was 0.964 ± 0.086 m/s whereby the mean velocity derived from the accelerometer was 1.331 ± 0.207 m/s and 0.944 ± 0.119 m/s for ay and atot respectively.

This research has shown that velocity information can be derived from acceleration data.

A lot of people use the accelerometer for research on swimming. How we know the measurement inside the water is the most difficult. Accelerometer is a small product, which is more easy for put in water proof and do research. In a lot of articles we can see that data obtained from 3-axis accelerometer gives good results.

Put the accelerometer on the part of body can disturb to swim, is inconvenient. Isn't also in good contact with skin. For this reason this work was carried out to create the most comfortable swimsuit with sensors inside so as not to disrupt the swim, for have every biomechanical parameters in real conditions.

Part V. Conclusion

10. Discussion and conclusion

Analyzing the swimming like worldwide, practiced sport is a relevant for personal and social health (active life style means prevention). In this thesis we found wearable technology as the actual spreading item. We developed a system for swimmers to explore technology performance in personal monitoring and its acceptance by users through high usability and comfort, or better, in a single word, ergonomics. The results show both these achievements.

The project is aimed at swimmers athletes and their coaches. The system is applied to a swim team, it would allow a great simplification of the work of the coach allowing him to keep an eye on all team members simultaneously and in real time from your tablet, PC or smatphone.

The device is able to automatically detect many of the parameters that are currently manually taken for each athlete. Can also do a complete layout of the entire workout for all tanks identifying the style, speed, timing, the efficiency of strokes, lateral movement and heart rate for all swimmers at the same time, putting the various parameters in relation to those of the previous training session or with the best results.

The exercise sessions can be analyzed in more depth post-workout, identifying possible problems, thus allowing to study the best strategy for the next training session or exercise specifically to improve the shortcomings of a single athlete. The data can be sent to colleagues or the swimmer in the same way that they can understand how to improve their performance.

This view is very far from the current situation in which new technologies are struggling to make their entry into the sport because of the many problems caused by water. For this reason, the coach is able to observe and measure the parameters of a swimmer at a time, creating problems, especially if people need to follow many athletes.

Swimsuit, may be adopted as a means of training as well as recreational swimmers or who don't have a coach. In this case, as it is set to the product, the swimmer may only have a feedback post exercise, transporting the collected data from the device to a computer.

The product could be implemented in order to better fit even for this category of swimmers, developing a computer wristwatch worn by the athlete (like a clock), where they are sent in real-time data collection. Could be more innovative application development for smart-watch, products that are starting to make their entry into the market, which can receive and process the data provided by this project.

To avoid interrupting a workout to watch wristwatch, the product may be combined with a wireless headset that communicates directly to the swimmer its real-time performance, or suggestions on how to improve.

This research started from personal skills to create a connection between sport and design. I finished the Physical Education University and I started the PhD program in Biomechanics of Sport (mechanics of movement during sports). In second year of my study I changed University and specialization for Design Industrial for find a technical system use-full for sport, rehabilitation and day use.

For the future development technological is need to transfer this project to industry and wider pilot tests.

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