MINISTRY OF EDUCATION
"BABEȘ-BOLYAI" UNIVERSITY CLUJ - NAPOCA
FACULTY OF PHYSICAL EDUCATION AND SPORT
DOCTORAL SCHOOL

Andrei Bitang

DOCTORAL THESIS

SUMMARY

Scientific leader
Prof. Univ. Dr. Habil. Grosu Emilia Florina

2024

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Optimize strategies for perfecting turns in technical swimming strokes

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Thank you page

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List of publications

1. A. Bitang, V. Bitang, V. Grosu, A. Ciorsac and A. Isvoran, Admet profiles of selected anabolic steroid derivatives, (2024), Journal of the Serbian Chemical Society, ISSN 2683-3867/2024, vol. 89, doi.org/10.2298/JSC23030803086B, https://www.shd-pub.org.rs/index.php/JSCS/index

2. Karol Görner, Ryszard Makarowski, Radu Predoiu, Andrzej Piotrowski, Alexandra Predoiu, Maurizio Bertollo, Selenia Di Fronso, Romualdas Malinauskas, Zermena Vazne, Doina Croitoru, Ole Boe, Andrei Bitang, Dumitru Barbu, Márta Miklósi, Klára Kovács, Néstor Vicente-Salar, Stress levels among winter swimmers, firefighters, martial arts athletes in Hungary, Italy, Latvia, Lithuania, Poland, Romania, Slovakia and Spain, (2023), ARCHIVES OF BUDO, 2023, Volume 19, pag 213-225, e-ISSN: 1643-8698, WOS Number:001135693100001, IDS Number DY6O1, https://archbudo.com/view/abstract/id/16389

3. Patenteu Ionut, Roman Gawrych, Mircea Bratu, Luciela Vasile, Ryszard Makarowski, Andrei Bitang, Sarah A. Nica, (2024), The role of psychological resilience and aggression in injury prevention among martial arts athletes, Frontiers in Psychology, Sec. Sport Psychology, Volume 15-2024,doi:10.3389/fpsyg.2024.1433835

4. Andrei Bitang, Vlad Teodor Grosu, Emilia Florina Grosu, Rodica Lucian, Pop Rares Mihai, Zadic Alexandru, Rozsnyai Radu Adrian, Viorel Bitang, (2023), The importance of joint mobility in learning to swim in 8-10 year olds, The 9th International Conference of Universitaria Consortium "FEFSTIM: Physical Education, Sports and Kinesiotherapy - Active People for a Healthy Future", Filodiritto Editore - Proceedings, pag. 66-73, ISBN 979-12-12-80225-75-7 DOI 10.26352/HX19-FEFSTIM2023, https://fefstim.uvt.ro/wp-content/uploads/2023

5. Andrei Bitang, Vlad Teodor Grosu, Corina Dulceanu, Viorel Petru Ardelean, Gyongyi Osser, (2023), Learning the technical elements of swimming in 5-7-year-old children, using leisure games, Designing for digital ellbeing, Peter Lang, Vol VII, chapter 13, pag 160-172, ISSN 978-3-631-89086-0, https://www.peterlang.com/document/1326422

6. Andrei Bitang, Viorel Bitang, Vasile Liviu Andrei, Corina Dulceanu, Roberto Gabriel Marconi, (2022), Joint mobility - essential motor skills in the correct acquisition of swimming technique in children aged 8-11. In book: Applied Research in Digital Welbeing-Implication for Psychological Research, 3rd edition, Designing for digital ellbeing, Peter Lang Publishing House, Berlin, ISSN 978-3-631-87105-8, https://www.peterlang.com/document/1326422

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Contents

Keywords: swimming, turns, explosive power, measurements, analysis, results, performance

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List of abbreviations:

ATP - adenosine triphosphate

FD- braking force

CD-coefficient of braking

P- liquid density

A-front air exposed to the flow

V-the speed of the body relative to the water

% - percent;

m - meters;

kg - kilograms;

m/s - meters per second

IMU - inertial measurement units

ISEA - International Sports Engineering Association Conference

Total Gym GTS GTS - complex workout machine

FMx - maximum force

FD- braking force

Hz - Hertz;

CD-coefficient of braking

DNA - deoxyribonucleic acid

FL - front left

FR - front right

BL - back left

BR - back right

COP - center of pressure

INTRODUCTION AND ARGUMENTATION OF THE TOPIC

Getting started

The improvement of the start and turns in technical swimming strokes also plays a very important role in the real improvement of swimming performance. By using land-based physical training means to improve the explosive force of the lower limbs and to determine in real time the evolution of the efficiency of the turns in technical swimming strokes, we will be able to obtain very good results in increasing the efficiency of the turns in technical swimming strokes, leading to superior performance.

Purpose and motivation for choosing the theme

Nowadays, achieving high-value sporting results cannot be achieved without streamlining the entire training process, respecting clearly defined requirements for each level of training.

In this context, this paper aims to bring improvements in the training of swimmers in our country, taking into account both the outstanding results obtained and the latest developments in international swimming.

The reason *that* led me to address this topic is the importance of swimming technique turns as a key factor in achieving superior performance in performance and high performance swimming in all events. Turn timing in these techniques is particularly important in achieving these performances.

Setting the theme in the context of scientific research

In the following I will refer to a few articles whose authors have made in-depth studies/research on the importance of improving the turns in technical swimming procedures:

- In the paper "Development of a pressure sensor for swimming turns", authors James Webster, Paul P. Conway, M. Cain, from the Institute of Sports Technology, Loughborough University, UK. Paper presented at the 5th Asia-Pacific Congress in Sports Technology (APCST), organized by the Sports Technology Institute, Loughborough University, Loughborough, their studies showed that turns were found to contribute 21% of the total stroke time in the 200m freestyle event, where a mere 1% increase in performance would have won the gold medal for the swimmer who finished third in the 200m freestyle Olympic final in London.

- In the paper "Image processing algorithms to extract swimming tumble turn signatures in real-time", N.Chakravorti, S. Slawson, J. Cossor, P. Conway, paper presented at the 9th Conference of the International Sports Engineering Association (ISEA), Procedia Engineering 34, pp 586 - 591.

In this paper, the authors (also from Loughborough University, UK) highlight the importance of swimmers' turning technique îto improve swimmers' performance. In the experiment, the authors used the analysis of video images recorded during the phases of the turns (attacking the wall, the actual turn, pushing off the pool wall and the underwater pathway traveled by the swimmer up to 15m, which is the maximum distance a swimmer can swim underwater according to the rules) to determine the causes that may hinder or improve swimmers' performance.

Sensors were used to measure the pushing force from the pool wall to measure the pressure exerted. LED markers were also used to track the motion of the swimmer during the turn. The use of the system was found to significantly improve the efficiency of the analysis process.

Thus, I consider that the choice of the topic "Optimization of strategies for the improvement of turns in technical swimming procedures" is extremely relevant, especially considering that in the local literature this issue has been addressed only in general terms.

Topicality of the topic

The topic addressed in this paper is a topical one in view of the numerous studies that have been carried out by researchers around the world and to obtain ways to improve sports performance in swimming events. The studies conducted by them showed that turns were found to contribute about 21% of the total stroke time in the 200m freestyle event.

In order to contribute to the improvement of the sport performances of Romanian swimmers, it is necessary to improve the pushing force from the pool wall during the turns in the technical swimming procedures, the technique of the turns as well as the development of the dominant motor skills involved in their realization with higher execution indexes, with special emphasis on the force (explosive, maximum). Improving these will lead to the increase of the performances that the swimmers will obtain in the events of the respective swimming procedures.

What's new

This paper aims to highlight a number of novel elements compared to the current information in the literature.

The first novelty is that we have created an original system for measuring the explosive force of the lower limbs pushing off the pool wall to improve performance in swimming events.

Secondly, with this system it will be possible to determine the causes that can hinder or improve swimmers' performance.

Thirdly this system can provide the possibility of analyzing the movements performed by the swimmers during the turns, which would lead to finding solutions on how to improve the technique of turns as well as determining (measuring) the pushing force from the pool wall as well as the speed at which the swimmers move after the turn.

PART I

THEORETICAL-SCIENTIFIC FOUNDATION OF THE PAPER

CHAPTER I.

TECHNICAL BASICS OF SWIMMING IN THE CRAUL PROCESS

1.1. Turns in the crawl swimming process

According to the course developed by Hahn (1991), a turn is a change in the direction of travel. In their desire to achieve outstanding performance, great swimmers have contributed over the years to perfect this technical element (Maglischo, 2003; Lynn, 2008).

Currently, several types of turns are known, varying in complexity, including the simple flip and the tumbling flip (Mcleod I., 2010). In practice, the tumbling flip is predominantly used, which resembles in structure a tumble on a gym mat. In certain events, depending on the length of the pool (25m or 50m), several lengths have to be covered, which involves changing swimming direction once or several times at an angle of 180°. A technically correct turn ensures minimal reduction in swimming speed. (Dick H., Nort, 2001) Regardless of the swimming stroke, the phases of the 1.1. (Day, Y., Lin, 1996), (MacKenzie, Cordoza, 2013) turn are as follows (Figure 1): attacking the wall, the actual turn, pushing off the wall and sliding, working underwater and surfacing, and continuing swimming in the stroke.

Figure no. 1 - Returning to the backstroke procedure
www. swimmingcoach.org

CHAPTER II
MOTOR QUALITY STRENGTH

2.1. Definition of driving quality force

Definition. The literature presents a number of definitions that do not differ essentially from each other: Force is the ability of an organism to overcome or resist external forces through muscular activity (Bompa, 2015); muscle force is the ability of a group of muscles to exert maximal tension against resistance in a single contraction (Robergs, Scott, 2000); force is the ability to generate maximal muscle tension under specific defined conditions (Zatsiorsky, 2002); force is the ability of a muscle to generate maximal tension during a single voluntary contraction (Baechle, 2012).

2.2. Forms of force

The authors who have studied this motor quality, according to their professional background - physiologists such as Fry (2001), Zatsiorsky (2006), Bota and Prodescu (1997) or specialists in physical education and sports methodology such as Zatsiorsky (2002), Bompa (2015), Cârstea (1993) - present various classification criteria, such as:

Depending on the muscle mass involved, strength can be classified as follows:

- General strength: developed by contracting the entire skeletal musculature.
- Local strength: refers to the strength of a single muscle or a group of muscles.

Depending on the activity performed, force can be categorized as follows:

- General strength: demanded by an individual's daily activities.
- Specific strength: developed through specific motor actions for a particular type of activity.

Depending on the mechanical work performed:

According to the mechanical work performed, force can be classified as follows: dynamic force, which occurs when muscle contraction produces mechanical work, representing the expression of force during the execution of a movement. It is subdivided into maximal force, which is the greatest force developed by the neuromuscular system during a muscle contraction, force-speed, which is the ability of the neuromuscular system to overcome resistance with the greatest possible speed of contraction, and dynamic force-resistance, which is the ability of the muscle to resist fatigue in long-term efforts.

Depending on the changes that occur in the muscle fibers during contraction, force can be classified as isometric (static) force, where the muscle does not change its length; plyometric (yielding) force, which involves increasing the length of the muscle fibers; and myometric (overcoming) force, which involves shortening the overall length of the muscle fibers.

Depending on the combination with other motor qualities (Figure 28), force is classified into force in the speed regime (explosive force), force in the resistance regime and force in the coordinative capacity regime.

2.3. Factors conditioning the force

The motor quality of strength is influenced by several factors, which can be grouped into three main categories: central factors, peripheral factors and psychological factors. Central factors include the focusing ability of essential nervous processes, the ability of muscle coordination (both intramuscular and intermuscular) and the level of muscle tone.

Peripheral factors include the diameter of the muscle involved in the contraction, the length of the muscle and the angle between the segments, the volume of the muscle (determined by its diameter and length), the structure of the muscle (the presence of fast-phase fibers that favor the development of force) and the energy reserves (ATP and phosphocreatine levels). The psychological factors that influence strength are motivation, emotional states, the ability to concentrate attention and willpower, including tenacity and perseverance.

2.4. Make them force

Bompa T.O. divides the methods of muscle strength development according to its periodization into five phases: the anatomical adaptation phase, the muscular hypertrophy phase, the phase of achieving maximum strength, the phase of conversion to strength and the phase of conversion to muscular endurance (Bompa, 2001).

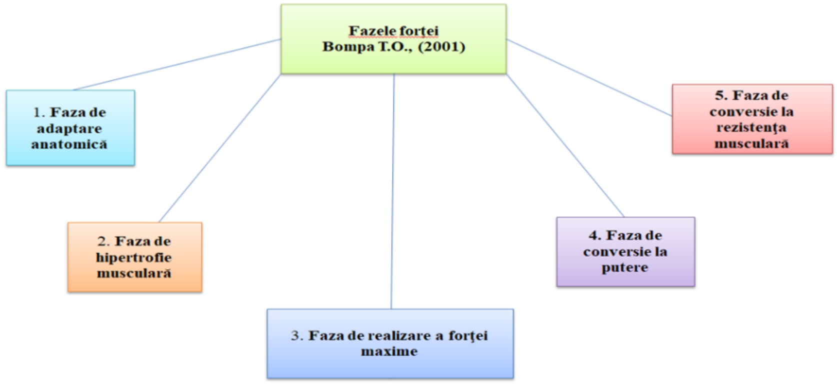


Figure 2 - Phases of force (after Bompa, 2001)

2.5. The role of force in swimming

The force acts on the water and the water in turn exerts an equal and opposite force on the body, called the braking force or drag. As the athlete moves through the water, forward resistance slows the sliding motion. Athletes must develop sufficient force to maintain speed and greater force to increase speed as they overcome the braking force.

According to Hay (1993), cited by Bompa and Carrera (2006), the braking force (drag) FdF_dFd acting on a body moving through water is calculated with Eq:

$$FD = \frac{CD \cdot P \cdot A \cdot V^2}{2}$$

waves:

- Fd - is the braking force
- CD - is the braking coefficient
- P - is the density of water
- A - frontal area exposed to the flux
- V - is the speed of the body through water.

CHAPTER III
THEORETICAL-METHODOLOGICAL ASPECTS OF FORCE DEVELOPMENT

3.1. Swimming strength training

Various methods have been used to improve muscle strength in swimmers, including isometric, isotonic, isokinetic and variable-load exercises. Isometrics is a form of resistance training in which the muscles oppose resistance by contraction, without displacement of body segments. Recent research suggests that isometric exercises may increase strength to some extent, but there is some doubt about the strength improvement (Maglischo, 1993).

Exercises for swimmers should target the main muscle groups involved in propulsion in the water, including the pectoralis, latissimus dorsi, rhomboid, trapezius, back muscles and anterior deltoid of the shoulders. In arm traction, the biceps, brachialis, brahioradialis, supinator of the upper arm and forearm for the inner S, and the middle and posterior deltoid for the outer S, under the body, are involved. In arm extension, the muscles involved are the triceps and the acone. Leg movement involves the calf extensor and flexor muscles, the thigh extensor and, for breaststroke swimmers, the adductor muscles of the legs. During starts and turns, the calf, thigh and ankle extensors are involved. Stabilization of the body during the pulling movement is provided by the abdominal muscles, the internal and external obliques, and the lower back muscles (Maglischo, 1993).

(Maglischo, 1993) proposes certain strength exercises for muscles, considered to be some of the best.

3.2. Defining the concept of power

Power is defined as "the rate at which muscles can produce force" (Enoka, 2002). It can also be considered the degree of force production, being the product of force and velocity (P = F x V), (Cronin and Sleivert, 2005), or the amount of work performed per unit time. Power is essential for any athlete who wants to be agile and fast. It is a function of maximal force (Bompa, 2001), so a high level of maximal force leads to an increase in power, resulting in a high level of speed, quickness and agility.

3.3. Power training

The peak of power produced by a muscle is directly dependent on the gains made in maximal force (Fitts and Widrick, 1996). Increases in power lead to increases in maximal velocity, and speed, agility and quickness cannot be improved without prior maximal strength training and its conversion to power. The conversion to power and the application of sport-specific training have been addressed in the context of periodization methods of strength development (Bompa, 2001).

Power training in swimming refers to the intensity of work in the water, influencing the frequency and force of pull. Traction power is calculated by assessing the length of a stroke, improving it and keeping the frequency constant contributes to increased sprint speed. Stroke length is the distance traveled by the swimmer's body in one stroke cycle (Maglischo, 1993). The relationship between frequency and stroke length is negative: increasing frequency leads to decreasing stroke length and vice versa. Frequency can be measured with a stopwatch, timing two or more arm cycles is one method used. Accurate measurement of the length of the draft is achieved by measuring the distance traveled in one arm cycle or by counting the arm cycles between the flags.

PART II

STUDY 1 - PRELIMINARY RESEARCH

CHAPTER 4

METHODOLOGICAL APPROACH OF THE PRELIMINARY RESEARCH

4.1. Background to the pilot research

Pre-testing the intervention at the individual level will lead to the identification of possible weaknesses of the intervention and the possibility to improve it.

4.2. Objectives of the pilot research

The overall objective of the pilot research is to test the effect of the intervention at the individual level and to check the feasibility of the proposed intervention program, to detect possible errors and to improve it for use in basic research.

The first specific objective is to test the participant recruitment process and the application of the protocol in the intervention.

The second specific *objective* is to test the measuring instruments and the functionality of the apparatus used in the intervention and to familiarize ourselves with its use.

The third specific objective is to test the effect of the intervention at individual level with selected athletes.

4.3. Aim and tasks of the pilot research

The aim of the pilot study is to identify the level of strength development of the lower limb musculature, as well as to verify the working and measuring instruments and to present measurable results of strength capacity and improvement of the efficiency of turns in technical swimming procedures.

Pilot study tasks:

- organizing the necessary framework for the implementation of the intervention and seeking the agreement of the sports club to which the athletes are affiliated;
- establishing a sample of 2-4 swimmers from the sports club;

- explaining to the athletes the purpose of the intervention;
- initial testing;
- applying the intervention in the established sample;
- final testing;
- investigating the feasibility of the intervention and adding possible modifications;

4.4. Period, place and research subjects

The research took place at the Iazvorani Olympic pool, part of the Sydney 2000 Olympic Complex. The research subjects were two swimmers from CS Navi Bucharest, and the intervention was implemented between October 2021 and February 2022.

4.5. Tests used in the project

Tests used on land:

- Test 1 - jumps executed from the spot in the vertical plane, performed with Optojump by Microgate - timing & sport version RX 1.10. A series of jumps were executed from the spot for 15".

Tests used in water:

- Test 1 - measuring the thrust force from the wall of the swimming pool and the explosive force using the system we created;

- Test No. 2 - underwater video footage that can be used to determine the exit velocity from the tank wall. This was done using a Go-Pro HERO BLACK BLACK 9 video system

4.6. Measuring instruments

a. For measuring the explosive force of the lower limbs (on land):

- Optojump by Microgate - timing & sport RX version

b. System for measuring the thrust force from the tank wall (contact plate) into the water:

- The system proposed by us was developed in collaboration with INCS Bucharest - with the support of Dr. Bidiugan Radu, composed of:

- A system for measuring the thrust force in the tank wall (Omega touch pad-contact plate) on which four force transducers were mounted, measuring the thrust force in the tank wall;

- Software needed to interpret measurements.

c. Go-Pro HERO BLACK BLACK 9 video system for underwater filming.

d. Dartfish Software that we used to break down and analyze the swimmers' movements and to measure the exit velocity from the pool wall after the turn.

4.7. Validation of the technical solution for the objectivization of swimming dynamics (return contact with the pool wall)

Force measurement solution requirements

The solution for the objectification of the dynamics in the chaining process must allow:

- taking measurements in the aquatic environment, i.e. in the pool.

- continuous or quasi-continuous measurement, the data acquisition frequency must be greater than or equal to 60 Hz ;

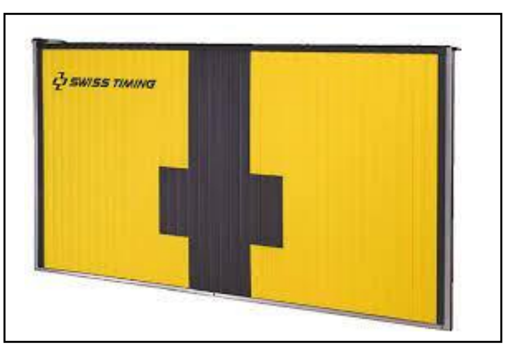
- the surface area to allow measurements to be made should be consistent with the surface area of the devices for chromatometry in competitions;

Materials used to develop the force measurement solution

The materials/equipment used to develop the solution are:

- OMEGA turntable
- balance board -Wii Balance Board
- duralumin plate (with honeycomb internal structure)

Wii Balance Board -represents a force plate based on 4 force transducers/sensors (FL, FR, BL, BR) that detect the force applied to them as well as changes in the center of pressure (COP) (Figure 37).



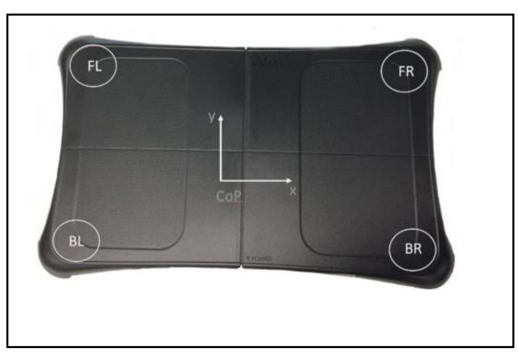


Figure no. 3 - Omega Turn Board Figure no. 4 - Wii Balance Board

Force measurement solution development

In order to meet the requirements for force measurement under real-life conditions, the materials used, the Omega return plate and the Wii Blance Bord force plate, were modified. The 4 force transducers/sensors, electronics for signal conditioning and data acquisition, a duralumin plate, and the OMEGA turntable were used in the development of the solution.

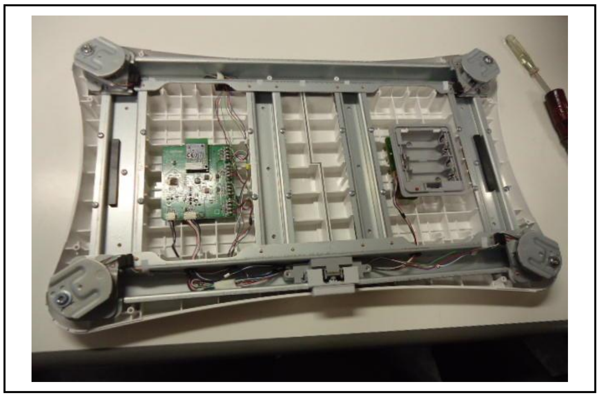


Figure no. 5 - Wii Balance Board, acquisition electronics, on force transducers

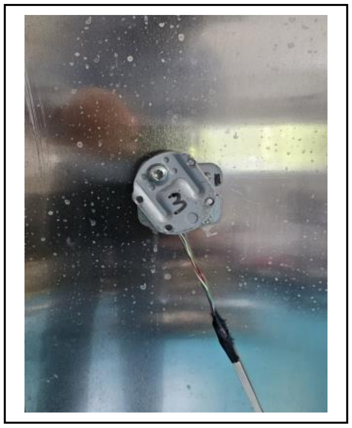


Figure no. 6 - Force transducer mounted duralumin plate

Structural strength

In order to ensure the mechanical stiffness of the technical solution, a duralumin plate with an internal honeycomb-type structure was used, capable of withstanding the stresses from the tests without deformation.

In order to ensure the contact of the technical solution for force measurement with the wall of the tank, the construction of special textolite supports was chosen, so that the use of the technical solution in real conditions (in the tank) does not cause damage to the tank wall.

The four force transducers were mounted on the duralumin plate, which was added to the center position at the rear of the Omega return plate.

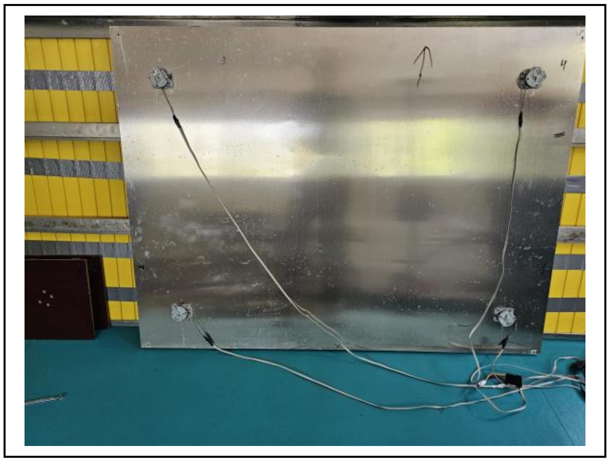


Figure 7 - Rear view of the technical solution, duralumin plate, force transducers

Calibration of the technical solution

In the construction of the technical solution necessary for the objectivization of the force acting on the basin wall, the acquisition mode of the Wii Balance Board was used, which performs the calculation of the force based on the information received from the four transducers.

The output data of the acquisition module, in a standard way, according to the functionality of the Wii Balance Board product, are represented by the force values measured in Kg, as well as the position of the projection of the center of mass in the reference system given by the geometrical structure of the Wii Balance Board.

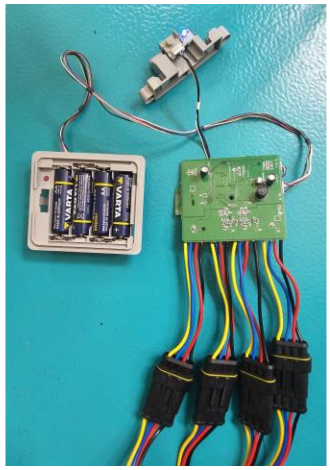


Figure no. 8 - Wii Balance Board data acquisition mode

As a result of the modifications made, i.e. modification of the geometry by mounting the force transducers on the duralumin plate and the addition of this plate, a calibration process was necessary to ensure the accuracy of the force measurements.

The tests performed in the Biomotry Laboratory of INCS, aimed to determine the correction values for the data acquisition module, so that the use of the technical solution in real conditions, in the swimming pool, with a vertical positioning, would allow the necessary corrections to be made to the output data of the Wii Balance Board acquisition module, respectively to measure the force that the athlete/scorer applies on the technical solution created.

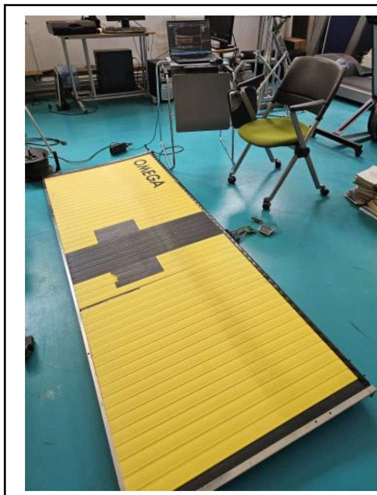


Figure nr. 9 - Technical solution, testing in the INCS biomotry laboratory

The calibration procedure was performed using three 20 kg weights in three steps, testing for a 20 kg, 40 kg, and 60 kg weight respectively to identify the linearity of the measurements using the technical solution.

Figure no. 10 - Calibration of the technical solution using disks of 20 kg weight

Identification of the reference value (12.4 kg), which is subtracted from the measured value with a load of 20, 40, 60 kg, being the correction value, expressed in kg, due to the changes made, no force being applied to the plate.

The means of the measured values, as well as the standard deviation for the three tests, are given in Table 2. The corrected value is the value measured by the technical solution from which the reference value of 12.4 kg was subtracted.

Table 1
Calibration values

kg applied	measured value	corrected value	standard deviation
20	32.2	19.8	0.2
40	52.1	39.7	0.4
60	72.8	60.4	0.2

Software application

For data acquisition an application was developed using the Bluetooth interface of the Wii Balace Board acquisition module for communication.

The development environment of the application was Visual Studio, using the WiimoteLib library (MIT license) for the .Net environment.

The application allows you to acquire and save the raw data, expressed in kg, received from the Wii Balace Board acquisition module.

To perform the mathematical calculations on the evolution of the force values, specific reference values were used for each data acquisition under real conditions in the swimming pool.

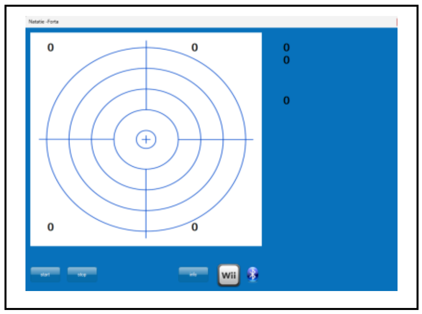


Figure no. 11 - Technical solution, testing in the INCS biomotry laboratory

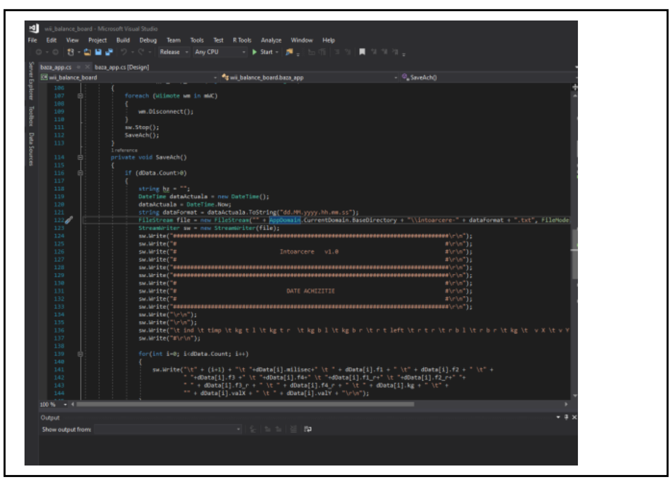


Figure no. 12 - Technical solution, testing in the INCS biomotry laboratory

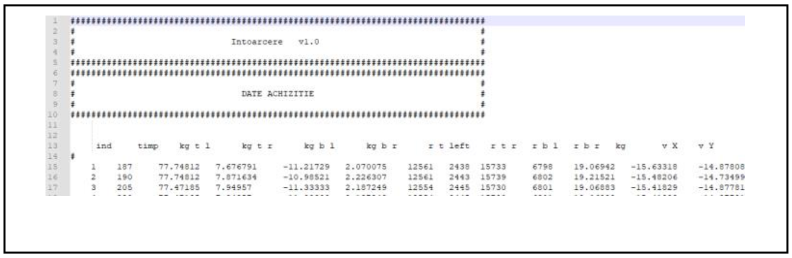


Figure no. 13 - Technical solution, testing in the INCS biomotry laboratory

4.8. Methodologies

Two subjects were selected to test the measurement system. Each subject was measured at two distinct times: TI (initial water force) and TF (final water force). The collected data were statistically analyzed to assess the consistency and variability of the measurements.

4.9. Data analysis

4.9.1. Thrust force results performed on land using Optojump (pilot study)

Table nr. 2 - Thrust force results performed on land using Optojump (pilot study)

Descriptive statistics

	T.I Optojump	T.F Optojump
Number of subjects	2	2
Arithmetic mean	34.5	37.6
Standard error	6.27	6.99
Median	34.5	37.6
Standard deviation	8.87	9.89
Amplitude	12.5	14.0
Minimum	28.3	30.6
Maximum	40.8	44.6

Validation of a measurement system is essential to ensure the accuracy and consistency of the data collected. In this study, the main objective was to validate a land-based force measurement system using two subjects. The parameters evaluated were initial force (T.I) and final force (T.F) measured with the Optojump system. Each subject was measured at two separate times and the collected data were statistically analyzed to assess the consistency and variability of the measurements.

Statistical analysis showed that the arithmetic mean and median for both parameters coincided, suggesting a symmetric distribution of the data. The standard error was small for both measurements, indicating low variability in the measurements. The standard deviation confirmed this observation, being higher for the final force compared to the initial force.

The amplitude was small for both measurements, indicating a low spread of values. The minimum and maximum values for both parameters showed that the measurement system captured a wide range of forces, which is important for its validation. The small standard error for both measurements indicates a high accuracy of the mean estimate, possibly due to the familiarization of the subjects with the measurement procedure or natural variations in the force on land.

The data suggest that the measurement system is capable of capturing the variability of the onshore force and that the initial and final measurements are consistent. To ensure robustness of the conclusions, it is recommended to expand the number of subjects to a larger sample. This will allow a more rigorous statistical analysis and the detection of possible variations between subjects.

Repeated measurements for each subject will also help to assess consistency and identify possible systematic errors.

In conclusion, preliminary data suggest that the measurement system is promising. Thus, the results obtained in this study provide a solid basis for further research and improvement of the land-based force measurement system.

4.9.2. Results of the thrust force from the basin wall in water (pilot study)

Table no. 3 - Results of the thrust force from the basin wall in water (pilot study)

Descriptive statistics

	TI Water Force	TF Water Force
Number of subjects	2	2
Arithmetic mean	1264	1602
Standard error	164	87.8
Median	1264	1602
Standard deviation	232	124
Amplitude	328	176
Minimum	1099	1514
Maximum	1428	1690

Measurement Consistency and Variability

The arithmetic mean and median for both parameters (TI and TF) are identical, suggesting a symmetric distribution of the data. The standard error and standard deviation are larger for TI than for TF, indicating a higher variability in the initial versus final measurements. This may suggest that subjects were more consistent in the TF measurements, possibly due to adaptation to the measurement system or improvement in the pushing technique

Amplitude and Value Spread

The amplitude for TI is 328 N, while for TF it is 176 N. This indicates a greater spread of initial values compared to final values, suggesting that the TF measurements are closer together. The minimum and maximum values for both parameters show that the measurement system captured a wide range of forces, which is important for its validation.

Standard Error and Precision Estimation

The standard error is smaller for TF (87.8 N) compared to TI (164 N), indicating a higher accuracy of the mean estimate for TF measurements. This may be attributed to a possible familiarization of the subjects with the measurement procedure.

Conclusions and Recommendations

Validation of the measurement system using two subjects provided valuable preliminary data. The data suggest that the measurement system is capable of registering the variability of the thrust force and that the final measurements (TF) are more consistent than the initial ones (TI).

4.9.3. Dartfish analysis results (pilot study)

Table no. 4 - Dartfish analysis results (pilot study)

Descriptive statistics

	T.I water speed	T.F water speed
Number of subjects	2	2
Arithmetic mean	2.67	2.37
Standard error	0.00500	0.0400
Median	2.67	2.37
Standard deviation	0.00707	0.0566
Amplitude	0.0100	0.0800
Minimum	2.67	2.33
Maximum	2.68	2.41

In this test, the main objective was to validate the system for measuring the speed of displacement in water after pushing, using two subjects. The measured parameters were T.I (initial speed in water) and T.F (final speed in water).

Two subjects were selected to test the measurement system. Each subject was measured at two distinct times: T.I (initial speed in water) and T.F (final speed in water). The collected data were statistically analyzed to assess the consistency and variability of the measurements.

The arithmetic mean and median for both parameters (T.I and T.F) are identical, suggesting a symmetric distribution of the data. The standard error is very small for T.I (0.00500 m/s) and somewhat larger for T.F (0.0400 m/s), indicating very low variability in the initial measurements and slight variability in the final measurements.

Amplitude and Value Spread

The amplitude for T.I was 0.0100 m/s, while for T.F it was 0.0800 m/s, indicating a very small spread of the initial values compared to the final ones.

Standard Error and Precision Estimation

The standard error is extremely small for T.I (0.00500 m/s) and larger for T.F (0.0400 m/s), indicating a higher accuracy of the mean estimate for T.I measurements.

Conclusions and Recommendations

Validation of the measurement system using two subjects provided valuable preliminary data. The data suggest that the measurement system is capable of capturing the variability of the water displacement velocity and that the initial measurements (T.I) are more consistent than the final measurements (T.F).

4.9.4. Pilot research results

- Consistency and accuracy of measurements: all three tests showed that the measurement systems are able to record the variability of the measured parameters, with a high accuracy of the mean estimation. The symmetric data distribution and low standard error values indicate a high degree of consistency in the measurements.

- Data variability: the tests showed a higher variability in the initial than in the final measurements, both for the pushing force in water and for the speed and force on land. This can be attributed to the subjects' familiarization with the measurement procedures or natural variations in the measured parameters.

- Wide range of measurements: the measurement systems demonstrated the ability to record a wide range of forces and velocities, which is essential for their validation. Minimum and maximum values showed good coverage of the data spectrum.

In conclusion, the results obtained provide a solid basis for further research and improvement of systems for measuring the thrust force in water, the speed of displacement in water after thrust and the force on land.

STUDY 2.

BASIC RESEARCH

CHAPTER 5 - FINAL EXPERIMENTAL RESEARCH

5.1. Research hypotheses

1. By including an intervention program focused on developing lower limb muscle strength as an integral part of an overall swimmers' fitness development program using specific exercises to increase explosive lower limb strength will lead to an improvement in lower limb strength.
2. By including an intervention program focused on developing lower limb muscle strength as an integral part of an overall program to develop swimmers' physical capabilities using specific exercises to increase explosive lower limb strength, we believe that it will also contribute to improving swimmers' sports performance.
3. By including an intervention program focused on lower limb muscle strength development as an integral part of an overall program to develop swimmers' physical abilities using specific exercises to increase explosive lower limb strength, we believe that swimmers will have higher levels of task-oriented achievement goals at the end of the intervention.

5.2. Methodological operational research approach - initial and final testing

On 20.04.2022 we carried out the initial testing at the Izvorani swimming pool of the Sydney 2000 Olympic Complex, and the final testing took place on 12.04.2023, also at the Izvorani swimming pool of the Sydney 2000 Olympic Complex. On this occasion we performed the following tests/measurements:

- Anthropometric measurements of groups of subjects;

- Jumps executed from the spot vertically from the spot for 15". The best jump will be considered. The measurement will be done with Optojump by Microgate - timing & sport RX 1.10, (figure no. 36);

- Measuring the thrust force from the pool wall/contact plate/touch pad using a system developed by us (Figures 37 and 38);

- Measuring the speed at which swimmers exit the pool wall after turning over a distance of 5m with a Go_Pro HERO BLACK 9 underwater video system (Figure 39). The underwater videos will be analyzed with Dartfish software.

For measuring the explosive force of the lower limbs (on land) - jumps executed from the spot in a vertical plane, we used:

- Optojump by Microgate - timing & sport RX version 1.10. It is an optical measuring system consisting of a transmit and receive bar.

- System for measuring the thrust force from the pool wall (contact plate). The system proposed by us was realized in collaboration with INCS Bucharest - with the support of Dr. Bidiugan Radu. The system includes 4 force transducers, which were mounted on the contact plate/touch pad used for timing swimmers in swimming competitions. These force transducers were connected to a computer/laptop in order to obtain more detailed results regarding the parameters involved in the swimming turns. The aim of the application is to acquire electronically the pushing force, manifested by the swimmers in real conditions, i.e. in the pool. The solution comprises two components, one hardware (the 4 force translators) and the other software.

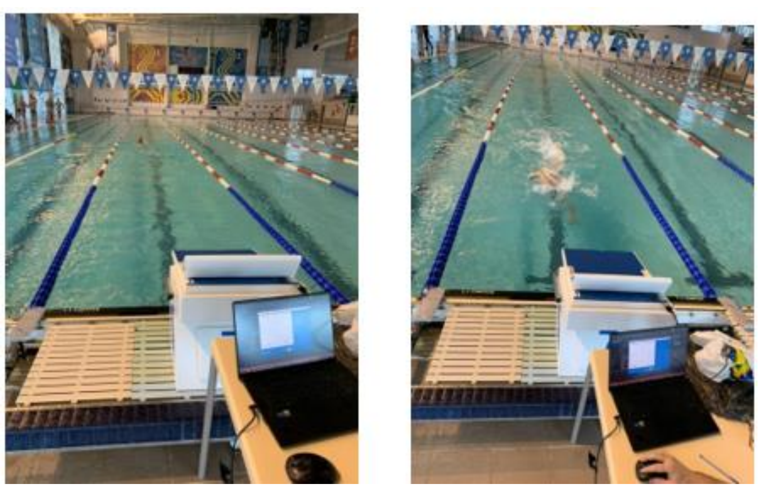


Figure no. 14- Images during testing with the system we built

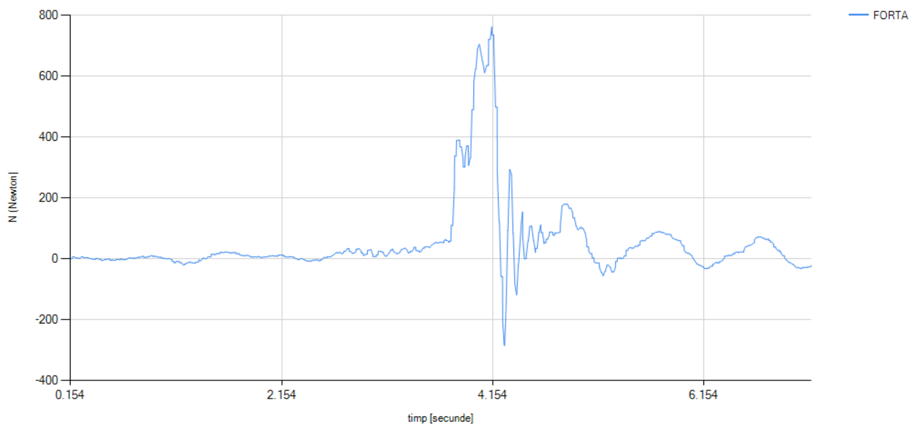


Figure no. 15 - Recording of the pushing force from the pool wall (initial testing) in one subject

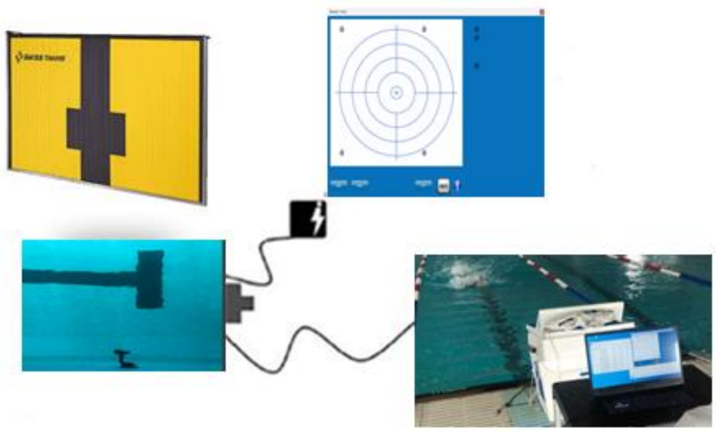


Figure no. 16 - Description of the components of the system for measuring the explosive force of the lower limb muscles in water

- Go Pro video system for underwater video to measure the speed at which the swimmers exit the pool wall after turning over a distance of 5m. Underwater videos were analyzed with Dartfish software (Figure 4).

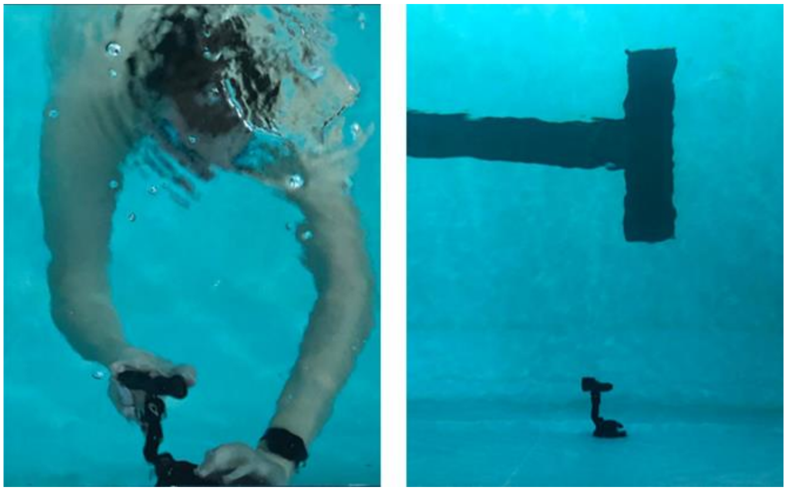


Figure 17 - Go Pro video system mounted on the swimming pool wall

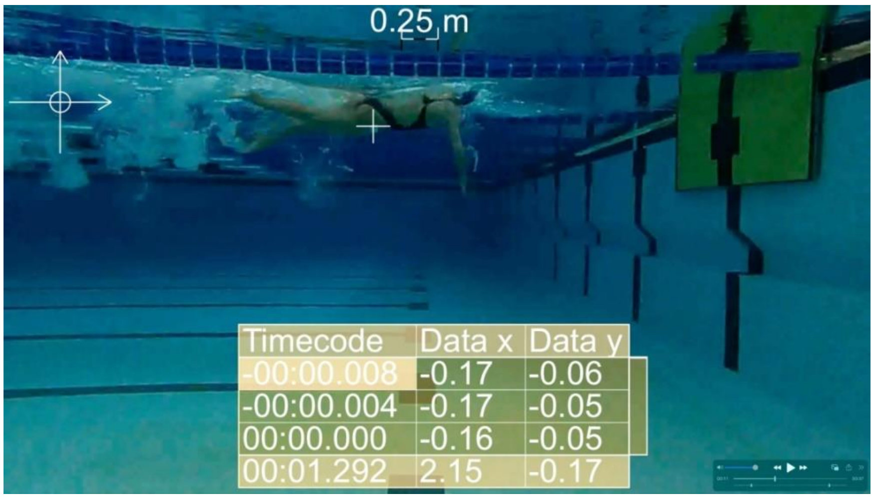


Figure 18 - Images during data processing using Dartfish software.

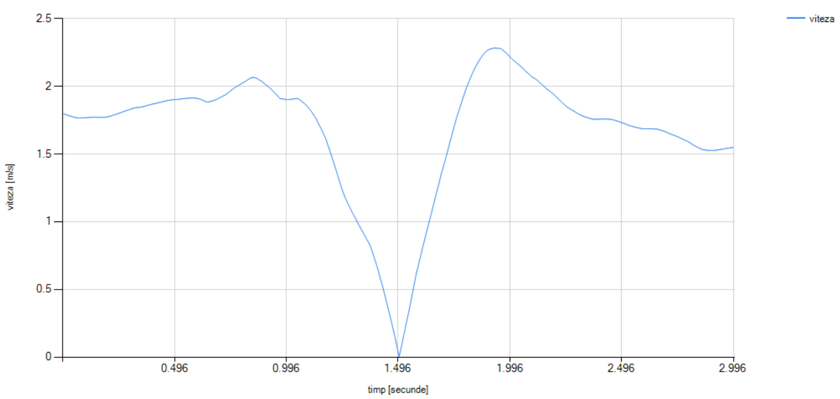


Figure no. 19 - Recording of the speed after pushing off the pool wall over a distance of 5m (initial test) in one subject

5.3. Subjects

CS Navi Bucuresti athletes were included in the experiment. In order to carry out the measurements necessary to write and defend the doctoral thesis, CS Navi Bucharest allowed the initial and final tests to be carried out in order to obtain the necessary data. Thus, CS Navi accepted the inclusion in the training program of the athletes' technical swimming procedures, which they performed both on land and in the water. There are 16 performance swimmers with notable results.

5.4. Onshore intervention program of the experimental group

The land-based intervention program of the experimental group comprised a set of 10 tools that were planned three times a week. They were carried out as a circuit and followed a carefully planned dosage. The means used were: squat jump, broad jumps, single-leg hops, sprints, box jumps, streamline squat, jumps on and over plyometric platforms, dumbbell lunges, dumbbell presses, barbell exercises.

5.5. Water intervention program of the experimental group

The water intervention program of the experimental group comprised a set of means that were planned three times a week. These followed a dosage that was carefully planned. Among the means used were: technique drills and approaching the wall, swimming at full speed followed by turns performed quickly, race-paced drills, video visualization exercise of own turns.

CHAPTER 6

PRESENTATION, ANALYSIS AND INTERPRETATION OF RESULTS

6.1. Results achieved

The experiment data were organized in tables, statistically analyzed and interpreted according to the research methodology in the field of physical activity science. In order to validate the hypothesis, data were analyzed, processed and interpreted using statistical methods.

6.2. Push force results performed on land using Optojump

This analysis combines the results obtained from descriptive statistics and t-test (inferential statistical analysis) for paired samples, providing a rigorous assessment of the effects of a training program on swimmers' dryland muscle performance. Focusing on changes in arithmetic mean, p-value statistic, effect size (Cohen's d), and distribution parameters (skewness and kurtosis), we interpret the impact and effectiveness of training.

Table no. 5 - T-test for paired samples - Optojump

			statistics	df	p		Effect size
TI Optojump	TF Optojump	Student's t	-5.87	15.0	< .001	Cohen's d	-1.47

Note. H_a μ $_{\text{Measurements 1 - Measurements 2}} \neq 0$

The use of paired samples t-test provided an in-depth assessment of the statistical significance of the observed improvements. The t-statistic value of -5.87 and a p-value of less than .001 indicate a significant difference between initial and final performance, with an effect size of -1.47 (Cohen's d). These inferential results confirm that the observed improvements are not the result of random variation, but of a tangible effect of training.

6.3. Results of the buoyancy force from the basin wall in water

Data were collected from a sample of 16 swimmers, before and after an intervention program designed to improve performance. Measurements included force expressed in terms of numerical values, with statistical details such as mean, median, standard deviation, amplitude, minimum and maximum values, as well as skewness and kurtosis coefficients.

Table no. 6 - Results of the thrust force from the tank wall in water at initial and final testing

Descriptive statistics

	T.I Water force	T.F Water force
Number of subjects	16	16
Arithmetic mean	989	1559
Standard error	59.6	65.8
Median	885	1572
Standard deviation	239	263
Amplitude	814	978
Minimum	754	1155
Maximum	1568	2132
Skewness	1.16	0.572
Std. error skewness	0.564	0.564
Kurtosis	0.674	0.335
Std. error kurtosis	1.09	1.09

Comparative analysis of swimmers' strength before and after an intervention program shows statistically significant and relevant changes. Initially, the arithmetic mean of the strength was 989, with a distribution showing a positive skewness (skewness = 1.16) and a kurtosis below normal (kurtosis = 0.674). These values indicate a distribution skewed towards lower values and a lower concentration of data around the mean than in a normal distribution. Post-intervention, the mean increased significantly to 1559, a result that highlights the effectiveness of the training program.

6.4. Dartfish analysis results

In the context of empirical evaluations of the effectiveness of training interventions on swimmers' underwater performance, detailed statistical analysis provides a comprehensive and validated insight into the impact of these strategies. By focusing on the evolution of the arithmetic mean, the significance of the alpha 'p' threshold, the magnitude of the Cohen's d effect and the distribution parameters (skewness and kurtosis), we can clearly appreciate the influence of specialized training in improving sports performance.

Table no. 7 - Dartfish software analysis results obtained in initial and final testing

Descriptive statistics

	T.I Dartfish	T.F Dartfish
Number of subjects	16	16
Arithmetic mean	2.32	2.55
Standard error	0.0344	0.0386
Median	2.27	2.54
Standard deviation	0.138	0.154
Amplitude	0.550	0.520
Minimum	2.09	2.33
Maximum	2.64	2.85
Skewness	0.920	0.133
Std. error skewness	0.564	0.564
Kurtosis	0.751	-0.584
Std. error kurtosis	1.09	1.09

The increase in the arithmetic mean from 2.32 in the baseline test to 2.55 in the final test indicates a statistically significant improvement in the swimmers' performance, a direct reflection of the application of the training methods. This progress not only demonstrates the effectiveness of the interventions, but also emphasizes the swimmers' ability to integrate and manifest the targeted technical improvements in their performance.

Table no. 8 - T-test for paired samples - results of analysis with Dartfish software

			statistics	df	p		Effect size
TI Dartfish	TF Dartfish	Student's t	-6.45	15.0	< .001	Cohen's d	-1.61

Note. H_a $\mu_{\text{Measurements 1 – Measurements 2}} \neq 0$

T-test results for paired samples revealed a t-value of -6.45, with significance $p < .001$, effectively rejecting the null hypothesis. This demonstrates that the changes in performance are not only statistically significant, but also directly attributable to the training interventions, thus eliminating the possibility of random variation as an explanation.

Cohen's d was calculated at -1.61, indicating a very strong impact. This effect size reiterates that the changes implemented within the training regimen are not only effective, but also produce remarkable improvements in the swimmers' athletic ability.

The changes in skewness and kurtosis values, ranging from 0.920 to 0.133 for skewness and from 0.751 to -0.584 for kurtosis, suggest a normalization of the data distribution. This reflects a more even spread of individual responses to training interventions, indicating a generalized adaptation of swimmers to new training methods.

CHAPTER 7

CONCLUSIONS

This paper aims to highlight the role of information in alternative and complementary methods of sports training, with specific application to swimming.

Information is the foundation of all knowledge, whatever the field.

In sports performance, information is becoming increasingly important, from genetic, biochemical and physiological information, to the information provided by technology, structure and methodology, which is gaining more and more ground in sports training.

There is a wide variety of equipment, particularly at international level, used in the land-based training of swimmers, each with advantages and disadvantages. There is an intense focus on providing fast and efficient information about the athlete's performance during training, with increasing emphasis on real-time feedback.

Feedback-based technologies belong to the category of extrinsic means of intervention and correction, transmitted from the coach to the athlete, with the coach being the key element. The quality of the coach's interventions depends on the quality of the subsequent changes in the 'sport system'.

This method allows the specific capabilities of each swimmer to be diagnosed in a short period of time, facilitating rapid stratification of the group and adaptation of individual training.

The rate of progress achieved by applying this method is very fast, allowing you to get in shape and achieve notable results in competitions.

This method should be used routinely during periods of increased training before major competitions.

The achievements of modern technology, the existence of well-developed principles for its use in practice, and the high requirements for the improvement of swimmers' motor skills imposed by modern sport call for continuous development and application of modern technologies and methodologies in swimming training.

In modern sports training there is a need to develop and experimentally substantiate new, more effective methodologies for training athletes.

We can state that this research confirms the proposed hypotheses and has helped to clarify the trends observed in the collectivities under statistical study.

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