THE IMPORTANCE OF TECHNOLOGY EQUIPMENTS IN HIGH PERFORMANCE SPORTS

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Abstract: Performance data of athletes, be as in specific training as competitions, require physiological power, response time and acceleration, and these are important information for development of them. That information can prove essential in support of improving the athlete’s performance once that, with this data is possible to perform specific and technical trainings, correcting either any non-conformities or deficiencies. To obtain these data reliably, it’s recommended the use of the sports technology and electronic devices capable of processing the signals, and convert the information collected in desirable and measurable greatness. Between these devices, we present three projects developed or in development in UTFPR/Ponta Grossa. That seek to unite engineering with sports. The first is a device to control/measure the time elapsed in a particular physical activity, with significant accuracy. The second is a device to analyze the agility and reflex of the athlete. The third is a power meter applied to cycling. This device is capable of measuring the physiological power developed by the cyclist on pedaling. What is common to all projects is the need to use electronic engineering with computing algorithms applied to improve the sports development. Therefore, this work presents the state of the art of cited devices and reports the initial development process, methodology of its use in training and technologies with potential for future applications to be developed.

Keywords: Technological equipment; Sports Performance; Athlete.

1. INTRODUCTION

Methods of collecting information on the athletes and scale their performance during sports practice has revolutionized the way the high performance sport is viewed and practiced in recent years (BORIN; PRESTES; MOURA, 2007). The responsibility for analyzing this data is as important as having them, because will determine the type and amount of training. The advantages are from not only the equipment and accessories, but also a better understanding of the sport and its specific characteristics. This understanding is fundamental for a correct practice and health improvement (NEPTUNE; MCGOWAN; FIANDT, 2009).

In this context, evaluations of physiological variables and monitoring of training can be determining factors in the success of athletes from different sports (REDKVA, 2012). The sporting performance is a comprehensive and very important issue, but the scope of this article aims some topics that in general can demonstrate the importance and influence of technological equipment in the sport.

An interesting feature of the computation used in high performance sports is the use of the database, a technological tool that helps in the understanding of the athlete and team performance. Because by recording relevant data, performance analysis in a given situation it becomes quantitative, fundamental tool for understanding regarding the performance and taken from athlete's decisions. Since one of the advantages of working with data is the ability to apply filters in the database when there is a need or desire of the analysis of a specific skill, thereby assisting in the analysis and comparison of performance among athletes. Making it then possible improvement of particular skill, but also the planning and control of training (LIEBERMANN et al., 2002).

For a better presentation of this work and delimitation of the topic discussed, were divided three main topics that exemplify the proposal studied here. The first topic is the physical assessment or performance evaluation, using two equipment: Sprint Test Device and Agility Test Device. Besides is presented the data that can be obtained with use of them. The second topic is the change of competition strategies and training using the physiological power meter for cyclists. The third topic is the discussion of other applications developing on Instrumentation in Biomedical Engineering and Sports Research Group at the Electronics Department (DAELE) UTFPR in Ponta Grossa, aimed at developing projects and equipment to improve athletic performance.

2. TECHNOLOGY FOR PHYSICAL ASSESSMENT

The athlete's physical evaluation aims to survey current conditions athlete. It's like taken a "picture" of the athlete, only in this case, this image would be the conditions in which he finds himself. Before any training or planning of any sports season, there needs to be an assessment up the parameters in which the athlete is. Information these that will be the basis for the control of the activities performed directly affecting the process of yield predictions and training programs (FOSTER et al., 2001).

In soccer, for example, during the pre-season are conducted several physical tests to collect the initial working condition. Usually, after a few days of specific physical work, a re-evaluation is made to scale the physical evolution of each athlete and what results the work is reaching (WRAGG; MAXWELL; DOUST, 2000).

These cited assessments can also be used as a criterion of choice and classification of athletes. Can be used as an example, referees who need to pass through at least two types of physicals examination. This tests determining whether they will be able to work adequately in a game, particularly as part of a performance evaluation that defines a rating for future work schedules.

To better illustrate the theme were chosen 2 projects to be detailed, harmonizing the use of electronic engineering, computer science and sports concepts for the development of devices that help in improving the performance of sports athletes. The first, developed for speed control and torn from athletes; and the second, for agility and reflex tests.

a) Sprint / Race Test Device (STD)

The first is a device to control, electronically, the evaluation process of and sprint or race for one or more athletes. This device is responsible for measuring the time spent on a particular physical activity (sprint or race), and as nominated Sprint / Race Test Device (STD). The time recorded can be correlated with the athlete's performance in this activity. It has long been used in various physical evaluation protocols, mainly to compose physiological factors such as anaerobic and aerobic power; fatigue index; among others.

The STD is based in photoelectric sensors unit that capture the passage of the athlete with high precision, thereby determining the start and the end of the timed activity. There are various types of photoelectric sensors, and in this work was opted by the used of infrared (IR) sensors. The IR sensors are easier to apply in embedded devices and to have good requirements are time response and low costs. There are three ways to use of these sensors: barrier, retro reflective and diffuse.

Diffuse mode (Figure 1) is when the transmitter transmits the signal (IR) in the empty and receiver captures this signal only when an object reflects it, so the stopwatch is triggered or stopped at the time the receiver is active (athlete presence). The diffuse mode was chosen because reduce the number of components that compose the device, decreasing the price and the complexity of system use.

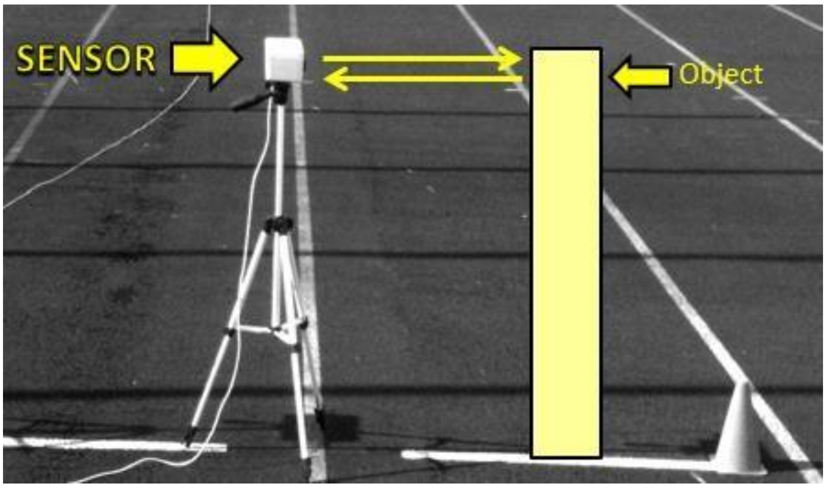

Figure 1 – Operation mode of photoelectric sensors: diffuse

To illustrate the importance of time information that the athlete spends on a given physical activity, it uses the evaluation protocol RAST (Running Anaerobic Sprint Test) to determining the anaerobic power output (peak and mean) of the athlete (equation 1). This protocol consists go six times a distance of 35 meters in the shortest possible time, and each try after a rest of 10 seconds for the athlete recovery, starting always stopped (ZAGATTO; BECK; GOBATTO, 2009). The power measured [Watts] is composed by three values: mass [kg] of the athlete, distance [m] of the test and the time [s] spends.

$$Power = \frac{mass * distance^2}{time^3} \quad (1)$$

In addition to power output, the same protocol can determine the athlete's fatigue index in relation to the physical activity (equation 2).

$$Fatigue\ Index = \frac{(Maximum\ Power - Minimum\ Power) * 100}{Maximum\ Power} \quad (2)$$

With these collected values, it is possible to develop a training program and development of the athlete, targeting a particular function during sports. To show how trainers and instructors can use this data, are presented in Table 1 values collected by Zagatto, Beck and Gobatto (2009) in a study with 40 members of the armed forces, everyone with military training and sports exercises, such as: soccer, basketball, volleyball and athletics.

The Peak power (P_{PEAK}) and Mean power (P_{MEAN}) are in Watts and are use to determining the anaerobic power output only. The P_{PEAK} per weight and P_{MEAN} per weight are in W/kg and representing the anaerobic power per kilogram of mass of the athlete. FI (%) is the fatigue index (equation 2).

Table 1 – Example of data collected with Sprint Test Device

	Mean	STANDARD DEVIATION	MINIMUM	MAXIMUM
PPEAK (W.kg-1)	10.38	1.74	7.81	13.48
PMEAN (W.kg-1)	8.20	1.34	5.78	10.33
PPEAK (W)	751.04	123.63	538.3	961.41
PMEAN (W)	590.62	90.79	388.86	736.48
FI(%)	40.62	9.11	28.03	56.74

Source: adapted Zagatto, Beck and Gobatto (2009), table 1, p. 1822.

As already mentioned, for the data collection was used the STD providing: precision, functionality and credibility of the data presented.

To understanding how the entire device works, the Figure 2 shows the operational blocks of the system highlighted on red block. Inside the microprocessor exist a programming logic that presented by the flowchart on right. There are three variables, two to identify the sensors and one called FLAG (auxiliary variable).

After reading the status of the sensors, the device compare the status and make a decision: trigger or stop the stopwatch. The FLAG sets the direction about sensors. Both sensors can trigger or stop the stopwatch that depends only the FLAG. If the FLAG is low the stopwatch is trigger. If the FLAG is high the stopwatch is stopped.

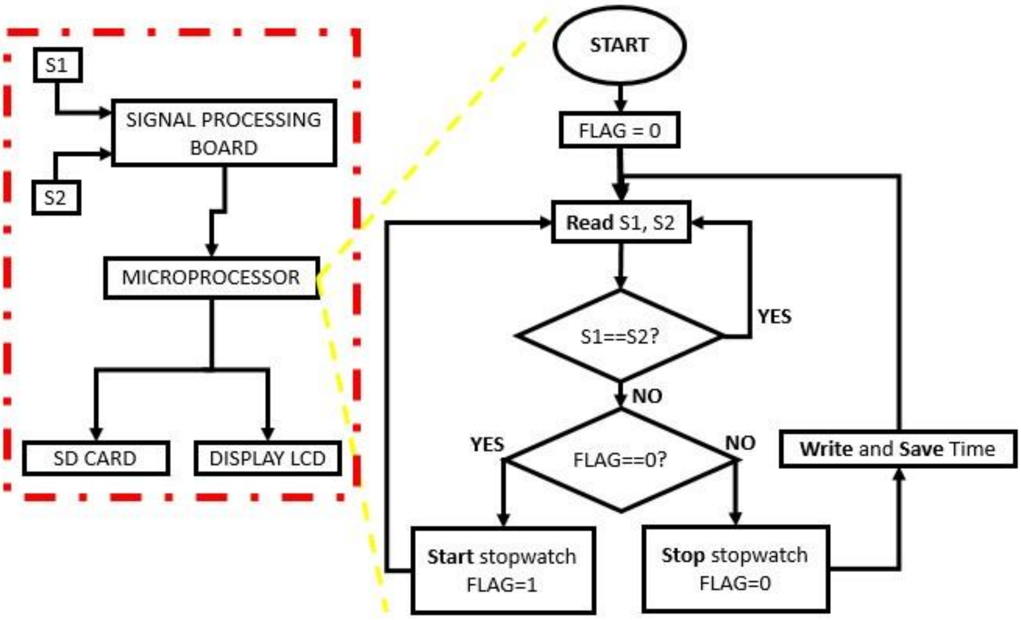

Figure 2 – Operational blocks of the STD and flowchart of the microprocessor

Aiming at the development of the national sport, the authors of this paper developed a STD (test version) costing less than 1/4 of the value paid in the current market (Figure 3). This STD is going through the validation process at this time, but has been used in various physical tests aimed at gathering data for research on the physiological area and sports training.

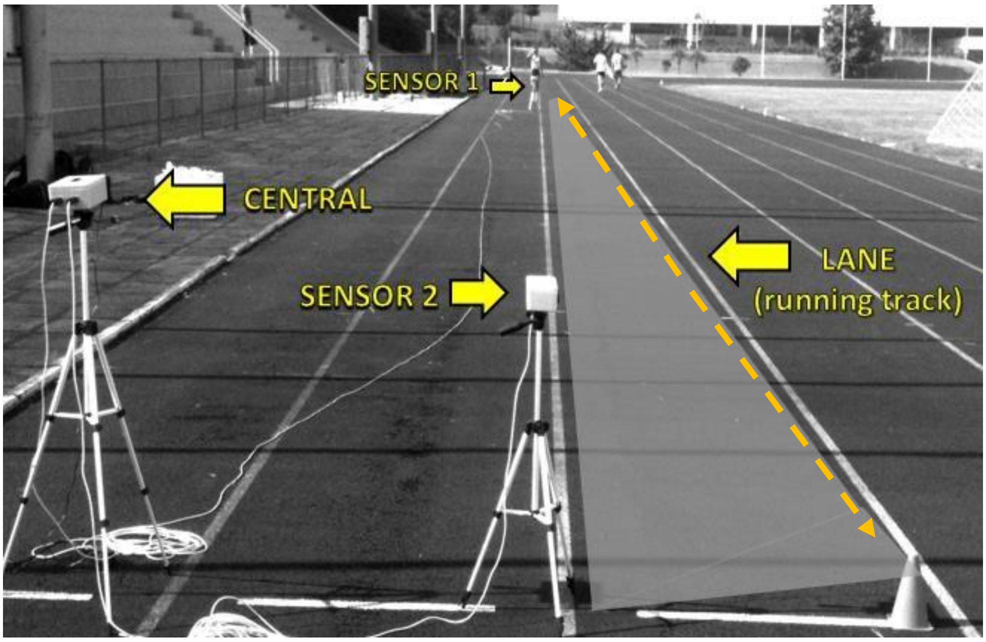

Figure 3 – STD developed by the authors, test version

Applying technology to sports, in special, in the developing of equipment as this previously presented, is possible to contribute in physical assessments, physiological and increase of athlete performance and providing research and innovation.

b) Agility Test Device (ATD)

Between the most important features that an athlete can to have are the quickness, change of direction, and time to reaction. So, is constantly required of the athletes the improvement of your skills and, every device developed to this purpose, with the possibility of identifying such improvements in function specifically of the sport practiced by the athlete, are welcome (CARREIRO; HADDAD JÚNIOR; BALDO, 2003).

The agility test can be used to evaluate athletes in various sports such as football, handball, basketball, tennis, and athletics, among others. Through this test, you can verify the athlete's status and compare with reference data or with other athletes. The agility test when combined with other tests is able to provide a detailed diagnosis of the physical condition of each athlete (LIMA et al., 2004).

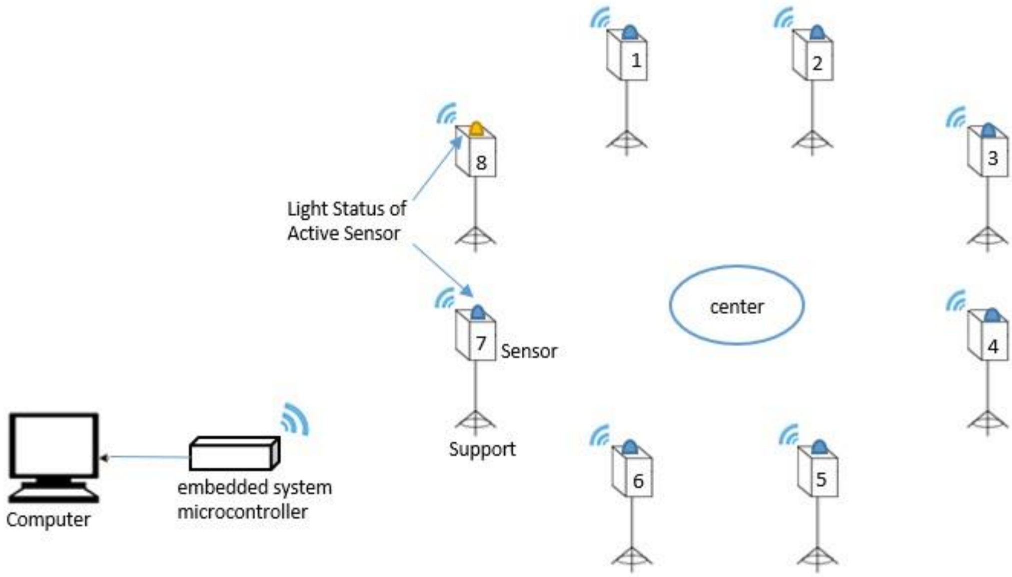

Figure 4 – Agility Test Device

The equipment being developed (Figure 4) consists of N sensors connected by wireless communication to a microprocessor, and this connected by wire to a computer. The sensors have the function of detecting the proximity of the athlete's hand, which indicates that he has moved to the position of the specific sensor. The microprocessor has the function of performing the acquisition of the signals from the sensors, define which sensor is activated and indicates the athlete through a LED located on this sensor, record the time elapsed in the athlete's displacement between the sensors and send these data to a computer for visualization by the user (Figure 5).

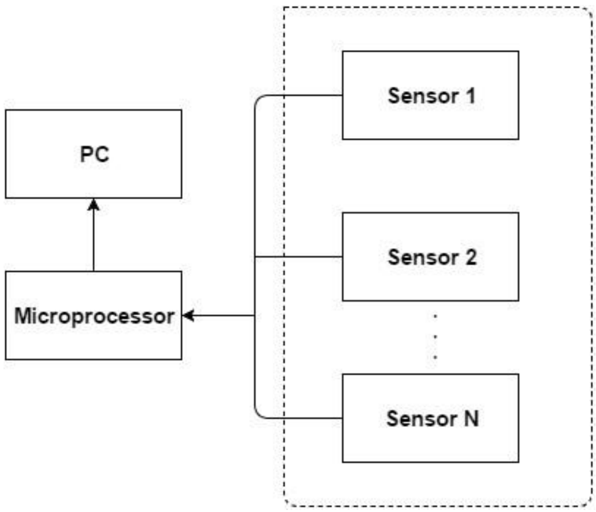

Figure 5 – Operation blocks of a generic Agility Test Device

With the sensors positioned and established the communication with the microprocessor, the athlete must remain in a central position until the test is started. When started, one of the sensors randomly will be chosen and by visual inspection of the colors emitted by the lights on top of the sensors, the athlete must locate the green and move to near this sensor, and meanwhile the other sensors will be presenting the red color. When a sensor is activated, this automatically starts displaying the color red and the other sensor is chosen at random, while the athlete has to move back to the center and then moves to the next sensor (Figure 6).

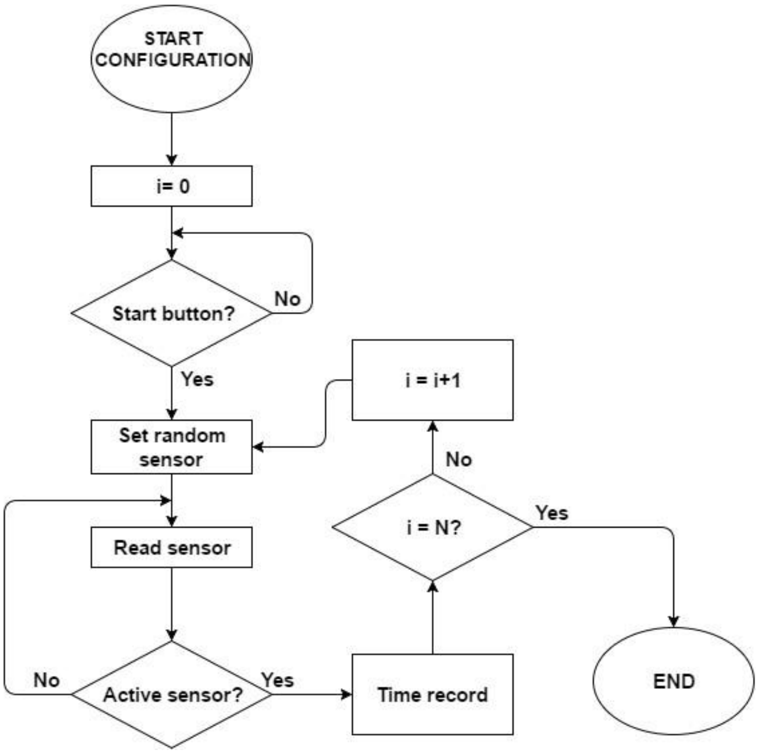

Figure 6 – Logic flowchart of the Agility Test Device developed by authors

This process can be repeated the number of times defined by the instructor. At the end of the process, the embedded microcontroller device sends the information to the computer, where the instructor will access the athlete's performance data. This system has been developing by the authors to integrate the technological devices of physics evaluation.

There are other devices that are used for physical and physiological evaluation in high performance athletes. Technological devices such that according Borin, Prestes and Moura (2007) have contributed positively to the understanding of different important variables in the sport, as for example: filming; jump platforms (dynamometric); accelerometers; dynamometers; and electromyography. Showing that increasing the technology is present in the understanding of the athlete, physically, physiologically, and in terms of performance.

3. TECHNOLOGY TO ESTABLISH COMPETITION AND TRAINING STRATEGIES

Technology is the contemporary support to understanding the load of training and working of the athlete. The recorded and processed information about the athlete condition is used to development of the elite sports (NEPTUNE; MCGOWAN; FIANDT, 2009; CARLING et al., 2008).

The information obtained on the athlete are essential to control over your income and the programming of their training. Then, put together a strategy for competition or training is complex and can directly influence the results later.

So many sports can be applied this development of technology devices: soccer, voleyball, ice hockey, running, swimming, etc. A classic example in this regard is cycling, because the information is fundamental to the training practices and strategy of a team in various forms of proof (Mountain, Time Trial, etc).

According to Ribeiro et al (2006) in a study of some Australian teams competing the main events in the world (Tour de France, Giro d'Italia, la vuelta (Spain), among others) a professional team needs a designated leader, surrounded by teammates (domestic); and thus maintain a high placement in the standings (team work and strategy).

Some studies have shown that two cyclists riding in single file (one right in front of the other) at a speed of 30km/h, cyclist who is behind plays 60W less for the same speed, and with the increase of this, the difference is even greater and 120W at 40km/h and 220W at 50km/h (McCole, 1990). Other studies analyzing athletes in competition show that in general, an athlete escorted by several companions and well positioned can accompany them generating 40% less power that is, spending 40% less of their energy (BASSET, 1999; McGann, 2006).

These data cited above demonstrate the importance of measuring the potency expended by the cyclist at the time of practice. Thus, a team can define who will "open" way saving the fellow who comes right back, which in turn, will have the final moments of the race to exercise maximum performance and try to conquer the winning.

Analyzing the potency can determine the aerobic and anaerobic thresholds; the maximum steady state; the fatigue index; and the energy required to have a speed rating for part of the race route. Thus, it’s possible to support an schedule based in intensity and duration workout, focused in the best physical condition for competition.

The time that the athlete can play for each physiological stage of those cited is crucial to determine their performance in the test. For example, Bertucci, Taiar and Grappe (2005) developed a study on the comparison the potency of seven cyclists performing a sprint in the laboratory and actual cycling conditions. Each of the riders did six tests on an ergometric bicycle and six tests in a gym. One of the data obtained from this research is that in a course of 25m, the minimum time to reach the maximum power in the laboratory was 1.57 ± 0,63s (standing) and 2.69 ± 0.7s (standing) in the gym (BERTUCCI; TAIAR; GRAPPE, 2005). This time is crucial in short duration and high intensity tests, such evidence velodrome and Time Trial.

Following the explanation presented in this topic, it is possible see the importance of measuring the power output in the current cycling. The disadvantage is that Brazil does not produce any power meter Model (physiological). All models in the market are imported, with high freight rates, taxes (about 88% more in value of the product) and difficult access to maintenance in authorized service shop.

Figure 7 presents three different commercial power meter models, based on three different parts of the bike: a) chainrings; b) hub; and c) pedals.

Figure 7 – Some models of commercial power meters, a) SRM; b) PowerTap e c) Garmin. (SRM; POWERTAP; GARMIN, 2015)

Taking this as the basis, on the last year the authors of this work have developed a low cost physiological power meter in DAELE - UTFPR, campus Ponta Grossa. This work was beginning its development through scientific initiation and course conclusion paper, already completed. Continued occurs today through research at post-graduate (Master), where the power meter is part of a sensor fusion applied to monitoring to improve performance in sports.

Studies in this regard involve both the technical part (which component is better and the best installation way) as well as the economic part (which is the best cost-benefit).

The forecast is that by November 2016, has become a prototype (Figure 8) validated and in use by LCCG (League of Campos Gerais Cycling). This prototype can be used in training, competitions and physical and physiological, as well as research in the area.

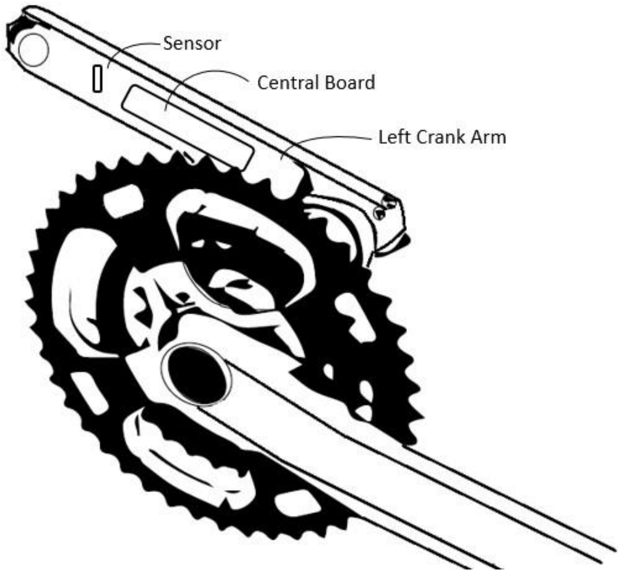

Figure 8 – Prototype outlook

For intellectual property protection equipment, has filed a patent with the INPI (National Institute for Industrial Protection) registered under number BR 2015100186339, on 04/08/2015. The title of the registered patent is: Physiologic Power Meter for Cyclists.

Each of the commercial models already presented use strain gages as a way to obtain the force applied by the athlete on the bike. This is the most common and reliable method to date for obtaining this data. According Hannah e Reed (1992), strain gages are devices capable of measuring mechanical deformations that transform variations of voltages in deformation measurements.

Another topic studied, are the sensors of professional applications. The model MEMS (microelectromechanical system) which in this case is applied to obtain the speed and bike cadence. The gyroscope installed in the central plate measures the cadence (rad/s) in which the crank arms rotate. Already the speed (km/h) is measured by the accelerometer, which is also installed on the board. Using these cited components, the project is developing, aiming a next prototype that can be used in test conditions.

The Figure 9 presents the operational blocks of the prototype, starting the operation with the two principal sensors: strain gage and gyroscope. After the acquisition of signal sensors, there is a block of signal conditioning sending the information to microcontroller to process it.

Wireless modules make the communication, i.e. Bluetooth®. The mobile device can be everyone which contains Bluetooth® communication, such as: tablets, smartphones, personal computer, etc.

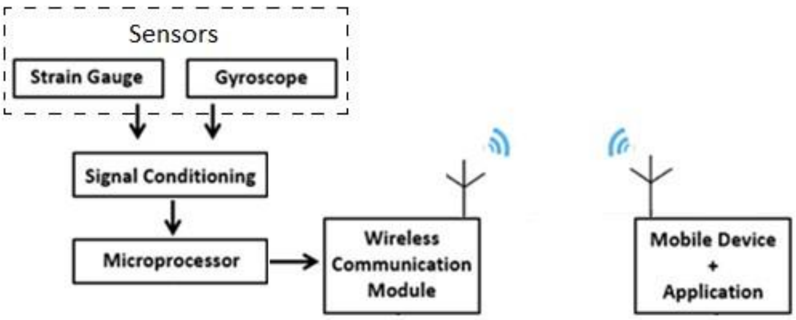

Figure 9 – Operational blocks of the prototype

Inside the microcontroller, an algorithm is running with the logic presented by the flowchart on Figure 10. The program begins with the acquisition of the signal and conditioning them. After, the values are ready to be used, there is a Simple Mobile Average (SMA) estimating both signals: angular speed (ω) and torque (T). The power output is obtained with the product of the following values: SMA(ω) and SMA(T). The conclusion of this segment is transmitting way Serial (wireless).

A mobile device (Figure 11) with Bluetooth® module is used to receive the data. After it was received, the message is unpacked and identified. The value of the power is showed to cyclist and saved on mobile device for further analysis.

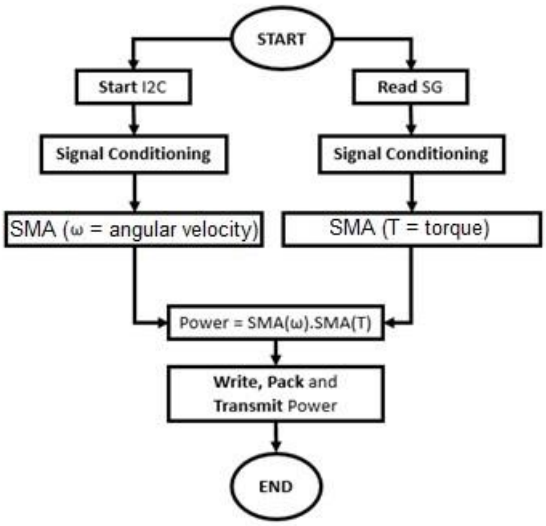

Figure 10 – Flowchart of the transmitter system prototype

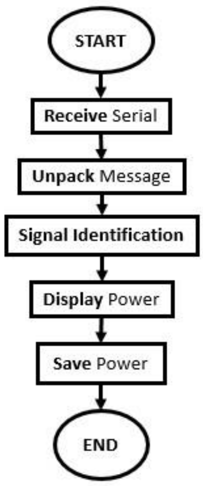

Figure 11 - Flowchart of the receiver system mobile device

This work is in continuous development through academic stages of the authors (scientific initiation, course conclusion paper and graduate studies) the first tests were carried out in laboratory conditions, as a result, the equipment installed in the left crank presented below (Figure 12).

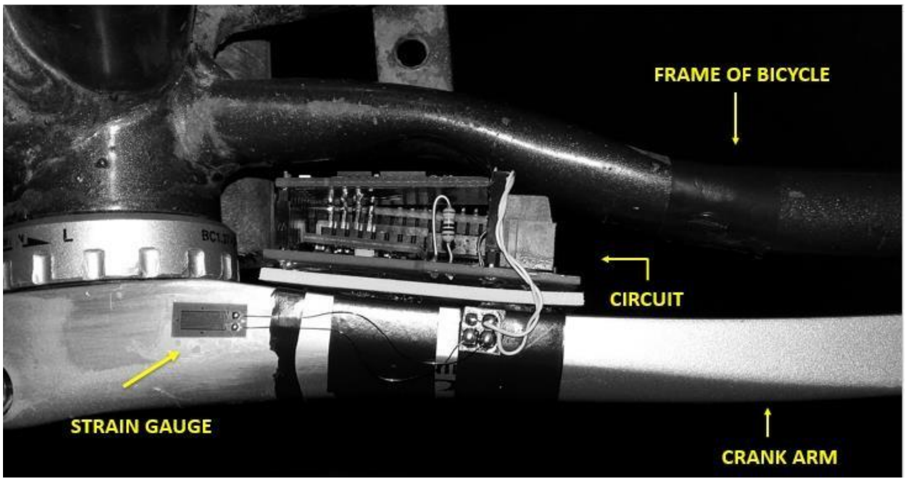

Figure 12 – Test version of the prototype installed on left crank arm of bicycle

For the visualization of data, there are two ways to analyze them: the cyclist see a screen with basic information in real-time, such as time, speed, power, distance and cadence; for other side, the instructor can analyze the data post ride, with graphics and values in time and intensity axis.

The Figure 13 shows these two ways explained before. In the left side, there is a screen where the player can monitor your data during the ride. In the right side there is a graphic with data collected in the lab, comparing the exactly moment of both screens.

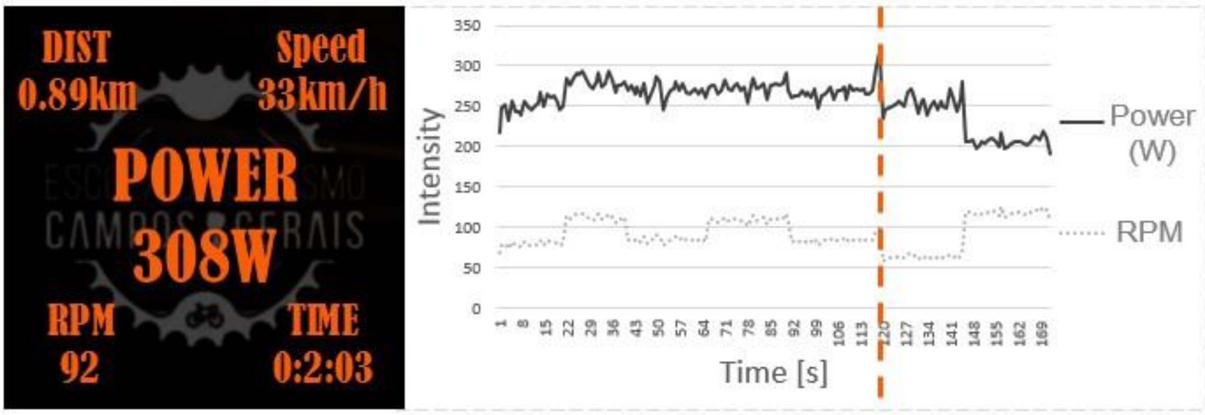

Figure 13 – Values of power and cadence in data collection

The collected data were used to verify the functioning of the system, but are still only as lab tests, not implemented at cyclists on the street. The graph above figures demonstrate the power output behavior in 170 seconds of data collection, separated for exemplification online prototype.

Other devices are also used for the definition of competition and training strategies. It has GPS (Global Positioning System) can monitor distances, altitude, direction of movement, beyond the time kept in speed ranges (RANGSEE; SUEBSOMBAT; BOONYANANT, 2013). Other equipment used for this purpose is the heart rate monitor, which can be used for training monitoring in sports that are dependent on cardiorespiratory conditions, for example running (DELGADO-GONZALO et al., 2015).

4. DEVELOPING APPLICATIONS

The development of the sport can be given by inserting engineering projects applied to sports. In addition to various applications in the sport can also be developed by Electric Instrumentation (sensing, control, electronics, etc.). There are other projects starting in DAELE, projects with direct applications to develop equipment geared to sports performance.

In this topic are presented six projects that are part of UTFPR/Ponta Grossa, Electronic Department researches, besides those already mentioned previously:

a) Gait analysis: instrumented system that checks the position, acceleration, speed, time and the slope of the human gait. Applied in sports that require a great march to its practice in high performance, such as race walking, running, marathon, triathlon, etc;

b) Analysis of impulse: system for physical assessment, measuring the time of vertical jump athlete, impact on arrival and the drive output. Equipment used for physiological checks as anaerobic power and maximum steady;

c) Tennis player analysis: vibration arm measurement with the contact of the ball on the racket (avoid injury), response time measurement in relation to beat the opponent (performance), lifting the trajectory of the strike movements (corrections), such as: right, left and serve (SELL et al., 2012);

d) Movement, strength and reaction time analysis in martial arts: gloves and instrumented leggings for lifting movement trajectory (attack and defense), reaction time due to the movement of the opponent, contact time and strength in attack (punches and kicks);

e) Pressure plant analysis: instrumental insoles installed in tennis (in-shoe system) that measuring plantar pressure in dynamic situations such as: jumping, running, walking, climbing, etc. The measurement of plantar pressure can corroborate with the following analysis: types of gear, types of stepped (pronated, supinated or normal), foot contact area depending on the mode (sprinters, distance runners, triathletes, jumpers, etc.), among others;

f) Swimming technique analysis: instrumented system that is installed on the athlete's body (wrists, calves, pelvis, etc.) enabling the analysis of the athlete's movement depending on the type of swimming; counting the number of armful and leg kicks; time and speed for performing each movement; reaction time and turn technique; classification of movements; and strategies analysis.

All these applications under development can be used separately by means of data processing, computer systems of classification and analysis of data and user interfaces. They can also compose a sensor fusion installed on the athlete and clothing accessories (bike, paddle, martial gloves, etc.), enabling simultaneous analysis and real-time feedback to the athlete and his instructor.

5. CONCLUSIONS

The technology is intrinsically present in modern sport, since in the location that take place to the equipment used, with the objective of performance and outstanding results. In addition to helping athletes overcome limits, also contribute significantly to the judge's decision to make the fairest result.

With the development of the equipment, it is possible to perform a complete analysis of the athlete, and obtain your actual physical and physiological condition. Develop specific training and monitor their progress throughout a season or predetermined period. Thus, compare and analyze results and data, is no longer a simple statistical and became something essential for high-level sports. After all, it offers a competitive advantage in the sense of understanding the sport practiced, a process that gets more and more investment and attention from the staff. This means that the possibilities are infinitely large, and it is virtually impossible to link any sport discipline that cannot have this kind of application.

Another advantage of sports technology is that it does not influence only on professional athletes, is also perceived in the social sphere, it provides stimulation of correct and healthy sports practice by the population in general.

REFERENCES

BASSET, D.R., KYLE, C.R., PASSFIELD, L, BROKER, J.P., BURKE, E.R. Comparing cycling world records, 1967-1996: modeling with empirical data. **Med Sci Sports Exerc**. 1999; 31: 1665-76.

BERTUCCI, W.; TAIAR, R.; GRAPPE, F.. Differences between sprint tests under laboratory and actual cycling conditions. **The Journal of Sports Medicine and Physical Fitness**, Torino - Italy, n. 45, p.277-283, 2005.

BORIN, João Paulo; PRESTES, Jonato; MOURA, Nélio Alfano. Characterization, Control and Evaluation: Limitations and Possibilities in Athletic Training Scope. **Revista Treinamento Desportivo,** [s.l.], v. 8, n. 1, p.6-11, 2007. (text in Portuguese).

CARLING, Christopher et al. The Role of Motion Analysis in Elite Soccer: Contemporary Performance Measurement Techniques and Work Rate Data. **Sports Med,** [s.l.], v. 38, n. 10, p.839-862, 2008.

CARREIRO L.R.R; HADDAD JÚNIOR H; BALDO M.V.C. The modulation of simple reaction time by the spatial probability of a visual stimulus. **Braz. J. Med. Biol. Res**. v.36, p.907-11, 2003.

DELGADO-GONZALO, Ricard et al. Evaluation of accuracy and reliability of Pulse on optical heart rate monitoring device. **2015. 37th Annual International Conference of The Ieee Engineering In Medicine And Biology Society (embc),** [s.l.], p.430-433, ago. 2015. Institute of Electrical & Electronics Engineers (IEEE). http://dx.doi.org/10.1109/embc.2015.7318391.

EBERT, Tammie R. et al. Power Output During a Professional Men's Road-Cycling Tour. **International Journal of Sports Physiology and Performance**, USA, v. 1, n. 1, p.324335, 2006. ORIGINAL INVESTIGATIONS.

FOSTER, Carl et al. A New Approach to Monitoring Exercise Training. **Journal of Strength And Conditioning Research,** [s.l.], v. 15, n. 1, p.109-115, 2001.

GARMIN. Vector. 2015. Disponível em: <https://buy.garmin.com/en-US/US/intosports/cycling/vector-/prod93569.html>. Acesso em: 27 maio 2015.

HANNAH, R. L.; REED, S. E.. **Strain Gage Users' HANDBOOK.** London: Chapman & Hall, 1992.

LIEBERMANN, Dario G. et al. Advances in the application of information technology to sport performance**. Journal of Sports Sciences**. Calgary, p. 755-769. 26 jan. 2002.

LIMA, Elessandro Váguino de et al. Study of the correlation between the velocity of motor reaction and blood lactate in different times of combat in judo. **Rev Bras Med Esporte,** [s.l.], v. 10, n. 5, p.344-348, 2004.

MCCOLE SD, CLANEY K, CONTE JC. **Energy expenditure during bicycling**. J Appl Physiol 1990; 68: 748-52.

MCGANN, B**. The Story of the Tour de France.** 2006. Volume 1: 1903-1964, Editora Perigee, pag. 4 e 5, ISBN 1-59858-180-5.

NEPTUNE, Richard R.; MCGOWAN, Craig P.; FIANDT, John M.. The Influence of Muscle Physiology and Advanced Technology on Sports Performance. **Annual Review of Biomedical Engineering,** [s.l.], v. 11, n. 1, p.81-107, ago. 2009. Annual Reviews. http://dx.doi.org/10.1146/annurev-bioeng-061008-124941.

POWERTAP. G3 - HUB. 2015. Disponível em: <http://www.powertap.com/catalog/hubswheelsets>. Acesso em: 27 maio 2015.

RANGSEE, Pattarakamon; SUEBSOMBAT, Paweena; BOONYANANT, Phakphoom. Simplified low-cost GPS-based tracking system for soccer practice. **2013 13th International Symposium on Communications and Information Technologies (iscit),** [s.l.], p.724-728, set. 2013. Institute of Electrical & Electronics Engineers (IEEE). http://dx.doi.org/10.1109/iscit.2013.6645948.

REDKVA, P.E., ZAGATTO, A.M.,GOMES, E.B., KAMINAGAKURA, E.I., PAPOTI, M. Prediction of Aerobic Performance in Distance from 1200 to 2800 M for Laboratory Testing with Military Runners. **Journal of Exercise Physiology** (online), v.15, n.5, p.107-114, 2012.

SELL, K. et al. Injury trend analysis from the US Open Tennis Championships between 1994 and 2009. **British Journal of Sports Medicine,** [s.l.], v. 48, n.7, p.546-551, 25 ago. 2012. BMJ. http://dx.doi.org/10.1136/bjsports-2012-091175.

SRM. PowerMeters. 2015. Disponível em: <http://store.srm.de/powermeteronly.html?limit=36>. Acesso em: 27 maio 2015.

ZAGATTO, Alessandro M; BECK, Wladimir R; A GOBATTO, Claudio. Validity of the Running Anaerobic Sprint Test for Assessing Anaerobic Power and Predicting Short-Distance Performances. **Journal of Strength and Conditioning Research,** [s.l.], v. 23, n. 6, p.1820-1827, set. 2009. Ovid Technologies (Wolters Kluwer Health). http://dx.doi.org/10.1519/jsc.0b013e3181b3df32.

WRAGG, C. B.; MAXWELL, N. S.; DOUST, J. H.. Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. **Eur J Appl Physiol,** [s.l.], v. 83, n. 1, p.77-83, 2000.