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PILOT STUDY ON THE USEFULNESS OF AN INSTRUMENTED CONSTANT BRAKE FOR THE EVALUATION OF THE PROPULSIVE FORCE OF THE FINS IN LIFESAVERS

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Resumen

Estudio de caso sobre la utilidad de un freno constante instrumentalizado para la evaluación de la fuerza propulsive de las aletas en socorristas
Resumen:
Antecedentes: Valorar el rendimiento físico es indispensable para mejorar los procesos de planificación y entrenamiento. Esta valoración es esencial en el salvamento y socorrismo tanto en su vertiente deportiva como profesional.
Objetivos: El objetivo de este estudio de explorar la idoneidad de una batería de test de medición de fuerza propulsiva y la utilidad de un test experimental de potencia en salvamento y socorrismo que arroje datos de fuerza, potencia y técnica.
Método: En este proyecto ha participado una deportista de talla mundial. Se ha realizado la misma batería de test en tres momentos de la temporada. Los test corresponden al test de fuerza propulsiva máxima, el test de fuerza propulsiva media y el test experimental de potencia.
Resultados: La fuerza propulsiva máxima ha mejorado un 10,8% a lo largo de la temporada, así como la fuerza propulsiva media (0,74%) y la potencia (49.11%). También otros parámetros como la amplitud de patada han aumentado (38,53%), mientras que la frecuencia de aleteo ha disminuido un 25% a lo largo de la temporada.
Conclusiones: Los test realizados aportan información relevante y están correlacionados entre sí. El test de fuerza propulsiva máxima y el test experimental de potencia podrían ser los que aportan información más relevante para prescribir el posterior entrenamiento.
Palabras clave: valoración, rendimiento, fuerza propulsiva, natación con aletas, potencia, salvamento y socorrismo.

Case study on the usefulness of an instrumented constant brake for the assessment of fin propulsive force in lifeguards
Abstract
Background: Assessing physical performance is essential to improve planning and training processes. This assessment is essential in lifesaving, both in its sporting and professional aspects.
Objectives: The objective of this study is to explore the suitability of a propulsive force measurement test battery and the usefulness of an experimental power test in lifesaving that yields data on force, power and technique.
Method: A world-class athlete has participated in this project. The same battery of tests has been carried out at three times of the season. The tests correspond to the maximum propulsive force test, the average propulsive force test and the experimental power test.
Results: The maximum propulsive force has improved by 10.8% throughout the season, as well as the mean propulsive force (0,74%) and power (49.11%). Also, other parameters such as kick amplitude (38,53%) have increased, while frequency has decreased by 25% throughout the season.
Conclusions: The tests carried out provide relevant information and they are correlated with each other. The maximum propulsive force test and the experimental power test could provide the most relevant information to prescribe subsequent training.
Keywords: assessment, performance, propulsive force, swimming with fins, power, lifesaving.

Estudo de caso sobre a utilidade de um freio constante instrumentado para avaliação da força propulsora das nadadeiras em nadadores salvadores
Resumo
Antecedentes: A avaliação do desempenho físico é essencial para melhorar os processos de planejamento e treinamento. Essa avaliação é essencial no resgate e primeiros socorros, tanto no aspecto esportivo quanto no profissional.
Objetivos: O objetivo deste estudo é explorar a adequação de uma bateria de testes de medição de força propulsora e a utilidade de um teste de força experimental em resgate e primeiros socorros que forneça dados de força, potência e técnica.
Método: Um atleta de classe mundial participou deste projeto. A mesma bateria de testes foi realizada três vezes durante a temporada. Os testes correspondem ao teste de força propulsiva máxima, ao teste de força propulsora média e ao teste de potência experimental.
Resultados: A força propulsiva de pico melhorou 10,8% ao longo da temporada, assim como a força propulsiva média (0,74%) e a potência (49,11%). Outros parâmetros, como a amplitude do chute, também aumentaram (38,53%), enquanto a frequência do wingbeat diminuiu 25% ao longo da temporada.
Conclusões: Os testes realizados fornecem informações relevantes e estão correlacionados entre si. O teste de força propulsora máxima e o teste de potência experimental podem ser os que fornecem as informações mais relevantes para prescrever treinamentos subsequentes.
Palavras-chave: avaliação, desempenho, força propulsora, natação com nadadeiras, potência, resgate e primeiros socorro.

Introduction

Physical performance assessment is essentially the basis for sports planning and development. It is also for lifesaving, both in its sporting and professional aspects. In this sports discipline there is a great variety of specialties that are revealed in the variety of skills necessary in the professional field. The demands of this sport and profession require mastering specific techniques in skiing, rescue boards, fins, running, swimming, cardiopulmonary resuscitation (CPR) techniques, etc. The fins are a key element in the lifesaving competition in the pool section and it is also a widely used tool in the approach to the victim in the professional field.

When reviewing the state of the art on this subject, little scientific literature has been found specifically related to lifesaving, which is why it is necessary to resort to the scientific literature of other sports disciplines such as swimming with fins and swimming itself.

In conventional swimming, the main propulsive forces are generated by the upper extremities. However, in finswimming, the propulsive motion starts at the hip and is based on the whole-body oscillation (Baly et al., 2001; Baly et al., 2002; Gautier et al., 2004a). Athletes avoid using the upper limbs and try to maintain a streamlined position, primarily using the lower limbs and trunk muscles to produce a propulsive motion (Kunitson et al., 2015). According to Gautier et al. (2004b) a finswimmer is a propulsive and propelled body. The propulsion movement starts from the hip, adapting it in frequency and amplitude depending on the distance. The swimmer must limit knee flexion and body tilt to promote greater hydrodynamics (Vogel, 1994). A greater amplitude of movement of the upper limbs means that the athlete will obtain less efficiency of kinetic energy (Gautier et al., 2004). For this reason, it is important to keep your hands and wrists horizontal to transfer speed (Kunitson & Port, 2017).

There are differences in technique depending on the swimmer's experience and gender (Gautier et al., 2004). Beginner swimmers produce greater upper body oscillation and greater knee flexion. With the increase in the distance covered, beginners increase the frequency compared to those expert swimmers, since a fast movement prevails over the efficiency of the kick technique. For both novices and experts, decrease frequency and speed as distance increases. Added to these modifications is the increase in the oscillation of all the joints. The existence of an adaptation of the movement as a function of the swimming distance is revealed.

When comparing the technique between genders, it was found that, within the group of experts, women flex their knees more than men (Gautier et al., 2004). This could be due to lack of strength. Leg strength and swimming speed have been shown to be linked to range of motion and technical errors. The lower the force, the lower the speed, the lower the amplitude of movement and the more technical errors.

Trappe & Pearson, (1994) state that strength and speed are factors that determine the performance of swimmers, so there are two types of finswimmers: fast sprinters and strong sprinters. (Kunitson et al., 2017). Fast sprinters are characterized by performing more kicks, that is, they have more gestural frequency but less kicking amplitude, while the so-called strong sprinters decrease kick frequency and increase their amplitude. The difference is also given by the hardness of the fins used, since there are soft fins (suitable for fast sprinters) and hard fins (suitable for strong sprinters). Stiffer fins induce greater force in the ankle joint while less rigid fins induce less force, therefore, the type of fins is a determining parameter in performance (Nicolas et al., 2010).

Regarding the dynamics of the lower limb, in a coordinated effort with the trunk and hip muscles, they produce a kicking movement that is similar to the classic butterfly style kick technique. The muscle groups responsible for this movement are the knee extensors, the hip flexors and the trunk flexors (Kunitson et al., 2015).

There are two phases to the fin kick: up and down. Nicholas et al. (2010) established that the downward phase of the kick produces more force than the upward phase. However, being able to measure the propulsion generated by the kicking of fins or being able to create curves of force or power of these two movements is not an easy task.

To measure the propulsive force in the aquatic environment, several proposals have been made over the years. These proposals have focused on the lift and drag forces of the upper limb. The maximum propulsive force test at zero speed and the mean propulsive force test (Llana Belloch, 2002) seem to provide useful results in fin performance. These evaluations are relevant due to the correlation they have shown with the results in speed tests (Colomina, 1992).

The object of study of this work is to measure the propulsive force in fins throughout a competition season of a high-level athlete. The objective is to explore the suitability of a propulsive force measurement test battery and the usefulness of an experimental power test in lifesaving fin tests.

Method

Sample

A lifesaver specialist in fins participated voluntarily in this study. This elite athlete is usually in the selection of the Royal Spanish Federation of Rescue and First Aid and she is one of the greatest world exponents in this discipline. The research protocol followed the principles of the Declaration of Helsinki on biomedical research involving human beings (64th World Medical Assembly 2013).

Measuring instruments

Maximum propulsive force test. The material used to carry out this test consists of a strain gauge (Chronojump Boscosistems, Spain) calibrated and tared in situ and fixed to the outlet podium of the vessel. This gauge is followed by an inextensible rope attached to a belt that is placed around the athlete's waist (figure 1). The test consists of performing a maximum flap beat on the surface for 10 seconds.

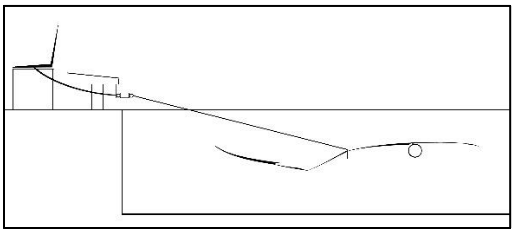

Figure 1. *Maximum propulsion force test items.*

Note. From left to right: data logging computer, connection cable, starting podium, strain gauge, inextensible rope and belt.

Mean propulsive force test. In this case, the inextensible rope is replaced by a elastic band also attached to the belt (figure 2). The test consists of performing a maximum underwater kicking until exhaustion or until reaching the bottom of the swimming pool.

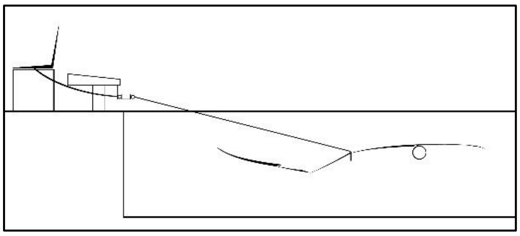

Figure 2. *Mean propulsion force test items,.*

Note. From left to right: data recording computer, connection cable, starting podium, strain gauge, surgical rubber and belt.

Experimental power test. This test is performed with the same strain gauge attached to the pool's starting podium. Next, a constant-resistance braking system and an inextensible rope tied to the swimmer's belt are installed (figure 3). The chosen resistance is 9,8 N so that it does not excessively influence the athlete's technique and, in turn, is sufficient to express the power curves. A video system is also installed that follows the movement of the athlete underwater to synchronize it with the power curves. The test consists of a maximum and underwater finning until reaching the wall on the opposite side of the pool.

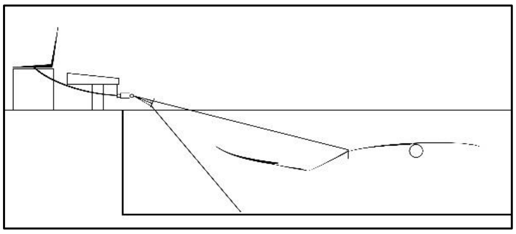

Figure 3. Experimental power test.

Note. From left to right: data logging computer, connection cable, starting podium, strain gauge, braking system, inextensible rope and belt.

All these tests are carried out without calibrating the result by the angle of the height at which the gauge is placed. By always doing it under the same conditions and due to the dynamics of the kicking of the butterfly technique, we believe that modifying this parameter can lead to error.

Variables

The variables recorded in the maximum propulsive force test were: maximum force (FPMax Max), mean force (FPMax Med), root mean square (FPMax RMS), frequency (FPMax F) and the amplitude (FPMax A) understood as the difference in force between the maximum peak and the minimum of each oscillation of the fin.

The variables provided by the mean propulsive force test were: maximum force (FPMed Max), mean force (FPMed Med) and the time invested (FPMed T).

The variables recorded in the experimental power test were: maximum power (P Max), average power (P Med) and the time invested (PT).

Study design

The case study consisted of the development of a new propulsive force measurement system and its comparison with previous methods already studied. Contrast information has been obtained using two widely tested evaluation methods: the maximum propulsive force test and the mean propulsive force test.

The evaluations were carried out under the same environmental conditions and in the same pool. The evaluation protocol consists of a competition warm-up with which the athlete was already familiar and always at the same moment of the different mesocycles of the season, at the end of it. The battery of tests begins with the maximum propulsive force test, then the average propulsive force test is carried out and it is concluded by carrying out the last test with the new measuring instrument.

Analysis of data.

To determine the degree of correlation of the variables of interest, an exploratory study of bivariate correlations has been carried out using the Pearson correlation coefficient.

Results

Maximum propulsive force test. In the maximum force values, a clear increase is observed from the first test to the last (10.8%). The average value is reduced (17,14%). In relation to the RMS, the values also decrease throughout the tests carried out in the season. Considering the frequency, a clear reduction is observed (25%) and considering the amplitude of the fins, an increase in its value is denoted (38,53%). (Table 1)

Table 1. Data collection of maximum force, mean force, RMS, frequency and mean amplitude of the maximum propulsive force test.

Test	1º (7/12/2020)	2º (10/03/2021)	3º (12/05/2021)
FPMax Max N	299,76	291,36	332,13
FPMax Med N (SD)	207,04(58,42)	191,42(55,46)	176,61(82.20)
FPMax RMS	215,11	199.28	194.78
FPMax F Hz	1,6	1,6	1,2
FPMax A N (SD)	164,66(29,31)	148,47(26,84)	228,10(20,07)

SD: standard deviation; F: force; N: newtons; Hz: hertz; FPMax Max: maximum force; FPMax Med: average force; FPMax RMS: root mean square, FPMax F: frequency; FPMax A: amplitude

Figure 4 shows the flap beat force profile. A large and clear curve is verified that coincides with the phase of maximum force production or descending phase and a small peak that coincides with the descending phase.

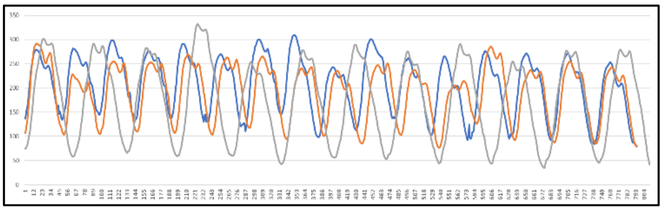

Figure 4. Comparative graph of the three maximum propulsive force tests performed.

Note. The blue graph corresponds to the first test, the orange graph to the second, and finally the gray graph to the last. Force on the y-axis and time on the x-axis.

Average propulsive force test: In this test it is observed that the maximum forces are reduced (3,51%) in the subsequent mesocycles. On the contrary, the mean values, which are the ones that best represent this test, increase slightly from the first to the third (0,74%) (Table 2).

Table 2. Data collection of maximum force and mean force and of the mean propulsive force test.

Test	1º (7/12/2020)	2º (10/03/2021)	3ª (12/05/2021)
FPMed Max N	160,81	159,54	155,16
FPMed Med N (SD)	94,26(49,77)	91,73(46,07)	94,96(43,42)
FPMed T ms	1068	1026	992

SD: standard deviation; F: force; N: newtons; ms: milliseconds; FPMed Max: maximum force; FPMed Med: mean force; FPMed T: time invested.

Figure 5 shows how each of the lines representing each force curve is reduced in size. The time invested in each test to reach the wall was less, being the difference between the first and the last of -7,12%.

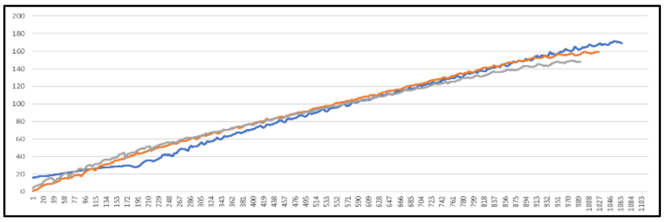

Figure 5. Comparative graph of the three average propulsive force tests performed.

Note. The blue graph corresponds to the first test, the orange graph to the second, and finally the gray graph to the last. Force on the y-axis and time on the x-axis.

Experimental power test: as a result of the data obtained in this test, we can see how the maximum watts have fluctuated, reaching their maximum in the first test. On the other hand, the average watts has increased a total of 49,11%. Finally, and in agreement with what was observed in the mean watts, the time has improved as the training mesocycles have progressed, reducing by 17,95% (table 3).

Table 3. Data collection of maximum power, average power and time of the experimental power test.

Test	1º (7/12/2020)	2º (10/03/2021)	3ª (12/05/2021)
P Max w	120,6	90,05	102,72
P Med w (SD)	25,21(14,10)	25,70(14,76)	37,59(14,76)
P T ms	1393	1368	1143

W: watts; SD: standard deviation; ms: milliseconds; PMax: maximum power; P Med: average power; PT; time invested.

Observing figure 6 we can compare the moments in which each of the tests were finished and the profiles of the power curves generated.

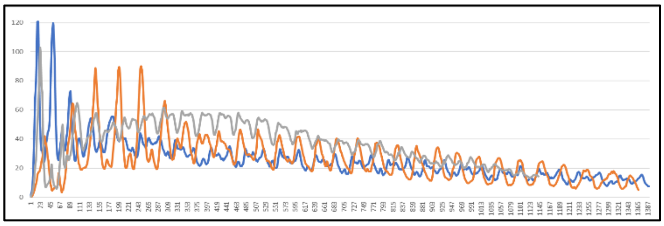

Figure 6. Comparative graph of the three tests carried out with the prototype.

Note. The blue graph corresponds to the first test, the orange graph to the second, and finally the gray graph to the last. Power on the y-axis and time on the x-axis.

Figure 7 shows the degree of correlation that exists between the different variables. The positive and significant correlation (r=1; p=0,02) between the maxima of the maximum propulsive force test (FPMax Max) and the amplitude of this same test (FPMax A) stands out. There is also a positive and significant correlation (r=0,99; p=0,029) between the mean force of the maximum propulsive force test (FPMax Med) and the mean force of the mean propulsive force test (FPM Med Med). In relation to the negative correlations, the relation between the frequency taken in the maximum propulsive force test (FPMax F) and the mean power value (P Med) collected in the experimental apparatus should be highlighted (r=0,99; p=0,022). Finally, we must name the correlative significance (r=0,99; p=0,036) between the mean power (P Med) and the time (PT) collected in the test with the new measurement instrument.

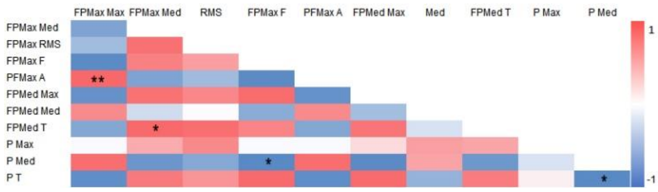

Figure 7. Comparative graph of the degree of Pearson correlation of the variables.

*Note. **. The correlation is significant at the 0.01 level (bilateral). *. The correlation is significant at the 0.05 level (bilateral).*

Discussion

The measurement of propulsive force in the aquatic environment has been object of study over the last 50 years. These experiments have been oriented towards classical swimming. Our intention is to explore these measurement instruments and compare them with a new experimental power measurement system. This design is mainly aimed at lifesaving.

The first exploration carried out was that of the maximum propulsive force at zero speed. Although the mere fact that the lifeguard is anchored can cause the technique to be distorted (Llana Belloch, 2002). It seems that this test can provide relevant information in relation to propulsion in the water and how to do it. In addition, it has been shown that this test correlates positively with the speed tests (Colomina, 1992), as it seems to emerge throughout the season in the athlete's different competitions. As the mesocycles took place, this test improved some of her parameters and the athlete managed to improve her marks in competition.

Based on the results (table 1), we see how the maximum force parameters (FPMax Max) have been improved in relation to the contributions of Colomina (1992). On the other hand, as her force parameters improve, her fin beat amplitude (FPMax A) increases and her frequency (FPMax F) decreases. These results agree with the statements of Kunitson & Port (2017). In their studies, they determined that swimmers with strong sprint fins are those who obtain greater amplitude while reducing their frequency. This fact is in line with the specific strength work that was carried out with our lifeguard, improving her parameters throughout the season. Going back to the amplitude data, we observe how the standard deviation decreases throughout the tests carried out, these data could mean that the athlete has improved her finning technique.

Regarding strength training in finswimming, Stavrou et al. (2018) establishes that the number of hours invested in the gym can predict the predominant test distance. Those swimmers in faster trials will spend more hours in the gym than those in longer trials. (<200m). In the case of swimmers under 200m, the average gym hours per day are 1,4 ± 0,6 and in the case of swimmers over 200m, the average hours per day are 1,1 ± 0,2. Training should include training sessions both in and out of the water, for endurance and strength work (Sadowski et al. 2012) to obtain positive effects on sprint performance. (Costill, 1999).
On the other hand, power training consists of ultra-short speed races. The objective of this is to increase the power of the stroke, as a result of the muscle force applied and the speed of application (Maglischo, 2009). For this reason, the strength test may not be representative of all the factors that affect performance in the fin test. For this, the experimental power test has been designed.

We believe that the maximum propulsive force test can provide us with relevant information on the athlete's finning profile. It allows us to interpret the force curves clearly and determine the amplitude, frequency and propulsive force.

The second exploration carried out was through the average propulsive force test. The results of this test (table 2) are positive in relation to the mean force recorded (FPM Med Med). We understand that the average force is the one that provides the greatest relevance since the main objective of this test is precisely to determine this parameter (Llana Belloch, 2002). The second relevant value in this test was the time spent (FPMed T) since in all three cases the athlete touched the opposite wall of the swimming pool. We can determine that, the shorter the time spent, the higher the swimming speed. The value of the time invested accompanies the value of the mean propulsive force, which reaffirms these findings.

The last test carried out was the experimental power test. While previous tests measure force directly using the strain gauge, this new method relates the constant braking resistance to the athlete's speed, resulting in a value in watts. Table 3 shows the variables of this test. In this table we see how the average watts (P Med) increase as it happened with the average newtons of the previous tests. On the other hand, we have the variable of the time invested (PT) in the movement of the athlete throughout the entire pool. In this sense, we also observe how as the power parameters improve, the time invested decreases, therefore, its speed increases.

By exploring figure 7, we can see how there are strong correlations between FPMax Max and FPMax A (r=1), being statistically significant (p=0.01). We found another positive and statistically significant correlation (r=0,99) between the variables FPMax Med and FPMed T (p=0.029), denoting the relationship between the improvement in mean force recorded in the maximum propulsive force test and the time spent in the mean propulsive force test.

The third significant value (r=-0,99) corresponds to the variables FPMax F and P Med (p=0.022) inversely relating the frequency values recorded in the maximum propulsive force test and the mean power recorded in the experimental test. As the mean power increases in the experimental test, the frequency observed in the maximum propulsive force test decreases. These values agree with the findings of Kunitson & Port, (2017).

The last of the significant and inverse values (r=-0,99) corresponds to the experimental test relating the average power (P Med) and the time invested (PT) (p=0,036). In line with the previous results, as the average power increases, the time invested decreases. We can observe more strong relationships between the different variables for which we have not obtained significant results.

Interpretations of these values must be taken with great caution since this exploration is only a case study at three different times of the season and only for an athlete.

The following lines of research will be aimed at improving the prototype's rope collection system to facilitate its use. On the other hand, once the possibilities have been explored, we believe that it is necessary to carry out a larger study with an adequate n to verify whether these first findings are relevant or not. Another question to explore is to contrast the speed of the athlete with the speed derived from power.

Conclusion

The maximum propulsive force test seems to provide relevant information about the lifesaver's fin beat profile: mean propulsive force, fin beat frequency and fin beat amplitude of the athlete.

The experimental power test seems to provide relevant information about the power exerted by the lifesaver: mean power and time.

The average force test, although it has provided relevant information (mean propulsive force and execution time), could be replaced by the experimental power test in favour of optimizing the time when performing the tests.

Practical applications

These tests can be used by both professional and sports lifeguards to assess their performance and make decisions that affect both their physical preparation and their finning technique.

By synchronizing the high-speed video recording with the data from the experimental power test we can get a clear picture of the athlete's biomechanics by coordinating speed, power and image.

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