
THE SWIMMING POWER. NEW METHOD TO TRANSFER THE POWER FROM DRYLAND TO THE WATER

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Резюме: Вивчено вплив метода силового тренування на потужність плавання 20 спортсменів-ветеранів, яких було умовно розподілено на дві групи – силової ($n = 10$, ST) і плавальної ($n = 10$, SW) підготовки. Тренувальні заняття проводилися упродовж 6 тиж. і включали в групі SW плавальну підготовку та силову з подальшим плаванням з максимальною швидкістю. Результати в обох групах оцінювали на основі максимальної–механічної–зовнішньої потужності (ММЕР), застосуванням ергометра для вимірювання сили, швидкості і потужності в воді. В групі ST спостерігали значне підвищення ММЕР (5,79 %; $p < 0,05$) разом із збільшенням сили (11,70 %; $p < 0,05$) і зниженням швидкості (4,99 %; $p < 0,05$). В групі SW виявлено зниження ММЕР, сили і швидкості (7,31, 4,16 % і 4,45 %; $p < 0,05$). Дослідження показало, що метод, заснований на поєднанні силового тренування (на суші) з подальшим швидким плаванням, істотно збільшує потужність плавання у спортсменів-ветеранів.

Ключові слова: екологічна валідність, тестування в польових умовах, тест потужності в воді, результат, силове тренування.

Резюме. Изучено влияние метода силовой тренировки на мощность плавания 20 спортсменов-ветеранов, которые были условно разделены на две группы – силовой ($n = 10$, ST) и плавательной подготовки. Тренировочные занятия проводились в течение 6 нед. и включали плавательную подготовку в группе SW и силовую, предусматривающую занятие силовой направленности с последующим плаванием с максимальной скоростью. Результаты в обеих группах оценивали на основании максимальной–механической–внешней–мощности (ММЕР) до и после 6 нед. занятий, с использованием эргометра для измерения силы, скорости и мощности в воде. В группе ST наблюдали значительное увеличение ММЕР (5,73 %; $p < 0,05$) наряду с увеличением силы (11,70 %; $p < 0,05$) и снижением скорости (4,99 %; $p > 0,05$). В группе SW выявлено снижение ММЕР, силы и скорости (7,31, 4,16 %, и 4,45 %; $p > 0,05$). Исследование показало, что метод, основанный на сочетании силовой тренировки (на суше) с последующим быстрым плаванием, существенно увеличивает мощность плавания у пловцов-ветеранов.

Ключевые слова: экологическая валидность, тестирование в полевых условиях, тест мощности в воде, результат, силовая тренировка

Introduction. The metabolic demands of the swimming competitions is very different, indeed aerobic and anaerobic systems [1] are related to the race time (from 20 sec for 25-m to 900 sec for 1500-m) Nevertheless, the performance of swimmers was continuously improved due the enhancement of technique [2], the evolution of the facilities [3] and the improvements of the physical skill of the athletes [2]. Swimming action recruits many muscles for propulsion, mechanical power, and for drag contrast [4]. Therefore, the muscle strength plays a crucial role to increase the swim velocity [5]. Although some authors [6, 7] have shown that the adjustments related to technical movements performed in «dry conditions» using overloads, may be useful to improve the technique of the swimmers in the water, this was not confirmed by field swimmer's coaches. Currently, two methods are mainly used for strength training purposes in swimmers: «dry-met-

hods», namely with session out of water composed by exercises with loads of general type [8–10], or by «simulating» the swimming movements [11]. The simulation approach was carried out with «aquatic-methods» training session, when the swim is overloaded with tethered [12] or tools that increase the dragging force [4].

However, it is not yet entirely clear on the actual effectiveness of these methods [1], as it appears difficult to increase the strength as the power of swimmers through «aquatic-methods» into load session [13, 14]. Similarly, an increasing strength method obtained with «dry-methods» showed some limits on the «transferability» on specific technical swim movements [9, 15]. Recently, several in-water methods [5, 16] were used to assess the strength and the power of the swimmers through the assessment of the drag, providing conflicting results [5, 16, 17]. The strength and power estimates from swimming

velocity doesn't seem adequate [8, 18, 19] because the swimming velocity was related to muscle power, and both propulsion efficiency and drag coefficient of swimmer [5]. In rare cases the use of tethered test has been reported with some limitations (the swimmer cannot **effectively** advance in water, and thus the technical gestures are altered).

Among the different methods of training alternating dry weights and swimming we chose the method proposed by Prof. Cometti [20]. Despite never having been studied with scientific rigor its principles are clear. This innovative method aimed to improve the swimmer performance, using an approach potentially valid even in other disciplines (such as Team Sport). Through the Cometti method [21] stimulate the muscle fibers using a weight of about 80 % of a maximum repetition immediately followed by the execution of technical movements specific of each discipline (in our case swimming [20, 21]). The goal would be to stimulate the muscle fiber with an overload in water, that is impossible to reproduce because of the lack of «stable points of resistance». Therefore the aim of this study was to verify a Cometti training method based on mixed «dry-land phase with overloads with a series of fast swimming» on the swimming power with a specific semi-tethered swimming test.

Materials and Methods

Participants

Twenty senior male master swimmers belonging to the same team were recruited for the study and randomly assigned to either the strength training (ST, $n = 10$) or swimming training (SW, $n = 10$) groups. Their main anthropometric data, as well as their best performances on 100 meter crawl. In order to be included in the study, participants had to: 1) participate in at least 90 % of the training sessions (see following chapter about training program), 2) have regularly competed during the previous competitive season, and 3) possess a medical clearance. There were no dropouts from the experiments and no injuries occurred during the experimental training or testing sessions. Indoor field tests were completed in a certified swimming pool. Baseline tests started at 5:00 p.m. ($26,5 \pm 0,12^\circ\text{C}$, water temperature), while post-assessments were carried out at 5:00 p.m. ($26 \pm 0,16^\circ\text{C}$, water temperature). The participants were healthy and clear of any drug consumption. The groups were homogeneous with regard to their training status (more 10 years background competitions). Each subject was fully informed and trained about the test's procedures and everyone gave the written informed approval to participate in the study in accordance with the guideline of the Muscle, Ligament and Tendons Journal [22]. All experimental procedures were approved by the University Human Research Ethics Committee,

which followed the ethical principles laid out in the 2008 revision of the Declaration of Helsinki.

Testing

A parallel, two-group, randomized, longitudinal (pre-test/post-test), single-blind experimental design was used. After baseline measurements, participants were randomly allocated to either the strength training (ST) or swimming training (SW) groups with an allocation ratio of one-to one [23]. The independent variable was «training type», so no control group was used. The study lasted 6 weeks (from September to November in pre-season) and consisted of one session of test (pre-and post-training) before and after one week training sessions. No additional strength, power and/or plyometric training was completed by the subjects out of the training intervention of the present study.

Training outcomes

Before and after (test-retest) the training period, participants performed one testing session of semi-tethered-swimming to assessment Maximal Mechanical External Power (MMEP). Before each testing session, participants were instructed not to eat for at least three hours before testing and not to drink coffee or beverages containing caffeine for at least eight hours before physical testing. Tests were completed at the same time of the day, with the operators unaware of the participant's allocation.

Maximal Mechanical External Power Test

The test consisted in 15 m all-out front-crawl swims across the pool while pulling a different load during each trial, besides the reliability of the test has been shown in previous studies to be very high (Intra-class Correlation Coefficient $> 0,80$) as shown by Dominguez-Castells et al. [24] After a standardized 800 m warm-up, the test started with a load of 45 N. The load increased by 25 N for each trial. Swimmers rested for 5 min between 2 consecutive 5 repetitions. The protocol ended when the swimmer was not able to complete a trial. Data related to the first and last 2,5 m was discarded to consider only constant speed conditions [24]. The MMEP parameters of interest were acquired by means of a dedicated custom ergometer designed and built by Tecnologicamente S.r.l. (Italy) with the collaboration of the workshop of the Department of Mechanical, Chemical and Materials Engineering of the University of Cagliari (Italy). The ergometer used for the experimental sessions was linked to the swimmer using a belt as described in the following.

This device is basically composed by a 28» wheel (acting as a drum with a winding circumference of 2092 mm), a cable, two sensors (force and speed) and an electronic apparatus necessary to properly conditions and transmits the data to a Personal Computer. The wheel is equipped with a disc brake (Shimano disc 160 mm diameter and Hayes Nine

brake caliper) and a reflective encoder wheel with 72 pulses per turn read by an optical speed sensor (Optek OPB704). A 500 N miniature tension-compression load cell (F2220, Tecsis GmbH, Germany) was hosted inside an aluminum cylindrical (160 mm long, 47 mm diameter with a nose cone to minimize the hydrodynamic resistance effects) that act as waterproof case and was connected to the swimmer through a belt equipped with a system composed by a light aluminum bar and four twines. The load-cell signal is conditioned and powered by a Mecos-train 2038 module embedded in the cylindrical aluminum case.

Prior to the tests, a calibration curve hydraulic pressure vs. resistant force was obtained using calibrated weights (corresponding to a $10 < 150$ N force range). Both force transducer and speed sensor signals were properly acquired by a National Instruments DAQ Module USB 6009 (8 channels, 14-Bit, 48 kS/s). A custom routine was developed in the National Instruments LabView® environment to collect and store data in form of ASCII files during the trial. The resulting files were then post-processed with a Matlab™ 10 software routine that transforms the raw data into a four-vectors text file containing time, traveled distance, instantaneous force, and speed values.

Training program

The training program was performed during six weeks, divided in three sessions for both groups in according to Cometti method [21]. All participants (ST–SW) after 15 minutes of standardized warm-up carried out the same set of exercises in water, that comprises several sprints in front crawl at maximum velocity with sets and recovery balanced. Each swimming session had a duration of approximately 2 hours and was repeated 5 times per week. During the swimming training the same distance was performed for both groups (ST–SW).

Particularly, ST group were performed as suggested by Cometti [20, 21], the strength training program during swimming training (mixed: weight training – swim maximum velocity and vice versa). The one repetition maximum (1-RM) test on bench press was conducted to determine maximal upper body strength as recommended by Padulo et al [25] one week before the training. Particularly, during the exercise with weight (85 % 1-RM [6]) or body load, subjects were asked to perform 6 fast repetitions [6] according to Cometti method [20, 21]. To minimize the effect of the passive recovery [20, 21] in-between weight training and swimming exercises (~5-s), each participant was encouraged by the coach.

Statistical analyses

Normality of the data was verified using the Shapiro-Wilk test. The null hypothesis was tested to reveal no difference between groups using multiple un-

paired *t*-tests. A two-way mixed analysis of variance (ANOVA) was used on each continuous dependent variable. The independent variables included one between-participants factor, training intervention with two levels (ST and SW), and one within-participant factor time, with two levels (pre-test and post-test). ANOVAs was used to test the null hypothesis of no difference in the change over time between ST and SW (training intervention \times time interaction), and the null hypothesis of no difference in the change over time in response to the training intervention (main effect for time). With this statistical design, the following variables were analyzed: MMEP (Watt), Force (N) and speeds ($\text{m}\cdot\text{s}^{-1}$). The effect sizes were also calculated (eta squared, η^2) for better interpretation of the results and *p*-value $< 0,05$ was considered significant. Test-retest reliability [26] was satisfied in previous study [24] using the Intra-class Correlation Coefficient (ICC). Statistical analysis was performed using Sigma-Plot™ software 11,0 (Systat Software, Tulsa, OK).

Results

There was no difference between groups at baseline conditions for age ($p = 0,070$), height ($p = 0,932$), body mass $p = 0,570$), BMI ($p = 0,524$), swimming performance on 50-m ($p = 0,563$) and 100-m ($p = 0,992$).

ANOVA with repeated measures revealed differences between the two groups in MMEP: $F_{(1,19)} = 2,403$, $p = 0,139$, and the interaction training type time $F_{(1,19)} = 11,367$, $p = 0,003$, while the Force showed $F_{(1,19)} = 3,227$, $p = 0,089$ ($\eta^2 = 0,152$), and the interaction training type \times time $F_{(1,19)} = 11,107$, $p = 0,004$ ($\eta^2 = 0,382$). Speed: $F_{(1,19)} = 0,443$, $p = 0,514$ ($\eta^2 = 0,024$), and the interaction training type \times time $F_{(1,19)} = 0,168$, $p = 0,686$ ($\eta^2 = 0,009$). Data from the ST revealed an improvement of force and MMEP: 11,70 % ($p = 0,012$) and 5,73% ($p = 0,050$) respectively, while the velocity decreased 4,99 % ($p = 0,070$) with respect to baseline conditions. Swimming training in SW group revealed a reduction in all variables studied.

Discussion

The results shown that the transfer is effective an improving MMEP in masters male swimmers and might represent a technique useful to achieve better performance. In the last years, several authors [27, 28] investigated new methods to improve the swimming performances. Particularly, in the swimming history, several reasons have limited scientific knowledge in water sports. Many technical approach were due to the environment that requires special equipment; in fact, it is still difficult to validate the different training methods so far tested in swimming [14]. Dominguez-Castells et al. [24] showed for the first time a new interesting method to assessing mechanical power output as a reliable predictor of per-

formance of the swimmers [24]; for this aim the Dominguez-Castells methodology has been used in the present investigation.

Our findings are partly in agreement with the results of Morouco [14], who showed the existence of a relationship between dry land strength and power measured during swimming performance [14, 29]. In dry conditions Morouco studied upper-lower limb muscle strength and revealed high associations between swimming performance vs. muscular strength method [29]. From our point of view, our work tries to change from that performed by Morouco particularly in two key points: entering the fast movements with weights (85 % 1 RM), and mixed training (weight training immediately followed by swimming sprints).

Force

Considering the effects of the this method [20, 21], the results indicate that mixed training increased the strength in ST group by 9.03-N (11,70 % increase). This effect could be emphasized especially for short time trials or several track competitions (e.g. 50–100 m) where the results are often highly contested with close finishes. The present study results are in line with Schmidtbleicher et al. [30] and Padulo et al. [6] that have shown that few repetitions and maximal loads (> 80% 1 RM) induced recruitment of fast-twitch motor units [6, 30] and increased muscle strength (10,20 % $p < 0,05$) for ST, compared to repetitions with low loads and free speed. This interesting improvement of the strength in ST obtained with a mixed model training can be analyzed as a further deepening of the understanding of the strength development in swimmers [13]. It seems that the adaptations of the swim intensity stimulate more than the mechanisms that trigger of aerobic capacity and limiting the development of the contractile muscle structure.

Conversely a decreased 4,16 % in SW does not stimulate fairly motor units. Indeed, swimmers train over many miles daily, and in the case of master swimmers this is more evident, at low intensity. Moreover the force applied in water requires particular sensitivity and gradation of effort [31]. The training for an enhanced MMEP, emphasizing neural adaptations, led to significant changes in rate of force development using weight training. These results showed an increased in rate of force development and thus power production, rather than the increased swimming workout. For this reason the MMEP was no changed in SW group. These results in the SW group can be related to lower stimulation of muscle strength with only swimming as a main training activity.

Velocity

The swimming speed was measured during the semi-tethered test at maximal load, because crucial component of the power value obtained. Concern-

ing the maximum speed the MMEP showed a dropping of ~5% ($0,04 \text{ m}\cdot\text{sec}^{-1}$) in both groups (ST–SW) that represented a decrease with respect to the pre-test value, resulting from the training interventions. Moreover, the velocity reported small differences (~5%) with no significant effects in both groups, in ST (min/max: $0,74\text{--}1,04 \text{ m}\cdot\text{sec}^{-1}$) this effects showed a shift on low speed of maximal power output (5,73% with $p < 0,05$). In according with Morouco et al. [29] the velocity must not be assessed as a negative effect on swim performances because this velocity represent the ratio between power output and force in MMEP.

Maximal-mechanical-external-power (MMEP)

The resultsshowed (Figure 2C) an increase of 4.04-w (MMEP), that representing 5,73% of pre-test values in ST. Improvements in ST of MMEP could be related to force production [32] more than in SW. The increased MMEP in ST on is in agreement with explosive movements on the neuromuscular systems [33]. In this regard, MMEP showed more accuracy in relationship to the ecological validity because in our semi-tethered test the swimmers performed 15 meters of swimming with external loads. As confirmed by Dominguez-Castells et al. [24] and Morouco et al. [29], the power test in swimming were altered when each subject were constrained to swim without wear on.

Combined effects of the variables studied

The innovative method suggested by Cometti highlights that for water sports, mixed training (land and water) is favorable to stimulate muscle strength, in relationship at the combination of movement in dry conditions (weight training) without other resistance as Drag. In addition, the various phases of eccentric/concentric [34] contractions during exercise in land are not altered by the hydrostatic pressure. On the same topic, di Prampero showed that the greatest fraction of the energy expenditure is utilized to overcome water resistance or Drag [17]. The 6 weeks explosive-type strength training resulted in considerable improvements in selected neuromuscular characteristics, although a large volume of endurance training was performed at the same time. An hypothesis is that training-induced alterations in neural control during stretch-shortening cycle exercises (such as running and jumping [35]) might take place in both voluntary activation, inhibitory and facilitatory reflexes [36].

From our point of view it is not clear if MMEP and strength increased in the ST, obtained through an intense workout of 6 weeks training with combinations «weight and swim training», has to be considered an important value to satisfy the research of mayor higher power. But again emphasizes how difficult it is to develop strength in the sport of swimming, as reported in considerations of other authors [13, 37].

We can conclude that many problems related to the development of strength in swimmers are to be found right on the most appropriate way to raise awareness of the motor gesture in the aquatic environment. The Cometti method [20, 21] that we tested in this work, proposes to include in its start-up phase muscle fast swimming immediate steps to address this problem. In our opinion, there are still elements to be explored as future developments mainly on the most appropriate periodization of the work-

load proposed. We believe that the work we propose is feasible to very experienced athletes and that, in its intensity, can give the most important effects of improvement after an appropriate period of tapering, as also proposed by other authors [28, 37].

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