Review Article

Effects of dry-land strength training on swimming performance: a brief review

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ABSTRACT

Morouço PG, Marinho DA, Amaro NM, Peréz-Turpin JA, Marques MC. Effects of dry-land strength training on swimming performance: a brief review. *J. Hum. Sport Exerc.* Vol. 7, No. 2, pp. 553-559, 2012. This article provides a brief review over the state of art concerning dry-land training for swimmers. It is important to understand the role of muscular strength for swimming performance and how it might be improved. Firstly, this article analyzes the relationships between strength or power assessment in dry-land and swimming performance. Secondly, the results of studies aiming to evaluate the influence of dry-land strength training to swimming performance improvement are presented. These results allow coaches to realize the benefits that may be obtained by an appropriate strength training program, according to gender and level. **Key words**: STRENGTH, POWER, FORCE, TESTING

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INTRODUCTION

Swimming performance is highly dependent on muscular strength and power (Sharp et al., 1982; Costill et al., 1986; Tanaka et al., 1993; Tanaka & Swensen, 1998; Girold et al., 2007). Using a variety of testing equipment, upper-body muscular strength and swimming power have demonstrated to be well correlated with swimming velocity (Sharp et al., 1982; Costill et al., 1986; Toussaint & Vervoorn, 1990; Hawley & Williams, 1991; Tanaka & Swensen, 1998; Aspenes et al., 2009). Therefore, improvements in arm strength may result in higher maximum force per stroke, subsequently in higher swimming velocities, specifically in sprint distances (Strzala & Tyka, 2009; Morouço et al., 2011a).

Dry-land strength training aims to increase maximal power outputs through an overload of the muscles used in swimming (Tanaka et al., 1993) and it may enhance swimming technique (Maglischo, 2003). If these two points of view are correct, then the increase of muscular strength would improve swimming performance. However, results from the available experiments remain inconclusive (Tanaka et al., 1993; Trappe & Pearson, 1994; Girold et al., 2007; Garrido et al., 2010). In this article it is presented a critical review of the swimming literature concerning the effects of dry-land strength training on the swimming performance, not taking into account the effects for starts and turns. It is aimed to summarize existent knowledge, in order to stimulate further researches.

Experiments available in the literature were gathered by searching databases (SportDiscus, PubMed, and Scopus). The search was carried with “swimming” as the main keyword, combined with the following words: “dry-land”, “power”, “strength”, and “force”. With the purpose of limiting the number of studies to be analysed, referred words were occasionally coupled. Additionally, references from relevant proceedings and abstracts were taken into consideration and added to review.

RELATIONSHIP BETWEEN DRY-LAND ASSESSMENTS OF STRENGTH/POWER WITH SWIMMING PERFORMANCE

The ultimate goal of a competitive swimmer is to expend the minimum time covering a known distance. Accordingly, as the distance to be swam diminishes so does the number of strokes executed. Therefore, for shorter competitive distances strength has been pointed as one of the main multi-factorial factor that may enhance swimming velocity (Toussaint, 2007). Moreover, relating strength and technique, it is assumed that, as the distance diminishes strength role increases, when comparing with technical parameters (Wilke & Madsen, 1990; Stager & Coyle, 2005; Morouço et al., 2011a).

From out the last three decades strength and power measurements in dry-land were performed using isokinetic and isometric strengths (Garrido et al., 2010; Morouço et al., 2011b). This assessment was pointed to be useful to understand how much does swimming performance relies on these parameters, and moreover to improve training programs. In one of the pioneer studies, Sharp et al. (1982) evaluated 22 female and 18 male swimmers, and stated that arm muscle power determined on a biokinetic swim bench is highly related with 25 yard swimming velocity in front crawl ($r = 0.90$). Latter, these findings were corroborated by experiments in a cycle-ergometer using arms-only. Hawley and Williams (1991) assessed the upper body anaerobic power of 30 age-group swimmers (14 males and 16 females), presenting moderate-high correlations of peak power, mean power and fatigue index with 50 m swimming velocity ($r = 0.82$; $r = 0.83$; $r = 0.41$, respectively). Additionally, the same research group (Hawley et al., 1992) stated that power indices for the legs did not increase the estimation for 50 m swimming performance, and that arm power is also important in longer swim events (400 m). Other studies supported these relationships

(Rohrs et al., 1990; Johnson et al., 1993; Strzala & Tyka, 2009; Garrido et al., 2010). Nevertheless, the validity of the correlations seems to be misleading in above referred studies through the use of heterogeneous samples in age, gender and possibly maturation. Doubtful conclusions from heterogeneous groups in swimming have long been recognized (Costill et al., 1983; Rohrs et al., 1990). Moreover, the use of biokinetic swim bench or a cycle ergometer using arms-only neglect the role of lower limbs and body roll, and their importance for body coordination.

Beneficial effects on work economy through different mechanisms (e.g. improved reflex potentiation, alterations of the synergists) may be caused by dry-land strength training (Aspenes et al., 2009). Moreover, dry-land strength training is a common practice in swimming training, though the scientific evidence is still scarce (Aspenes et al., 2009; Garrido et al., 2010). Actually, few studies have assessed associations between force parameters in strength training (e.g. bench press) and swimming performance. Johnson et al. (1993) assessed one repetition of maximum bench press (results not presented in paper) of 29 male swimmers, with ages ranging between 14 and 22 years, and 25 yard swimming velocity (ranging from 1.72 to 2.31 m.s-1). These authors suggested that this measure of dry-land strength did not contribute significantly to the prediction of sprint velocity. It must be noticed that the spectrum of ages should be taken into consideration, especially when within this range significant changes in somatotype occur. By means of a more homogenous group, Garrido et al. (2010) presented a moderate but significant correlation between 6 maximum repetitions of bench press and swimming performance (both 25 and 50 m performance times; $\rho \sim -0.58$; $p < 0.01$) with young competitive swimmers. To the best of our knowledge, the only authors that assessed strength parameters using more exercises were Crowe et al. (1999). Their study evaluated one maximum repetition in bench press, lat pull down and triceps press, for male and female swimmers. Although significant relationships were obtained between the 3 exercises and tethered swimming forces, significant correlations with swimming performance were only verified in lat pull down for the female swimmers group ($r = 0.64$, $p < 0.05$).

The above referred studies only evaluated maximum load that swimmers could achieve during maximum repetitions, which is more related to maximum force than with explosive force (González-Badillo & Sánchez-Medina, 2010). In order to overcome these limitations, Dominguez-Castells and Arellano (2011) using a velocity linear wire encoder measured the power developed in bench press maximum velocity repetitions. The authors stated a moderate relationship between maximum bench press power and swimming power ($r = 0.63$) but did not present the r value with swimming velocity. This is a first approach to new insights related to strength training suggesting that more studies are necessary.

In summary, the incongruous results of experiments developed so far, point out that the associations of dry-land strength and swimming performance remains uncertain. More studies are necessary and they should: (i) evaluate homogeneous groups of subjects; (ii) assess strength/power parameters in more strength exercises with muscular solicitations similar to the swimming movements; and (iii) study which parameters (e.g. one maximum repetition or velocity displacement) are more appropriate to explain the variation in swimming velocity. Further approaches may lead to an elucidation of the role of muscular strength and/or power to swimming performance.

EFFECTS OF STRENGTH TRAINING OVER SWIMMING PERFORMANCE

An optimal level of strength and power is necessary for successful performance in swimming (Newton et al., 2002) as it is dependent on the maximization of the ability to generate propelling forces and minimizing the resistance offered by the liquid environment (Vilas-Boas et al., 2010). Therefore, strength training programs are a common practice for swimmers (Aspenes et al., 2009; Garrido et al., 2010) even if beneficial effects are controversial in specialized literature (Tanaka et al., 1993; Trappe & Pearson, 1994; Girold et al., 2007). Moreover, the benefits of strength training are questioned as many coaches think that it may cause an increase on the muscular mass (hypertrophy) or a decrease on flexibility levels, which would negatively affect swimming ability and increase drag forces (Newton et al., 2002). Accordingly, two assumptions emerge: (i) there are many components of a dry-land strength training program and the improvement of power is certainly one of the most important one (Toussaint, 2007); (ii) the selected exercises should be consistent with the types of movement that are involved in swimming (Maglischo, 2003).

To the best of our knowledge, concerning the effects of strength training programs for swimming performance enhancement, few experiments were performed. In one of the initiate conducted experiments, Strass (1988) in adult swimmers (n = 10), detected improvements of 20 to 40% on muscle strength after a strength program using free weights. These improvements corresponded to a significant 4.4 to 2.1% increase in performance over 25 and 50 m freestyle, respectively. However, few years later, Tanaka et al. (1993) questioned if the strength gained on land could be positively transferred to propulsive force used in water, as the specificity of training seems to differ. These authors applied a strength training program 3 days per week over 8 weeks, using weight lifting machines and free weights. It was reported an increase of 25 to 35 % in muscular strength but this did not correspond to an improvement on swimming performance, as corroborated by Trappe and Pearson (1994). These inconsistent results pointed that more studies were necessary in order to evaluate the amount of muscular strength improvement required to enhance swimming performance.

More recently, three studies investigated the effects of dry-land strength training on swimming (Girold et al., 2007; Aspenes et al., 2009; Garrido et al., 2010). Girold et al. (2007) applied the dry-land strength program twice a week (45 min each session) during 12 weeks with an intensity between 80 to 90% of maximum load; Aspenes et al. (2009) between 1 to 3 sessions per week during 11 weeks were carried out with the heaviest load possible at each session; and Garrido et al. (2010) implemented a strength training regimen twice a week during 8 weeks and lasting approximately 20 min each session. Secondly, the intervention group varied between n = 7 (Girold et al., 2007) coupling indifferently male and female swimmers (16.5 ± 2.5 years-old), n = 11 (Aspenes et al., 2009) with 6 boys and 5 girls (17.5 ± 2.9 years-old), to n = 12 (Garrido et al., 2010) with 8 boys and 4 girls (12.0 ± 0.78 years-old). If strength gains during preadolescence exhibit quite similar rates among boys and girls (Faigenbaum et al., 2002), after puberty, boys tend to present higher muscle strength levels than girls (Bencke et al., 2002), which may mislead the conclusions of Girold et al. (2007) and Aspenes et al. (2009). Finally, swimming performance assessment was made after a warm-up not described or of 2000 m (Girold et al., 2007), with in-water starts (Garrido et al., 2010), or with diving start (Girold et al., 2007; Aspenes et al., 2009) in a 25-m pool. The effects of warm-up are controversial but may influence swimming performance, especially in short distances with maximum intensity (Neiva et al., 2012; Balilionis et al., 2012). Moreover, the diving, glide and turns, are responsible for of the overall performance and this may be taken into consideration when assessing swimming performance. Overcoming the refereed limitations, these studies point that combining swimming and dry-land strength training is more efficient than the swimming program alone to increase 50 m (Girold et al., 2007) and 400 m (Aspenes et al., 2009) freestyle performance. Although this could not be proven to prepubescent swimmers, there seems to be a tendency to enhance swimming performance in 25 and 50 m freestyle due to strength training (Garrido et al., 2010).

In conclusion, strength training using dry-land regimens may enhance the ability to produce propulsive forces in-water, especially in short distance events. More studies are essential to identify appropriate volume and intensities of training programs, according to gender and level. Additionally, movement velocity should be taken in consideration as it may improve the specificity of the exercises performed (González-Badillo & Sánchez-Medina, 2010).

CONCLUSIONS

The present article highlighted the available experiments in the literature conducted with the aim of establishing associations between dry-land strength or power measurements and swimming performance, and the experiments aiming to analyze the effects of dry-land strength training programs in swimming performance. Some new insights are suggested for future investigations.

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