CHARLES UNIVERSITY
Faculty of Physical Education and Sport

The General Development of Strength in Swimming

Bachelor Thesis

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Abstract

Topic: The general development of strength in swimming

Goals: The objective of this research is to demonstrate the importance which the general development of strength has.

Methods: Through a comprehensive literature review it is expected that some very important guidelines regarding the general development of strength in swimmers will be emerged.

Results: The results that emerged illustrate that the general development of strength in swimmers can be increased through different methods and techniques of dry land training. The selection of the most proper technique and method within resistance training depends on the level of the athlete, the training cycle and the goals he/she wants to achieve. Moreover, the aspect of explosiveness can be improved in a large extent through strength training exercises.

Keywords: strength training, crawl technique, swimming performance, explosiveness.

Content

1. Introduction

The sport of swimming is one of the most exciting sports. In order for a swimmer to become competitive, many hours of training in the pool as well as outside of it are necessary. The great competition seen at major sporting events such as World Championships and Olympic Games, as well as the continuous record breaks, show that competitive athletes adopt and apply many different training methods to achieve the best results. In all swimming events, ranging from 50 meters to 1500, not to mention open sea swimming competition races that might reaching up to 25 kilometers, swimmers activate various energy mechanisms to improve their performance. In this respect, the general development of strength can help swimmers to improve their performance as well as other dimensions of training.

The trigger to proceed with this study is for identifying the appropriate training methods used by swimmers to increase their performance. Although, as expected, the main workout can not be more than swimming, however, an important part of the general development of the swimmers is also the training out of the pool. Specifically, dry land strength training is one of the most widespread methods regarding the increased performance of swimmers. Due the fact that swimming is a full - body sport that requires the correct synchronization of all body muscles (legs, hands, core) in the case which a muscle group is not function well during swimming, this can have unpleasant consequences, ranging from an injury to a poor performance. Dry strength training can help swimmers to build strength and physical balance while also it develops the proper cooperation of muscle groups to better promote the swimmer in the water.

Additionally, although swimming is not a sport with weight lifting and pressure on various joints (like for example running), repeated use of the arms and legs can cause injuries, mainly in shoulders and knees; however, strength training can reduce the risk of injury to the above joints. Moreover, because swimming takes place in the water, has a special place in the sport world. Since swimmers have to produce strength by pushing repeatedly the water, they have to be more trained and stable than other athletes. Therefore, the general development of strength can help swimmers move faster in the water by enhance parameters like explosiveness and power. Finally, it must be noted that due the fact that swimming includes 4 different styles, therefore the proper exercises should be selected for each muscle group. Exercises specifically selected for each style individually will help swimmers to improve strength and elasticity that are required for these styles.

However, the fact that a big number of techniques and methods of training are

available, it is hard for both coaches and athletes to find and choose the right program for their training so as to achieve the best possible results. In relation to this problem, I decided to study and present this paper, where the aim is to provide a vast of information and data regarding the appropriate methods and exercises used by swimmers worldwide through a literary search. The results expected to emerge can be valuable for swimmers of all levels as well for other athletes, like triathletes, for which swimming constitutes an inextricable part.

2. Theoretical part

2.1 Competitive Swimming

If a swimmer wants to become successful in competitive swimming, then, specialized interventions that deal with every phase of the competitive race as an integral part of the swimmer's overall development plan, are more than necessary. As shown in the example launched by Mason and Fowlie in the past (1997), as well as through newer and more advanced researches (Slawson et al., 2011), swimming performance is conventionally separated into four main stages consisting of the start, free swim, turns, and finish. Every one of the swimmers compete in races that cover distances more than 50 m, either in a long course 50-m pool or short course 25-m pool, will complete each one of these significant swimming phases.

To begin with, free swim phase has been recognized as the biggest sole independent variable affecting swim performance and eventually competition results (Mason and Cossor, 2000). Whereas free swim phase constituted the main center of examination, notable research regarding the other three phases of a swim race has been made from notable theoreticians in the field (Masson and Cossor, 2000; Chattart and Stewart, 2011). Undoubtedly, each swimming phase helped the swimmers to cover in a particular time the overall race; nevertheless, these contributions vary in proportion since other factors influence the whole process, like for example whether the race is in a 50-m (long course) or 25-m (short course) pool.

A study conducted in this field, has been quantified the initial swim phase in order to identify its input to the general race performance of a 50 m race; the findings showed that this phase counts for the 30% of the overall race time (Kinduff et al., 2011). However, in contrast to the start and free swim phases, not a lot research has been conducted that investigates the effect of the turn phase on the whole swimming performance. However, as the results of some researches showed, turn time affection ranged from 21-33% of the overall race time in a short course (25 m) pool (Lytte and Mason, 1997; Chow et al., 1984) a factor that is very important for the whole race. As it can be seen, as the distance increases, the swim turn has a notable influence to the overall race time as it is applied more times in contrast to a shorter course. As a result, it is regarded as a key parameter to the overall swimming race performance (Mason and Cossor, 2000; Kinduff, 2011).

2.2 The Importance of Strength in Swimming Performance

According the above, the best possible level of strength and power is essential for good performance in swimming (Newton et al., 2002). Specifically, swimming performance is relied on the maximization of swimmer's capability to produce propelling forces as well to the reduction of the resistance that is involved within the water (Vilas-Boas et al., 2010). For that reason, strength training programs constitute a familiar method of training for swimmers (Aspenes et al., 2009; Garrido et al., 2010). However, the gains of strength training are challenged by a number of coaches who think that strength training might increase muscular mass (hypertrophy) or reduce flexibility levels, both of which would harmfully impact on swimming capacity as well it will enhance drag forces (Newton et al., 2002). In view of that, two statements surfaced.

- A big number of components exist in relation to a dry-land strength training program and the development of power is definitely one of the most central in this field.
- The preferred strength training exercises should be in harmonization with the kind of movements that taking part in swimming.

A number of researches were conducted in order to identify the effects of strength training programs to the overall performance of athletes. In one of the studies that performed by Strass (1988), the results showed that adult swimmers (n = 10), experienced improvements of 20 to 40 % on muscle strength subsequent to a strength program with the use of free weights. The specific improvements in strength referred to a noteworthy increase of 4.4 % in performance of both swimmers participated on25 m and 50 m freestyle, respectively.

However, a number of researchers (Tanaka et al., 1993), seemed to question these results by claiming that it is unsure if the strength achieved on a dry environment could be certainly transported to the form of force used in water, since the specificity of dry-land strength training appears to be different. Particularly, Tanaka et al., (1993) put into practice a strength training program for 3 days per week for a period extended up to 8 weeks, through a combination of weight lifting machines and free weights. The results showed that an increase that ranged from 25 to 35 % in muscular strength was noticed; however, these gains do not correspond to the improvement on swimming performance. As it can be seen, these contradictory results demonstrate that a bigger number of studies are necessary to be conducted, so as to assess the necessary muscular strength improvements that should be emerged for the increase of swimming performance.

In more recent results, three researches examined the impact which the dry-land

strength training has on swimming performance (Girold et al., 2007; Aspenes et al., 2009; Garrido et al., 2010). To begin with, Girold et al. (2007) implemented its specialized strength program just two times weekly, with each session last for 45 minutes for a period 12 weeks, with the intensity of training ranged between 80 to 90 % of maximum load of participants. On the other, Aspenes et al., (2009), set their training sessions from 1 up to 3 times per week for a period of 11weeks, were the swimmers lift the heavier load with free weights they could handle at each session. Finally, Garrido et al., (2010) applied a strength training regimen for two times per week for the both the lesser period, that is, 8 weeks, as well as the smallest sessions (20 minutes) in comparison to the other two studies. As the main results showed, these studies highlight that the combination of swimming and dry-land strength training seems to be more efficient in respective to a single swimming program alone regarding the enhancement of 50 m (Girold al., 2007) and 400 m (Aspenes et al., 2009) freestyle performance respectively. Moreover, the findings by Garrido et al., (2010) indicate that might also be an inclination regarding the improvement of swimming performance in 25 and 50 m freestyle because of strength training.

Conclusionary, strength training in dry environments may improve the capability of athletes to generate propulsive forces within water, mainly in short distance events. More studies are necessary to recognize suitable volume and intensities of training strength programs, according to gender, age, swimming style etc.

2.3 Resistance Training and Swimming

Swimming performance is affected by a multifaceted communication of physiological, morphological, neuromuscular, biomechanical and technical aspects. Particularly, swimming velocity produced out of stroke rate and stroke length. In this respect, it has been found that stroke rate or stroke length can improve overall swimming performance (Girold et al., 2006). Moreover, in order for the improvement of swimming performance to occur, programmers that involve components of high frequency, duration and intensity are necessary. However, it is not clear in the current literature whether resistance training enhances stroke rate or stroke lengthy and consequently overall swimming performance (Crowley et al., 2017).

Resistance training is usually defined as the ability of a particular muscle or group of muscles to produce muscular force under particular conditions. Resistance-training programs are usually constituted a very well-known method for increase the overall swimming performance and for that reason are commonly implemented by swimming coaches worldwide (Aspenes et al., 2009; Garrido et al., 2010).

The various modes used in resistance-training aimed to the overload of muscles which the swimmers used in order to increase their maximal power output. Despite the various physiological benefits emerged from resistance training the most important concern increases in phosphagen stores, anaerobic power output, protein synthesis and hypertrophy of fast-twitch muscle fibres (Goodwin and Cleather, 2016). In addition, some researches state that resistance training can increase the maximum strength of the swimmer as a parameter that lead to the increase rate of force development (Suchomel et al., 2016). For some commentators, swimming performance is in a large extent determined by power and muscular strength (Girold et al., 2007; Tanaka et al., 1993).

2.3.1 Methods of Adjusting the Volume of Strength Training

Training to Failure

Undoubtedly, the lifting of heavy loads will develop eventually the whole aspect of muscular strength. A widespread belief is that if the training with resistance performed until failure (TF), then only an athlete can achieve bigger gains in relation to hypertrophy and strength (Bunker et al., 2016).The TF concept stands on the thought that through the training with RM (repetition maximum) loads the athlete can achieve superior strength adaptations in comparison to submaximal loads. However, the findings from a study showed that TF does not generate greater gains while also might possibly be unfruitful (Davies et al., 2016). The same investigators implied that experts programs regarding the implementation of TF, should be applied sporadically in order to avoid possible injuries as well as overtraining.

Furthermore, the idea of implementing TF for extended training periods cannot be applicable, particularly if constitutes a part of a broader training regime. Moreover, TF for repeated sets may considerably decrease the amount of repetitions an athlete can do at particular loads (Willardson and Burkett, 2006); this condition might require from the experts to decrease the recommended loads for an athlete in an attempt to sustain the particular training volume for a specific training stage. Still, it should be cleared that the decrease of the load may effect in a minus effectual stimulus regarding muscular strength adaptation. Despite the fact that there are training segments in which the main importance should be the lifting of exceptionally heavy loads (90-95% 1RM) to develop maximal strength features, TF is not usually recommended in an athlete's RT program (Krieger, 2009).

Mixing Heavy and Light Loads

As declared in the previous part, training with heavy loads develops muscular

strength. Nevertheless, due the type of strength phase goals (e.g. increased force production and RFD development from beginning), it may perhaps useful for the practitioners to apply a mixed loading plan that combines both heavy and light loads. Literature on the field showed that as maximal strength, in the same way RFD underpins power (Suchomel et al., 2016). As a result, even as the main importance will be given to the use of heavier loads throughout maximal strength stages, submaximal loads may help an athlete's RFD; specifically, submaximal loads can eventually assist to RFD and power development for subsequent phases that are commonly known as strength-speed and speed-strength. Studies in the field support the use of a mixed loading tactic for the improvement of an athlete's force-velocity features (Haff and Nimphius, 2012).

The recommended training loads must harmonized with the exercises that are being selected. For instance, heavier loads may be recommended for core exercises (e.g. squats, and presses) and specific weightlifting movements (e.g. power clean) which entailed characteristics that highlighting to high force production. In antithesis, minimal loads may be recommended to stress higher velocities through ballistic exercises (e.g. jump squat, lunges). Mixture loading could also be accomplished throughout the performance of weight training (high force) as well as plyometric exercises (high velocity).

A successful combined strength training system is to schedule heavy/light training days in which the same exercises are prescribed on other days of the week (Harris et al., 2000) while the second day the loads must be lighter than the previous day. The particular technique offers a velocity-power range crosswise the week while also it highlights on the aspect of fatigue management. In this respect, Harris et al.(2000) showed that bigger training responses achieved by employing a mixed loading method based on which the athletes were doing back squats at 80% 1RM on their heavy day and back squats at 60% 1RM on their easy day. Therefore, a mixed loading program may generate the expected strength adaptations at the same time as it will also supporting RFD and power adaptations that are vital aspects for an athlete's performance. Nevertheless, it should be cleared that developments in strength and strength-related traits do not necessarily display statistical differences (e.g. p-value) when weighted against dissimilar regimes of strength training (Suchomel et al., 2018).

2.3.2 Nonspecific Strength Training

Bodyweight exercises are vital resistance training exercises used by athletes as main training means or as a component of a sequence that lead to more multifarious or difficult exercises. The most well-known bodyweight exercises concerns squats, push-ups, pull-ups,

dips and sit-ups. Despite the fact that bodyweight exercises produce a big number of advantages like that they concentrate to multiple muscle groups, they improve the general strength and they enhance versatility, their capacity to offer an overload stimulus is pretty low, and as a result they reach to a certain plateau in relation to the maximum strength which an athlete could achieve through different resistance training methods (Harrison, 2010).

Nevertheless, the increase of bodyweight exercises efficiency can be achieved through more repetitions or modification of the movement (e.g. squats can be done in one leg). Furthermore, in some instances, like for example of young children that are still in their developmental phase, amateurs or athletes returning from an injury, the implementation of bodyweight exercises can help to the creation of a foundation based on which the athletes could progress to more specific training methods that may offer a bigger overload stimulus. In addition, bodyweight or minimal-bodyweight exercises are found to have a notable involvement for increasing explosive performance when training the low-load, high-velocity end of the force-velocity range (Sheppard et al., 2011).

As these exercises have to be performed quite often as they are the foundation for other more demanding strength exercises, some examples are:

- Push-ups: 20-40 repetitions, 3 sets, 1 minute rest between sets.
- Pull-ups: To failure, 3 sets, 1 minute rest between sets.
- Squats: 20-30 repetitions, 2 sets, 2 minutes rest between sets.
- Planks: 30-90 seconds, 2 sets, 2 minutes rest between sets.
- Lunges: 15 repetitions to each leg, 2 minutes rest between sets.

Isolated Movements in Weight Machines

The main use of machine-based exercises or free-weight isolation exercises refers to the injury rehabilitation for specific tissue ability development. Nevertheless, the implementation of single-joint, machine-based exercises for developing strength-power features that are related to the increase of sport performance, are pretty controversial due the fact that athletic movements are not usually involve muscle groups performing in an separated way. Though, exercises that include numerous muscle groups may offer a greater training option for evolving strength-power features (Stone et al., 2000).

Specifically, the isolation of a single-joint that is naturally completed throughout machine-based exercises may perhaps advance an athlete's strength, but may well not succeed to develop coordinative ability that is vital for sporting performance because of the absence of transfer of coordinative outlines. In addition, literature showed that free-weight exercises

might employ muscle stabilizers to a larger degree in comparison with machine-based exercises (Stone et al., 2000).

However, it seems that free-weight exercises that involved multiple joints to work demand larger harmonization and muscle recruitment requests that may generate superior strength-power adaptations that linked to overall sport performance. Nonetheless, it can be assumed that free-weight isolation and multi-joint machine exercises may possibly help athletes to create a foundation upon which they could design their training programs according to the period they want to use these exercises either as a preparatory stage for heavier loads or as a method for recovering from injuries. The recommended strength training exercises for swimmers are:

- Butterfly machine: 12-15 repetitions, 70 % 1RM, 3 sets, rest between sets 1-2 minutes.
- Cable crossovers: 12-15 repetitions, 70 % 1RM, 3 sets, rest between sets 1-2 minutes.
- Low-cable crossover: 12-15 repetitions, 70 % 1RM, 3 sets, rest between sets 1-2 minutes.
- Leg-Press: 10-12 repetitions, 70-80 % 1RM, 3 sets, rest between sets 2-3 minutes.
- Cable straight arm pull-down: 12-15 repetitions, 70 % 1RM, 3 sets, rest between sets 1-2 minutes.

Weightlifting Exercises

The training with weightlifting movements, such as snatch, clean, and jerk, as well as their derivatives has been found to generate higher strength-power adaptations in contrast to traditional resistance training (Hoffman et al., 2004), jump training (Tricoli et al., 2005) and kettlebell training (Otto et al., 2012). In addition, weightlifting movements might permit for more effectual incorporation of a form of resistance that is exterior. As a result, weightlifting movements managed to become routine inside programs of resistance training. The efficiency of weightlifting movements lies in the fact that they can take advantage of both the force and velocity dimensions of power by shifting moderate-heavy loads (Suchomel et al., 2017). Eventually, through these movements positive neuromuscular adaptations might produce which in turn, they can improve strength-power traits.

Experts usually recommend weightlifting movements that comprise the catch phase that is constituted by movements like the power snatch/clean (Suchomel et al., 2016). Even as the particular exercises have been found to create positive strength-power advantages, weightlifting pulling derivatives that exclude the catch phase, like for example jump shrug, it could offer exceptional force-velocity overload stimuli through which additional benefits

regarding strength-power adaptations can be promoted (DeWeese and Scruggs, 2012).

For Bishop et al (2013), in relation to the lower body of swimmers , lifts such as the back squat and deadlift can provide the essential foundation for developing the gluteal complex and quadriceps in preparation for progressing on to weightlifting. For these writers, weightlifting found to be to be a very good training method for enhancing the aspect of RFD (rate of force development) in relation to both phases of the start and the turn in competitive races. Some indicative weightlifting exercises that can included in a training regime are:

- Clean – 8-10 repetitions, 70-80 % 1RM, 3 sets, rest between sets 2-3 minutes.
- Squat: 8-10 repetitions, 60-70 % 1RM, 3 sets, 2-3 minutes rest between sets.
- Deadlift: 8-12 repetitions, 60-70 % 1RM, 3 sets, 3-4 minutes rest between sets.
- Shoulder press: 8-10 repetitions, 70-80 % 1RM, 3 sets, 2-3 minutes rest between sets.
- Dumbbell row: 8-10 repetitions, 70-80 % 1RM, 3 sets, 2-3 minutes rest between sets for each arm.
- Bench press: 8-10 repetitions, 70-80 % 1RM, 3 sets, 2-3 minutes rest between sets.

Plyometric training

Plyometric exercises referred to explosive movements that make use of the stretch-shortening cycle, based on which a concentric muscle action is enhanced by a prior eccentric muscle activity. Even though are not usually given in the course of exclusively training programs targeted to muscular strength, their addition in resistance training regimes based to the fact of their ballistic nature as well as to their capacity to transmit highest strength to both power production and RFD. In a relative study, it has been found that plyometric training may perhaps generate analogous improvements in vertical jump height as in the case of weightlifting movements (Hackett et al., 2016). Nonetheless, a number of other researches showed that weightlifting movements can produce better power adaptations and let for progressions over a wide-ranging field of performance (Tricoli et al., 2005). While literature might look to be controversial, the usefulness of plyometric training cannot be ignored.

A possible restriction of bodyweight plyometric exercises is their capacity to repeatedly supply an overload stimulus that generates constructive strength adaptations. Even as little loads may possibly added to plyometric exercises, experts should be aware that bigger loads will result in bigger impact forces while also it will increase the length of the transition time flanked by eccentric and concentric muscle actions and as a result it will reduce the general training stimulus. As an alternative of an extra load to a specific plyometric exercise, experts may think to select a form of plyometric exercise that involves moderate to high

intensity or even regulate accordingly the training volume so as to generate the needed adaptations (Jarvis and Graham-Smith, 2016). In relation to swimming, plyometric exercises have been found that it can improve explosiveness and velocity of athletes in the whole range of swimming movements (Bishop et al., 2013). The recommended exercises in this section are:

- Squat jumps: 10-15 repetitions, 3-4 sets, 1 minute rest between sets.
- Box jumps: 10-15 repetitions, 2-3 sets, 1 minute rest between sets.
- Burpees: 10-20 repetitions, 2-3 sets, 2 minutes rest between sets.
- Frog hops: 10-20 repetitions, 2-3 sets, 1 minute rest between sets.

Kettlebell Training

Kettlebells constitute pieces of equipment that synthesized by a weighted ball and a handle. The most usual kettlebell exercises include swings, goblet squats, and adjusted weightlifting exercises. Studies showed that training with kettlebells can develop a variety of parameters regarding muscular strength as well as jump performance (Otto et al., 2012) that is crucial for swimmers. Nonetheless, another study (Jay et al., 2013) showed that vertical jump was not improved after kettlebell training in comparison to the control group. This claim is supported also by the fact that kettlebell exercises are effective only in some degree, since their capacity to offer an overload stimulus to the lower limps is pretty limited. For instance, a competitor who is able to lift a load of 100 kg in clean and jerk, might not be able to achieve a kettlebell swing with the same load despite the application of the appropriate technique (Suchomel et al., 2018).

In addition, kettlebell's handle size is usually getting larger as the load raises, a fact that makes the whole venture more difficult for an athlete to his/her effort to grip the whole weight. In relation to other resistance training systems, very little research has been done regarding the investigation of long-term strength-power advantages that can be emerged from kettlebell training. As a result, additional research is required to verify the function of kettlebells within programs of resistance training targeted on strength development and explosiveness. Still, due their explosive nature, experts may find significant to implement kettlebell exercises in training periods where high velocity training is required, like for example competitive swimming (Suchomel et al., 2018). Some of the most suitable exercises for swimmers are:

- Hang Cleans: 5-10 repetitions in each hand, 3-4 sets, 30 seconds rest between sets.

- Turkish get-up: 10 repetitions, 3-4 sets, 1 minute rest between sets.
- Kettlebell swing: 15-20 repetitions, 3-4 sets, 1 minute rest between sets.

Ballistic Training

These most usual applied ballistic exercises may consist of jump squats, a variety of weightlifting derivatives, and jump lunges. The present literature demonstrated that ballistic exercises generated higher force, velocity, power, and muscle activation in contrast to the equal exercises performed in a fast manner (Newton et al., 1996). Additional research exhibited that ballistic exercises could also produce superior effects in terms of explosiveness in comparison to non-ballistic training exercises (Suchomel et al., 2016). Furthermore, the supremacy of ballistic exercises as an explosive training stimulus is also displayed and in other researches Suchomel et al., 2018), while for the same authors, relative power outputs produced throughout a mixture of ballistic and non-ballistic exercises, was also indicated another significant advantage of ballistic exercises over non-ballistic exercises.

Undoubtedly, ballistic exercises encompass the capacity to create superior relative power outputs in antithesis to non-ballistic resistance training exercises like for example the back squat, deadlifts, and lunges. Therefore, it should be clear why the ballistic exercises are implemented in so large extent from various training programs. Even as these exercises may be applied during the whole training period, the objective of every single training phase may change the recommended exercises For instance, jump squats may not be recommended for the period of a strength-endurance stage of training because of advance work capacity. At last, ballistic exercises may be recommended for all athletes who aim to increase their explosive strength. Nevertheless, it should be cleared that ballistic exercises may not be suitable in the resistance program of an athlete until this athlete reaches his/her maximal strength (Cormie et al., 2010). A number of ballistic exercises that can be adopted by swimmers are:

- Med Ball Chest Pass: 10-20 repetitions, 2-3 sets, 30 seconds rest between sets.
- Overhead Med Ball Throw: 10-20 repetitions, 2-3 sets, 30 seconds rest between sets.
- Bench Med Ball Throws: 10-20 repetitions, 2-3 sets, 30 seconds rest between sets.

Explosive training

Explosive training constitutes a topic that is very important for a big number of strength and conditioning experts, athletic practitioners, academics, athletes, as well as individuals that interested to study aspects of human performance. Executing exercises in an

explosive way has been revealed to generate positive results in relation to athletic and overall human performance in the daily tasks (Brown and Whitehurst, 2003; Haff et al., 2001). In addition, the results emerged from explosive power constitutes the major determinant of performance in sports and activities involving moves of jumping, throwing, striking, accelerating, and quickly changing course. Still, this form of movement is also valuable to a broad range of humans, from teenagers to seniors, who simply execute normal daily activities.

The explosive resistance training involves executing the eccentric (lowering) portion of a lift at a typical speed at the same time as the concentric (lifting) portion is performed as speedily and powerfully as an individual can. Specifically, explosive training is created in order to enhance muscular power. Furthermore, the explosive performance of any given exercise seems to increase simultaneously the rate of force development as well as the rate of velocity development or more particularly, an individual's capacity to generate force and velocity in the shortest possible time (Brown and Whitehurst, 2003).

The neural adaptations which take place throughout explosive training offer the best justification for their efficiency. To begin with, improved motor unit recruitment usually account for the majority of the most significant adaptations occurred through explosive training programs. Because of the fact that bigger motor units (composed mainly of Type II muscle fibers, or fast twitch) entail bigger neural thresholds in comparison to minor motor units, as a result they are stimulated exclusively with intensity training. The form of explosive training accomplishes this requirement, concerns the recruitment of the bigger and more dominant motor units. The explosive training might lead in adaptations that provide to athlete the capacity to recruit bigger motor units in a shortest period of time or even more effectively (Haff et al., 2001).

An additional neural adaptation that takes place throughout explosive training refers to the rate coding mechanism. Specifically, rate coding is described as the rate of neural impulses transmitted to motor neurons. In this manner, force is augmented without the need for further recruitment of extra motor units. Explosive training prompts an increase in rate coding, which could work in combination with motor unit recruitment to offer maximal neural adaptations resulting in additional power production.

Explosive training usually produces very high power outputs that undoubtedly affect the overall performance of the athlete especially for sport actions that demand high speed movements. A relative study (Tricoli et al., 2005) displayed that individuals executing Olympic lifts exercises (in the framework of explosive training) generated higher performance results when in contrast to subjects who did not execute the same method of training.

Despite that the increase of power constitutes a temping reason for executing explosive exercises as a segment of a training program, the benefits which an athlete can acquire are more than that. Given that the absolute weight lifted is less for the duration of explosive training, it must be cleared that the higher power do not automatically means also that the parameter of strength will be also increased. This perception should be taken into account during the construction of any training program, as maximum strength has been found to have a solid relationship to athletic performances which based on the factors of speed and power (Stone et al., 2002).

Core Training

In the study by Patil et al., (2014), the aim of the researchers was to evaluate the additional effect of core strengthening on swimming performance of young competitive swimmers. In the past, a number of other researches were conducted through which the efficacy of various exercise protocols in improving performance in young competitive swimmers was evaluated. However, this improvement was articulated in relation to alterations in the values of sprint time and stroking features. Neverthless, Patil et al., (2014) concentrate their efforts to answer the research question concerning the efficiency of a core strengthening program in improving the performance in the young competitive swimmers. The participants were 60 young competitive swimmers (mean±SD, Age 14.2 ± 1.49) of both sexes that were divided in two groups. (N=60, n1= 30, n2= 30). Researchers evaluated outcome measures before as well as after a period of 6 weeks of a supplementary core strengthening program. As the results indicate, considerable differences among values of outcome measures were emerged between experimental and control group at $p < 0.05$. Therefore, the inclusion of a semi-specific training method like the core exercises can help to the strengthening of core muscles which in turn enhance the performance of young competitive swimmers since they experience major improvements in 50 m freestyle sprint time, velocity and stroke index.

Running

Athletes, including swimmers, have to integrate different exercises into their training routines in order to achieve muscle variance and cardiovascular fitness. In this respect, running constitutes an accepted cross-training exercise for swimming since it concerns a very good form of cardio that assist athletes of various field to maintain a healthy weight. Despite the fact that swimmers may perhaps run only for cross-training, it is still significant to combine the workouts so as to make use of various muscles and prevent injury as well as

training monotony. Distance running can help swimmers construct cardiovascular fitness. The most of the running should be executed at a moderate pace, since through that tempo the athlete can achieve the build of a solid aerobic base.

Furthermore, swimmers can adopt running interval training that requires short bursts of intensity followed by a long or small recovery period. Specifically, running intervals is alike to pool training since the swimmer has to perform running for a short period. For example, while in the pool the swimmer might sprint for 50 meters and recover for 75 meters, in running it might sprint for 45 seconds followed by two minutes recovery (Cahill, 2019).

Another form of running that can help swimmers to build the muscles in their lower body and allow them to be more powerful and gain more strength, concerns hill training. More specifically, running uphill puts more resistance on quadriceps and hamstrings. Both these muscles allow to swimmers to have a powerful kick while they training in the pool. Hill training can be done on a hill in a park, or simply by choosing an incline value on a treadmill. Swimmers must speed on the way up, and recover by reducing their speed on the way down. The frequency of training on hills should be done once day a week for 30 minutes (Cahill, 2019).

2.3.3 Semi-Specific Training Methods

Semi-specific training can be described as a moving exercise that does not resemble maximum performance with its intensity, length, and nature of exercise, but is practiced in the performance environment. In swimming, we can include methods under semi-specific training that develop either endurance or maximum speed. For example, a 100m crawl race requires a maximum power of approximately 50 seconds, so if we want to use the endurance method for training, it will not be appropriate because the endurance parameters are not appropriate for the performance. If we want to use sprinter training, the problem is similar because the development of maximum speed takes place within a maximum of 10 seconds. So we use both endurance and sprinter training in the swimmer's training, but we can't talk about specific training for maximum performance, we can only talk about training semi-specific (Daniel Jurak, oral statement, 30. 3. 2019).

So, if we want to use continuous or interval training we have to provide some brief introduction how the aerobic and the anaerobic systems of energy functioned.

The anaerobic system is the best source of energy in short-lived high-intensity activities where the cardiovascular system does not provide the required oxygen with the muscles, so the energy must be produced without oxygen. The anaerobic energy production

system is distinguished in anaerobic saline and anaerobic lactate system (Patel et al., 2017).

Instead, the aerobic energy system, also called the "oxygen system", is mainly used in restless situations and in low to high intensity activities. With this system, energy is produced in the presence of oxygen. Aerobic exercise is also called "cardiovascular exercise" (cardio in English), a term that has been attributed to the many benefits to cardiovascular health. Its main fuel is carbohydrates and fats (Patel et al., 2017).

Muscles and aerobic exercise

Our muscle system consists of 2 types of muscle fibers: "Type I and II fibers. Type II is divided into a and b. To begin with, Type I are the so-called "slow" muscle fibers which are mainly used in long-term aerobic exercise and have the main feature of endurance. The energy used by these fibers is produced almost exclusively using oxygen and athlete's body prefers to "burn" fat with oxygen to produce this energy (Patel et al., 2017).

On the other, Type II are so-called "quick" muscle fibers, which are mainly used in short anaerobic activities. Unlike the slow ones, they will be used when athletes need to overcome a lot of load because they have a low durability time, but a high power capacity powered by the anaerobic energy system, which quickly provides energy to the muscles to overcome the load (Patel et al., 2017).

This is not done by burning fat in the presence of oxygen but mainly by the use of glycogen. In this respect, glycogen refers to a substance that offers quick energy and is stored in the liver and muscles. It is produced by the carbohydrate metabolism we consume. After training, it is exhausted and it can be replenished through food (Patel et al., 2017)

The following workouts concern the continuous training which a swimmer can incorporate in his/her program in order to improve his/her performance (Cyphers, 2016). It must be noted that these workouts must be performed in the range of 60-85 % of maximum heart rate.

Continuous training

Continuous training is a form of exercise that is performed at one intensity throughout and doesn't involve any rest periods. It typically involves aerobic activities such as running, biking, swimming and rowing. These activities use large muscle groups performing repetitive movements over a prolonged period of time.

It can be performed at a low, moderate or moderate/high intensity depending on what you want to achieve from the training and your current fitness levels (Goulding, 2019).

Continuous exercise requires your body to use oxygen to produce energy which means it will improve your respiratory system (your lungs and breathing) and also your cardiovascular system (your heart), (Goulding, 2019).

Example of a continuous training session on swimming (Goulding, 2019):

- 5 minute warm up gradually building your heart rate up to 60% max HR,
- swim 30 minutes at a target heart rate of 70% max HR,
- 5 minute cool down letting your heart rate return below 60% max HR.

Interval training

On the other, interval workouts employ a mixture of high-intensity activity followed by a low-intensity activity. Such an amalgamation permits swimmers to recover during the low-intensity period while also enables greater overall conditioning and therefore, improve of their performance. Despite that interval training is used in many sports, swimming constitutes one of the most suitable sports for employing interval workouts (Williams, 2015). The following interval workouts should be performed in the range of 80-95% maximum heart rate.

Workout 1

Stroke Intervals

The objective of an interval workout is for a swimmer to work hard, since it needs to build its workout to an anaerobic (oxygen depletion) level, and after that move towards a recovery phase. The best manner to employ this during swimming is through the tracking of time. The first workout goes like this:

Swim an 8 by100 set of crawl. This is eight single sets comprised of four laps, where a lap is 25 meters. This set can also be adjusted to another stroke, if the swimmer prefers. On the odd sets, swimmers have to perform as fast as they can. On the even sets, the swimmers must perform in a slow manner in order to recover. The rest between sets should not be more than 30 to 45 seconds for every 100 meters (Williams, 2015).

Workout 2

Drill intervals

For a pull interval, swimmers should make use of their pull paddles in order to aid their workout. Swim a 4 by 50 set. This is four single sets of two laps, where a lap is 25 meters. Focus on swimming with high intensity on the odd sets and swimming slowly to

recover on the even sets, while the rest should not exceed 30 seconds between sets. Swimmers have to concentrate on their form to make sure that they don't over rotate their shoulder as well to make sure that they breathe on each side so as to steer clear of injury (Williams, 2015).

2.3.4 Specific Training

The counting of strokes in swimming is a great way for a swimmer to increase his/her DPS (Distance Per Stroke). The best swimmers in the world are quicker, because they move faster through their stokes and not because they move their hands faster. During their training, swimmers should Keeping track of the number of strokes the achieve at a certain distance, since this parameter will help to the lengthening of the strokes as well as to the addition of extra speed and meters in the pool; moreover, the increase of DPS will help the pulse rate to remain in low levels, a factor that can save energy for later in the swimming training or during the race (Franken et al., 2013).

Therefore, it is important for swimmers to find their target number of DPS; the goal must be to reduce the strokes on average by length. Famous swimmers, such as Alexander Popov or Michael Phelps now may be able to swim in the water at a speed record while doing 30 strokes per 50 meters; nevertheless, this extremely low figure should not be the target number for amateur swimmers (Franken et al., 2013).

Firstly, swimmers must define a range of strokes within they swim. Then swimmers must try to swim most of the time at the low end of their range or with fewer strokes than their lower number. In this respect, swimmers shouldn't worry about speed since they have to learn first the "ideal" number of strokes according their level and their long-term targets (Bachlin and Troster, 2013). Below, an example of a set in the frame of specific training is given, through which swimmers can reduce the strokes and increase the length of strokes in the water:

- Perform a set of 50m-100m-150m-200m-200m-150m-100m-50m.
- In each different distance up o 200 m, the swimmer must stop for 10 to 30 seconds between.
- In each different distance the swimmer have to measure the strokes.
- At the return, that is, from 200m-50m, the swimmer must try to keep the same strokes as before or even to reduce them.

Moreover, controlled breathing is perhaps the most important factor for an efficient

crawl swimming. Swimmers who extend their exhalation by combining it harmoniously with crawl can better hold the basic principles of balance, relaxation, hand synchronization, body hydrodynamics, stroke length and efficient application of strength within the water. Swimmers with good breath control take deep breaths quickly and easily after long exhalations. This procedure gives swimmers enough time in each stoke cycle so as to keep their body long, relaxed and in the proper rhythm (Bachlin and Troster, 2011).

For this reason, young swimmers are encouraged to make a comfortable breathing pattern, either only on one hand in each hand circle or alternately. On the other, experienced swimmers prefer a way of breathing that can provide them with more oxygen so they achieve the best possible better performance and faster speed. A combination of 4, 5, 6 strokes in each breath within the workout allows swimmers to focus more on style technique. Regardless of the number of strokes achieved while breathing, it is important for swimmers to have an efficient and relaxed breathing pattern (Franken et al., 2013).

Breathing in the crawl starts with a quick inhalation. In the case which the swimmer take out all the air normally during the exhale of the previous stroke cycle then he/she will get air through a reflexive way. As the head returns into the water, the eyes should look at the bottom of the pool. A number of swimmers hold their breath for a moment before they exhale. Regardless of when swimmers exhale or not, inhalation should be a process that lasts less than the exhalation. In this respect, swimmers must exhale shortly before the head comes out of the water while they should be also prepared for the following inhalation. Especially when the hand in front is almost stretched and the head is ready to get out of the water, just before it comes out, swimmers should dispose the rest of the air with a strong blow. Many swimmers also use the mouth and nose for this blast, which not only results in pulling out the rest of the air, but also removing water from the face so as to perform exhalation without water (Couto et al., 2015).

If the body and the head are properly placed during breathing, the head will create a natural wave allowing swimmers to breathe with their mouth just below the surface of the water. Exhalation should be at least twice as high as inhalation. Extending the exhalation and letting the air come loose, provides swimmers with more time in each stoke, a fact that gives the opportunity to swimmers to balance their body and be rhythmic and efficient (Couto et al., 2015).

The maintenance of body balance can be achieved while breathing by keeping the head the back and the neck aligned. Many swimmers often lift their heads when they swim; such a thing is negative since their legs fell low and as a result their front of the hand is

decreased. This in turn causes the body to lose its hydrodynamic position and its straight line that is important for a lasting exhalation and a more relaxed swimming. Generally, the process of breathing in the crawl is something that wants to be practiced a lot. Swimmers must be familiar with the water and be more relaxed. Familiarity means for a swimmer to be able to inhale and exhale when he/she is in water without thinking it (Couto et al., 2015).

Another important specific method of increasing swimming performance is sprint training. Before launching into the workouts, swimmers have to know the two major mistakes that can be made in this type of training. The first mistake is not going fast when it's time to move fast in the water. Swimmers must have an obvious difference between their steady pace and their fast pace. Moreover, the second error that usually performed by swimmers is that they decrease the amount of recovery between swims on the initial workout. Swimmers usually believe that the least amount of rest during a set, is better for the increase of their performance; however, the aspect of recovery is very important as it will be illustrated through the following sprint training workout (Bernhardt, 2017).

Warm-Up

- 200-meter (m) swim
- 100m of different drills
- 400m pull with or without paddles

Main Set

Depending on the level, the swim speed and existing training time, swimmers should perform 3-5 sets of the following workout. Before beginning, swimmers have to select a swim interval that corresponds to their current steady pace time, plus 40 seconds. For instance, if the present steady pace is 1:30 per 100, the swim interval will be 2:10. That means for the swimmers that will have to leave the wall every 2 minutes and 10 seconds. The real rest time will be different and in relation to each swimmer's speed.

- 4 x 100m with a whole minute of rest between rounds:
- No. 1 – Swim 75m at the existing steady pace, then 25m fast
- No. 2 – Swim 50m at the present steady pace, then 50m fast
- No. 3 – Swim 25m at the present steady pace, then 75m fast
- No. 4 – Swim 100m fast

Recovery

- Finish up with 300m pull, with or without paddles, and 100m very effortless
- Entire distance = 2300m to 3100m

2.4 Training Recommendations

There are a lot of ways through which swimmers can improve their swim performance. Swimmers of all levels can improve their swim speed, for instance, when competing with other athletes or preparing for any particular competition. Among others, the improvement of swimming technique entails reducing drag, improving balance, and swimming taller, along with a number of several tips.

The following checklist, as provided by Luebbers (2017), involves a number of items that are specific swimming training methods through which an athlete can enhance its performance. Since swimming is a specific sport, the initial evident step for swimmers is to enter the pool and start swimming.

Swim frequently

While swimmers don't average about three swims in a weekly basis into their training regime, they have a tendency to drop the feel for the water while also their technique starts to get worse. This results in absence of feel, bad technique, and lack of speed (Luebbers, 2017)

Despite that swimmers might be performing a grand swim training one or even two times weekly for the majority of swimmers, that seems not be enough. While there is this alternative that refers to the execution of one or two long workouts in comparison to three or four shorter workouts, swimmers tend to perform better when they choose to adopt the second option. This selection based on the fact that swimmers will swim more frequently in contrast to only having one or two workouts each week, despite the fact that these workouts might be longer in terms of time (Luebbers, 2017).

Swim with good technique

Another aspect of specific training methods for increase the swimming performance, is that swimmers must seek to preserve the best possible technique at all swimming speeds for the duration of a workout. In the case which the swimmers attempt to go fast with reduced technique, they will waste their energy levels. Despite the fact that some of them might have a solid aerobic base and they probably swim pretty fast, eventually he/she will not help itself to

be developed into better swimmer (Luebbers, 2017).

In this respect, swimmers have to teach themselves move fast in the pool along with the use of the best possible technique, so as to achieve better results . For instance, features like controlling a freestyle breathing technique, achieving a good body rotation, and placing the hand in the water at the correct angle (goggle line) are all ways that help a swimmer to improve swimming technique (Luebbers, 2017).

Make drills in every workout

It's significant for swimmers to perform a mixture of particular technique work to strengthen fine swimming skills. These can be completed before, throughout, or subsequent to a swimming training.

Performing swim strokes and giving notice to hands, arms, elbows, shoulders, as well as other bodily parts, can help to boost a swimmer's alertness in the pool. Specifically, the performing of drills constitutes an indisputable part of a swim workout that will help swimmers achieve a better technique (Luebbers, 2017).

Swimmers can center on a drill that enhances their swimming skill, whether this concerns the increasing of speed or a drill that will help to the reinforcement of their weakness. For example, swimmers can work on balancing on their side by performing kicking drills. Swimmers have the opportunity to practice diverse types of freestyle exercises, as for example the closed-fist freestyle, head-up freestyle, or freestyle with dolphin kicks (Luebbers, 2017).

Complete challenging workouts

Swimmers can train challenging workouts one or two times in a weekly basis in order to improve their general performance. In relation to the frequency they swim, the addition of a variety of workouts can help out swimmers concentrate on particular improvements. For instance, in the case which all of their workouts are centred on the aspect of technique, they will eventually improve; nevertheless there are also a number of other challenges for swimmers to look, like for example:

- Learning the way to swim faster with no being tired or led their technique to fade
- Practicing intervals and drills to boost endurance and overall swim condition
- Testing out a variety of swim strokes, freestyles, and levels of intensity like for example enlarge upon distance per stroke ratio (Luebbers, 2017).

Accomplishing easy workouts

In relation to each swimmer's goals, usually it's not necessary to perform more than one or two hard workout sessions in weekly basis. As long as swimmers execute some easier workouts throughout the week, then performing one or two demanding sessions is acceptable in the course of a training regime (Luebbers, 2017).

The general improvement in swimming will take place when swimmers train hard on the more specialized workouts as well as achieve easier workouts each week. The combination of these two types of workouts is necessary so as to achieve good results (Luebbers, 2017).

In the case of competitive swimmers, they can use minimum equipment for a beginner or intermediate swimming workout entailing 400-800 yards more than a few times a week. For more demanding workouts, swimmers can swim a distance of 1850 yards or more, once or twice a week (Luebbers, 2017).

Perform streamlines

A streamlined form is usually applied underwater throughout swimming strokes. Even as it might refer to a start, a push-off, or a turn, swimmers must constantly do things the same manner. Therefore, swimmers have to streamline and then move into the transition between the streamline and swimming (Luebbers, 2017).

It's very vital for swimmers to streamline first. In this respect, the improvement at pushing off the wall is the plainest way to reduce overall time for a particular distance of swimming. Despite that this specific method does not develop fitness, it nevertheless help swimmers perform better in many aspects (Luebbers, 2017).

Leave the wall the same way as before

It's significant for swimmers for all the time to push off the walls the manner they would if they were coming out of a turn. Specifically, when starting a session, swimmers have to push off the wall precisely with the same way that they would be pushing off the wall if they were coming out of a turn. The majority of races engage more turns than starts, and for this reason, the addition of extra practice with any part of a turn constitutes a vital tool for the improvement of overall performance (Luebbers, 2017).

Throughout professional relays, swimmers have to be aware of taking off early by watching when and how their feet leave the block earlier than the next swimmer touches the wall. Whereas swimmers have the opportunity to move, time is of the essence for the reason

that false starts have a tendency to take place while the swimmer does not swim all the way toward the wall (Luebbers, 2017).

3. Conclusion

Undoubtedly, the general development of swimming strength is a very important parameter. The development of strength has other positive effects beyond increasing performance in competitions, such as avoiding injuries, as well the capacity for larger and more qualitative workouts. While the strength can be increased in the water by the swimming training itself, however, the muscle imbalances that may exist can be repaired only through strength training exercises.

As has been shown in the main part of our work, swimming is a fairly competitive sport. For this reason, workouts can not only be restricted at the pool area as there are other techniques and methods that swimmers can use to increase their performance. One of these methods is the dry land strength training which aims at increasing factors such as strength and explosiveness while also it can function as a shield to avoid injuries. Although this method is one of the most widespread ways to increase performance, however, the variety of techniques and approaches can often confuse athletes about which one of them is right, always in relation to the athletes' level and goals.

The results that emerged through the systematic review of the literature, illustrate that each of the methods adopted to increase strength and explosiveness should take into account the athlete's level, physical characteristics, coaching plan and generally the goals which any athlete aims to achieve. The main results show that each of the training methods in the context of dry land strength training, can improve athletes' performance according to the training phase they reside in for the particular period.

Some suggestions that can be given in theory are that more studies need to be conducted with regard to the effect of the method of resistance training in relation to the swimmers of all levels. The reason for this specialization in the research, is that swimmers are involved in many different distances ranging from 50 to 1500 meters. In this respect, the researchers conducted in relation to the development of strength in swimmers, should take account that some exercises that are appropriate for sprint events like 50 or 100 meters might not be appropriate for lengthier events like the 1500 meters.

Another suggestion is that researchers should create guidelines for all different levels of swimmers. The reason for this necessity lies in the fact that there are different requirements for each athlete level and therefore the appropriate instructions and the appropriate training program for these athletes should be also available. For example, the demands of junior

swimmers who are still in a phase of physical development and of the adult athletes who are highly competitive are undoubtedly very different. For this reason, swimmers can not adopt a general strength development program without the supervision of a coach. In this respect, swimming coaches need the publication of more researches that will help them to grow professionally and consequently to help in turn the general development of strength of their athletes.

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