THE EFFECT OF CONCURRENT RESISTANCE TRAINING ON TETHERED FORCE, LOWER LIMBS STRENGTH, ANAEROBIC CRITICAL VELOCITY AND SWIMMING PERFORMANCE IN REGIONAL AGE-GROUP BREASTSTROKE SWIMMERS: A RANDOMIZED CONTROLLED TRIAL

XITONG LIU

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR MASTER DEGREE OF SCIENCE

IN EXERCISE AND SPORTS SCIENCE

FACULTY OF SPORT SCIENCE

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ผลของการฝึกแรงต้านแบบควบคู่ที่ส่งผลความสามารถในการออกแรง
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The Thesis of Xitong Liu has been approved by the examining committee to be partial fulfillment of the requirements for the Master Degree of Science in Exercise and Sports Science of Burapha University

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65910128: MAJOR: EXERCISE AND SPORTS SCIENCE; M.Sc. (EXERCISE AND SPORTS SCIENCE)
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XITONG LIU : THE EFFECT OF CONCURRENT RESISTANCE TRAINING ON TETHERED FORCE, LOWER LIMBS STRENGTH, ANAEROBIC CRITICAL VELOCITY AND SWIMMING PERFORMANCE IN REGIONAL AGE-GROUP BREASTSTROKE SWIMMERS: A RANDOMIZED CONTROLLED TRIAL. ADVISORY COMMITTEE: PHORNPOT CHAINOK, RADOMYOS MATJIUR WIRAT SONCHAN 2024.

This study investigates the effects of concurrent resistance training on tethered force, lower limb strength, anaerobic critical velocity, and swimming performance in age-group breaststroke swimmers. A randomized controlled trial was conducted with 24 swimmers aged around 15-16, divided into an experimental group and a control group. The experimental group followed a 10-week training program combining aquatic and land-based resistance exercises, while the control group maintained regular training. Key performance indicators, including tethered force, 1RM squat, anaerobic critical velocity, and swimming performance over 50, 100, and 200 meters, were measured. Results demonstrated significant improvements in the experimental group for lower limb strength (20.57%, $p < 0.01$), tethered force (30.04%, $p < 0.05$), and anaerobic critical velocity (4.2%, $p < 0.05$), alongside enhanced swimming performance ($p < 0.05$). No significant changes were observed in the control group. These findings suggest that concurrent resistance training is effective in improving both strength and swimming performance and should be incorporated into regular training programs. Further research should explore its long-term impacts on endurance and technique.

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CHAPTER 1
INTRODUCTION

1.1 Background of the study

Strength training is crucial for the growth of young swimmers, as it contributes to their general development, assists in preventing injuries, and improves muscular strength (Toussaint & Vervoorn, 1990 ; Sammoud et al., 2019; Amara et al., 2022). Besides, strength training is an important factor in the development of explosive power, which is particularly vital in sprint swimming (Sammoud et al., 2021). In response to the recognized importance of strength training, the scientific of swimming science community has investigated the incorporation of resistance training into regular swimming practices, especially for young swimmers (Alberty et al., 2008)(Amaro et al., 2017; Crowley, Harrison & Lyons, 2017; Kojima et al., 2018; Zacca et al., 2020).

In response to the recognized importance of strength training in swimming, the majority of propulsive forces in swimming are produced from the upper body, with strong correlations between upper body strength and sprint performance (Morouco et al, 2012; Crowley，Harrison & Lyons, 2017; Wirth et al., 2022). Furthermore, swimming coaches have recommended dry-land practices over time to enhance many aspects of swimming performance, such as starts, clean swimming, turns, and finishes (Cuenca-Fernández， Lopez-Cotreras & Arellano, 2015; Mujika et al., 1995; Thng, Pearson & Keogh, 2019; Hermosilla et al., 2021; Wirth et al., 2022).

From the perspective of dry land strength and conditioning training for swimming, the improvement of swimming performance depends on the specificity of the training methods and training intensity (Girold et al., 2007; Wirth et al., 2022). More recently, research has focused on the effects of dry land strength training on specific swimming style and distance that have directly improved sprint and middle distances performance such as 50 and 100m breaststroke (Invernizzi et al., 2015), 100 m butterfly performance (Naczk et al., 2016; Amara et al., 2022), 50, 100m backstroke (Alshdokhi, Petersen & Clarke, 2020) 50m (Girold et al., 2007; Lopes et al., 2021), 100m (Girold et al., 2007; Lopes et al., 2021), 200 m (Gourgoulis et al., 2019), 400 front crawl (Aspenes et al., 2009; Potdevin, 2011; Papoti et al., 2017).

Studies examining the effects of dry land strength and conditioning on swimming performance have been conducted in depends on the specificity of the training methods (Tanaka & Swensen, 1998) and training intensity (Mujika et al., 1995; McBride et al., 1999). Regarding training methods, there were mainly three perspectives comprised dry-land strength training, specific in-water resistance training, and concurrent training (Mujika & Crowley, 2019).

Dry-land strength training refers to a typical resistance training method that utilizes a gym-based strength training program and swim-like resistance training using swim bench (Sadowski et al., 2012) to primarily enhance a swimmer's strength and power (Crowley & Harrison & Lyons, 2017; Fone & Tillaar, 2022). Significant in-water submaximal strength training was conducted through specific in-water resistance training, which involved swimming with leg kicking training (Konstantaki & Winter, 2007), resistance bands, hand paddles, or parachute to overcome an increased resistance (Girold et al., 2006; Dragunas， Dickey &Nolte, 2012; Gourgoulis et al., 2019; Barbosa et al., 2020). Concurrent training in competitive swimmers in which the associated strength training programme and swimming training (Mujika & Crowley, 2019) seems to improve physiological adaptations in both aerobic and anaerobic abilities, energy cost of locomotion, and maximal power (Arsoniadis et al., 2022)

When considering the intensity of training for young swimmers, it has been recommended that they utilize an age-appropriate strength and conditioning (S & C) program. This program not only reduces the risk of injury but also offers opportunities for the development of a diverse range of movement skills, which are considered to be extremely important (Nugent, Comyns &Warrington, 2018). Specifically, strength and conditioning programs designed for young swimmers would need to have included a wide variety of strength training practices in their periodized strength training programme (Pyne & Sharp, 2014; Mujika & Crowley, 2019). When organizing training microcycle systematically, it is generally accepted to incorporate aerobic, aerobic/anaerobic, transition, taper or competition phases (Pyne & Goldsmith, 2008).

Traditionally, strength and conditioning programs following periodization prioritize building muscular endurance by using moderate external loads. This involves performing 2-3 sets of 6-8 repetitions, using weights that are 50-75% of the individual's maximum weight they can lift (1RM) (Garrido et al., 2010; Amaro et al., 2017). On the other hand, to enhance maximum strength, high loads are used. This includes performing 3-5 sets of 3-5 repetitions, using weights that are greater than 85% of the individual's 1-RM, with a rest period of 2-3 minutes between sets (Aspenes et al., 2009; Garrido et al., 2010). Additionally, for developing speed strength and power, it has been found effective to train with light to medium loads, typically ranging from 30-60% of the individual's 1-RM (Wirth et al., 2022).

In fact, when conducting strength and conditioning studies for young swimmers, coaches, strength and conditioning coaches and sports scientist must consider the maturation status of the athletes in their group in order to distinguish between prepubescent, pubescent, and post pubescent individuals (Nugent, Comyns & Warrington, 2018). From the perspective of the individual mutation, bio-banding is a relatively new approach to categorizing young athletes (those between the ages of 11 and 15) into distinct "bands" for the purpose of training and competition (Malina et al., 2019). A multi-age-grouping paradigm has been suggested in swimming to account for substantial differences in maturity status among young swimmers. These variations in physical growth patterns and muscle quantity and quality may have a direct impact on swimming performance (Kojima, Jamison & Stager, 2012).

A strength and conditioning program appropriate for young swimmers has been suggested. Research shows that strength improvements during preadolescence are similar for both boys and girls (Faigenbaum et al., 2016; Amaro et al., 2017). However, after this period, boys tend to have higher levels of muscle strength compared to girls (Bencke et al., 2002; Amaro et al., 2017). Theoretically, before puberty, optimal strength gains in strength and power are achieved through enhanced neural coordination (Ford et al., 2011; Lloyd et al., 2016; Cumming, 2017). Optimal increases in strength and power throughout and after puberty are achieved by an integrated balance of neural and structural adaptations. The latter is a consequence of several variables, including as hormonal and metabolic alterations, training stimuli, and nutrition (Cumming, 2017., Ford et al., 2011; Lloyd et al., 2016;). Monitoring maturation status frequently with straightforward techniques, such as the Mirwald equation (Mirwald et al., 2002), can therefore assist in guiding the development of programs that are more suitable for the requirements of pubescent individuals.

Most of the strength and conditioning training for young swimmer's studies concerning strength training focused mainly on crawl technique (Girold et al., 2007; Gourgoulis et al., 2019; Aspenes et al., 2009; Potdevin et al., 2011; Papoti et al., 2017; Lopes et al., 2021), while less attention has been paid to lower limbs strength and power in breaststroke particularly in young swimmers. Breaststroke is a technically complex stroke characterized by discontinuous propulsive phases, large intracycle velocity variation and low mean velocity (Nicol et al., 2022). Even with the technical constraints imposed on swimmers in breaststroke competitions, from beginner's to elite swimmers, there is plenty of opportunity for variations among individuals in terms of timing, coordination, neuromuscular activity, and pacing profiles (Leblanc et al., 2006; Gourgoulis et al., 2019). The variety of variables which have been found to affect breaststroke swimming performance makes it challenging to determine the best training and competitive strategies (Nicol et al., 2022).

From a biomechanical and physiological perspective, the breaststroke technique varies in terms of how much the upper and lower limbs contribute to generating propulsive forces. It is important to note that increased power leads to an increase in propulsive force particularly the contribution of the lower limbs is more important (Invernizzi et al., 2015; Nicol et al., 2022). Consequently, coaches and trainers use strength and conditioning programs to improved kinematics, temporal patterns and increase neuromuscular activity. To the best of our knowledge, concerning the effects of strength training programs for breaststroke performance enhancement (from 50 to 200m), few experiments were performed and not yet clarified in the literature.

Therefore, this study aimed to investigate the effect of concurrent resistance training on tethered force, lower body strength, anaerobic critical velocity and swimming performance in regional age-group breaststroke swimmers. We hypothesized that after ten weeks of training program, the experimental group would be more sensitive and improve on tethered force, lower body strength, anaerobic critical velocity and swimming performance. Since the present study sheds new light on the effect concurrent training, we have centered our attention and seek to evaluate the effectiveness of significant concurrent training in which the associated strength training programme and swimming training on the selected variables in regional age-group breaststroke swimmers.

1.2 Research objective

This study used a controlled experiment, with 24 athletes randomly assigned to two groups, and completed pretests and predictions before and after ten weeks of training, and investigate the effects of ten weeks of concurrent resistance training which is combined resistance training (aquatic and dry land resistance) on tethered force, lower limbs strength, anaerobic critical velocity and swimming performance in regional age-group breaststroke swimmers.

1.3 Hypotheses of the study

We hypothesized that after ten weeks of training program, the experimental group would be more sensitive and improve on tethered force, lower body strength, anaerobic critical velocity and swimming performance. Since the present study sheds new light on the effect concurrent training, we have centered our attention and seek to evaluate the effectiveness of significant concurrent training in which the associated strength training programme could improve lower body strength and anaerobic performance and subsequently optimize swimming performance.

1.4 Definition of terms

Concurrent resistance training: A specific concurrent water and dry-land consisted of combined resistance training in aquatic and dry land resistance training during a ten-week intervention period was applied to examine the characteristics and improvements on tethered force, lower body strength, anaerobic critical velocity and swimming performance (50, 100 and, 200-m). The periodization that encompass 10-week swimming preparation for a regional championships including macrocycle 1: general phase (weeks 1-6), macrocycle 2: specific phase (weeks 7-10) were used for monitored in the present study.

The control group (CG) followed their usual training based on general body strength (2 sessions per week: 60 to 75 min per session). General body strength consisted of a general warm-up (dynamics stretching, functional and mobility and cardiorespiratory adaptation), general strength exercises (body weight, medicine ball throw, abdominal exercises). Regarding the aquatic resistance training, The water parachute, fins and paddles set were used through the intervention period (general phase: weeks 1- 6, 3 sets × 6 reps × 15 m with 60 s and 5 min of rest; specific phase: weeks 7- 10, 2 sets × 4 reps × 25 m with 60 s and 5 min of rest

The dry land S & C program for experimental group (EG) included two sessions weekly. Each session started with a 15 min standard warm-up featuring dynamics stretching, functional and mobility and aerobic exercises. Subsequently, subjects performed three lower body strength exercises, which were specific to lower leg strength including back squat, reverse lateral lunge, sumo Romanian deadlift RDL with moderate contraction velocity and complete motion angle. The back squat exercise was performed with an intensity between 60% and 85% of 1RM. The sets varied between 2 and 3 and repetitions between 6 and 12 (Amara et al., 2022). The reverse lateral lunge and sumo Romanian deadlift RDL exercises consisted of 6 to 8 sets with 6 to 12 repetitions. The recovery between sets and exercises was fixed at 3 min.

Aquatic resistance training which is including specific kicking sets, parachute and hand paddles was composed of two sessions per week. The water parachute, fins and paddles set were used in both experimental and control groups (2-3 sessions in a week) immediately after the warm-up (500 -800 m of aerobic training (55% to 80% of maximum heart rate) on Tuesday and Thursday. On general phase (weeks 1- 6), swimmers completed 3 sets × 6 reps × 15 m with 60 s and 5 min of rest between repetitions and sets, respectively. On specific phase (weeks 7- 10), swimmers completed 2 sets × 4 reps × 25 m with 60 s and 5 min of rest between repetitions and sets (Amara et al., 2022).

The specific kicking set was included in only EG (2 sessions in a week) immediately after the warm-up (500-800 m of aerobic training (55% to 80% of maximum heart rate) on Wednesday and Friday. On general phase (weeks 1-6), swimmers completed 3 sets × 6 reps × 50 m (25 m kick, 25m drills) with 60 s and 5 min of rest between repetitions and sets, respectively. On specific phase (weeks 7-10), swimmers completed 2 sets × 5 reps × 50m with 90 s and 5 min of rest between repetitions and sets, respectively.

Tethered force: Tethered swim test 30-s was done following the proposals of Morouço et al., (2014) each swimmer performed a 30-s maximum intensity breaststroke tethered swimming test. The measuring device was a load-cell system connected to the swimmer, recording at 100 Hz with a measurement capacity of 1,000 N. (Swimforce V1.0.0, Germany). The maximum tethered swimming tests was performed using full breaststroke, similarly to familiarization. Force data were exported to a laptop via Swimforce V1.0.0 software with the connected to an analogic/digital data acquisition system. All continuous force data were obtained during 30s at a 100 Hz frequency, exported to the Acknowledge 4.0 software, and filtered with a 15 Hz cut-off digital filter (FIR - Window Blackman -61dB). The cut-off value was selected based upon FFT analysis to minimize artefact noise. The force variables obtained in individual force-time curves were (i) maximum force (F_{max}), (ii) mean force (F_{mean}), (iii) fatigue index (Fatindex).

Lower body strength: Maximum lower body strength was measured using 1RM back squat test. Age-group swimmers completed a warm-up for 3 min, followed-up by 5 min of overall static stretching. Thereafter, subjects performed 1 set of 8 reps and 1 set of 3 reps at 50% and 70% of their estimated 1RM back squat, respectively. The load was gradually increased (10% to 20%), 2 to 3 repetitions and 2 to 4 min of rest were performed. Thereafter, a small increase in the load (5%) and 2 to 4 min of rest were carried out to reach the 1RM squat. The test was finished when the subjects failed to complete the squat, and the last successful attempt presents the 1RM back squat (Amara et al., 2022).

Anaerobic critical velocity: Anaerobic performance was evaluated by anaerobic critical velocity (AnCV) as proposed by Fernandes, (2008). AnCV was calculated for each swimmer using the slope of the distance-time (Dd-t) relationship, plotting the following swimming time performance over time: 10, 15 and 25 - m. The equation of the regression line obtained was of y = ax + b type, where here y is distance swam, x is time and a = Anaerobic critical velocity (i.e & strait-line slope), b is y-interception value.

Musculoskeletal screening: Shoulder range of motion including shoulder internal and external rotation (IR, ER), abduction in internal rotation (ABIR) and combined elevation (CE), and lower limbs range of motion including active straight leg raise (SLR) were evaluated (Walker et al., 2016; West et al., 2022) using Dartfish software (Dartfish Software 10.0 ProSuite Version, Dartfish, Fribourg, Switzerland). The iPad Pro (Apple Inc, Cupertino, CA) was used to record the motion which is starting in a neutral position in each measurement then moved to achieve their maximum ROM and returned to their neutral position.

Swimming performance: The 50, 100 and 200 m race time of breaststroke block starting all-out performance were measured by a qualified timekeeper per stopwatch (SEIKO S120-4030, Tokyo, Japan) and noted in seconds. Three of the most frequently referenced kinematic parameters in breaststroke swimming biomechanics including stroke rate (SR) stroke length (SL) and stroke index (SI) are obtained together with time and average speed. SR was obtained using the time to perform one complete arm stroke cycle, considering the time to perform three arm strokes cycles (T3C) at the 10 m zone, as described in the Equation.

Stroke rate (SR) = $(t_{stroke}^{-1)}$ *60

SL was determined by the ratio

Stroke length (SL) = average speed (SV) / (SR * 60^{-1})

Defined as an athlete's ability to travel at a specified velocity with the fewest number of strokes, breaststroke efficiency may be assessed using stroke index (SI)

Stroke index (SI) = swimming velocity * stroke length (SL)

(Nicol, 2022).

CHAPTER 2
LITERATURE REVIEWS

2.1 Introduction to breaststroke swimming

2.1.1 An overview of breaststroke swimming

Breaststroke, a swimming form imitating a frog swimming, is widely accepted because swimmers can easily observe the obstacles ahead to avoid hitting when swimming in this way. The movements of breaststroke are decomposed into three parts, including leg motion, arm motion, and breathing (Figure 2.1). The breaststroke differs from freestyle and backstroke by not utilizing a flutter kick. The movement imitates a frog kick, starting with the legs straight and together, then bending the knees outward while maintaining the feet together. The feet should be brought closer to the body. Swimmers should maintain the position of their knees, then spread their feet apart to straighten their legs into a diagonal "V" form, then promptly bring their legs back together to return to the initial position.

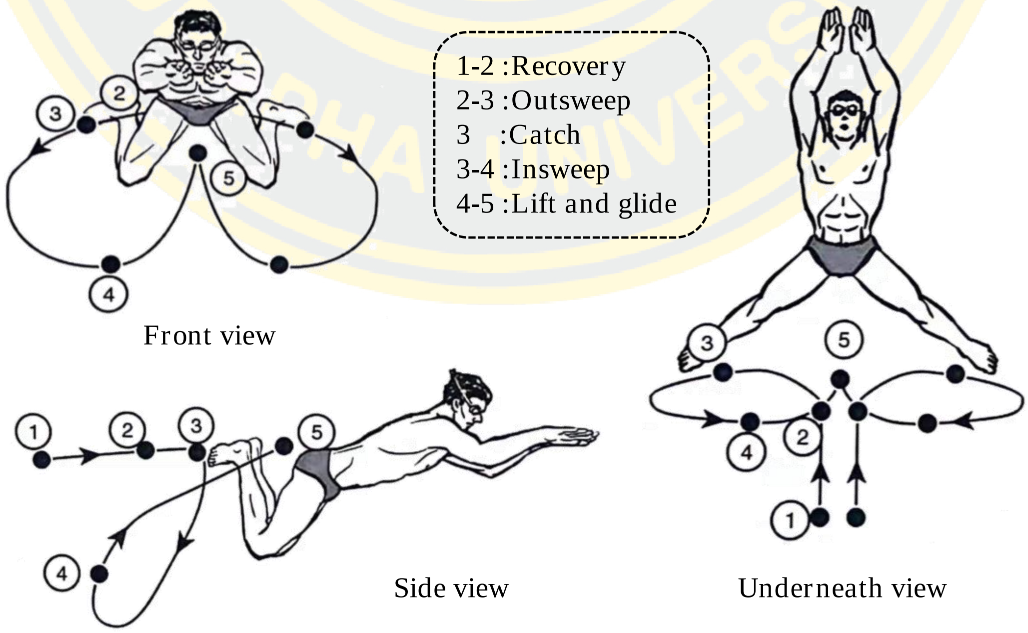

Figure 1The breaststroke patterns of motion from the typical side, front, and underneath view which is drawn relative to the water.

Initially, the hands break away from the streamlined posture and then travel rearward till they reach the thigh. Secondly, the elbows begin to bend and the hands go forward from the thigh until the arms are fully stretched out. During the leg movement, the knees initially flex as the feet rise, and then the knees lengthen as the feet lower to their lowest point. Continuously repeat the movements of the arms and legs to maintain swimming. Breathing in breaststroke often happens after the stroke and between leg movements, helping to maintain the breaststroke technique effectively.

The breaststroke arm pull has four parts: glide, outsweep, insweep, and recovery. Considering glide, an initiate the movement by extending the arms in front of the body with palms facing down and fingertips pointing forward, ensuring the sides of the thumbs are touching. Place the hands together in front of the chest in a prayer stance, with the fingertips pointing forward away from the body. Next, propel the arms forward and completely extend them straight in front of the body. For the outsweep starts with rotate the hands outward with the thumbs pointing slightly downward. Keep the arms straight as extend them out to the sides until they create a "Y" shape with the body.

For the outsweep, swimmers rotate hands outward with the thumbs pointing slightly downward. Swimmers need to keep the arms straight as extend them out to the sides until they create a "Y" shape with the body. During the insweep phase, swimmers must flex their elbows and lower their forearms while bringing their hands together in front of their chest in a prayer motion. This part of the breaststroke pull is crucial as it generates the force to propel the body ahead. This step involves raising the head above the water to breathe. To recover, swimmers should extend their arms forward slightly below the surface to reach the glide phase and then restart the cycle.

Considering the competition, breaststroke technique is raced over 100 m and 200 m distances at the Olympic Games, and an additional 50 m event at the World Championships. The technical rules of breaststroke constrained by Federation Internationale De Natation (FINA, 2017) lead to differences from other competitive strokes (backstroke, butterfly, and freestyle) with two discontinuous propulsive phases (Takagi et al., 2004) and high resistive drag forces, which are caused by underwater limb recoveries. Therefore, breaststroke swimming possesses the lowest average speed and the highest level of intercyclic speed variation among the competitive strokes. Additionally, individual diversities such as coordination patterns, neuromuscular activity, temporal characteristics, and pacing profiles can also affect the breaststroke process (Nicol et al., 2022).

Considering the arm–leg coordination during the underwater pull-out sequence in the 50, 100 and 200 m breaststroke start, It stated that the model including the underwater sequence with seven key points for arm actions (A- to F) and eight for leg actions (0 to 7), together with seven time-gaps (T0 to T6) were measured and shown in Figure 2.1. (A) First arm action, when the hands start to separate to break the initial streamlined position, (B) Start of pull-out, when the hands start to move backwards following the initial streamlined position, (C) End of pull-out, when the hands stop moving backwards at the thigh, (D) Start of the recovery, when the elbows start flexing and the hands start moving forward from the thigh, (E) End of recovery, when the arms are fully extended to make the second streamlined position before the breakout, (F) The first arm action following the second streamlined glide (beginning of the first cycle of the surface swimming); (1) Start of dolphin kick recovery, when the knees start flexing and feet go upward, (2) Start of dolphin kick, when the knees start extending and the feet move downward, (3) End of dolphin kick, when the feet reach their deepest position, (4) Start of leg recovery, when the knees start flexing and the feet go upward, (5) Start of leg propulsion, when the feet move backward after the knees show their maximum flexion, (6) End of outsweep, when the legs are fully extended, (7) End of insweep, when the feet are maximally closed after the leg extension, (T0) Initial glide, from feet entering the water until the first active arm or leg action, (T1) Glide phase, following the arm pull-out with arms at the side until the beginning of arm recovery, (T2) Coordination between the beginning of arm and leg recovery, (T3) Coordination between the end of arm and leg recovery, (T4) Coordination between the dolphin kick and the start of the arm pull-out, (T5) Coordination between the start of the dolphin kick and the end of the arm pull-out, (T6) Coordination between the end of knee extension in the breaststroke kick and the start of the first arm action of the first swimming stroke.

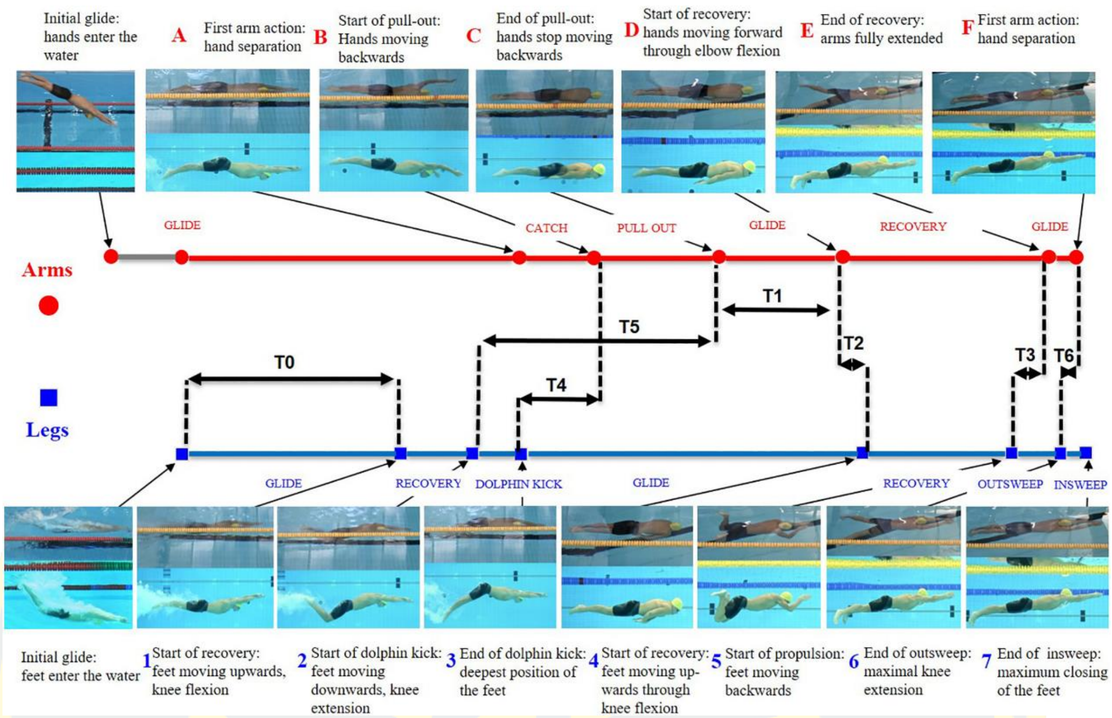

Figure 2 Key points, phases and time-gaps of the breaststroke movements (Olstad et al., 2021).

2.1.2 The physiological demands of breaststroke swimming

As muscles generate the energy or power to propel the body through the water when swimming, the performance can be related to the energy transformation efficiency of swimmers (Toussaint & Hollander, 1994). Same as in any form of exercise, chemical processes transform the chemical energy (adenosine triphosphate) stored within the muscle or borne by the blood that is obtained from the breakdown (catabolism) of food into mechanical energy (Rodríguez & Mader, 2011). Both aerobic and anaerobic system are the important contributors to the energy expenditure (Barbosa et al., 2006), and the suggested relative contribution of the energy systems during swimming are listed in Table 1. With the goal of swimming fastest, swimmers have to achieve their maximal velocity, which is consistent with the maximal total energy expenditure according to Tiago, (2009). Besides, it is known by the calculation process of energetic sources, the swimmer's technical ability and the overall efficiency are the main influence factors.

There are many reasons determining high physical endurance in young swimmers (Strzala et al., 2015). Indices of physical fitness on swimming speed have been under examination for many years as these parameters, which with swimming technique, directly determine the ability of high-performance swimming (Morouco et al., 2011). Generally, breaststroke swimmers are always tall with leanness (to minimize drag) and muscle strength and power (to promote propulsion). In comparison, male swimmers are required for more muscle and less body fat, while relative size, skinfolds, and somatotype will also implicate the water resistance and propulsive forces, finally influencing the energy consumption. Furthermore, it has been proved that the energy capacity and its recovery can be improved with proper training (Pyne & Sharp, 2014).

Competitive pool events include races from 50 up to 1,500 m. The metabolic power needed to swim at maximal speed and the relative contribution of the three energy systems vary depending on the distance and, thus, on the swimming time at maximal intensity (Rodríguez & Mader, 2011). Table 2.1 summarizes studies estimating the relative contribution of the energy delivery systems during freestyle swimming events from 50 to 1,500 m.

Table 1 Suggested relative contribution of the energy systems during swimming. (Rodríguez & Mader, 2011).

Distance (m)	Phosphagen(%)	Glycolytic(%)	Aerobic (%)
50	15-80	2-80	2-26
100	5-28	15-65	5-54
200	2-30	25-65	5-65
400	0-20	10-55	25-83
800	0-5	25-30	65-83
1,500	0-10	15-20	78-90

2.1.3 Stroke kinematics, temporal patterns and pacing strategy of breaststroke swimming

At present, research on breaststroke training mostly focuses on stroke kinematics, temporal patterns and pacing strategy. The two most frequently used kinematic parameters in the biomechanics of breaststroke swimming are stroke rate

(SR) and stroke length (SL) when the former increases and the latter decreases with increased intensity. However, the various directions of this kinematics are inconsistent in the course of an event (Nicol et al., 2022). In addition, stroke kinematics also changes due to some athlete characteristics such as sex, swimming efficiency, and muscular strength. Although boys with taller height and longer arms are supposed to swim faster, better swimming efficiency of females will make up for what they lack in males in muscle strength, height, etc.

Temporal analysis, as a well-established technique that is divided into two stages of pull and kick, is usually associated with stroke stages and coordination patterns (Garland, Hibbs & Kleshnev, 2009). Various stroke phase models are utilized to describe the phase number differences. By examining component differences in temporal patterns, it was found that temporal differences were associated with changes in racial distance, experience level, and sex. For instance, the relative time spent on the propulsion and recovery phases of arm and leg during the 50-meter stroke is longer compared to the 200-meter stroke. On the whole, the speed of swimming can be improved by reducing the rate of deceleration throughout the glide phase and ensuring acceleration generated during the leg propulsion phase is applied along the horizontal axis.

This energy distribution during exercise is regarded as 'pacing' or the 'pacing strategy', which may significantly affect athletic performance (Mauger, Neuloh & Castle, 2012) playing an increasingly important role. It is extremely important in swimming because of the inherent low mechanical efficiency and high electrical resistance of water. In swimming, the pacing profile adopted in a particular event is dependent on both race distance and stroke. As for breaststroke swimming of 50, 100 and 200 m stroke, keeping swimming velocity throughout the race is a major factor determining the swimmer's success regardless of gender (McGibbon et al., 2018).

2.2 Training the young swimmers

2.2.1 Physical and physiological development of the young swimmers

Studies have shown that variables such as height, arm span and hand length are related to swimming speed (Lätt et al., 2009) During the first two decades of life, especially the years associated with childhood and adolescence, there is substantial growth and change in the human body. Some of the most obvious changes are related to changes in body (body) body proportions, reflecting growth. In breaststroke, swimmers with longer upper limbs and wider girth have a significant advantage (i.e & better performance within 100 meters), which allows late adolescent swimmers to swim faster. In addition, late adolescent athletes had greater body weight, chest circumference, watch area, frontal area, trunk transverse area, and body surface area (Morais et al., 2015) which is also the reason of swimming faster.

A study designed to identify the major body variables in the sport of swimming in adolescents acknowledged that all swimmers benefit from less body fat, wider shoulders and hips, and longer waists and forearm girth in the 100-meter breaststroke (Nevill, Oxford & Duncan, 2015) Figures 2.3 and 2.4 provide an illustrative overview of growth throughout childhood and adolescence. The occurrence of height gain (cm) according to age (years old) is summarized in Figure 2.3, while Figure 2.4 illustrates the accumulated height per year (cm/year) throughout childhood and adolescence. It should be noted that both figures demonstrate a re-acceleration of height accumulation at approximately 10-11 years for girls and 12-13 years for boys, respectively. This period of re-accelerated growth is commonly referred to as puberty or maturation, during which individual anthropometric and physical developments progressively transition into the adult mature state.

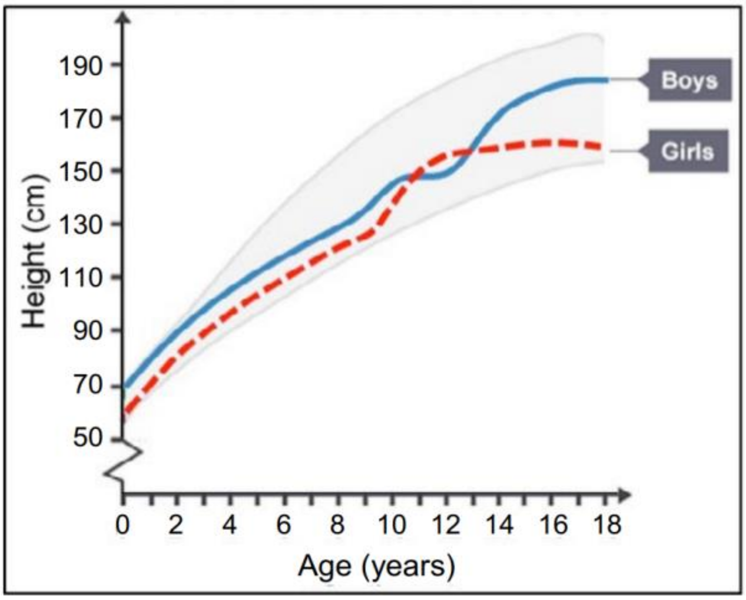

Figure 3 Illustration of normative accumulated height according to age and sex.

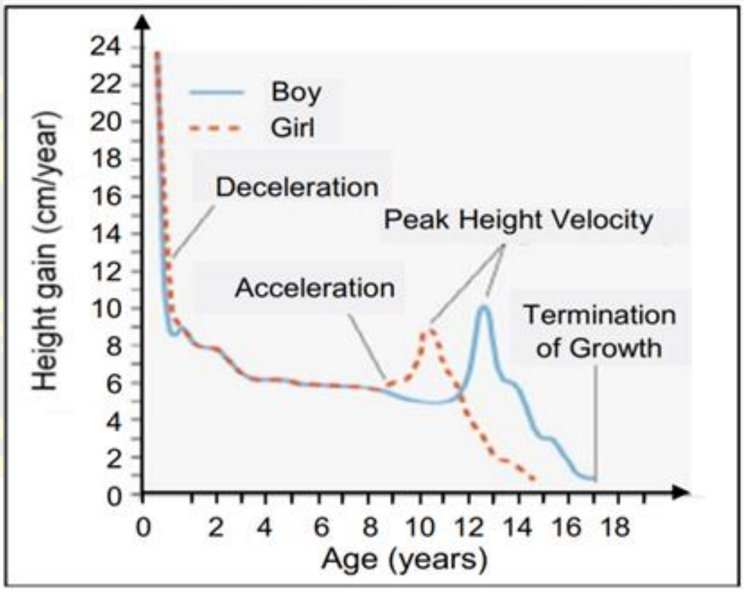

Figure 4 Overview of normative growth as shown by accumulated height (cm per year) according to age and sex.

Though height and weight are common measures of this growth, it should be acknowledged that the growth of the body includes a variety of components, such as the growth of bone and muscle tissue and hormonal changes. The onset of maturation is affected by a range of factors including genetic (e.g ethnicity), socioeconomic status, the physical environment (e.g climate), stress and stressful life events, chronic illness, nutrition and diet. There is no clear evidence to suggest that intensive sports training influences the timing of maturation (Malina, 1994). The maturity growth spurt can occur in females between 9.5-14.5 years of age; while it occurs later for boys, generally between 12-16 years, with an average of 14.4 years for normative populations (Stang & Story, 2005).

During maturation, males generally gain between 10-30 cm in height, while females typically experience between 20-25 cm of height gain (Barnes & Fahreus, 1975). As the timing and tempo of the final growth spurt can vary substantially across individuals during maturation, it is common to observe individuals reporting different chronological age time-points of peak growth (see Figure 2.5). Figure 2.5 shows how an 'earlier maturer' is associated with a greater growth magnitude at earlier chronological ages compared to the 'average' or 'later maturer' (Tanner & Whitehouse, 1966). Regardless of these development trends, overall adult height is not necessarily affected, as 'later matures' may experience a longer pre-pubertal growing period which counter-balances their potentially less heightened final growth spurt relative to 'early matures' (Hill et al., 2010).

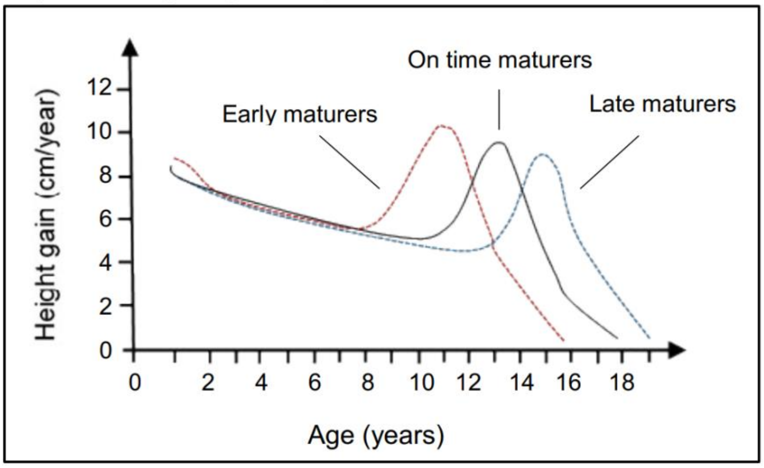

Figure 5 Overview of 'early', 'average' and 'late maturity' status as reflected by accumulated height (cm per year) according to age in boys.

However, some studies suggested that swimming is beneficial for maintaining weight and gaining muscle during adolescent physical development (Faigenbaum et al, 2009). Greater muscle mass will result in higher hemoglobin concentration of youth swimmers, which is benefit for the development of aerobic fitness. In addition to the rate at which energy can be produced by aerobic processes, the total amount of energy that can be produced by the anaerobic energy systems is important for training and performance in swimming. In general, children do not have a well-developed anaerobic metabolic system, which has been demonstrated by lower blood lactate levels at peak VO_2, and lower concentration of enzymes responsible for glycolysis, compared with un-trained male adults (Eriksson, Gollnick & Saltin, 1973). Both boy and girl swimmers show similar sprint speeds in their childhood, due to the rapid growth of the central nervous system (Ford et al., 2011). During puberty, the increase in muscle substrates and enzymes, along with developing muscle size and length improves speed immediately before and during adolescence, which improve the function of anaerobic systems.

2.2.2 Bio-banding in youth sports: swimming perspective

The three processes of growth, maturity and development characterize the lives of children and young people between birth and adulthood. Inter-individual differences in biological maturation also play a central role in the latter, as they affect body size, strength, power and motor performance, as well as infusion behavior, especially during adolescence (Malina, Bouchard & Bar-or, 2004). In the beginning, age was often used as a sign to judge the maturity of an athlete and judge his training program accordingly. However, follow-up studies have shown that the physical maturity of different adolescents at the same age is not the same, and their uniform swimming training is not universal. Therefore, bio-banding has been proposed to match athletes based on physical characteristics and maturity rather than chronological age, benefiting both precocious and late-maturing athletes.

The two commonly used indicators of maturity timing are age at peak height velocity (PHV) and age at menarche. Recently, predicting the age of PHV of adolescent athletes has been increasingly used in studies of adolescent athletes (Malina et al., 2019). The sex-specific equations require CA, height, sitting height, estimated leg length, and weight. Modified equations limited to CA and height or CA and sitting height in boys and CA and height in girls are also available. Using anthropometric variables (Mirwald et al., 2002) developed a noninvasive, practical method for predicting years from peak height velocity (maturity offset) and cross-validated it in two different samples, resulting in a coefficient of determination (R_2) of

0.92 for the boy model and 0.91 for the girl model. In swimming, the advantages associated with maturity usually appear around the age of 12 - 13 (Malina et al., 2019)

In swimming perspective, there is no standardized categorization system for children in youth sports other than chronological age in swimming due to the complexity and logistical challenges of maturity evaluations. Internationally, there is no agreed-upon competitive categorization system for children that is considered the most suitable and just. Several swimming federations often bring together more than two different age categories for competitions (Kojima, 2010). Varying levels of development among young swimmers lead to significant disparities in the size and strength of competitors in multi-age groupings. Competitive results are often determined mainly by maturity-based performance advantages rather than by skill or training-induced enhancements. In the 11–12 age group, 12-year-old swimmers tend to be taller, stronger, and quicker than 11-year-old swimmers. Age-related variations in swimming ability have been documented in unskilled students aged 11–17 years (Pelayo et al., 1997) Age-related enhancements and gender-based disparities in swimming performance were attributed to the maximum exercise capacity resulting from age-related muscle property improvements, especially noticeable in boys.

2.2.3 Young swimmer development models

Based on insights from Olstad（2007）the recommended training phases are designed to align with these growth stages and the evolving capabilities of young swimmers.

Active start (Ages 0–6)，This phase focuses on introducing children to swimming and developing physical literacy in an aquatic environment. Key skills include breath control, buoyancy, floating, gliding, kicking, arm propulsion, and coordination. A connection or feel for the water is established, alongside basic water safety activities. Emphasis is on making these activities enjoyable.

FUNdamentals (Females: Ages 5–8; Males: Ages 6–9)，The first stage of formal training where fundamental movement skills are developed. Activities should be structured yet fun, with a focus on learning all swimming strokes and beginning to build technique.

Learn to train (Females: Ages 8–11; Males: Ages 9–12)，During this pre-growth spurt period, there's a focus on skill repetition towards mastering stroke mechanics and racing skills such as starts, turns, and finishes. This stage is critical for laying a solid technical foundation.

Train to train (Females: Ages 11–14; Males: Ages 12–15)，This stage emphasizes aerobic conditioning, speed work, and developing anaerobic capacity, marking the beginning of more individualized fitness and technical training. Introduction to correct weight lifting techniques is also appropriate here, with a continued focus on training over competition.

Train to compete (Females: Ages 14–16; Males: Ages 15–18)，As athletes mature, the focus shifts to optimizing physical conditioning, emphasizing race pace work and anaerobic system development. This stage fosters individual strengths and event selection, continuing to develop strength, core body strength, and maintain flexibility. Swimmers are encouraged to compete at both national open and age meets for experience and to strive for national team representation and international exposure.

Compete to win, The ultimate goal is to achieve and sustain international podium success across multiple Olympiads, representing the pinnacle of an athlete's competitive journey；Active for Life，Beyond competitive swimming, the goal is to maintain a healthy, physically active lifestyle throughout life. These training phases outline a holistic approach to swimmer development, ensuring physical, technical, and psychological growth is addressed at each stage, from early exposure to swimming through to achieving elite performance and beyond.

(1) Determinant factors of long-term performance development in young swimmers

The “Long Term Athlete Development” (LTAD) model is driven by participant development and, with a foundation in physical literacy (commonly termed movement competency), an individual can opt out at any stage of the model but remain within a recreational lifelong physical activity pathway (Lloyd et al., 2015). It is primarily a physiological perspective that presents an advancement of understanding of developing athletic potential alongside biological growth (Ford et al., 2011). However, a large survey of master's swimmers with previous competitive youth swimming experience found that only 30% of them joined masters swimming within10 years of ending their youth swimming participation (Larson et al., 2019). Youth swimmers have high levels of burnout and attrition, which can be attributed to the intense training that takes place almost all year round.

In order to keep the long-term performance development of young swimmers, it is necessary to cushion the negative effects of high-load training by meeting their psychological needs. Thus, maintaining a positive relationship between athletes and coaches is crucial. In addition, coaches and parents should encourage young swimmers to use enjoyment, friendship, health benefits and personal development as motivations to increase their passion for swimming, rather than focusing solely on performance results. What's more, allowing them to participate in sports and activities other than swimming is also another determining factor in maintaining their long-term development for swimming (Larson et al., 2019).

(2) Long term athlete development model in swimming: English perspective

The Swimmer Pathway, a swimming-specific LTAD model, was introduced in 2003. This model categorizes swimming as a late-specialization sport and includes the following stages: FUNdamentals (boys aged 6-9 and girls aged 5-8), Learning to Train (boys aged 9-12 and girls aged 8-11), Training to train (boys aged 12-16 and girls aged 11-15), Training to compete (males aged 16-18 and females aged 15-17), Training to win (males aged over 18 and females over age of17), and retirement/retention. However, unlike the generic LTAD model, the swimmer pathway specifies the frequency of swim training sessions as well as weekly volume that should be covered (Table 2.2).

Table 2 Framework suggested for athletes under the swimmer pathway according to age and sex.（Lang & light, 2010）

	FUNdamental	Swim Skills	Training to Train	Training to Compete	Training to Win
Chronological/ biological age	Male: 6-9 Female: 5-8	Male: 9-12 Female: 8-11	Male: 12-15 Female: 11-14	Male: 15-18 Female: 14-16	Male: 18+ Female: 16+
Recommended no. of sessions/week	5-6 general sports of 30-45 minutes each	4-6 swim specific, additional participation in other sports	6-12 swim specific, including land work	8-12 swim specific, including land work	10-15 swim specific, including land work
Recommended training hours/week	Sessional	4-7 hours in pool 1-2 hours land work	12-24 hours in pool 2-3 hours land work	16-24 hours in pool 3-4 hours land work	20-24 hours in pool 3-6 hours land work
Recommended training volume/week	None stated	8,000-16,000 meters	24,000-32,000 meters	24,000- 52,000+ meters	Min. 44,000 meters, depending on specialism(s)

Lang (2010) interviewed 11 swimming coaches in northern England to try to find out what they thought of the LTAD model used in England swimming. The study revealed that professors had reservations about the LTAD swimming model, indicating that there is a need to revise the implementation of the model, or at least to investigate, in order to benefit the long-term future of swimming as a sport in the UK and to maintain its continued growth. The strongest reservation expressed by coaches in the study was the impact of excessive volume on skill development and, to a lesser extent, motivation.

Given the importance of developing good skills before the age of 13, this needs to be emphasized in any training programme aimed at long-term development. The UK model recommends 4-6 times a week of swimming between 8,000-16,000 meters for males aged 9-12 and 8-11 years and 6-12 times a week of swimming between 24,000-32,000 meters for males aged 12-15 and 11-14 years. This suggests that either the UK model requires excessive volume or the problem is that some coaches have exceeded the requirements of the swimmer's path. Furthermore, most coaches expressed concerns about the rules and regulations of competitions, which largely relate to the issue of excessive volume and time for competitions.

Greyson（2010) argue that LTAD has both advantages and disadvantages. This suggests that the LTAD is being misinterpreted. However, due to some coaches' misunderstanding of LTAD or lack of understanding of its physiological aspects, they adopted the wrong training methods and did not develop aerobic exercise, leading to the lower potential of swimmers. As for training volume and durations, it should be emphasized that LTAD is a guideline, not an inflexible prescription. That is, the swimming training must be gradual, adapting to the intensity of one level of training before moving to the next level, rather than simply increasing the intensity or number of training sessions. Greyson（2010) also suggested that treating swimmers as individuals by coaches will also increase the chances of swimmers staying in the sport longer.

(3) Long-term athlete development model in swimming: Australia perspective

The Australian swimming development model is a comprehensive, systematic approach designed to develop swimmers for the long-term development from adolescence to adulthood. This model focuses on early participation and basic training, allowing athletes to learn basic swimming skills and build good water skills from an early age. As age increases, the focus of training shifts to improving technical proficiency, including the technical details of various swimming styles and the improvement of turning and starting techniques, as shown in Table 2.4 In addition, athletes undergo specialized physical training, including strength, speed, endurance and flexibility training, to improve overall athletic ability. Australian swimmers gain experience by competing at a variety of levels, including interstate, national and international competitions. These competition experiences are crucial to improving athletes' competitive level and psychological quality. Mental training is also part of the training for Australian swimmers, including learning how to manage competition pressure, set goals, improve focus and competition strategy.

In addition, Australian swimmers learn how to support their training and competition with appropriate diet and recovery strategies. They typically receive guidance from professional coaches who have extensive experience and professional certifications and can provide personalized training plans and technical guidance. Training for Australian swimmers is typically systematic and includes regular evaluation and feedback to help athletes understand their progress and adjust their training plans. Swimming Australia also focuses on the development of young athletes, providing young athletes with opportunities to showcase their talents by organizing youth training camps and trials. These camps and tryouts often include technical training, sports science lectures and competition experiences to help the young athlete develop as a whole.

At university level, Australian swimmers also have the opportunity to continue their swimming careers on university swimming teams. College swimming programs often provide high-level professional training and competition opportunities, while athletes can also obtain higher education. For Australian swimmers who perform well, they may go on to pursue a professional swimming career, compete internationally, or even compete in the Olympics. The aim of the Australian swimming development model is to develop internationally competitive swimmers while focusing on their personal growth and wellbeing. Through this model, Australian swimmers are able to achieve excellence on the international stage.

Table 3 Multiyear age-group swimmer development model.

Age	Training Period	Training	Time Per	Week	Volume/ session	Yearly Training	Volume (Pool)	Training Objectives	Motor Learning Objectives
8 ±1 year	2 years	Pool	2-4 Sessions	40 min - 1 hr	0.75 - 2 Km.	24 - 30 Weeks	75 -250 Km.	*Technique all strokes *Racing skills starts, turns, pace *Aerobic endurance *Sculling drills *Speed at 25-50m *Simple training sets and games *Flexibility *General body strength *Movement co-ordination *Group activities	1. Develop a feel for the water, the ability to make corrections in movement patterns. 2. Learn the technical skills of all four strokes 3. Develop general body co-ordination and strength. 4. Learn good habits for maintaining and improving natural flexibility. 5. Learn to maintain correct technique on longer (submaximal) swims 6. Learn to maintain correct technique on short sprints
		Land	1-2 Sessions	15-25 min					
10±2 year	2 years	Pool	3-5 Session	1-1 1/4 hr	2 - 3.5 Km.	30-36 Weeks	250- 500 Km.	*Technique *Racing skills *Aerobic endurance *Speed (< 50m) &acceleration *Greater mix of Training Methods *Increase strength to body weight ratio *Even development of all muscle groups *Flexibility *Improve 'core' body strength	1. Improve stroke technique and learn race skills (such as turns, starts, pacing, and acceleration). 2. Consolidate stroke development 3. Improve conditioning components of endurance and speed while main-training stroke technique. 4. Develop simple race strategy and tactics .
		Land	2 Session	20-30 min					
Girls 12 / Boys 13 ± 1 yeas	2 - 3 years	Pool	4-6 Session	1 1/4- 1 1/2 hr	3.5- 6Km.*	36-44 Weeks	500- 1000 Km	*Technique *Increased Volume *Racing Skills *Speed (< 50m) &Acceleration*Introduce some Intense Interval Training *Musculo-Skeletal Assessment *Body Weight Exercises &Simple Gym Equipment *Flexibility &Body Strength	1. Maintain efficient technique as body proportions change. 2. Accommodate increases in muscle strength to improve swimming efficiency. 3. Retain diversity of performance goals (compete in various stroke events and distances). 4. Improve both steady pace and sprint performance using ideal stroke technique (all strokes).
		Land	2-3 Session	30-45 min					
14±2year	3 - 5 years	Pool	6-10 Session	1 1/2- 2 hr	4- 8Km.*	40 - 46 Weeks	1000- 2500 Km	*Increase Volume and Intensity of Training *Integrated Training Model *Begin to Specialize *Perfect Technique & Skills *Periodise Strength Program *Transfer Power into Swimming Performance *Cross Training Activities *Maintain Flexibility	1.Adapt to diverse training methods 2. Refine stroke technique during all speeds & intensity of swimming 3. Apply strength and power to swimming performance. 4. Specialize in strokes and competition distances 5. Retain range of motion and muscular co-ordination at all swimming speeds 6. Refine race skills (starts & turns, tactics, pace, etc.) 7. Learn to taper for peak performance.
		Land	2-3 Session	45 min - 1 hr					

(4) Long-term athlete development model in swimming: Ralph Richards Perspective

The structured training program for young swimmers based on Ralph Richards' multi-year age-graded swimmer development model shoed in table 2.4. This model outlines a progressive training plan segmented by age groups and provides specific guidelines for the number of swimming and dry land sessions, their duration, training volume per session, annual training volume, and key technical and strength objectives.

Age groups and training periods: 8±1yr (2-year training period): This age group focuses on young swimmers, roughly 7 to 9 years old, and they are expected to train over a period of two years. 10±2yr (2-year training period): Swimmers around 8 to 12 years old fall into this category, also with a two-year training plan. Girls 12±1yr, Boys 13±1yr (2-3-year training period): Reflecting the onset of puberty and differing development rates, the training plan is adjusted between 11 to 14 for girls and 12 to 15 for boys. 14±2yr (3-5-year training period): For adolescents around 12 to 16 years old, the model extends the training period to accommodate more advanced development.

Training composition: Each age group has an assigned number of swimming (pool) and dry land training sessions per week, with specified durations. For example, the youngest group starts with 2-4 pool sessions and 1-2 land sessions, while the oldest group scales up to 6-10 pool sessions and 2-3 land sessions. Volume/Session: The distance swum per session increases with age, starting from 0.75-2 km for the youngest swimmers to 4-8 km for the oldest. Yearly training weeks: The number of weeks dedicated to training annually also grows with age, ranging from 24-30 weeks for the youngest to 40-46 weeks for the oldest. Volume (Pool): The annual swimming distance increases significantly with age, from 75-250 km in the youngest group to 1000-2500 km in the oldest group.

Technical and strength objectives: Technique and racing skills: All age groups have objectives that emphasize swimming technique across all strokes, racing skills (like starts and turns), and pace. As the swimmers mature, the focus also includes speed, acceleration, interval training, and an integrated approach to training. Aerobic activities and endurance: The model emphasizes the development of aerobic endurance, starting with simple training sets and games, and advancing to more complex and mixed training methods. Strength training: initially focusing on basic body movements and coordination, the model gradually introduces more complex exercises to improve strength-to-body-mass ratio, core strength, and musculoskeletal health. Older swimmers integrate periodized strength training and cross-training to transfer power into swimming effectively.

Overall, the Ralph Richards multi-year age-group swimmer development model is designed to systematically build a swimmer's capabilities, from foundational skills and strength in younger swimmers to advanced training techniques and specialization as they mature. The aim is to ensure steady progress while avoiding burnout and injury, thereby promoting long-term success in competitive swimming.

Table 4 Ralph Richards multi-year age-group swimmer development model. (Pyne & Mujika 2009)

Ralph Richards multi-year age-group swimmer development model								
Age	8±1yr		10±2yr		Girls 12 ± 1, Boys 13 ±1yr		14 ±2yr	
Training period	2yr		2yr		2-3yr		3-5yr	
Pool Land	2-4 sessions, 40-60 min 1-2 sessions, 15-25 min		3-5 sessions, 60-75 min 2 sessions, 20-30 min		4-6 sessions, 75-90 min 2-3 sessions, 30 -45 min		6-10 sessions, 90-120 min 2-3 sessions. 45-60 min	
Volume Session	0.75 -2 km		2 -3.5 km		3.5 -6 km		4-8 km	
Wearly Training	24 -30 weeks		30 -36 weeks		36 -44 weeks		40 -46 weeks	
Volume (Pool)	75 -250 km		250-500 km		500-1000 km		1000-2500 km	
Technique and Strength Objectives	**Technique** all strokes Racing skills - starts. turns. pace Aerobic endurance Sculling drills Speed at 25-50m Simple training sets and games	**Strength** Movement coordination Group activities	**Technique** Racing skills Aerobic Activities Speed<50m Acceleration Greater mix of training methods	**Strength** Increase strength to body mass ratio Even development of muscle groups Core strength	**Technique** Increase training Volume Racing skills Speed(<50m) Acceleration Interval Training	**Strength** Musculo-skeletal assessment Body weight Exercises Simple gym Flexibility Body strength	**Technique** Increase Volume And intensity of training Integrated model Specialisation Perfect technique and skills	**Strength** Periodize strength Transfer power into Swimming Cross-training Maintain flexibility

(5) Normative data and percentile curves for long-term athlete development in swimming

Swimmers' long-term development standard data and percentile curves are important tools for measuring athlete performance at different age groups and training levels. They can help coaches and athletes understand the athlete's development level, develop appropriate training plans, and evaluate training effects. These standards and curves include technical, performance, physical, psychological, recovery and nutritional requirements. Technical standards involve technical requirements for various swimming styles, such as leg movements in breaststroke.

The performance standards are aimed at athletes of different ages and genders, setting standard results for various distances and swimming styles. Physical fitness standards include requirements for strength, speed, endurance and flexibility. Psychological criteria assess an athlete's psychological qualities such as competition stress management, goal setting, concentration and competition strategy (Lang & Light, 2010). Recovery and nutrition teach athletes how to support training and competition through appropriate recovery methods and nutritional strategies. The percentile curve represents the athlete's percentile position relative to the same age group on a certain indicator. For example, an athlete's 100-meter freestyle score may be in the 80^{th} percentile of the same age group.

When developing long-term development plans, coaches and athletes can use these standards and curves to set goals, monitor progress, and adjust training plans as needed. In addition, these data and curves can also be used to identify potential weaknesses in athletes for targeted training and improvement. It is important to note that the long-term development standards and percentile curves are constantly updated and adjusted based on developments in swimming, new training methods, and technological advances. Therefore, coaches and athletes need to regularly monitor new data and information released by relevant agencies to ensure that their training and evaluation methods are always up to date. By focusing on these standards and curves, coaches and athletes can better plan for the long-term development of swimmers and help them achieve excellence on the international stage.

The long-term development plan moves slowly and steadily towards a tipping point reached sometime between the ages of 13 and 15 This is probably equivalent to 2000-2500 km of training per year over 42-46 weeks, including approximately 400 training sessions. (Sweetenham & Atkinson, 2003) I have always believed that the ideal development is to achieve a breakpoint of 13 (girls), 14 (boys), but with flexibility and consideration of school effects, individual maturation rates, and training history. The fact that former World record holders Tracey Wickham (AUS) and Janet Evans (USA) set world records in the 800m freestyle at the age of 15 is evidence of this training propensity among our young female distance swimmers. Thus, around the age of 14 is probably the golden age for swimmers and has a research value.

2.3 Training periodization and training zone in young swimmers

2.3.1 Training periodization

To delve deeper into the topic of training periodization for young swimmers, it's important to recognize the nuanced approach required to optimize their development and performance. This involves a sophisticated interplay of training cycles, each designed to progressively build athletic capabilities while minimizing the risk of overtraining and injury（Pyne & Goldsmith, 2008). A mesocycle, in this context, is not merely a preparatory phase for competitions but a meticulously planned period that incorporates a mix of training volumes and intensities, adjusted according to the swimmer's evolving capabilities and the proximity to key events. It is essential for fostering physical adaptation and psychological readiness.

Within each mesocycle, macrocycles serve as focused blocks where specific training goals are targeted, such as enhancing aerobic base, increasing strength, or honing technical skills. The structuring of these cycles allows for a strategic build-up towards achieving peak performance, ensuring that swimmers are not only physically prepared but also mentally attuned to the demands of competition. macrocycles, the most granular level of periodization, demand careful consideration of daily and weekly training loads, recovery needs, and the individual's academic and social commitments. The design of macrocycles reflects a balance between pushing for performance gains and allowing adequate rest, critical in preventing burnout and ensuring sustainable progress.

Effective periodization in young swimmers thus requires a dynamic, flexible approach that respects the individuality of each athlete, the physiological demands of swimming, and the importance of long-term athlete development. This approach ensures that young swimmers not only peak at the right time but also build a foundation for continued improvement and success in the sport.

2.3.2 Training zone

Through physiological differences, Ireland divided swimming training into five zones,

which are aerobic low intensity and aerobic maintenance/development, anaerobic threshold, aerobic overload, lactate production and lactate production/tolerance, and sprinting - ATP-PC.

The parameters for each zone are listed in table 2.5, revealing that the training model gradually varied from aerobic to anaerobic as the increased exercise intensity along with lower value of HR and higher value of BLa and RPE. And the corresponding physiological responses of different exercise intensity domains are presented in Figure 2.6.

According to Figure 2.6, the upper limits of moderate and heavy intensity domains are lactate threshold, and maximal lactate steady stat, respectively. Continuous swimming for a given speed within the former domain will cause a likely decrease in blood lactate concentration and $\dot{V}O_2$ steady state, while within the latter domain can maintain a high but stable blood lactate and oxygen consumption levels. Then, a very heavy intensity domain is demarcated by the critical velocity, where the blood lactate gradually increases but may not reach $\dot{V}O_{2max}$. The next and above intensity domain named as severe intensity domain is demarcated by the $\dot{V}O_{2max}$, blood lactate concentration climbs rapidly in this domain and $\dot{V}O_2$ will reach to maximum. After that, the swimmer will be eventually exhausted within a short period.

Table 5 A five-zone training model commonly utilized in Irish swimming (Sweetenham & Atkinson, 2003).

Training Zone	Description	HR (bbm)	[La-] (mM)	RPE
Zone 1	Aerobic Low Intensity (i.e. Base conditioning and technical training)	>50	2	<9
	Aerobic Maintenance/Development (i.e. Base aerobic training)	40-50	4	0-12
Zone 2	Anaerobic Threshold (i.e. Training at maximal lactate steady state)	20-30	6	4-15
Zone 3	Aerobic Overload (i.e. High-intensity training at VO_{2max}.Includes heart rate and critical velocity training)	5-20	12	7-19
	Lactate Production (i.e. Race pace training)	5-15	5-15	7-19
Zone 4	Lactate Production/Tolerance (i.e. High-intensity training with medium rest)	0-10	12-20	9-20
Zone 5	Sprinting-ATP-PC (i.e. High intensity training of short duration with long rest intervals)	n/a	n/a	n/a

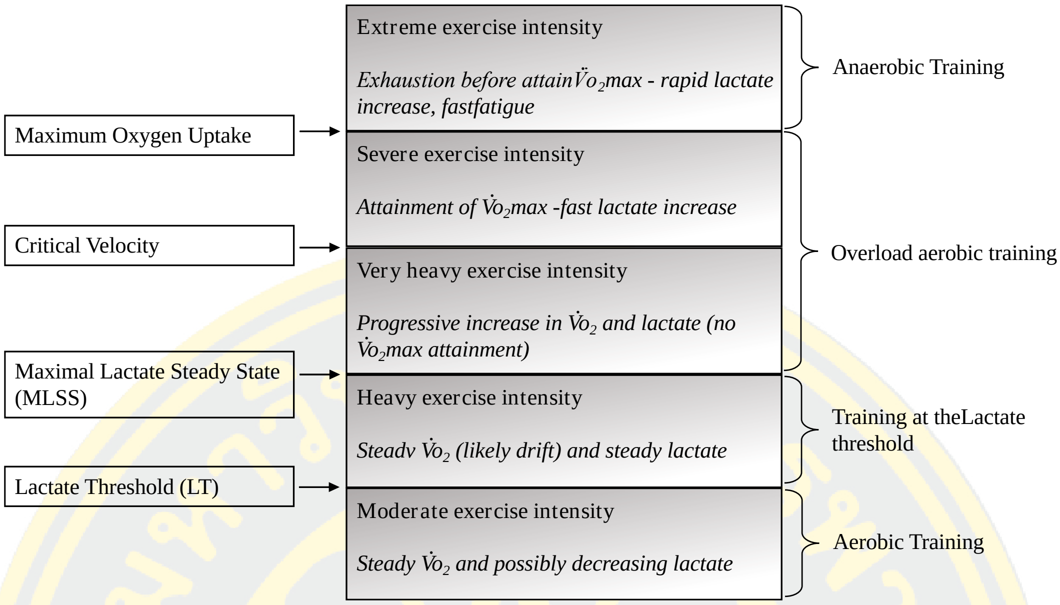

Figure 6 Exercise intensity domains during continuous exercise and their respective physiological responses (Toubekis & Tokmakidis, 2013).

Peyrebrune（2005）adapted and published 'British swimming - training classification' based on research by G. Phillips. This document provides a detailed set of guidelines for the classification of training intensity for British swimming training. The classification system is based on the principles of exercise physiology and divides swimming training into different intensity zones, each with specific physiological goals and training recommendations.

The two charts illustrate a detailed training classification system used by British swimming to categorize workouts by intensity and physiological focus. The first chart delineates the British swimming training classification, defining training intensities from zones 1 to 5. Zone 1 focuses on low-intensity, foundational aerobic conditioning; Zone 2 moves to a slightly higher intensity, targeting the anaerobic threshold; Zone 3 pushes into high-intensity efforts that challenge VO_2 max; Zone 4 is geared towards race pace, inducing maximal lactate production; Zone 5 emphasizes sprinting, necessitating high-intensity, short-duration bursts to improve anaerobic energy systems and fast-twitch muscle fibers are presented in Figure 2.7.

The second chart maps these training zones against other established systems, showing equivalences and promoting a shared understanding. For example, the aerobic maintenance work of British swimming's A2 is parallel to Zone 1's A2 of sweetenham and Atkinson, and EN1 of Maglischo’s system, all of which aim to improve cardiovascular efficiency and are characterized by moderate heart rate and lactate levels. Such detailed classifications are pivotal in periodized training plans, where progression through these zones is meticulously planned over a season to peak athletes' performance. Texts like Maglischo's "Swimming Fastest" would typically provide empirical data supporting these methodologies, emphasizing the necessity of manipulating physiological variables to achieve optimal training adaptations presented in Figure 2.8

BRITISH SWIMMING TRAINING CLASSIFICATION
Description and Training Intensity Measurement

Training Zones	Name	Description	HR (bbm)	LA[4] (mM)	PRE
Zone 1	A1	**Aerobic Low Intensity** Base conditioning and technical training; warm-up and warm-down *Predominantly Fat Metabolism; largely slow-twitch fiber recruitment*	>50	<2	<9
	A2	**Aerobic Maintenance/Development** Base aerobic training *Improves cardio-respiratory system; enhances Lactate Removal*	40 - 50	2 - 4	10 - 12
Zone 2	AT	**Anaerobic Threshold** Maximal Lactate Steady State where Lactate production = Lactate removal *Optimal intensity for development of aerobic capacity*	20 - 30	3 - 6	14 - 15
Zone 3	$V0_2$	**Aerobic Overload** High intensity work at approximately VO_{2max} This type of training includes Heart Rate and Vcrit sets *Improves VO_{2max} and aerobic power*	5 - 20	6 - 12	17 - 19
Zone 4	LP	**Lactate Production** Training intensity results in the maximal speed of lactate build up This type of training includes Race Pace training *Enhances rate of glycolytic energy production*	5 - 15	8 - 15	17 - 19
	LT	**Lactate Tolerance** High intensity work with medium rest to improve buffering *Developing the ability to tolerate lactate/acidity in the muscle*	0 - 10	12 - 20	19 - 20
Zone 5	Speed	**Sprinting-ATP-PC** High intensity, short duration, long rest repeats *Designed to improve alactic energy production (ATP-PC), neuromuscular coordination and fast-twitch muscle fiber recruitment*	N/A	N/A	N/A

Figure 7 Description and training intensity measurement (British swimming).

BRITHSH SWIMMING TRAINING CLASSIFICATION Relationship between different training classification systems								
Training Zones	**British Swimming**	**Description**	**HR[2] (bbm)**	**Log book (simplified)**	**Sweetenham and Atkinson[3]**		**Maglisch[4]**	**Olbrecht[5]**
1	**A1**	Aerobic Low Intensity	>50	Aerobic	Zone 1	A1	EN1	AEC
						A2		
	A2	Aerobic Maintenance	40-50			A3	EN2	
2	**AT**	Anaerobic Threshold	30-40 20-30		Zone 2	AT		
3	**VO_2**	Aerobic Overload	10-20	Race Pace	Zone 3	MOV_2	EN3	AEP
4	**LP**	Lactate Production	0-10		Zone 4	LP	SP2	ANC
	LT	Lactate Tolerance	0-10			LT	SP1	ANP
5	**Speed**	Basic Speed ATP-PC	N/A	Race Speed	Zone 5	Sprint	SP3	Sprint

Figure 8 Relationship between different training classification systems. (Peyrebrune, 2005).

2.4 Strength training in young swimmers

2.4.1. Concept of strength training for improving swimming performance

To compete successfully at the national or international level, swimmers must contain a year-round resistance training program to maintain or increase strength and strength, improve movement patterns, and limit the risk of injury (Newton et al., 2002) Strength training can achieve a positive transfer of swimming performance by improving physiological and biomechanical parameters. upper body strength, especially in swimming, is critical due to that most of the propulsive swimming speed is generated by the upper body muscle tissue.

Mujika & Crowley, (2019) considered that latissimus pull down back is the dry-land test most relevant to swimming performance, while the bench press is only associated with generating force within the water arm and jumping with the tethered forces legs during counter-motion jump only. These and other similar concepts emphasize the requirement of evaluate force-velocity characteristics of the arms and legs separately and to consider these measures in training design (Nikolaidis, 2012).

Neuromuscular adaptations, such as improved motor unit recruitment, synchronization, contraction, rate coding, intra-and inter-neuromuscular coordination, and neural inhibition, have been identified as unique ways to increase the ability to generate strength in swimming are presented in Figure 2.9.

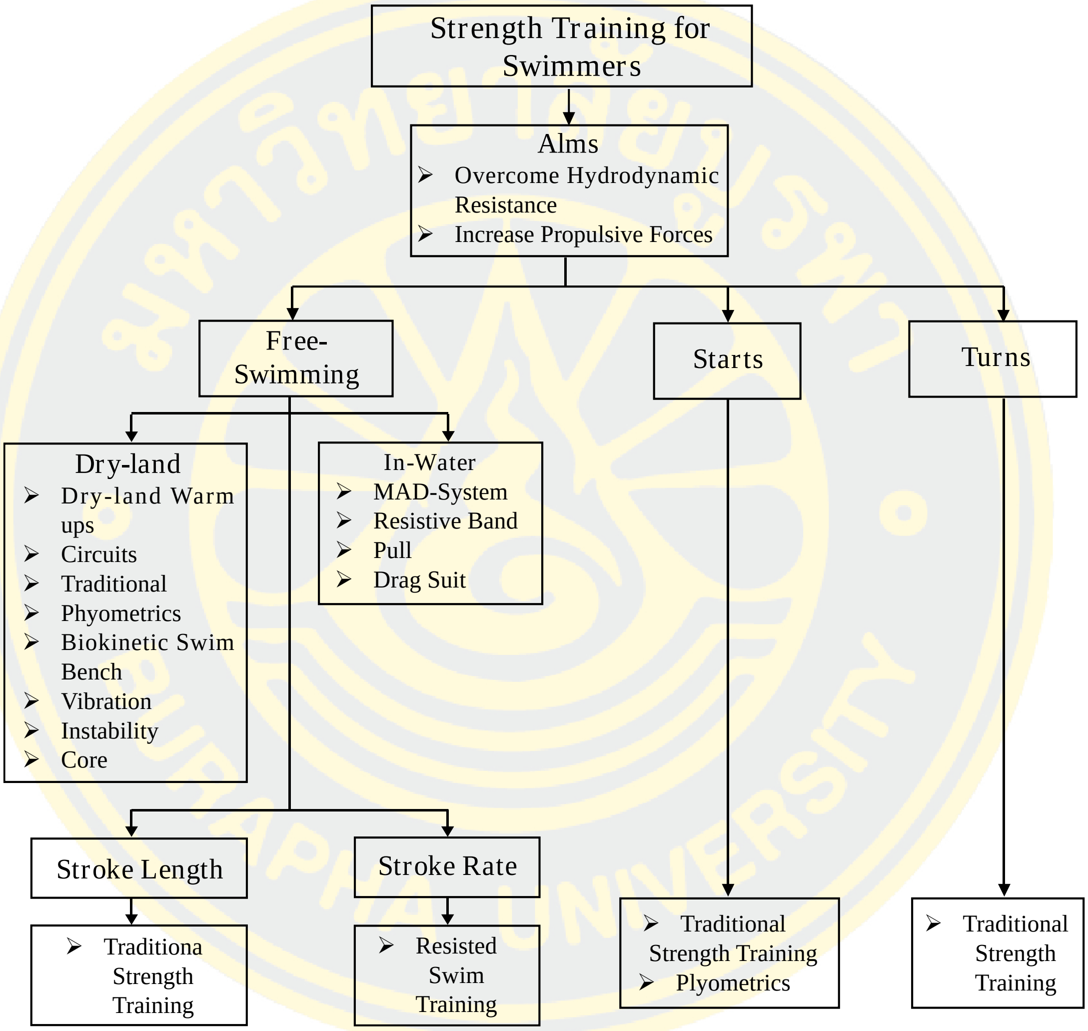

Figure 9 Illustration of the strength training methods prescribed to improve swimming performance and results from the literature.

2.4.2 Impact of strength and power on swimming performance.

A swimming jump is made up of a unique coordinated effort of reaction time, vertical forces, and horizontal forces. The lower-body strength, a key component of starting performance, which is closely related to swimming starting performance (West et al., 2011) especially in restarting performance. Therefore, elite swimmers with superior lower body strength may produce higher horizontal and vertical pulses than non-elite swimmers.

Theoretically, the fastest turning performance results from reduced drag, peak propulsion, and increased wall push time. To achieve this, studies have shown that greater power in the squat jump, counter-motion jump height, vertical height, and speed at launch (Cronin, Jones & Frost, 2007) can improve the speeds for swimmers. Trainings of short-term ballistic and maximum strength are able to enhance the characteristics of leg extensor strength, thus improving the propulsion stage of swimming turns for elite swimmers Free swimming is another stage of pool swimming. Studies have shown that low volume, high speed/strength and special strength training programs will exhibit a positive impact on free swimming performance (Mujika & Crowley, 2019). Above all, the increase of muscle strength and power in upper body should be translated into an improved ability to generate propulsion in the water, an increased stroke length and rate, and an increased free-swimming speed. Besides, the strength and power of lower body result in faster starts and turns.

2.4.3 Impact of strength training on swimming biomechanical parameters

Factors such as training, intensity, physiological ability, race distance, gender, and swimming technique verified swimming speed through influencing the relationship between stroke length and rate (Alberty et al., 2008) Therefore, coaches often prescribe training to improve these technical parameters. It is unclear whether low repetition and high strength training lead to a growth in stroke length (Girold et al., 2006). however, practice cases indicate that a high level of strength is benefit of swimmers achieving maximum speed. For example, a training intervention using resistance swimming will improve 100-meter swimming performance thanks to that the swimmer must generate enough propulsion to move forward through the increased batting average, rather than being pulled back by the resistance band. In addition, the second half of the 100-meter swimming race is faster, which suggests that resistance to swimming can improve the endurance of muscle strength.

2.4.4 Training methodology to improve swimming performance

(1) Dry-land strength training

The improvements in the power and strength of swimmers are mainly from dry-land training, but a proper training program can improve strength and the in-water results that can be obtained with strength training (Newton et al., 2002). A better understanding of the relationship between strength training, anaerobic factors and medium & long distance performance in endurance events in general, especially swimming, is essential, given the beneficial effects of strength training on anaerobic performance. In addition, there is a demand for a better understanding of the time invested in strength training in dry-land. Due to the lack of research on its strengths, more research is required to explore the effects of different long-term cyclicalization strategies to provide detailed guidelines for athletes and coaches (Wirth et al., 2022).

(2) In-water strength training

Mujika et al. (1995) found that swimming specific strength training such as arm pulling, kicking, and swimming specific strength training seemed to cause a negative impact on performance in the short term, while its medium- and long-term contribution to performance was uncertain. For example, the breaststroke kick motion is displayed in figure 2.5. Girold et al, (2006) indicated that the application of resistance training in water is able to increase swimming performance and emphasize the necessary for specific resistance training of swimming Stewart & Hopkins, (2000). have shown that improvements in swimming performance can be observed after four rounds of swimming specific resistance training (i.e. resistance elastic) followed by maximum sprints. The use of resistance elastic bands as a resistance training tool may have attributed to the improvement in swimming performance and provided a dynamic resistance training method to develop the muscle strength specific to swimming, again emphasizing the need for specificity (Crowley, Harrison & Lyons,2017).

(3) Concurrent training in swimming

Single training method cannot meet the requirements due to the complexity of high-performance swimming training. The study found that swimming training, including low and high-intensity endurance training, can provide the necessary physiological adaptation to improve swimming performance (Crowley, Harrison &

Lyons,2017). Concurrent training leads to conflicting adaptive responses, regardless of the characteristics of each training. Endurance training involves manipulation of intensity, duration, and frequency of training sessions over days, weeks, and months.

In addition, long slow distance, lactate threshold training, and high-intensity interval training (HIT) are all familiar terms for exercising within different regions on the intensity scale. Aerobic endurance training in the intensity range of approximately 50% to 100% of VO_2 max is divided into five somewhat arbitrary intensity zones as table 2.6. However, molecular signals generated by endurance training have been shown some interferences, so a series of science-based recommendations were developed by Baar, (2014) to optimize concurrent training. In addition, future studies should focus on the interference of endurance training in the relationship between resistance training and neural adaptation, not only myofibrillar hypertrophy adaptation.

Table 6 Example of a five-zone intensity scale to prescribe and monitor training of endurance athletes. (Seiler, 2010)

Intensity zone	VO_2 max (%)	Heart rate (% max)	Lactate ($mmol \cdot L^{-1}$)	Typical accumulated duration within zone
1	50-65	60 -72	0.8-1.5	1-6h
2	66-80	72-82	1.5-2.5	1-3 h
3	81-87	82-87	2.5- 40	50- 90 min
4	88-93	88- 92	4.0 -6.0	30- 60 min
5	94-100	93-100	6.0-10.0	15-30 min

2.5 Concurrent training for young swimmers

Concurrent training refers to the combination of endurance and strength training routines within the same training cycle or period. When assessing the effects of concurrent training in young swimmers, the literature generally explores how this multifaceted approach can impact athletic performance, including swimming speed, endurance, strength, and power. Competitive swimmers frequently engage in concurrent training, balancing aerobic swimming sessions with strength training. This approach aids in improving muscle strength and aerobic endurance, which are critical for swimming performance across different distances and events. Exercises during dry-land training sessions are geared towards improving swimmer's strength and power (Mujika & Crowley, 2019).

Dry-land resistance training is a common practice concurrent with swimming training, often performed on the same day. Both training methods may lead to performance enhancements, varying training content, athlete profiles, and the timing between sessions could significantly affect the outcomes (Arsoniadis et al., 2022). Aspenes et al.'s research suggests that incorporating targeted dryland resistance training into swimmer training can help improve performance, especially in mid distance events. It highlights the need for a strategic approach to concurrent training that maximizes the unique adaptations from both strength and endurance modalities without one negatively impacting the other (Aspenes et al., 2009).

Garrido 's research suggests that dry-land strength programs, when combined with regular swim training, can fortify strength in young competitive swimmers and potentially improve short-distance swim times. However, without a clear indication of improved swim performance due to strength training alone, it's emphasized that continuous regular swimming practice remains a cornerstone for swimmer development. This research could influence swim coaches' training strategies, particularly in planning strength work alongside swimming sessions for young athletes (Garrido et al., 2010).

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2.6 Monitoring and testing in young swimmers

(1) Monitoring training load and performance in swimming

Chatard, J.-C & Mujika, I.'s research suggests that training load for competitive swimming is composed of volume, intensity, frequency, and dry-land training, with elite swimmers often undergoing significant fluctuations in these components across the season. Tapering, which entails reducing the training load, is commonly practiced leading up to competitions, with research supporting the benefits of high intensity and low volume training before high-load and tapering phases. Each swimmer's response to training load alterations can be quite individualistic, relying on factors like initial training status and performance level. (Chatard & Mujika, 1999).

The study by Sara Ferreira et al, (2021) concluded that structured training across a season with appropriately periodized macrocycles could lead to meaningful enhancements in young swimmers' performance. It also highlighted the importance of both physiological adaptations and technical improvements in achieving this progress. (Ferreira et al., 2021) The acute recovery and stress scale (ARSS) was used for daily monitoring, proving to be efficient in assessing the recovery-stress state in a detailed manner. Session-RPE (sRPE) and acute: chronic workload-ratio (ACWR) were the methods compared for internal training load measurement concerning their relationship with the recovery-stress state. Significant inter-individual variability in weekly training loads with substantial week-to-week fluctuations, indicating the need for personalized training and recovery strategies (Collette et al., 2018).

(2) Specific physical swimming tests

2.1 Lower extremity strength testing

Strength testing for the lower extremities is crucial because it significantly impacts a swimmer's performance during starts and turns. The 1RM (one-repetition maximum) back squat test is widely recognized as the gold standard for measuring maximal lower body strength (Baechle, Earle & Wathen, 2008) It assesses an individual's maximum strength by determining the heaviest weight they can lift for one repetition with proper form. This test not only gauges lower body strength but also provides insights into an athlete's potential for power generation.

The application of the 1RM test in various forms has been attributed to strength and conditioning professionals seeking to quantify progress in athletes' strength programs. Figures in the field, such as Dr. Thomas DeLorme, have contributed to the foundation of resistance training methodologies from which 1RM testing evolved. In practice, the 1RM back squat test involves a structured warm-up followed by progressively heavier lifts until the maximum weight that can be squatted once with correct technique is identified, ensuring reliability (Baechle, Earle & Wathen, 2008).

Research by McBride et al. (1999) has demonstrated a positive correlation between lower body strength as measured by the 1RM back squat and performance in power-dependent sports, including swimming. These studies underscore the test's relevance for swimmers, particularly for sprint events where explosive starts and turns can shave precious seconds off a race time. Therefore, the 1RM back squat test serves as a pivotal assessment tool for lower extremity strength, indispensable for competitive swimmers who rely on leg power for effective starts and turns.

2.2 Swimming specific test for propulsion force (Tethered force)

Tethered swimming tests serve as an instrumental tool for evaluating a swimmer's force and power output by measuring the force exerted against a static resistance in the water. This method provides a controlled environment where external variables, such as waves and turns, are eliminated, allowing for a direct assessment of a swimmer's propulsive capabilities. Swimmers are typically connected to a fixed point, such as the edge of the pool or a specialized tethering system, and they swim in place, allowing for the measurement of the force they generate. The concept of tethered swimming is not attributed to a single inventor but has been developed and refined by various researchers and coaches over the years. However, specific protocols, like the 30-second maximum strength breaststroke tethered swim test cited by Morouço et al. (2014), have been standardized to optimize the test's reliability and validity.

The 30-second tethered swim test, as recommended by Morouço et al. (2014) involves swimmers performing at their maximal effort for a duration of 30 seconds while being tethered. The test typically requires swimmers to wear a waist belt connected to a load cell or similar device to record the force exerted during each stroke. This method quantifies the swimmer's propulsive power in a manner that is highly relevant to swimming performance. Morouço et al. (2014) study and others like it have provided valuable insights into the application of tethered swimming as a performance measure. These studies suggest that improvements in the force readings from tethered swimming tests can be an indicator of a swimmer's increased ability to apply propulsive power in the water, which, in turn, can translate to enhanced swim speed in untethered conditions.

In conclusion, tethered swimming tests, such as the 30-second maximum strength breaststroke test, offer a valuable metric for gauging a swimmer's propulsive force, which is a critical component of competitive swimming performance. When used in conjunction with dry land strength assessments, such as the 1RM back squat, tethered tests can provide a comprehensive view of a swimmer's strength and power profile.

2.3 Anaerobic performance (Anaerobic critical velocity:AnCV)

Anaerobic critical velocity (AnCV) is an assessment of a swimmer's anaerobic capacity, indicating the maximum speed at which they can swim while maintaining a specific level of lactic acid, beyond which lactic acid accumulates, leading to fatigue. This measure is crucial for understanding the intensity at which an athlete can operate before crossing the threshold into severe metabolic stress, where energy production becomes less efficient, and performance declines.

The concept of critical velocity, which has parallels to the critical power concept in cycling, has been studied and utilized by exercise physiologists and coaches to gauge an athlete's endurance and capacity for high-intensity work. While the development of this measure is not attributed to a single individual, it has been refined through research by various scholars in the field of sports science. For instance, Wakayoshi et al., (1992) conducted studies to determine critical velocity as a swimming fatigue threshold.

In the context of swimming, AnCV is typically established through a series of short sprint tests, each of increasing distance or duration, under maximal or near-maximal effort. For instance, a swimmer might complete a set of 50-meter, 100-meter, and 200-meter sprints, with sufficient rest between each to avoid undue fatigue. The times of these sprints are then plotted, and the slope of the linear relationship between distance and time represents the swimmer's anaerobic capacity or critical velocity.

These sprint tests allow coaches to calculate the swimmer's AnCV and set training intensities accordingly. By regularly training at or near the anaerobic threshold, swimmers can improve their body's ability to tolerate and buffer lactic acid, thus enhancing their capacity for short-duration, high-intensity efforts that are especially relevant in competitive swimming events. Wakayoshi et al. (1992) provided a framework for the utilization of critical velocity in swimming, demonstrating its effectiveness as a predictor of performance and a guide for training intensity. Further research has continued to validate AnCV as a significant indicator of a swimmer's capacity for anaerobic work, making it an essential component of competitive training programs.

2.4 Breaststroke swimming performance (50, 100, 200m)

Performance in the breaststroke races over varying distances (50m, 100m, 200m) is monitored over time to assess a swimmer's speed and endurance. Technique analysis often accompanies these time trials to identify areas of improvement and ensure that strength and conditioning work transfers effectively to in-water performance. Stroke efficiency, turn technique, and start efficiency are key focus areas to maximize performance in these events. Stroke kinematics, such as stroke rate and stroke length, differ between 100 m and 200 m events, and between genders, with the 100 m event usually demonstrating higher stroke rates and lower stroke lengths compared to the 200 m event. Men generally have higher stroke lengths and spend more time in propulsive phases than women at the same competitive level, (Nicol et al., 2022).

CHAPTER 3
MATERIALS AND METHODS

Chapter 3 is divided into three sections: (1) the objective of the study, (2) the methods and research design, and (3) the procedure for statistical data analysis.

3.1 The purpose of the study

This study investigated the impact of ten-weeks program that incorporated resistance training in both aquatic and dry land environments on tethered force, lower limb strength, anaerobic critical velocity, and swimming performance in regional age-group breaststroke swimmers. Our hypothesis was that the experimental group would exhibit increased sensitivity and improvement in tethering force, lower body strength, anaerobic critical velocity, and swimming ability after ten weeks of training. Given the new insights provided by this study, our focus is to assess the efficacy of concurrent training in enhancing lower body strength, anaerobic performance, and eventually, swimming performance.

3.2 Materials and Methods

3.2.1 Study design

In this randomized controlled study, twenty-four male swimmers specializing in breaststroke were randomly assigned to either an experimental group (EG) or a control group (CG). The EG participated in a training program that combined aquatic exercises (using a parachute, fins, paddle, and specific kicking sets) with dry land resistance exercises (which included back squats: BS, reverse lateral lunges: RLL, and sumo Romanian deadlifts: sRDL). The CG, on the other hand, followed their regular training routine. The study measured the full crawl tethered swimming force, maximum muscle strength (1RM back squat), anaerobic critical velocity (AnCV), and swimming performance and technique (velocity, stroke rate: SR, stroke length: SL, and stroke index: SI) in 50-m, 100-m, and 200-m breaststroke swimming. These measurements were taken before and after ten weeks of both training conditions. Crucially, swimmers were explicitly told not to engage in any additional physical training routine focused on velocity and power throughout the duration of the trial. Before the beginning of their practices, all participants were free from any injuries.

3.2.2 Participants

A total of twenty-four breaststroke swimmers, who compete at the national and regional level in their respective age groups, voluntarily agreed to take part in the present study. The participants were assigned at random to participate in either the control group (CG, N = 12; age: 15.08±0.51 years; height: 176.42±1.88 cm; body mass: 67.41±1.76 kg; 19.69±0.27% of fat mass; competitive swimming experience: 3.88±0.83 years; 560.75±52.96 200m breaststroke Word aquatic points); on the experimental group (EG, N = 12; age: 15.08±0.67 years; height: 176.83±2.08cm; body mass: 65.89±1.49 kg; 19.31±0.48% of fat mass; competitive swimming experience: 4.04±0.72 years;578.42±36.66 world aquatic points of 200m breaststroke)

The inclusion criteria were as follows: (i) had a minimum of 5 years of training experience; (ii) participated in at least 90% of the training period; (iii) free from current injury in the ten-weeks training period; and (iv) not participate in any other training program during the current study. Exclusion criteria were as follows: (i) poor health status and physical condition with potential medical problems, and (ii) incomplete participation in the training and testing program. Parents were informed about the benefits, risks of taking part and the entire evaluative and experimental process in the current study prior to signing an informed consent form, which was approved by the ethics board of the local university code G-HS047/2567(C1) and performed according to the Helsinki Declaration.

3.2.3 Procedures

(1) Pool-based training and swimming performance tests took place in a 50-m indoor pool with 26 and 27.3°C water and air temperatures (respectively), and 64% relative humidity. Dry-land training and strength tests were performed in a bodybuilding room.

(2) Aquatics resistance training. Aquatic resistance training which is including specific kicking sets, parachute and hand paddles was composed of two sessions per week. The water parachute, fins and paddles set were used in both experimental and

control groups (2-3 sessions in a week) immediately after the warm-up (500 -800 m of aerobic training (55% to 80% of maximum heart rate) on Tuesday and Thursday. On general phase (weeks 1- 6), swimmers completed 3 sets × 6 reps × 15 m with 60 s and 5 min of rest between repetitions and sets, respectively. On specific phase (weeks 7-10), swimmers completed 2 sets × 4 reps × 25 m with 60 s and 5 min of rest between repetitions and sets (Amara et al., 2022).

The specific kicking set was included in only EG (2 sessions in a week) immediately after the warm-up (500-800 m of aerobic training (55% to 80% of maximum heart rate) on Wednesday and Friday. On general phase (weeks 1-6), swimmers completed 3 sets × 6 reps × 50 m (25 m kick, 25m drills) with 60 s and 5 min of rest between repetitions and sets, respectively. On specific phase (weeks 7-10), swimmers completed 2 sets × 5 reps × 50m with 90 s and 5 min of rest between repetitions and sets, respectively.

(3) Dry-land training. The dry-land programmer was applied by experienced strength and conditioning coaches. The CG was invited to continue the usual dry-land training, characterized by general body strength consisted of body weight, medicine ball throw, and abdominal exercises. The dry land S & C program for experimental group (EG) included two sessions weekly. Each session started with a 15 min standard warm-up featuring dynamics stretching, functional and mobility and aerobic exercises.

Subsequently, subjects performed three lower body strength exercises, which were specific to lower leg strength including back squat, dumbbell sumo Romanian deadlift and, reverse lateral lunge with moderate contraction velocity and complete motion angle. The back squat exercise was performed with an intensity between 60% and 85% of 1RM. The sets varied between 2 and 3 and repetitions between 6 and 12 (Amara et al., 2022). The dumbbell sumo Romanian deadlift was performed with an intensity between 60% and 85% of 1RM. The sets varied between 2 and 3 and repetitions between 6 and 10. The reverse lateral lunge consisted of 6 to 8 sets with 6 to 12 repetitions. The recovery between sets and exercises was fixed at 2 min.

(4) Monitoring of training and well-being status. The training content of energetics contribution for age-group swimmers was monitored and quantified as the average training volume (Ferreira et al., 2021; Zacca et al., 2020). Additionally,

individual biological responses to training were assessed using the modified relation between acute to chronic workload data (ACWR) (Collette et al., 2018). The acute load refers to the mean training volume (measured in kilometers) during a period of one week, whereas the chronic training load represents the ongoing average training volume for each training macrocycle.

This method allows for straightforward and accurate calculation of ratios due to the presence of a suitable and consistent rolling average training volume for each training macrocycle. This, in turn, simplifies the monitoring and optimization of training periodization. The well-being status was also used for daily monitoring of the recovery-stress state and average weekly self-reported questionnaire with a 7-point scale including perceived levels of stress, fatigue, muscle soreness, and sleep quality and the sum of the four subjective ratings was reported as Hooper index score was taken into consideration (Hooper et al., 1995).

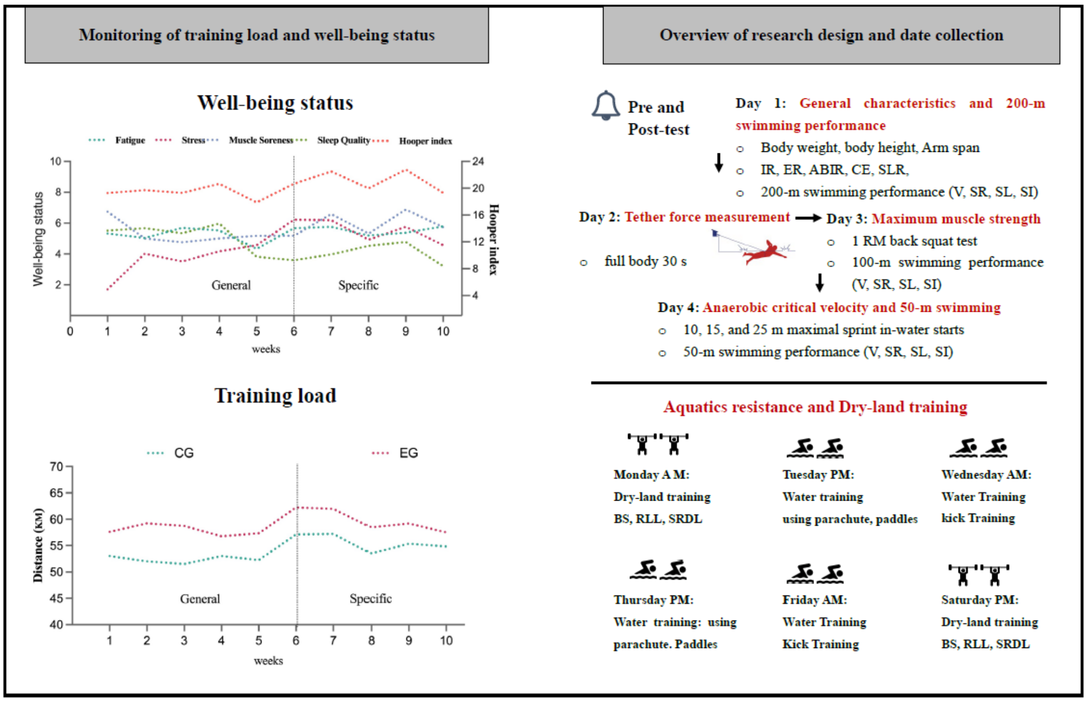

Figure 10 An explanation of the training monitoring, well-being status, research design and data collection.

3.2.4 Testing procedure.

All the tests were performed within four consecutive days (standardized order), before the start of pre-season training; in day one, anthropometric and body composition (weight, height, fat and arm span), glenohumeral internal rotation external rotation (IR, ER), abduction in internal rotation (ABIR), combined elevation (CE), and lower limbs range of motion including active straight leg raise (SLR), (Walker et al., 2016; West et al., 2022) 200-m swimming performance were conducted ; in day two, tethered swimming force was recorded with full crawl stroke; in day three, maximum muscle strength (1RM back squat) 100-m swimming performance were conducted ; in day four, anaerobic critical velocity (10, 15, and 25-m swim) and 50-m swimming performance was carried out. All physical performance tests were carried out during the day between 15:00 and 18:00 to control the circadian rhythm, which can have a direct impact on metabolism and other bodily functions.

(1) Anthropometric and body composition. Upon arrival at the swimming pool, a series of anthropometric measures were taken, including body mass, height, arm span and percentage of body fat was obtained using the techniques of the international society for the advancement of Kin anthropometry. The standing height, body weight and percentage of body fat were measured by the bioelectrical impedance analysis (BIA)(Body composition analyzer: Inbody270, Yi Hui Medical Co, Ltd &China). In the standing upright position, arm span was measured with a flexible anthropometric tape. The distance between each hand's third fingertip was taken into consideration (Morais et al., 2015).

(2) Lower limb muscle strength. maximum lower limb strength was measured using 1RM back squat test. Age-group swimmers completed a warm-up for 3 min, followed-up by 5 min of overall static stretching. Thereafter, subjects performed 1 set of 8 reps and 1 set of 3 reps at 50% and 70% of their estimated 1RM back squat, respectively. The load was gradually increased (10% to 20%), 2 to 3 repetitions and 2 to 4 min of rest were performed. Thereafter, a small increase in the load (5%) and 2 to 4 min of rest were carried out to reach the 1RM squat. The test was finished when the subjects failed to complete the squat, and the last successful attempt presents the 1RM back squat (Amara et al., 2022).

(3) Tethered force: Tethered swim test 30-s was done following the proposals of Morouço et al. (2014) each swimmer performed a 30-s maximum intensity breaststroke tethered swimming test. The measuring device was a load-cell system connected to the swimmer, recording at 100 Hz with a measurement capacity of 1,000 N. (Swimforce V1.0.0, Germany). The maximum tethered swimming tests were randomized performed with full breaststroke. Force data were exported to a laptop via Swimforce V1.0.0 software with the connected to an analogic/digital data acquisition system. All continuous force data were obtained during 30s at a 100 Hz frequency, exported to the Acknowledge 4.0 software, and filtered with a 15 Hz cut-off digital filter (FIR - Window Blackman -61dB). The cut-off value was selected based upon FFT analysis to minimize artefact noise. The force variables obtained in individual force-time curves were (i) maximum force (F_{max}); (ii) mean force (F_{mean}); (iii) fatigue index (Fatindex);

(4) Musculoskeletal screening: The Iphone (Apple Inc, Cupertino, CA) was used to record the motion which is starting in a neutral position in each measurement then moved to achieve their maximum ROM and returned to their neutral position. Shoulder range of motion including shoulder internal and external rotation (IR, ER), abduction in internal rotation (ABIR), combined elevation (CE), and lower limbs range of motion including active straight leg raise (SLR) using Kinovea software analysis, (Walker et al., 2016; West et al., 2022).

(5) Anaerobic critical velocity: Anaerobic performance was evaluated by anaerobic critical velocity (AnCV) as proposed by (Fernandes,2008). AnCV was calculated for each swimmer using the slope of the distance-time (Dd-t) relationship, plotting the following swimming time performance over time: 10, 15 and 25 - m. The equation of the regression line obtained was of y = ax + b type, where here y is distance swam, x is time and a = Anaerobic critical velocity (i.e & strait-line slope), b is y-interception value.

(6) Swimming performance: The 50, 100 and 200 m race time of breaststroke block starting all-out performance were measured by a qualified timekeeper per stopwatch (SEIKO S120-4030, Tokyo, Japan) and noted in seconds. Three of the most frequently referenced kinematic parameters in breaststroke swimming biomechanics including stroke rate (SR) stroke length (SL) and stroke index (SI) are

obtained together with time and average speed. SR was obtained using the time to perform one complete arm stroke cycle, considering the time to perform three arm strokes cycles (T3C) at the 10 m zone, as described in the Equation;

$$\text{Stroke rate (SR)} = (\text{tstroke}^{-1}) * 60$$

SL was determined by the ratio;

$$\text{Stroke length (SL)} = \text{average speed (SV)} / (\text{SR} * 60^{-1})$$

Defined as an athlete's ability to travel at a specified velocity with the fewest number of strokes, breaststroke efficiency may be assessed using stroke index (SI) :

$$\text{Stroke index (SI)} = \text{swimming velocity} * \text{stroke length (SL)}$$

(Nicol et al., 2022)

3.3 Statistical analysis

All data are presented as mean and SD, mean difference, partial difference in percentage, and 95% confidence interval. The baseline between-group differences were computed through independent sample t-tests. Normality and sphericity of the data were tested and confirmed using Shapiro–Wilk test and Mauchly test, respectively. pre and post test reliability was assessed using the intraclass correlation coefficient Repeated measures ANOVA was used to identify the differences between pre- and post-test in the two groups (time factor). The statistical significance was set at $p < 0.05$. A two-way ANOVA was conducted to examine the effects of training methods and breaststroke swimming distance (50,100 and, 200m) on interest in swimming performance and technique variables. post hoc comparisons were conducted with Bonferroni's correction. The effect size (ES) was assessed by converting partial Eta-squared to Cohen's d. ES was classified as trivial ($d < 0.25$), small ($0.25 \leq d < 0.50$), moderate ($0.50 \leq d < 1$) and large ($d \geq 1$) [20]. The level of significance was established at $p \leq 0.05$.

CHAPTER 4
RESULTS

The researcher analyzed the data and the results of data analysis were divided into four parts as follows:

Part 1. The participant's general characteristics and musculoskeletal screening

Part 2. Detail description of 10-weeks training volume, acute and chronic ratio and well-being status for the Control Group (GC) and the Experimental Group (EG).

Part 3. An analysis of the effect of concurrent resistance training on tethered force, lower limbs strength, anaerobic critical velocity and swimming performance.

Part 4. An examine the effects of training methods and breaststroke swimming distance (50,100 and, 200m) on interest in swimming performance and technique variables.

4.1 Participant's general characteristics and musculoskeletal screening

Table 7 Participant's general characteristics from the control group and experimental group.

Participant's characteristics	Control Group (N=12) (Mean±SD)	Experimental Group (N=12) (Mean+SD)	Total (N=24) (Mean+SD)
Age (yrs)	15.08±0.51	15.08±0.67	15.17±0.56
Height (cm)	176.42±1.88	176.83±2.08	176.62±1.95
Weight (kg)	67.41±1.76	65.89±1.49	66.65±1.80
Arm span (cm)	185.00±2.09	184.75±1.82	184.88±1.92
Body mass index ($kg{\cdot}m^{-2}$)	19.69±0.27	19.31±0.48	19.5±0.44
Competitive swimming experience (yrs)	3.88±0.83	4.04±0.72	3.96±0.76
200 m World aquatic points	560.75±52.96	578.42±36.66	569.58±46.40
ABIR (°)	142.88±8.62	144.74±3.91	143.81±6.76
IR (°)	40.08±9.42	39.53±9.67	39.8±9.34
ER (°)	98.37±10.57	94.57±8.74	96.47±9.68
CE (°)	11.56±1.71	11.9±1.32	11.73±1.5
S.L.R (°)	83.46±14.74	83.37±15.08	83.41±14.58

Descriptive statistics of participant's general characteristics are presented in Table 4.1 their main anthropometric, performance and training background characteristic means and standard deviations values were (control group and experimental group, respectively) as follows: 15.08± 0.51 and 15.08 ± 0.67 years of age, 176.42 ± 1.88 and 176.83 ± 2.08 cm of height, 16.69 ± 0.27 and 19.31 ± 0.48 kg of body mass, 185 ± 2.09 and 184.75 ± 1.82 cm of arm span, 3.88±0.83 and 4.04±0.72yrs of swimming experience and 560.75±52.96 and 578.42±36.66 of 200m breaststroke Word aquatic points.

In addition, musculoskeletal screening revealed the following results for the control group and experimental group, respectively: abduction in internal rotation (ABIR) angles were 142.88 ± 8.62° and 144.74 ± 3.91°, internal rotation (IR) angles were 40.08 ± 9.42° and 39.53 ± 9.67°, external rotation (ER) angles were 98.37 ± 10.57° and 94.57 ± 8.74°,combined elevation (CE) angles were 11.56 ± 1.71° and 11.9 ± 1.32°, and straight leg raise index (S.L.R) angles were 83.46 ± 14.74° and 83.37 ± 15.08°.

4.2 Detail description of 10-weeks training volume, acute and chronic ratio and well-being status for the Control Group and the Experimental Group.

Table 8 Detail description of 10-weeks training volume, acute and chronic ratio and well-being status for the Control Group and the Experimental Group.

Variables	Groups	General Period (6 weeks)							Specific Period (4 weeks)				
		W1	W2	W3	W4	W5	W6	Average	W7	W8	W9	W10	Average
Total training volume	CG	53,000	52,000	51,500	53,000	52,250	57,100	53,141.67	57,200	56,500	55,350	54,850	55,975
	EG	57,600	59,240	58,740	56,775	57,825	62,000	57,681.67	61,950	58,450	55,527	52,751	57,170
Average training volume	CG	8.80	8.70	8.58	8.80	8.70	9.50	8.84	9.50	9.38	9.19	9.11	9.30
	EG	9.60	9.60	8.82	9.40	7.90	8.70	9.00	10.30	9.70	9.21	8.75	9.49
ACWR	CG	1.00	1.02	1.03	1.00	1.01	0.93	0.99	0.96	1.03	1.00	1.00	0.99
	EG	1.00	0.97	1.08	1.01	1.00	0.92	0.99	0.95	0.98	1.00	1.03	0.99
Fatigue	CG	5.34±0.25	4.96±0.26	5.63±1.67	5.48±0.96	4.33±0.72	5.66±1.07	5.23±0.47	5.58±0.72	4.00±0.96	5.33±0.67	5.12±1.33	5.01 ± 0.60
	EG	5.33±0.23	5.03±0.3	5.7±0.24	5.52±0.86	4.33±0.66	5.67±1.09	5.26±0.47	5.76±0.65	5.2±1.00	5.38±0.78	5.79±0.71	5.23 ± 0.73
Stress	CG	1.63±0.62	3.98±0.83	3.49±0.89	4.16 ± 0.90	4.44 ± 0.96	6.12 ± 0.80	3.97 ± 1.33	6.14 ± 0.8	3.99±0.82	5.96±0.94	4.32±1.13	5.10 ± 0.96
	EG	1.71±0.67	4.02±0.71	3.51±0.95	4.18 ± 0.86	4.56 ± 0.91	6.22 ± 0.86	4.03 ± 1.34	6.19 ±0.84	4.92±0.77	5.76±0.69	4.57±0.44	5.13 ± 0.88
Muscle Soreness	CG	6.59 ± 0.74	5.00 ± 1.07	4.58 ± 1.20	5.00 ± 0.70	5.16 ± 0.62	5.15 ± 1.02	5.25 ± 0.63	6.41± 0.64	4.83±0.8	6.71±1.09	5.71±0.67	5.92 ± 0.72
	EG	6.74 ± 0.72	5.00 ± 1.15	4.75 ± 1.21	5.00 ± 0.74	5.17 ± 0.64	5.18 ± 1.04	5.31 ± 0.66	6.59± 0.73	5.32±0.83	6.88±0.79	5.74±0.73	6.01 ± 0.80
Sleep Quality	CG	5.49 ± 1.37	5.67 ± 0.72	5.31 ± 0.85	6.03 ± 0.94	3.85 ± 0.64	3.41 ± 0.68	4.96 ± 0.97	4.03± 0.74	3.86± 0.81	4.34±0.66	3.39±0.45	3.91 ± 0.34
	EG	5.51 ± 1.34	5.67 ± 0.65	5.35 ± 0.93	5.97 ± 0.97	3.82 ± 0.62	3.59 ± 0.76	4.99 ± 0.93	3.97± 0.79	4.53± 0.86	4.77±1.04	3.22±0.56	3.94 ± 0.55
Hooper index (HI)	CG	19.08±0.90	19.58±1.16	19.08±1.16	20.67±0.78	17.75±0.97	20.33±0.98	19.81±1.94	22.17±0.94	16.75±1.06	22.33±0.89	18.5±0.96	19.92 ± 2.6
	EG	19.33±1.23	19.75±0.97	19.33±1.07	20.67±3.50	17.83±0.94	20.75±1.91	19.61 ± 2.02	22.50±1.17	19.97±1.15	22.75±0.75	20.67±0.78	20.31 ± 2.68

Both training programmers (CG and EG) were performed for 10 weeks (6-sessions · week^{-1}) General Period (6 weeks): The CG performed average 53.14 km of total training volume and 8.8 km of each week. The EG performed average 57.68 km of total training volume and 9.00 km of each week. Specific Period (4weeks): The CG performed average 55.98 km of total training volume and 9.30 km of each week. The EG performed average 57.17 km of total training volume and 9.49 km of each week. The relation between acute to chronic workload data (ACWR) were about 0.93-1.03 for CG and 0.92-1.08 for EG, respectively. Descriptive statistics of Hooper index (HI), and each wellness status of regional age-group breaststroke swimmers through the ten-weeks are presented in table 9 The Hooper index was about 16.75-22.33 for CG and 17.83-22.75 for EG, respectively.

4.3 An analysis of the effect of concurrent resistance training on tethered force, lower limbs strength, anaerobic critical velocity and swimming performance.

Table 9 Changes in tethered force, lower limbs strength, anaerobic critical velocity and swimming performance after 10-weeks of training for both groups.

Variables	Groups	PRE	POST	p-value	Difference [95%CI]; (%Δ)	Effect size (d)
Swimming tethered force						
Maximal force (N)	CG	399.08±84.73	438.83±82.02	0.26	-109.18, 29.68 (9.96%)	0.35, small
	EG	406.08±116.57	484.17±31.50	0.03*	-147.52, -8.65 (19.23%)	0.69, moderate
Mean force (N)	CG	95.47±29.00	109.58±26.23	0.27	-39.65, 11.44 (14.78%)	0.33, small
	EG	103.97±44.50	135.27±18.65	0.02*	-56.85, -5.75 (30.04%)	0.75, moderate
Fatigue index (%)	CG	11.93±8.79	16.00±8.75	0.32	-12.24, 4.09 (34.12%)	0.30, small
	EG	10.71±13.55	9.55±7.55	0.77	-7.00，9.33 (-10.83%)	0.09, trivial
Lower limbs strength						
1RM back squat (kg)	CG	80.29±5.14	84.86±5.32	0.07	-9.48, 0.31 (5.69%)	0.50, moderate
	EG	80.42±5.33	96.96±6.95	0.01**	-21.43, -11.65 (20.57%)	2.05, large
Anaerobic critical velocity						
Anaerobic critical velocity (m/s)	CG	1.20±0.08	1.22±0.06	0.39	-0.08， 0.03 (1.67%)	0.26, small
	EG	1.19±0.05	1.24±0.08	0.04*	-0.11， 0.00 (4.2%)	0.61, moderate
Swimming Performance and technique variables.						
200 m performance (s)	CG	164.57± 5.43	161.57±6.70	0.21	-1.79, 7.79 (-1.82%)	0.38, small
	EG	165.58±6.86	158.33±6.16	0.01**	2.13, 11.70 (-4.38%)	0.88, moderate

Variables	Groups	PRE	POST	p-value	Difference [95%CI]; (%Δ)	Effect size (d)
Stoke rate (cycles/s)	CG	32.27±2.00	34.14±1.93	0.03*	-3.54, -0.20 (5.79%)	0.68, moderate
	EG	31.80±2.32	34.96±1.85	0.01**	-4.83, -1.49 (9.94%)	1.15, large
Stroke length (cycle/s)	CG	2.27±0.08	2.18±0.06	0.01**	0.02,0.15 (-3.96%)	0.82, moderate
	EG	2.29±0.09	2.17±0.07	0.01**	0.06,0.18 (-5.24%)	1.18, large
Stroke index (m^2/1)	CG	2.76±0.03	2.70±0.11	0.06	-0.01, 0.11 (-2.17%)	0.57, moderate
	EG	2.76±0.04	2.73±0.05	0.24	-0.02,0.09 (-1.09%)	0.36, small
100 m performance (s)	CG	74.82±4.33	71.87±1.16	0.02*	0.46, 5.45 (-3.94%)	0.72, moderate
	EG	75.47±2.66	71.41±3.12	0.01**	1.56, 6.56 (-5.38%)	0.90, moderate
Stoke rate (cycles/s)	CG	34.57±0.87	35.36±1.50	0.25	-2.15, 0.58 (2.29%)	0.35, small
	EG	34.07±0.30	35.88±2.81	0.01**	-3.20, -0.44 (5.31%)	0.8, moderate
Stroke length (cycle/s)	CG	2.33±0.11	2.37±0.07	0.31	-0.11, 0.04 (1.72%)	0.31, small
	EG	2.34±0.08	2.35±0.10	0.66	-0.09, 0.06 (0.43%)	0.14, trivial
Stroke index (m^2/1)	CG	3.12±0.29	3.29±0.09	0.04	-0.33, -0.01 (5.45%)	0.63, moderate
	EG	3.10±0.21	3.30±0.13	0.02*	-0.36, -0.03 (6.45%)	0.73, moderate
50 m performance (s)	CG	35.69±1.55	34.56±1.16	0.05	0.01, 2.25 (-3.17%)	0.61, moderate
	EG	35.18±1.46	33.48±1.33	0.01**	0.59, 2.83 (-4.83%)	0.92, moderate
Stoke rate (cycles/s)	CG	38.93±0.60	39.53±1.92	0.32	-1.80, 0.60 (1.54%)	0.31, small
	EG	39.56±2.07	39.72±0.41	0.78	-1.37, 1.80 (0.4%)	0.09, trivial
Stroke length (cycle/s)	CG	2.16±0.10	2.20±0.10	0.33	-0.11, 0.40 (1.85%)	0.29, small
	EG	2.16±0.10	2.26±0.90	0.02*	-0.18, -0.02 (4.63%)	0.75, moderate
Stroke index (m^2/1)	CG	3.04±0.26	3.19±0.20	0.12	-0.34, 0.04 (4.93%)	0.48, small
	EG	3.07±0.20	3.28±0.26	0.01**	-0.49, -0.11 (6.84%)	0.96, moderate

Descriptive statistics (mean ± SD) comparison changes and improvement for swimming tethered force, lower limbs strength, anaerobic critical velocity and swimming performance (50,100, 200-m) before and after a ten-weeks of CG and EG program are presents in table 4.3. A significant improvement in tethered force, lower limbs strength, anaerobic critical velocity was found in EG group while remained unchanged was found in CG group. The most improvements after the ten-weeks concurrent resistance training were found in the mean force (30.04%, p = 0.02; d = 0.75; moderate) following by 1-RM back squat (20.57%, p = 0.01; d = 2.05; large), maximal force (19.23%, p = 0.03; d = 0.69; moderate), fatigue index (-10.83%, p = 0.77; d = 0.09; trivial) and anaerobic critical velocity (4.2%, p = 0.04; d = 0.61; moderate) respectively.

Regarding the swimming performance,100-m performance time was the most improved (-5.38%, p=0.01, d=0.90, moderate) following by 50-m performance time (-4.83, p=0.01, d=0.92, moderate) and 200-m performance time (-4.28%, p=0.01, d=0.88, moderate) in the EG, respectively. However, the swimming techniques variables that could have potentially significant effects on swimming performance (SR, SL, SI) yielded mixed results in both CG and EG group.

4.4 An examine the effects of ten-weeks on training methods and breaststroke swimming distance (50,100 and, 200m) on interest in swimming performance and technique variables.

Table 10 Effects of 10-Week Training on Performance and Technique Variables Across 50m, 100m, and 200m Breaststroke Distances.

Variables		Control Group	Experimental Group	p-value	Difference [95%CI]; (%Δ)	Effect size (d)
Swimming tethered force						
Maximal force (N)		438.83±82.02	484.17±31.5	0.20	-114.77, 24.10 (10.33%)	0.40, small
Mean force (N)		109.58±26.23	135.27±18.65	0.05*	-51.25, -0.15 (23.44%)	0.61, moderate
Fatigue index (%)		16.00±8.75	10.55±7.55	0.12	-1.71, 14.63 (34.10%)	0.48, small
Lower limbs strength						
1RM back squat (kg)		84.88±5.32	96.96±6.95	0.01**	-16.98, -7.19 (14.23%)	0.75, moderate
Anaerobic critical velocity						
Anaerobic critical velocity (m/s)		1.22±0.06	1.24±0.08	0.58	-0.07, 0.04 (1.64%)	0.084, trivial
Swimming Performance and technique variables.						
Time	50m	34.56±1.16	33.48±1.33	0.45	-1.76, 3.92 (-3.12%)	0.19, trivial
	100m	71.87±1.56	71.41±3.12	0.75	-2.39, 3.30 (0.64%)	0.09, trivial
	200m	161.57±6.71	158.67±3.70	0.05*	0.06, 5.74 (1.79%)	0.50, moderate
Velocity	50m	1.45±0.05	1.50±0.06	0.02*	-0.09, -0.01 (3.45%)	0.59, moderate
	100m	1.39±0.02	1.40±0.06	0.56	-0.05, 0.03 (0.72%)	0.14, trivial
	200m	1.24±0.05	1.26±0.03	0.29	-0.06, 0.02 (1.61%)	0.26, small
SI (m^2/1)	50m	3.19±0.20	3.38±0.26	0.03*	-0.36, -0.02 (5.96%)	0.54, moderate
	100m	3.29±0.09	3.30±0.13	0.95	-0.17,0.16 (0.30%)	0.06, trivial
	200m	2.7±0.11	2.73±0.05	0.30	-0.08, 0.03 (1.11%)	0.32, small
SR (cycles/s)	50m	39.54±1.92	39.72±0.41	0.69	-1.10, 0.73 (-0.46)	0.11, trivial
	100m	35.36±1.50	35.88±2.81	0.45	-1.89, 0.85 (1.47%)	0.23, trivial
	200m	34.14±1.93	34.96±1.85	0.33	-2.49, 0.85 (2.40%)	0.30, small
SL (cycle/s)	50m	2.20±0.73	2.26±0.09	0.11	-0.13, 0.01 (2.73%)	0.40, small
	100m	2.37±0.07	2.35±0.10	0.74	-0.06, 0.09 (-0.84%)	0.11, trivial
	200m	2.18±0.06	2.17±0.07	0.67	-0.06, 0.08 (-0.46%)	0.13, trivial

Descriptive statistics (mean ± SD) comparison between the control group (CG) and the experimental group (EG) for swimming performance and technique variables across 50m, 100m, and 200m breaststroke distances after ten weeks of training are presented in Table 4.4. The EG demonstrated a significant improvement in 1RM back squat strength (14.23%, p=0.01, d=0.75, moderate effect), followed by a significant increase in mean tethered force (23.44%, p=0.05, d=0.61, moderate effect), indicating notable strength gains in the EG. In terms of swimming performance, the EG showed significant improvements in 50m velocity (3.45%, p=0.02, d=0.59, moderate effect) and 200m time (1.79%, p=0.05, d=0.50, moderate effect).

Additionally, the stroke index (SI) for 50m in the EG was significantly higher than in the CG (5.96%, p=0.03, d=0.54, moderate effect). Other variables, such as maximal force (10.33%, p=0.20, d=0.40, small effect), fatigue index (34.10%, p=0.12, d=0.48, small effect), anaerobic critical velocity (1.64%, p=0.58, d=0.084, trivial effect), stroke rate (SR), and stroke length (SL) did not reach statistical significance, indicating limited improvements in these areas.

Table 11 Two-way analysis of variance for the effects of training and swimming distance on swimming performance and technical variables.

Variables	Training Methods		Swimming distances		Training methods x Swimming distance	
	F	p	F	p	F	p
Swimming time (s)	3.24	0.08	8276.40	<0.01**	0.80	0.46
Swimming velocity (m/s)	5.46	0.02	131.34	<0.01**	0.88	0.42
SR (cycle/s)	475.75	<0.01	687.76	<0.01**	438.70	<0.01
SL (cycle/s)	0.28	0.60	31.75	<0.01**	1.43	0.25
SI (m2/1)	3.98	0.05	104.94	<0.01**	2.42	0.10

Note: F-values and p-values are the results of two-way ANOVA for the variability of factors interactively induced by training methods and swimming distances; * means significant difference ($p < 0.05$) and ** means significant difference ($p < 0.01$).

In the two-way ANOVA, the results for swimming time show no significant effect on training methods (F = 3.24, p = 0.08) and the interaction (F = 0.80, p = 0.46), but a significant effect on swimming distances (F = 8276.40, p < 0.01), with regard to the difference, 50m had faster time than 100m (p =0.01, mean =-37.63) and in the 200-m (p =0.01 , mean =-126.10). For swimming velocity, there are significant effects of training methods (F = 5.46, p = 0.02,) and swimming distances (F = 131.34, p < 0.01), with regard to the difference, 50m had faster time than 100m (p =0.01, mean =0.08) and in the 200-m (p =0.01, mean =0.22), and with no significant interaction (F = 0.88, p = 0.42).

Stroke rate (SR) shows significant effects of training methods (F = 475.75, p < 0.01), swimming distances (F = 687.76, p < 0.01), and their interaction (F = 438.70, p < 0.01). Stroke length (SL) reveals no significant effect of training methods (F = 0.28, p = 0.60) or interaction (F = 1.43, p = 0.25), but a significant effect of swimming distances (F = 31.75, p < 0.01). Stroke index (SI) shows a marginal effect of training methods (F = 3.98, p = 0.05), a significant effect of swimming distances (F = 104.94, p < 0.01), and no significant interaction (F = 2.42, p = 0.10)

CHAPTER 5
DISCUSSION

This study aimed to evaluate the effects of a 10-week concurrent resistance training program, incorporating both aquatic and dry-land exercises, on tethered force, lower limb strength, anaerobic critical velocity, and swimming performance in regional age-group breaststroke swimmers. Overall, there were significant improvement in swimming tethered force (mean force, maximal force), lower limbs strength (1-RM back squat), anaerobic critical velocity and 50-200m breaststroke swimming performance in experimental group after ten-weeks of concurrent resistance training. Combining aquatics resistance with parachute, fins, paddle and specific kicking set and dry-land (Back squats: BS, Reverse lateral lunges: RLL, and sumo Romanian deadlifts: sRDL) resistance training after 10 weeks improved mean force of tethered force, lower limbs strength, 200-m swimming performance and 50-m stroke index compare to control group. These findings emphasize the effectiveness of the concurrent resistance training program, leading to significant improved in both strength and swimming performance in the experimental group as previous evidence in freestyle (Amara et al., 2021) and butterfly swimming (Amara et al., 2023) in age-group swimmers.

Monitoring the association and interaction of internal loads with psychological and physical well-being is a critical process in the context of the quality and quantity of training loads, as it is essential for the observation of training adaptations in young swimmers (Zacca et al., 2020; Fereira et al., 2021). In the present study, the average total weekly training load in the general phase (9.00 km) and specific phase (9.49) were higher than those reported most other studies (Chatard & Mujika, 1999; Toubekis et al., 2011; Saavedra et al., 2013) in age-group swimmers. One possible reason for this difference is that the first macrocycle of training at the start of the season needs to focus on building aerobic endurance up to the lactate threshold along with strength and conditioning. This is because the main goal of endurance training is to make physiological, psychological, and technical changes that set the stage for age-group swimmers' competitive performances (Pollock et al., 2019; Hermosilla et al., 2021).However, our training volume in both general and specific phase are consistent with elite swimmers (Pollock et a., 2019) in the sense that some training plans showed mean training volumes as high as 58,000 m and peak volumes as high as 70,000 – 80,000 m have been reported anecdotally for some international IM and distance swimmers.

Considering the ACWR which is about 0.9 -1.0, indicating that the training progression is very effective way to balance training loads, enhance performance, and prevent injuries. Furthermore, these findings are consistent with previous results indicating ratio between 0.8 and 1.3 is often considered the "safe zone," where the workload is balanced, and the risk of injury is relatively low in age-group swimmers (Collette et al., 2018).It's interesting that the Hooper index scores were less varibility during the general and specific training periods. This suggests that the structured resistance training program carried out together with the pool training program did not have a negative effect on adaptability, homeostasis restoration, or ever well-being status.

Considering changes and improvement of the tethered force, lower limb strength, anaerobic critical velocity, and swimming performance after ten-weeks combining aquatics resistance with parachute, fins, paddle and specific kicking set and dry-land (Back squats: BS, Reverse lateral lunges: RLL, and sumo Romanian deadlifts: sRDL), the most significant observation from the data comparison was mean force of 30-s tethered force following by 1-RM back squat, maximal force , fatigue index and anaerobic critical velocity, respectively. Combined resistance training for 10-weeks increased the significantly improvement of the tethered swimming force. This improvement is in accordance with previous studies conducting combined strength and endurance training interventions (Aspenes et a., 2009) and 12 weeks of strength training (Girold et al., 2007) Also, age-group swimmers improved their tethered mean force by 30% and their maximal force by 19% when aquatic resistance with a parachute, fins, paddle, and a specific kicking set and dry-land was used. This is higher than what was reported for age-group swimmers (6.9% for males and 7.3% for females) (Aspenes et al., 2009). Moreover, concurrent aquatic and lower limb dry-land resistance training enhanced the fatigue index in the experimental group, suggesting that the training improves both muscle strength and endurance, hence decreasing the fatigue index.

For the perspective of lower limbs strength improvement, combined aquatics and dry-land resistance training with the intensity between 60% and 85% 1RM increased the 1RM back squat by 20% which was slightly higher than the values reported before in the national competitive freestyle swimmers (15%) (Amara et al., 2022) but lower than the improvement of age-group butterfly swimmers (22%) after 8 weeks of combining high intensity interval training and maximum strength training. Our study is in line with previous studies, linking dry-land training to swimming performance gain. As the swimmers progresses to the specific phase of training, it is important to maintain the level of physical development established during the preparatory phase (Hermosilla et al., 2021). Our study confirmed previous findings (Amar et al., 2022; Amara et al., 2023) that the concurrent resistance training through the training marcocycle improved swimming performance and lower limbs strength. Being relevant that, maximum strength training could involve exercises as abductor and abductor muscles and hamstrings group with one or two sets with an intensity between 60 – 85% 1 RM and 4- 6 repetitions, particularly in breaststroke swimmers.

Concerning the relationship between tethered swimming, anaerobic critical velocity, dry-land strength, and swimming performance, Ruiz-Navarro et al. (2021) stated that 50-m swimming performance was positively associated with AnCV, tethered-swimming variables. Interestingly, AnCV improved in the experimental group after training intervention. Hence, 10 weeks of concurrent resistance training at 60 – 85% of 1RM yields improvements in the swimmers's anaerobic capacity and speed endurance which is reflects the highest velocity a swimmer can maintain using predominantly anaerobic energy system. As such, the aquatic and dry land program design for this research is as effective as others reported in the literature. However, this study is the first investigation that studied the effect of combined resistance training on AnCV in age-group breaststroke swimmers; for this reason, it is challenging to benchmark these results against previous findings.

The results of this study showed that 50-m, 100-m and 200-m breaststroke swimming performance improved after 10 weeks with concurrent training (4.38, 5.38, 4.83%). In the same context, Amara et al. (2022) and Amara et al. (2023) indicated that 8-10 weeks of combining training between dry-land training and high intensity interval training could optimize the time of the 100-m maximal freestyle swim

(4.41%) and the time of 100-m maximal butterfly swim (3.55%), respectively. Being relevant that, the neuromuscular adaptations represented by the learning and coordination of the combined aquatics and dry-land resistance training during the 10 weeks of training, the training quantity and quality, which could favor the specificity of the adaptation to the training in general and specific phases, and the transfer of gain of strength may be indirect evidence that justifies the results obtained at the swimming performance from 50-m to 200-m distance.

Swimming efficiency (SI) improved during the 50-m (6.5%) and 100-m (6.8%) in experimental group. This improvement could be due to the improvement in maximum lower limbs muscle strength and endurance. More specifically, the transfer of force gain from the lower limb to the mean force of the tethered force was clearly evident in the experimental group (135N) better than in the control group (110 N) with a difference of 23 %, and this explains the effective role of combining aquatics resistance with parachute, fins, paddle and specific kicking set and dry-land in improving the swimming efficiency particularly in sprinting distances (50-100m) (Morouco et al., 2014).

Finally, future research should take into account a number of potential limitations that may have influenced the results obtained. Firstly, the impact of concurrent resistance training on specific physiological variables, bioenergetics particularly cardiorespiratory adaptation (AnT, VO2max and energy cost), has not been taken into account. Secondly, it should be noted that the results of the current study are only appropriate for young regional age-group level and should not be generalized to other swimming performance levels. This means that the swimmers who have different performance levels from the regional age-group swimmers of the current study, such as young elite and elite’s swimmers, might show different results. Third, a study with an intervention that does not complete the full periodization cycle has notable limitations, such as incomplete adaptations, inaccurate performance measurements, and the inability to generalize results to long-term training scenarios.

In conclusion, concurrent training that combines dry-land and aquatic resistance exercises can significantly improve in swimming tethered force (mean force, maximal force), lower limbs strength (1-RM back squat), anaerobic critical velocity and 50-200m breaststroke swimming performance after 10-weeks of concurrent resistance training. Although, coaches should incorporate periodized training plans that integrate dry-land exercises, including an abductor and adductor muscles and hamstrings muscle group with aquatic resistance exercises, such as using parachutes, paddles and specific kicking training set to optimize strength gains and swimming performance. For breaststroke swimmers, particularly young regional-level athletes, this study demonstrates that concurrent resistance training can enhance lower-body strength and anaerobic capacity, which are critical for short-distance swimming. Besides, future study should explore the long-term effects of concurrent resistance training across multiple training cycles, examine its impact on different age groups and competitive levels, and compare the effectiveness of various resistance training methods, including dry-land, aquatic, and concurrent training, for improving swimming performance.

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APPENDIX

Overview of overall training program schedule

Days	Periods	
	AM	**PM**
Monday	-	Pool training + Dry-land training: BS, RLL, SRDL
Tuesday	-	Pool training + Aquatics resistance training: Parachute, Fin, Paddles
Wednesday	-	Pool training + Aquatics resistance training: Kick training
Thursday	-	Pool training + Aquatics resistance training: Parachute, Fin, Paddles
Friday	-	Pool training + Aquatics resistance training: Kick training
Saturday	Pool training + Dry-land training: BS, RLL, SRDL	-
Sunday	Rest	

Summary detailed of dry land resistance training conducted by the experimental group

Week (Sessions)	Phases	Exercise	Sets x Repetition x Intensity; Recovery between sets and Exercise (2 min)
1 (1)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 6 x 60 % 1RM 2 x 6 x 60 % 1RM 6 x 6
1 (2)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 6 x 60 % 1RM 2 x 6 x 60 % 1RM 6 x 6
2 (3)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 8 x 65 % 1RM 2 x 8 x 65 % 1RM 6 x 8
2 (4)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 8 x 65 % 1RM 2 x 8 x 65 % 1RM 6 x 8
3 (5)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 10 x 65 % 1RM 2 x 10 x 65 % 1RM 6 x 10
3 (6)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x10 x 65 % 1RM 2 x 10 x 65 % 1RM 6 x 10
4 (7)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x12 x 65 % 1RM 2 x 12 x 65 % 1RM 6 x 12
4 (8)	General	Back squat Dumbbell sRDL Reverse lateral lunge	2 x12 x 65 % 1RM 2 x 12 x 65 % 1RM 6 x 12
5 (9)	General	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 8 x 70 % 1RM 3 x 8 x 70 % 1RM 7 x 10
5 (10)	General	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 8 x 70 % 1RM 3 x 8 x 70 % 1RM 7 x 10
6 (11)	General	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 10 x 75 % 1RM 3 x 10 x 75 % 1RM 7 x 10
6 (12)	General	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 10 x 75 % 1RM 3 x 10 x 75 % 1RM 7 x 10

Summary detailed of dry land resistance training conducted by the experimental group (Cont.)

Week (Sessions)	Phases	Exercise	Sets x Repetition x Intensity; Recovery between sets and Exercise (2 min)
7 (13)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 6 x 80 % 1RM 3 x 6 x 80 % 1RM 8 x 10
7 (14)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 6 x 80 % 1RM 3 x 6 x 80 % 1RM 8 x 10
8 (15)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 6 x 85 % 1RM 3 x 6 x 85 % 1RM 8 x 10
8 (16)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 8 x 85 % 1RM 3 x 8 x 85 % 1RM 8 x 10
9 (17)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 10 x 85 % 1RM 3 x 10 x 85 % 1RM 8 x 12
9 (18)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	3 x 12 x 80 % 1RM 3 x 12 x 80 % 1RM 8 x 12
10 (19)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 8 x 75 % 1RM 2 x 8 x 75 % 1RM 6 x 10
10 (20)	Specific	Back squat Dumbbell sRDL Reverse lateral lunge	2 x 8 x 70 % 1RM 2 x 8 x 70 % 1RM 6 x 8

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training** 1.1 General warm-up 5-10 min 1.2 Resistance training ● **Back Squat:** Intensity:60 % 1RM Sets/Reps: 2 set x 6 reps Rest: 2 minute ● **Dumbbell Sumo Romanian Deadlift:** Intensity: 60 % 1RM Sets/Reps: 2 set x 6 reps Rest: 2 minute ● **Reverse Lateral Lunge:** Intensity: Body weight Sets/Reps: 6 set x 6 reps Rest: 2 minute **2. Pool training** ● **Warm up** 6*100 on 2:00(Odd:kick,Even:swim) ● **Drill** 8*50 on 1:30 Odd: Fr 6kick 3Pull / Even: Br 2kick 1Pull ● **Swim** 2*100 on 1:50 (25kick+25drill+50swim) 4*50 on 0:55 DES 1-4 8*25 on 0:30 ● **2 Round** Cool Down 200	IM FR/BA FR/BA FR/BA FR FR	A1 A2 VO2 Speed A2 A1	Z1 Z1 Z2 Z5 Z1 Z1

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training** ● **Warm up** 6*100 on 2:00(Odd: kick, Even:swim) ● **Drill** 8*50 on 1:30 Odd: Fr 6 kick 3Pull / Even: Br 2kick 1Pull ● **Swim** 2*100 on 1:50 (25kick+25drill+50swim) 4*50 on 0:55 DES 1-4 8*25 on 0:30 ● **2 Round** Cool Down 200	FR FR/BR FR FR FR FR	A1 A1, A2 A2 VO2 Speed A1	Z1 Z1, Z2 Z1 Z3 Z4 Z1

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
3	Wednesday (PM)	**1. Pool training**			
		• **Warm up**			
		8*100 on 2:00(Odd:kick, Even:swim)	IM	A1	Z1
		• **Drill**			
		10*25 on 45 Odd: 1-1-1 Fly / Even: FR kick Pull BR	FLY/BR	A1	Z1
		• **Swim**			
		12*50 on 1:00	FR	VO2	Z2
		8*50 on 1:30	BR	AT	Z3
		4*50 on 1:00	FR	VO2	Z2
		2*50 max dive on 3:00	BR	VO2	Z4
		Cool Down 200		A1	

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
4	Thursday (PM)	**1. Pool training**			
		• **Warm up**			
		8*100 on 2:00(Odd:kick,Even:swim)	FR	A1	Z1
		Pull with Paddles			
		3*100 on 2:05	FR	A2	Z1
		4*25 on 50	BR	LT	Z5
		4 Round			
		• **Swim**			
		4*75 on 1:45 25FR+25BA+25FR	FR/BA	A2	Z1
		2*50 on 3:00 MAX	BA	A1	Z1
		Cool Down 200	FR	A1	Z1

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
5	Friday (PM)	**1. Pool training**			
		• **Warm up**			
		8*100 on 2:00(Odd:kick,Even:swim)	FR	A1	Z1
		Drill			
		8*50 on 1:30 Odd: Fr 10kick 3Pull / Even: Br 2kick 1Pull	FR	A2,AT	Z1
		• **Swim**			
		8*100 on 2:00	IM	VO2	Z2
		8*75 on 1:45	FR	AT	Z2
		8*50 on 1:00	IM	VO2	Z4
		8*25 on 60 each 2 Stroke	FR	A1	Z1
		Cool Down 200		A1	

Week 1			General phase		
Sessions	**Days**	**Training Program**	**Strok e**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training** 1.1 General warm-up 5-10 min 1.2 Resistance training • **Back Squat:** Intensity:60 % 1RM Sets/Reps: 2 set x 6 reps Rest: 2 minutes • **Dumbbell Sumo Romanian Deadlift:** Intensity: 60 % 1RM Sets/Reps: 2 set x 6 reps Rest: 2 minutes • **Reverse Lateral Lunge:** Intensity: Body weight Sets/Reps: 6 set x 6 reps Rest: 2 minutes **2. Pool training** • **Warm up** 8*100 on 2:00(Odd:kick,Even:swim) • **Pull with Paddles** 8*50 on 1:00 4*25 on 0:50 ***4 Round*** • **Swim** 4*75 on 1:45 50FR+25BA 2*50 on 1:15 Cool Down 200	FR FR BR FR/B A BA	A1 A2 LT A1 A1 A1	Z1 Z1 Z5 Z1 Z1 Z1

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
		1.Dry land resistance training			
		1.1 General warm-up 5-10 min			
		1.2 Resistance training			
		● **Back Squat:**			
		Intensity:65 % 1RM			
		Sets/Reps: 2 set x 8 reps			
		Rest: 2 minutes			
		● **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 65 % 1RM			
		Sets/Reps: 2 set x 8 reps			
		Rest: 2 minutes			
		● **Reverse Lateral Lunge:**			
1	Monday (PM)	Intensity: Body weight			
		Sets/Reps: 6 set x 8 reps			
		Rest: 2 minutes			
		2.Pool training:			
		● **Warm up:**			Z1
		1*300 on 7 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5 Kick with Board Last 15m. Fast	Kick	A2	Z1
		1*100 on 2:30 Fast	IM	AT	
		● **Drill**			
		8*100 on 2 Kick with Fins			Z1
		8*50 on 1:30 Descend 1-4	FR	A2	Z1,Z2
		● Swim	FLY	A2,VO2	
		4*50 on 1:30 Long Descend 1-4 （odd: FR,			Z1,Z2
		even: BR）	FR,BR	AT,VO2	
		4 Round			Z1
		Cool Down 200	FR	A1	

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
		1. Pool training			
		● **Warm up**			
		1*300 on 7:00 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5:00 Kick with Board Last 15m Fast	Kick	A2	Z1
		1*100 on 2:30 IM	IM	AT	Z1
		● **Drill**			
2	Tuesday (PM)	30*25 on 45			
		10-time Kick with snorkel and Fins	FR/IM	A2	Z1
		10-time Single arm with snorkel and Fins			
		10-time Swim Fly	FLY	AT,VO2	Z1,Z2
		● **Swim**			
		6*100 on 1:45 odd: FR/Even:	FR	A1	Z1
		4 Round			
		Cool Down 200	IM	A1	Z1

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
3	Wednesday (PM)	**1. Pool training**			
		• **Warm up**			
		1*300 on 7 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5 Kick with Board Last 15m. Fast	Kick	A2	Z1
		1*100 on 2:30 IM Fast	IM	AT	Z1
		• **Pull Set**			
		4*150 on 2:45 Descend 1-4 with Paddles and Buoy	FR	A2,AT	Z1
		4*50 on 1:15 Hard pull with Paddles and Buoy	BR	A2,VO2	Z1,Z2
		4 Round			
		• **Swim**			
		8*25 on 40 Smooth time	FR,BR	VO2	Z4
		1*50 on 2 Easy	FR	A1	Z1
		4 Round			
		FR on 40 /BR on 50			
		Cool Down 4*100 on 2:30 FR 25m. +BA 25m.	FR	A1	Z1

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
4	Thursday (PM)	**1. Pool training**			
		• **Warm up**			
		1*300 on 7 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5 Kick with no Board Last 15m. Fast	Kick	A2	Z1
		1*100 on 2:30 IM Fast	IM	AT	Z1
		• **Pull Set**			
		4*200 on 3:30 Paddle Des1-4	FR	A2	Z1
		8*100 on 2:00 Des. 1-4	FR	A2, AT,	Z1, Z2
		8*50 on 1 25m.Fast +25m.Easy	BR/FR	VO2	Z5
		*** Paddles and Buoy***		VO2, LT	
		• **Swim**			
		1*50 on 1	FR	A1	Z1
		1*50 on 1:30 with Paddle	BR	VO2	Z3
		3 Round			
		Cool Down 4*100 on 2:30 （FR 25m. +BA 25m.）	FR/BA	A1	Z1

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
5	Friday (PM)	**1. Pool training**			
		• **Warm Up**			
		1*300 on 7 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5 Kick with Board Last 15m. Fast	Kick	A2	Z1
		1*100 on 2:30 IM Fast	IM	AT	Z1
		• **Drill**			
		4*25 on 50 2kick 1Pull BR / 1-1-1 FLY	FYL/BR	A1	Z1
		4*25 on 45 Swim BR/FLY	FYL/BR	A1, A2	Z1
		4 Round			
		• **Swim**			
		8*100 on 1:50	FR	A2, AT,	Z1, Z2,
		3 Round			
		Cool Down 4*100 on 2:30 FR 25m. +BA 25m. W/Fins	FR/BA	A1	Z1

Week 2			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10 min			
		1.2Resistance training			
		● **Back Squat:**			
		Intensity: 65% 1RM			
		Sets/Reps:2 sets x 8 reps			
		Rest: 2minute			
		● **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2setsx 8reps			
		Rest: 2minute			
		● **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 6sets x 8 reps			
		Rest: 2minute			
		2.Pool Training:			
		1*300 on 7 25Kick+25Drill+25Swim	IM	A1	Z1
		1*200 on 5 Kick with no Board Last 15m. Fast	Kick	A2	Z1
		1*100 on 2:30 IM Fast	IM	AT	Z1
		● **Speed Kick**			
		4*15 on 45 Max	FYL/BR	Speed	Z5
		1*50 on 2 Easy	FR	A1	Z1
		4 Round			
		● **Speed Pull**			
		4*15 on 45 Max Fast	IM	Speed	Z5
		1*50 on 2 Easy	FR	A1	Z1
		4 Round			
		● **Swim**			
		4*50 on 1:15 IM Drill	IM	A2, VO2	Z1, Z2
		4*25 on 45 IM MAX Dive	IM	VO2	Z2
		4 Round			
		Cool Down 4*100 n 2:30			
		（FR 25m. +BA 25m）	FR/BA	A1	Z1

Week 3			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2Resistance training			
		● **Back Squat:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2 sets x 10 reps			
		Rest: 2minute			
		● **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2 sets x 10 reps			
		Rest: 2minute			
		● **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 6 sets x 10 reps			
		Rest: 2minute			
		2. Pool training			
		8*50 on 1 UWK 5 times every wall	FR	A1	Z1
		8*50 on 1:30 BR Long	BR	A1	Z1
		8*25 on 50 Build up IMO	IM	A1, A2	Z1
		● **Kick Set**			
		8*100 on 1:50 Kick with Fins	FR	A2	Z1
		8*50 on 1:20 Descend 1-4	BR	A2, VO2	Z1,Z2
		● **Swim**		VO2	Z4
		8*150 on 2:40	FR/BR	AT,VO2	Z2,Z3
		（50FR+50BR Fast+50FR）			
		Cool Down 200	FR	A1	Z1

Week 3			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		● **Warm up**			
		8*50 on 1 UWK 5 times every wall	FR	A1	Z1
		8*50 on 1:30 BR Long	BR	A1	Z1
		8*25 on 50 Build up IMO	IM	A1,A2	Z1
		● **Drill**			
		8*50 on 1:30	FR/BR	A1	Z1
		Odd: Fr 6kick 1Pull / Even: Br 2kick 1Pull			
		Kick			
		3*75 on 2:30 100 BR Pace	BR	LP	Z4
		1*75 on 4 Easy FR	FR	A1	Z1
		3 Round			
		● **Swim**			
		1*100 on 1:50 Smooth	FR	A1	Z1
		1*75 on 1:45 25BA+25BR	BA/BR	A2	Z1
		1*50 on 1 max Dive	BR	VO2	Z3
		1*25 on 1 max Dive	FLY	Speed	Z5
		Cool Down 200	FR	A1	Z1

Week 3			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
		1. Pool training			
		• **Warm up**			
		8*50 on 1 UWK 5 times every wall	FR	A1	Z1
		8*50 on 1:30 BR Long	BR	A1	Z1
		8*25 on 50 Build up IMO	IM	A1, A2	Z1
		• **Pull Set**			
		4*200 on 3:20 Descend 1-4			
3	Wednesday (PM)	with Paddles and Buoy	FR	A2, AT	Z2
		4*100 on 2 Hard pull			
		with Paddles and Bzuoy 50FR+50BR	FR/BR	VO2	Z3
		3 Round			
		• **Speed set**			
		8*50 on 1:30 Long and Smooth	FR/BR	VO2	Z3
		1*50 on 3 Easy	FR	A1	Z1
		4 Round FR on 1:30 /BR on 1:40			
		Cool Down 200	FR	A1	Z1

Week 3			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
		1. Pool training			
		• **Warm up**			
		8*50 on 1 UWK 5 times every wall	FR	A1	Z1
		8*50 on 1:30 BR Long	BR	A1	Z1
		8*25 on 50 Build up IMO	IM	A1, A2	Z1
		• **Power Set**			
		4*25 on 1 Kick with Chute	FR/BR	AT	Z2
4	Thursday (PM)	4*25 on 50 Swim Pace 200 with Chute	FR/BR	AT	Z3
		Round 1 FR / Round 2 BR			
		• **Pull Set**			
		6*75 on 1:45 Race Pace100m	FR	AT, VO2	Z3, Z4
		1*25 on 1:30 Easy	FR	A1	Z1
		3 Round	FR	A1	Z1
		• **Swim**			
		6*100 on 1:45 Des with Fins	FR	A1	Z1
		Cool Down 200	FR	A1	Z1

Week 3			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
		1. Pool training			
		• **Warm up**			
		8*50 on 1 UWK 5 times every wall	FR	A1	Z1
		8*50 on 1:30 BR Long	BR	A1	Z1
		8*25 on 50 Build up IMO	IM	A1, A2	Z1
		• **Drill**			
5	Friday (PM)	4*25 on 50 kick FR Pull BR / single arm FLY			
		4*25 on 45 Swim BR/FLY	BR/FLY	A2	Z1
		4 Round	FR/BR	A2	Z2
		• **Swim**			
		5*100 on 1:50 100mPB+10s	FR	VO2	Z3
		1*100 on 2:30 Easy	FR	A2	Z1
		3 Round			
		Cool Down 200	FR	A1	Z1

Week 3			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training** 1.1General warm-up 5-10min 1.2 Resistance training • **Back Squat:** Intensity: 65% 1RM Sets/Reps: 2 sets x 10 reps Rest: 2minute • **Dumbbell Sumo Romanian Deadlift:** Intensity: 65% 1RM Sets/Reps: 2 sets x 10 reps Rest: 2minute • **Reverse Lateral Lunge:** Intensity: Body weight Sets/Reps: 6 sets x 10reps Rest: 2minute **2.Pool training:** • **Warm up** 8*50 on 1 UWK 5 times every wall 8*50 on 1:30 BR Long 8*25 on 50 Build up IMO • **Power Set** 4*25 on 1 Kick with Chute 4*25 on 50 Swim Pace 200 with Chute ***Round 1 FR / Round 2 BR*** • **Swim** 4*100 on 2:15 IMO Des 1-4 4*50 on 1:10 FR Race Pace 100 Cool down 200	FR BR IM FR/BR FR/BR IM FR FR	A1 A1 A1, A2 AT AT A2, AT VO2 A1	Z1 Z1 Z1 Z2 Z3 Z2, Z3 Z4 Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat:**			
		Intensity: 65% 1RM			
		Sets/Reps:2 sets x 12 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2 sets x 12 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 6 sets x 12 reps			
		Rest: 2minute			
		2.Pool training:			
		• **Warm up**			
		400 with fins 75 free - 25 no Free on 8	FR	A1	Z1
		300 25 kick -25 drill-25swim on 6	IM	A1	Z1
		200 IM swim with fins UWk 4 time every wall on 3:45	IM	A1	Z1
		100 Backstroke Smooth on 2	BA	AT	Z1
		• **Pull Set**			
		10*75 on 1:45 50m FR+25m BR Fast	FR/BR	A2, AT	Z2
		8*50 on 1:20 BA 25m+BR 25m Fast	BA/BR	A2, AT	Z2
		All paddles with Buoy			Z2
		• **Swim**			
		4*75 on 1:15 FR Smooth	FR	A2, AT	Z2
		4*25 on 40 BR fast	FLY/BR	VO2	Z4
		2 Round FLY / 2 Round BR			
		Cool Down 200	BA	A1	Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		• **Warm up**			
		400 with fins 75 free - 25 no Free on 8	FR	A1	Z1
		300 25 kick - 25 drill-25swim on 6	IM	A1	Z1
		200 IM swim with fins UWK 4 time every wall on 3:45	IM	A1	Z1
		100 Backstroke fast with Long on 2	BA	AT	Z2
		• **Kick**			
		3*100 on 1:50 Smooth	FLY	A2	Z1
		1*100 on 1:30 Fast	FLY	Speed	Z3
		2 Round			
		• **Swim**			
		1*100 on 2 Descend	FR	A1	Z1
		1*100 on 1:30 Fast	FR	VO2	Z3
		10 Round			
		Cool Down 200	FR	A1	Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
3	Wednesday (PM)	**1. Pool training** ● **Warm up** 400 with fins 75 free - 25 no Free on 8 300 25 kick - 25 drill-25swim on 6 200 IM swim with fins UWK 4 time every wall on 3:45 100 Backstroke Long on 2 ● **Drill** 8*50 on 1:30 BR 3Pull Out 3 swim ● **Pull Set** 8*100 on 1:40 Descend 1-4 with Paddles and Buoy 8*50 on 1:15 Hard pull with Paddles and Buoy ● **Swim** 4*100 on 1:30 Smooth 1*50 on 2 Easy ***4 Round*** Cool down 200	FR IM IM BA BR FR BR FR FR BA	A1 A1 A1 AT A1 A2, AT VO2 VO2 A2 A1	Z1 Z1 Z1 Z2 Z1 Z1, Z2 Z2 Z2, Z3 Z1 Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
4	Thursday (PM)	**1. Pool training** ● **Warm up** 400 with fins 75 free - 25 no Free on 8 300 25 kick -25 drill-25swim on 6 200 IM swim with fins UWK 4 time every wall on 3:45 100 Backstroke fast Long on 2 ● **Vertical Kick** 4*30s BR kick Fast 2*25m on 45 BR kick Fast ***4 Round*** ● **Pull Set** 6*75 on 2 Race Pace100 BR 1*25 on 1:30 Easy ***3 Round*** ● **Swim** 6*100 on 1:45 Smooth FR with Fins Cool down 200	FR IM IM BA BR BR BR FR FR FR	A1 A1 A1 AT VO2 VO2 VO2 A1 A1, A2 A1	Z1 Z1 Z1 Z2 Z2 Z4 Z3 Z1 Z1 Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
		1. Pool training			
		• **Warm up**			
		400 with fins 75 free - 25 no Free on 8	FR	A1	Z1
		300 25 kick - 25 drill-25swim on 6	IM	A1	Z1
		200 IM swim with fins UWK 4 time every wall	IM	A1	Z1
		on 3:45			
		100 Backstroke fast Long on 2	BA	AT	Z2
5	Friday (PM)	• **Drill**			
		4*25 on 50 kick FLY Pull BR / 1-1-1 FLY	FLY/BR	A1	Z1
		4*25 on 45 Swim BR/FLY	FLY/BR	A1	Z1
		4 Round			
		• **Swim**			
		20*50 on 1 Best Smooth	FR	VO2	Z2
		8*25 on 45 12.5m BR Max+12.5m Easy	BR	Speed	Z5
		Cool Down 200	Choice	A1	Z1

Week 4			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
		1.Dry land resistance training			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2sets x 12 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 65% 1RM			
		Sets/Reps: 2sets x 12 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 6 sets x 12 reps			
		Rest: 2minute			
6	Saturday (AM)	**2.Pool training**			
		• **Warm up**			
		400 with fins 75 free - 25 no Free on 8	FR	A1	Z1
		300 25 kick - 25 drill-25swim on 6	IM	A1	Z1
		200 IM swim with fins UWk 4 time every wall			
		on 3:45	IM	A1	Z1
		100 Backstroke fast Long	BA	A1	Z1
		• **Power Set**			
		4*25 on 1 Kick with Chute	FR/BR	AT	Z2
		4*25 on 50 Swim Pace 200 with Chute	FR/BR	AT	Z2
		Round 1 FR / Round 2 BR			
		• **Swim**			
		4*100 on 2:10 IM Des 1-4	IM	AT	Z2
		4*50 on 1:30 BR with Paddles Race Pace 100	BR	AT	Z2
		3 Round			
		Cool down 200	BA	A1	Z1

Week 5			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat :**			
		Intensity: 70%1RM			
		Sets/Reps:3 sets x 8 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 70%1RM			
		Sets/Reps:3 sets x 8 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 7 sets x 10 reps			
		Rest: 2minute			
		2.Pool training			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	VO2	Z1
		• **Pull Training**			
		10*75 on 1:45 25m FR+50m BR Fast	FR/BR	VO2	Z2
		8*50 on 1:30 BR 50m Fast	BR	LP	Z3
		All paddles with Buoy			
		• **Swim**			
		6*150 on 2:30 FR	FR	VO2	Z2
		4*25 on 45 12.5m Max	BR	Speed	Z5
		1*50 on 2 Easy	FR	A1	Z1
		***3 Round ***			
		Cool down 200	FR	A1	Z1

Week 5			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	VO2	Z1
		• **Kick**			
		4*50 on 1:15 Smooth	BR	VO2	Z2
		1*50 on 1:30 Fast	BR	VO2	Z3
		4 Round			
		• **Swim**			
		1*100 on 2 Smooth	FR	A1	Z1
		2*50 on 1:15 Fast	BR	VO2	Z3
		10 Round Swim with Paddles			
		Cool Down 200	FR/BA	A1	Z1

Week 5			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
3	Wednesday (PM)	**1. Pool training**			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	A2	Z1
		• **Drill**			
		8*50 on 1:30 BR 3under 3Nomal swim	BR	A1	Z1
		• **Pull Set**			
		16*50 on 55 with Paddles and Buoy	FR	A2	Z2
		8*50 on 1:15 Hard pull with Paddles and Buoy	BR	A2	Z2
		• **Swim**			
		8*50 on 1:30 Smooth	FR/BR	VO2	Z2, Z3
		1*50 on 3 Easy	FR	A2	Z1
		2 Round FR / 2 Round BR			
		Cool down 200	BA	A1	Z1

Week 5			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
4	Thursday (PM)	**1. Pool training**			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	VO2	Z1
		• **Vertical Kick**			
		4*30s Second BR kick Fast	BR	VO2	Z2
		2*25 on 45 BR kick Fast	BR	LP	Z4
		4 Round			
		• **Pull Set**			
		6*75 on 2 Race Pace100 BR	BR	VO2	Z3
		1*25 on 1:30 Easy	FR	A1	Z1
		3 Round			
		• **Swim**			
		6*100 on 1:45 Smooth FR with Fins	FR	A1, A2	Z1
		Cool down 200	FR	A1	Z1

Week 5			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
5	Friday (PM)	**1. Pool training**			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	A2	Z1
		• **Drill**			
		4*25 on 50 kick FLY Pull BR / 1-1-1 FLY	FLY/BR	A1	Z1
		4*25 on 45 Swim BR/FLY	FLY/BR	A1	Z1
		4 Round			
		• **Swim**			
		20*100 on 1:45	FR	A2, AT	Z1, Z2
		Cool Down 200	BA	A1	Z1

Week 5			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1. Dry land resistance training**			
		1.1General warm-up 5-10 min			
		1.2 Resistance training			
		• **Back Squat :**			
		Intensity: 70%1RM			
		Sets/Reps: 3sets x 8reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 70%1RM			
		Sets/Reps: 3 sets x 8 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps: 7 sets x 10 reps			
		Rest: 2minute			
		2. Pool training			
		• **Warm up**			
		1*200 on 5 50m Kick + 50m Swim IMO	IM	A1	Z1
		2*150 on 3:30 IM No FR UWK 4 time every wall	IM	A1	Z1
		1*100 on 2 FR Fast Long	FR	A2	Z1
		• **Power Set**			
		4*25 on 1 Kick with Chute	FR/BR	AT	Z2
		4*25 on 50 Swim Pace 200 with Chute & Paddles	FR/BR	AT	Z2
		Round 2 FR / Round 2 BR			
		• **Swim**			
		1*50 on 2 Easy	FR	A1	Z1
		1*50 on 1 Fast BR with Chute & Paddles & Fins	BR	LP	Z3
		10 Round			
		Cool down 200	FR	A1	Z1

Week 6			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1. Dry land resistance training** 1.1General warm-up 5-10min 1.2 Resistance training • **Back Squat :** Intensity:75%1RM Sets/Reps:3sets x 10reps Rest: 2minute • **Dumbbell Sumo Romanian Deadlift:** Intensity: 75%1RM Sets/Reps:3sets x 10reps Rest: 2minute • **Reverse Lateral Lunge:** Intensity: Body weight Sets/Reps:7 sets x 10 reps Rest: 2minute **2. Pool training** • **Warm up** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) • **Speed** 10*25 on 45 12.5m Max + 12.5 Easy • **Pull Set** 4*75 on 2 Pull with Paddles Des 1-4 4*25 on 50 Pull with Paddles Fast ***2 Round FR / 2 Round BR*** • **Swim** 6*100 on 1:45 FR Smooth ***3 Round*** Cool Down 200	BR FR/BR FR/BR FR FR	Speed A2, AT LP LP A1	Z5 Z1, Z2 Z3 Z2, Z3 Z1

Week 6			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training** • **Warm up** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) • **Kick** 4*75 on 1:15 FLY Kick Smooth 1*50 on 1:30 FLY Fast Kick ***4 Round*** • **Swim** 2*100 on 2 Smooth 2*50 on 1:10 BR Race Pace 200 2*25 on 50 BR Fast ***6 Round*** Swim with Paddles Cool Down 200	FR FLY FLY FR BR BR FR	A1 A2 VO2 A2 VO2 VO2 A1	Z1 Z1 Z3 Z1 Z4 Z4 Z1

Week 6			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
3	Wednesday (PM)	**1. Pool training** • **Warm up** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) • **Kick Set** 3*50 on 40 with Fins FLY 1*50 on 2 Easy ***5 Round*** • **Swim** 4*100 on 2 IM Des 1-4 8*50 on 55 ***3Round*** Cool down 200	FR FLY FR IM FR FR	A1 A2 A1 A2, AT VO2 A1	Z1 Z2 Z1 Z2, Z3 Z3 Z1

Week 6			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
4	**Thursday (PM)**	**1. Pool training** • **Warm up** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) • **Vertical Kick** 4*30 Second BR kick Fast 2*25 on 45 BR kick Fast ***4 Round*** • **Pull Set** 6*75 on 2 Race Pace100 BR 1*25 on 1:30 Easy ***3 Round*** • **Swim** 6*100 on 1:45 Smooth FR with Fins Cool down 200	FR BR BR BR FR FR FR	A1 A2 LP VO2 A1 A1, A2 A1	Z1 Z2 Z4 Z3 Z1 Z1 Z1

Week 6			General phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
5	Friday (PM)	**1. Pool training** • **Warm up** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) • **Drill** 4*25 on 50 kick FLY Pull BR / 1-1-1 FLY 4*25 on 45 Swim BR/FLY ***4 Round*** • **Swim** 10*100 on 1:45 20*50 on 60 15m. Fast + 35m. Easy Cool Down 200	FR FLY/BR FLY/BR FR CHOICE FR	A1 A1 A1 A2,AT LT A1	Z1 Z1 Z1 Z1, Z2 Z5 Z1

Week 6			General phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1. Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat :**			
		Intensity:75%1RM			
		Sets/Reps: 3sets x 10reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity:75%1RM			
		Sets/Reps: 3sets x 10reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge:**			
		Intensity: Body weight			
		Sets/Reps:7sets x 10reps			
		Rest: 2minute.			
		2. Pool training			
		• **Warm up**			
		8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins)	FR	A1	Z1
		• **Power Set**			
		4*25 on 1 Kick with Chute	FR/BR	AT	Z2
		4*25 on 50 Swim Pace 200 with Chute & Paddles	FR/BR	AT	Z2
		Round 2 FR / Round 2 BR			
		• **Swim**			
		1*50 on 2 Easy	FR	A1	Z1
		1*50 on 1 Fast with Chute & Paddles & Fins	FLY /BR	VO2	Z3
		5 Round FLY / 5 Round BR			
		• **Swim**			
		6*100 on 2 50m. Kick + 50m. Swim All Fins	CHOICE	A1	Z1
		Cool Down 200	FR	A1	Z1

Week 7			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat**			
		Intensity:80%1RM			
		Sets/Reps:3 sets x 6 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity:80%1RM			
		Sets/Reps:3 sets x 6 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge**			
		Intensity: Body weight			
		Sets/Reps:8sets x 10 reps			
		Rest: 2minute			
		2.Pool training			
		• **Warm up**			
		6*100 on 2 (Odd:FR/Even:IM)	FR/IM	A1	Z1
		12*50 on 1:30 IMO last 15m Fast	IM	A2/Speed	Z1
		1*100 on 3 Easy	FR	A1	Z1
		• **Speed**			
		10*25 on 45 12.5m Max + 12.5 Easy	IM	Speed	Z5
		Pull Set			
		4*100 on 1:45 Pull with Paddles Des 1-4	FR	AT, VO2	Z2, Z3
		4*25 on 1 Pull with Paddles Fast	FR / BR	Speed	Z5
		2 Round FR / 2 Round BR			
		• **Swim**			
		10*100 on 1:40 FR	FR	A2, AT	Z2
		2 Round			
		Cool Down 200	FR	A1	Z1

Week 7			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		• **Warm up**			
		6*100 on 2 (Odd:FR/Even:IM)	FR/IM	A1	Z1
		12*50 on 1:30 IMO last 15m Fast	IM	A2/Speed	Z1/Z5
		1*100 on 3 Easy	FR	A1	Z1
		• **Kick**			
		8*75 on 2:30 BR Kick = PB100m. Swim	BR	VO2	Z4
		1*100 on 3 Easy	FR	A1	Z1
		• **Swim**			
		8*25 on 45 Race Pace 100	FR / BR	VO2	Z4
		1*100 on 3 Easy	FR	A1	Z1
		***3 Round FR / 3 Round BR ***			
		Cool Down 200	FR	A1	Z1

Week 7			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
3	Wednesday (PM)	**1. Pool training** • **Warm up** 6*100 on 2 (Odd:FR/Even:IM) 12*50 on 1:30 IMO last 15m Fast 1*100 on 3 Easy • **Kick Set** 16*50 on 1:30 25m. Fast + 25m. Easy • **Swim** 8*25 on 50 Fast 1*50 on 2 Easy ***2 Round BR / 2 Round FR*** Cool down 200	 FR/IM IM FR IM BR / FR FR FR	 A1 A2/Speed A1 Speed Speed A1 A1	 Z1 Z1 Z1 Z5 Z5 Z1 Z1

Week 7			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
4	Thursday (PM)	**1. Pool training** • **Warm up** 6*100 on 2 (Odd:FR/Even:IM) 12*50 on 1:30 IMO last 15m Fast 1*100 on 3 Easy • **Vertical Kick** 4*30s BR kick Fast 2*25m on 45 BR kick Fast ***4 Round*** • **Pull Set** 6*75 on 2 Race Pace100 BR 1*25 on 1:30 Easy ***3 Round*** • **Swim** 4*100 on 1:45 Smooth FR with Fins 8*25 on 40 Hight Tempo ***1 Round FLY / 1 Round BR*** Cool down 200	 FR/IM IM FR BR BR BR FR FR FLY / BR FR	 A1 A2/Speed A1 VO2 VO2 AT A1 A1, A2 Speed A1	 Z1 Z1 Z1 Z2 Z4 Z3 Z1 Z1 Z5 Z1

Week 7			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
5	Friday (PM)	**1. Pool training** • **Warm up** 6*100 on 2 (Odd:FR/Even:IM) 12*50 on 1:30 IMO last 15m Fast 1*100 on 3 Easy • **Drill** 4*25 on 50 kick FLY Pull BR / Single Arm FLY 4*25 on 45 Swim BR/FLY ***4 Round*** • **Swim** 6*50 on 55 6*50 on 50 6*50 on 45 ***3 Round*** Cool Down 200	 FR/IM IM FR BR FLY / BR FR FR FR BA	 A1 A2 A1 A1 A2 A2 AT VO2 A1	 Z1 Z1 Z1 Z1 Z2 Z2 Z3 Z4 Z1

Week 7			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training** 1.1General warm-up 5-10min 1.2 Resistance training • **Back Squat** Intensity:80%1RM Sets/Reps: 3 sets x 6 reps Rest: 2minute • **Dumbbell Sumo Romanian Deadlift:** Intensity: 80%1RM Sets/Reps:3sets x 6 reps Rest: 2minute • **Reverse Lateral Lunge** Intensity: Body weight Sets/Reps:8sets x 10reps Rest: 2minute **2.Pool training** • **Warm up** 6*100 on 2 (Odd:FR/Even:IM) 12*50 on 1:30 IMO last 15m Fast 1*100 on 3 Easy • **Power Set** 4*25 on 1 Kick with Chute 4*25 on 50 Swim Pace 200 with Chute & Paddles ***Round 2 FR / Round 2 BR*** • **Swim** 1*50 on 2 Easy 1*50 on 1 Fast with Chute & Paddles & Fins ***5 Round FLY / 5 Round BR*** Cool down 200	FR/IM IM FR FR/BR FR/BR FR FLY /BR BA	A1 A2/Speed A1 Speed Speed A1 VO2 A1	Z1 Z1/Z5 Z1 Z5 Z5 Z1 Z4 Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training** 1.1General warm-up 5-10min 1.2 Resistance training ● **Back Squat** Intensity:85%1RM Sets/Reps:3sets x 6reps Rest: 2minute ● **Dumbbell Sumo Romanian Deadlift:** Intensity: 85%1RM Sets/Reps: 3sets x 6reps Rest: 2minute ● **Reverse Lateral Lunge** Intensity: Body weight Sets/Reps: 8sets x 10reps Rest: 2minute			
		2.Pool training ● **Warm up**			
		3 Round IM 4*75 on 1:30 (25kick with no board+25 drill+25swim)	IM	A1	Z1
		● **Pre-Set**			
		2*200 kick on4:15/4:30	FR/IM	VO2	Z1
		2*200 pull on3:45	FR	VO2	Z1
		● **Main Set**			
		4*100(25SP IM+75FR) on1:50	FR+IM	A2,LT	Z2, Z4
		4*100(75FR+25SP IM) on1:50	FR/BR	AT,LT	Z2,Z4
		8*100Kick (Odd:easy,Even:MAX) on2:30	FR	AT,Speed	Z3,Z4
		Cool Down 200	IM	A1	Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1.Pool training** ● **Warm up**			
		1*200 on 4 50m. Catch up + 50 Swim	FR	A1	Z1
		4*50 on 1:15 Big Side Kick FLY	FLY	A1	Z1
		4*25 on 45 Swim FLY Build up!!!	FLY	A2	Z1
		1*50 on 3 Easy	FR	A1	Z1
		● **Speed**			
		10*25 on 45 12.5m Maximum + 12.5 Easy / IM Order	IM	Speed	Z5
		● **Pull Set** 4*100 on 1:45 Pull with Paddles Des 1-4			
		4*25 on 1 Pull with Paddles Fast	FR	A2, A3	Z1, Z2
		2 Round FR / 2 Round BR	FR /BR	LT	Z4
		● **Swim**			
		12*50 on 45 FR	FR	A3, AT	Z1, Z2
		2*50 on 1:30 Easy ***3 Round***	BA	A1	Z1
		Cool Down 200	FR	A1	Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
3	Wednesday (PM)	**1. Pool training**			
		• **Warm up**			
		4*100 on 2:00			
		(25 kick with no board+25 drill+25 smooth+25 Fast swim)	IM	A1	Z1
		• **Kick Set**			
		3*50 on 1:00 with Fins	FR	VO2	Z2
		1*50 on 2:00 Easy Swim	IM	A1	Z1
		4 Round			
		• **Swim**			
		4*100 on 2:00 IM Des 1-4	IM	A2, VO2	Z2, Z3
		8*50 on 50	FR	VO2	Z3
		3Round			
		Cool down 200	FR	A1	Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
4	Thursday (PM)	**1. Pool training**			
		• **Warm up**			
		3 Round IM			
		4*125 on 2:30			
		(25 kick with no board+25 drill+25 smooth+25 Long+25 Fast swim)	IM	A1	Z1
		• **Pull Set**			
		8*100 paddle			
		(Odd: easy on1:40, Even: Fast on2:10)	FR	A2	Z2
		Main Set			
		1*150 on2:40	FR	AT	Z3
		1*50 max Dive+1*50 easy on 3:00	IM	LP	Z5
		4 Round			
		• **Swim**			
		6*100 on 1:45 Smooth FR with Fins	FR	A1, A2	Z1
		Cool down 200	FR	A1	Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
5	Friday (PM)	**1. Pool training**			
		• **Warm Up**			
		400（each 50 change storke）on8:00 300 back on6:30	IM	A1	Z1
		• **Main Set**			
		（100Kick+100 Double arm+100Swim）	BA	A1	Z1
		200 kick on4:00	IM	A1	Z2
		• **Swim**			
		100 swim（25fast+25ez+25fast+25ez）	BA	A2	Z2
		10*50 swim dive max @3:00	BA	LP	Z5
		Cool Down 200	IM	A1	Z1

Week 8			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat**			
		Intensity: 85% 1RM			
		Sets/Reps:3sets x 6 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 85% 1RM			
		Sets/Reps: 3sets x 6 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge**			
		Intensity: Body weight			
		Sets/Reps: 8 sets x 10 reps			
		Rest: 2minute			
		2.Pool training			
		• **Warm up**			
		8*100 on 2:15	FR	A1	Z1
		(no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins)	FR/BR	AT	Z2
		• **Swim**			
		1*50 on 2 Easy	FR	A1	Z1
		1*50 on 1 Fast with Chute & Paddles & Fins	FLY/BR	AT	Z3
		5 Round FLY / 5 Round BR			
		• **Swim**			
		6*100 on 2 50m. Kick + 50m. Swim All Fins	CHOICE	A1	Z1
		Cool Down 200	FR	A1	Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat**			
		Intensity:85%1RM			
		Sets/Reps:3 sets x 10 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 85%1RM			
		Sets/Reps:3 sets x 10 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge**			
		Intensity: Body weight			
		Sets/Reps:8 sets x 12 reps			
		Rest: 2minute			
		2.Pool training:			
		• **Warm up**			
		3 Round IM			
		4*75 on 1:30			
		(25kick with no board+25 drill+25swim)	IM	A1	Z1
		400 social KIck	FR	A2	Z1
		• **Main Set**			
		1*100 on2:00 Last 25m no breVO2he	FR	VO2	Z2
		1*50 on1:00 Bre<3	FR/FLY	LT	Z4
		6*25 on30s No Bre	FR/FLY	Speed	Z5
		4 Round			
		Cool Down 200	IM	A1	Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		• **Warm up**			
		400	IM	A1	Z1
		• **Pre-Set**			
		6*100 Pull on1:50	FR	A2	Z1
		• **Main Set**			
		5*100 swim on1:45	FR	VO2	Z3
		4*100 swim on1:45	FR	VO2	Z3
		3*100 swim on1:45	FR	VO2	Z4
		2*100 swim on1:40	FR	LP	Z4
		1*100 swim on4:00 max Dive	FR	LP	Z5
		Cool Down 200	IM	A1	Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
3	Wednesday (PM)	**1. Pool training**			
		• **Warm up**			
		3 Round IM			
		4*100 on 2:00	IM	A1	Z1
		(25 kick with no board+25 drill+25 smooth+25 Fast swim)			
		• **Kick Set**			
		1*100 Kick on2:10	IM	AT	Z3
		2*50 Kick on1:05	IM	VO2	Z4
		4*25 Kick on30s	IM	Speed	Z5
		4 Round			
		• **Swim**			
		1*100 swim on2:45	FR	AT	Z3
		1*50 swim on1:20	FR	LT	Z4
		1*100 swim on2:45	FR	LP	Z3
		2*25 swim on0:30	FR	Speed	Z5
		Cool Down 200	IM	A1	Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
4	Thursday (PM)	**1. Pool training**			
		• **Warm up**			
		3 Round IM			
		4*125 on 2:30	IM	A1	Z1
		(25 kick with no board+25 drill+25 smooth+25 Long+25 Fast swim)			
		• **Main Set**			
		1*100 kick on2:30	FR	VO2	Z3
		2*50 on1:15	FR	LP	Z4
		2*100 on1:50	FR	LP	Z4
		2*50 on1:15 5pull bre	FR	LP	Z4
		1*100 kick on2:30	FR	VO2	Z3
		1*100 swim on2:00 5pull bre	FR	LP	Z4
		4*25 uwk on40s	FR	LP	Z5
		12*50 cVO2ch up	FR	A2	Z3
		Cool down 200	IM	A1	Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
5	Friday (PM)	**1. Pool training** ● **Warm Up** 400（each 50 change storke）on8:00 ● **Main Set** 300 back on6:30 （100Kick+100 Double arm+100Swim） 200 kick on4:00 100 swim（25fast+25ez+25fast+25ez） 10*50 swim dive max @3:00 Cool Down 200	IM BA IM BA BA IM	A1 A1 A1 A2 LP A1	Z1 Z1 Z2 Z2 Z5 Z1

Week 9			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
6	Saturday (AM)	**1.Dry land resistance training** 1.1General warm-up 5-10min 1.2 Resistance training ● **Back Squat** Intensity:80%1RM Sets/Reps:3sets x 12 reps Rest: 2minute ● **Dumbbell Sumo Romanian Deadlift:** Intensity: 80%1RM Sets/Reps: 3sets x 12 reps Rest: 2minute ● **Reverse Lateral Lunge** Intensity: Body weight Sets/Reps:8sets x12reps Rest: 2minute **2.Pool training:** 8*100 on 2:15 (no.1 FR / no.2 50Kick+50swim / no.3 50Drill+50Swim / no.4 FR with Fins) ● **Pre-Set** 4*100 1IM+3FR Des on2:10 6*50 swim des-max bre,8.6.4 on1:15 ● **Main Set** 15*100(on2:00-1:50-1:40) 7*50 pull bre<7 on1:10 Cool Down 200	FR FR/IM FR FR FR FR	A1 AT LP LP AT A1	Z1 Z2 Z4 Z4 Z3 Z1

Week 10			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
1	Monday (PM)	**1.Dry land resistance training**			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat**			
		Intensity: 75%1RM			
		Sets/Reps:2 sets x 8 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 75%1RM			
		Sets/Reps: 2 sets x 8 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge**			
		Intensity: Body weight			
		Sets/Reps: 6 sets x 10 reps			
		Rest: 2minute			
		2.Pool training			
		• **Warm up**			
		1*300 on 25kick-25drill-25swim	IM	A1	Z1
		4x50 on 1 IM kick with no board	IM	A1	Z1
		1*300: on 3:30	IM	A1	Z1
		25single arm+25 single arm+25swim			
		4x50 on 1 Desc.1-4 (descending) with fins BREAST	BR	A2, VO2	Z1, Z2
		Speed			
		10*25 on 45 12.5m Max + 12.5 Easy / IMO	IM	Speed	Z5
		• **Pull Set**			
		3*100 on 1:50 Pull with Paddles Des 1-4	FR	AT, VO2	Z2
		2*25 on 1 Pull with Paddles Fast	FR / BR	Speed	Z5
		2Round FR / 1Round BR			
		• **Swim**			
		5*100 on 1:45 FR	FR	A2, AT	Z2
		2 Round			
		Cool Down 200	FR	A1	Z1

Week 10			Specific phase		
Sessions	**Days**	**Training Program**	**Stroke**	**Intensity**	**Zone**
2	Tuesday (PM)	**1. Pool training**			
		• **Warm up**			
		1*300 on 25kick-25drill-25swim	IM	A1	Z1
		4x50 on 1 IM kick with no board	IM	A1	Z1
		1*300: on 3:30	IM	A1	Z1
		25single arm+25 single arm+25swim			
		4x50 on 1 Desc.1-4 (descending) with fins Breast	BR	A2, VO2	Z1, Z2
		• **Kick**			
		8*50 on 1:30 Desc. 1-4 BR Kick	BR	A2, VO2	Z1, Z2
		1*50 on 2 Easy	FR	A1	Z1
		• **Swim**			
		6*25 on 50 Race Pace 100	FR / BR	VO2	Z4
		1*100 on 3 Easy	FR	A1	Z1
		***2 Round FR / 2 Round BR ***			
		Cool Down 200	FR	A1	Z1

Week 10			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
3	Wednesday (PM)	**1. Pool training** • **Warm up** 1*300 on 25kick-25drill-25swim 4x50 on 1 IM kick with no board 1*300: on 3:30 25single arm+25 single arm+25swim 4x50 on 1 Desc.1-4 (descending) with fins BREAST • **Kick Set** 6*50 on 1:30 25m. Fast + 25m. Easy • **Swim** 4*25 on 50 Fast 1*50 on 2 Easy ***1 Round BR / 1 Round FR*** Cool down 200	 IM IM IM BR IM BR / FR BA BA	 A1 A1 A1 A2, VO2 Speed VO2 A1 A1	 Z1 Z1 Z1 Z1, Z2 Z5 Z4 Z1 Z1

Week 10			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
4	Thursday (PM)	**1. Pool training** • **Warm up** 1*300 on 25kick-25drill-25swim 4x50 on 1 IM kick with no board 1*300: on 3:30 25single arm+25 single arm+25swim 4x50 on 1 Desc.1-4 (descending) with fins BREAST • **Vertical Kick** 2*30s Second BR kick Fast 1*25 on 50 BR kick Fast ***2 Round*** • **Pull Set** 3*50 on 1:30 25m. Fast + 25m. Easy 1*25 on 1:30 Easy ***2 Round*** • **Swim** 4*50 on 45 Smooth FR with Fins 2*25 on 40 Desc ***1 Round FR / 1 Round BR*** Cool down 200	 IM IM IM BR BR BR FR / BR FR FR FR / BR FR	 A1 A1 A1 A2, VO2 Speed Speed Speed A1 A1 AT, VO2 A1	 Z1 Z1 Z1 Z1, Z2 Z5 Z5 Z5 Z1 Z1 Z2 Z1

Week 10			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
		1. Pool training			
		• **Warm up**			
		1*300 on 25kick-25drill-25swim	IM	A1	Z1
		4x50 on 1 IM kick with no board	IM	A1	Z1
		1*300: on 3:30	IM	A1	Z1
		25single arm+25 single arm+25swim			
5	Friday (PM)	4x50 on 1 Desc.1-4 (descending) with fins	BR	A2, VO2	Z1, Z2
		BREAST			
		• **Swim**			
		4*50 on 60	FR	A2	Z1
		4*50 on 55	FR	AT	Z1
		4*50 on 50	FR	VO2	Z2
		2 Round			
		Cool Down 200	BA	A1	Z1

Week 10			Specific phase		
Sessions	Days	Training Program	Stroke	Intensity	Zone
		1.Dry land resistance training			
		1.1General warm-up 5-10min			
		1.2 Resistance training			
		• **Back Squat**			
		Intensity: 70%1RM			
		Sets/Reps :2sets x 8 reps			
		Rest: 2minute			
		• **Dumbbell Sumo Romanian Deadlift:**			
		Intensity: 70%1RM			
		Sets/Reps: 2sets x 8 reps			
		Rest: 2minute			
		• **Reverse Lateral Lunge**			
		Intensity: Body weight			
		Sets/Reps: 6 sets x 10 reps			
		Rest: 2minute			
		2.Pool training			
6	Saturday (AM)	• **Warm up**			
		1*300 on 25kick-25drill-25swim	IM	A1	Z1
		4x50 on 1 IM kick with no board	IM	A1	Z1
		1*300: on 3:30			
		25single arm+25 single arm+25swim	IM	A1	Z1
		4x50 on 1 Desc.1-4 (descending) with fins	BR	A2, VO2	Z1, Z2
		BREAST			
		• **Power Set**			
		4*25 on 1 Kick with Chute			
		4*25 on 50 Swim Pace 200 with Chute &	FR/BR	Speed	Z5
		Paddles	FR/BR	Speed	Z5
		Round 2 FR / Round 2 BR			
		• **Swim**			
		1*50 on 2 Easy	FR	A1	Z1
		1*50 on 1 Fast with Chute & Paddles & Fins	FLY /BR	VO2	Z4
		MAX			
		2 Round FLY / 2 Round BR			
		Cool down 200	BA	A1	Z1

BIOGRAPHY

NAME	Xitong Liu
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