T.C.

YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF SPORTS PHYSIOTHERAPY

THE EFFECT OF STRETCHING THE PECTORALIS MAJOR, STERNOCLEIDOMASTOID, AND ILIOPSOAS MUSCLES ON 800 METERS SWIMMING PERFORMANCE IN MASTER SWIMMERS

MASTER THESIS

ŞAFAK ÖZSÖNMEZ, PT

ADVISER
ASSIST. PROF. ŞULE BADILLI HANTAL, PT

CO-ADVISER
ASSIST. PROF. ELİF DEVELİ, PT

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	Unvanı, Adı-Soyadı (Kurumu)
Jüri Başkanı:	
Tez danışmanı:	Dr. Öğr. Üyesi Şule BADILLI HANTAL Yeditepe Üniversitesi
Üye:	Dr. Öğr. Üyesi Elif DEVELİ Yeditepe Üniversitesi
Üye:	
Üye:	

ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun …………………tarih ve .... sayılı kararı ile onaylanmıştır.

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Şafak Özsönmez, PT.

DEDICATION

I dedicate my thesis to my mother, Melek Özsönmez, and my father, Şafak Özsönmez, who supported me morally and materially throughout my academic career. I could not have done so without them.

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LIST OF SYMBOLS AND ABBREVIATIONS

SFL	Superficial Front Line
SCM	Sternocleidomastoid
FSP	Forward Shoulder Posture
MS	Myofascial System
FORCE	Foundation of Osteopathic Research and Clinical Endorsement
WAnT	Wingate Anaerobic Test
FINA	Fédération internationale de natation
MET	Metabolic Equivalent of Task
SC	Stroke Cycle
V	Velocity
SR	Stroke Rate
SL	Stroke Length
SI	Stroke Index
Ds	Distance per Stroke
Fd	Drag Force
dV	Center of Mass
ATP	Adenosinetriphosphate
CP	Creatine Phosphate
AMP	Adenosinemonophosphate
ADP	Adenosinediphosphate
TCA	Tricarboxylic Acid
O	Oxygen
CO2	Carbon Dioxide
ETC	Electron Transport Chain
NADH	Nicotinamide Adenine Dinucleotide Hydrogen
CoA	Acetyl-coenzyme A
Hz	Hertz
N/m	Newton/Mass
ms	Milisecond

ABSTRACT

ÖZSÖNMEZ, Ş. (2023). The Effect of Stretching The Pectoralis Major, Sternocleidomastoid, and Iliopsoas Muscles on 800 Meters Swimming Performance In Master Swimmers.
Yeditepe University, Institute of Health Science, Department of Sports Physiotherapy Master Thesis, Istanbul.

This study aimed to examine the effect of stretching exercises applied to the Pectoralis major, Sternocleidomastoid and Iliopsoas muscles on 800-meter swimming performance in master swimmers. This randomized study included 30 volunteer master swimmers who were divided into an Experimental Group (n=15) and a Control Group (n=15). While the participants in the Experimental Group performed stretching exercises every day for six weeks in addition to their swimming training, the participants in the Control Group continued their regular swimming training. All participants' 800-meter performance measurements and muscle flexibility were evaluated before and after the interventions by timing and using the MyotonPro Device. As a result of the study, a statistically significant improvement was observed in the 800 meters of both groups ($p<0.05$), but no statistically significant result was obtained between the groups ($p>0.05$). In the measurements made using the MyotonPro device, no statistically significant change was observed in either group ($p>0.05$). As a result, it was observed that swimming training affected on the 800-meter time of master swimmers. However, it has not yet been determined whether stretching exercises specifically increase swimming performance.

Keywords: Master Swimmer, Stretching Exercise, 800 Meters, Swimming, Performance

ÖZET

ÖZSÖNMEZ, Ş. (2023). Master Yüzücülerde Pektoralis Major, Sternokleidomastoid ve İliopsoas Kaslarının Gerilmesinin 800 Metre Yüzme Performansına Etkisi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Spor Fizyoterapisi Anabilim Dalı Yüksek Lisans Tezi, İstanbul.

Bu çalışma, master yüzücülerde Pektoralis majör, İliopsoas ve Sternokleidomastoid kaslarına uygulanan germe egzersizlerinin 800 metre yüzme performansı üzerine etkisini incelemeyi amaçlamaktadır. Bu randomize çalışma, Deney Grubu (n=15) ve Kontrol Grubu (n=15) olarak ayrılan 30 gönüllü master yüzücüyü içermektedir. Deney Grubu'ndaki katılımcılar yaptıkları yüzme antrenmanına ek olarak 6 hafta boyunca her gün germe egzersizlerini yaparken Kontrol Grubundaki katılımcılar sadece olağan yüzme antrenmanlarına devam etmişlerdir. Tüm katılımcıların 800 metre performans ölçümleri ve kas esneklikleri müdahalelerden önce ve sonra süre tutularak ve MyotonPro Cihazı kullanılarak değerlendirildi. Çalışmanın sonuçlarında ise her iki grubun 800 metre derecelerinde istatistiksel olarak anlamlı bir iyileşme gözlendi ($p<0.05$) fakat gruplar arasında istatistiksel olarak anlamlı bir sonuç elde edilemedi ($p>0.05$). MyotonPro cihazı ile yapılan ölçümlerde ise her iki grupta da istatistiksel olarak anlamlı bir değişim gözlenmedi ($p>0.05$). Sonuç olarak, çalışmada yüzme antrenmanlarının master yüzücülerde 800 metre derecesine etkisi olduğu gözlendi. Ancak yapılan germe egzersizlerinin spesifik olarak yüzme performansını arttırdığı sonucu saptanamamıştır.

Anahtar Kelimeler: Master Yüzücü, Germe Egzersizi, 800 Metre, Yüzme, Peformans

1. INTRODUCTION AND PURPOSE

The benefits of swimming are nearly endless. Swimming is important not only as a sport but also for evaluating leisure time, building strength, and healing. This allows some muscles to grow symmetrically and consistently. There were no malfunctioning muscle groups during swimming. Even when swimming with minimal effort, one can easily move with relatively low force. Additionally, it establishes a sense of trust (5).

Human performance declines with age, and this is true for both sprint and endurance sports and for all competitions/disciplines. Even though the consequences of aging are frequently exacerbated by disuse, the study of master athletes is of considerable interest because it allows researchers to analyze the effects of aging in general, with the aging athlete serving as a model of "successful aging." (1,2). Swimming is almost certainly the most popular sport or at least one of them. It puts less effort on the body, as it does not require carrying one's weight, and is thus especially ideal for elderly persons (3). Swimming uses the lifting power of water to push the body forward by beating the hands and feet (4).

Sportive swimming is described as an athlete's ability to complete specific distances in water in the quickest amount of time using freestyle, backstroke, breaststroke, or butterfly strokes (6). The backstroke technique was performed in the supine posture, whereas the other techniques were swam in the facedown, horizontal, and near-horizontal positions. Various approaches have varied characteristics in terms of body position, leg kick, arm pulling, head position, respiration, and condition (7,8).

Biomechanically, our myofascial connections also help swimmers to swim. Tightening Superficial Front Line (SFL) causes hip flexion, and the trunk in motion also produces hyperextension at the top of the neck (26). The large muscles of the pectoralis and latissimus provide the motive force for large movements of adduction and extension, such as swimming strokes (26). Vertical fibers in the fascia on the profound side of the epimysium of the pectoralis major connect from the rectus attachment to the lower part of the fascia colli superficialis (and sternocleidomastoid (SCM))(26). The lower extremity also coordinates stability, whereas the upper part of the body initiates movements between phases. The iliopsoas starts hip flexion, followed by the rectus femoris, initiating knee extension to continue horizontal movement in the water (18).

Because of the demands of sports, swimmers have a more rounded forward posture. When the head is forward, the cervical spine is hyperextended, the thoracic spine is in slight flexion, and the lumbar spine is in slight extension; this is known as the forward posture. Muscle imbalances in the shoulders blame this forward posture (9). During the recovery phase of swimming, the scapula must retract and protract along the thoracic wall. The subacromial space is reduced with protraction because of swimmers' adaptation to sports (10). In a study age-related mobility loss is joint-specific has been analyzed with 6,000 "Flexitest" results with people age 5 to 92 years. The results of the study showed that joint mobility due to flexibility decreases with age, but the three lowest flexibilities outcomes are shoulder, trunk, and hip mobilities (34). Stretching the scapular protractors such as the pectoralis major muscle has been shown to have a considerable impact on the degree of forward shoulder posture (FSP) in healthy people (14). In addition, swimmers with shoulder pain due to more active trigger points can develop mechanical hypersensitivity compared to those who do not have any shoulder pain (16).

As summarized above, swimming athletes generally adopt a forward posture because of their adaptation to water. In our opinion, this posture may be due to the tension of the anterior group myofascial structures, and releasing the fascia by stretching may affect swimmers' performance. Master swimmers have adapted far more than young swimmers have. Therefore, we can better observe the effects of Sternocleidomastoid, Pectoralis major, and Iliopsoas muscle stretching on swimming performance by testing swimmers at a distance of 800 meters.

Regarding these points mentioned above, the study aimed to investigate the effect of stretching the sternocleidomastoid, pectoralis major, and iliopsoas muscles on 800 meters freestyle swimming performance in master swimmers.

Two hypotheses of this study were:

H0: There is no significant difference between the 800-meter performance measurements of the people in the group that added stretching of specific muscles to their regular training and those in the group that did not add stretching.

H1: There is a significant difference in the 800-meter performance measurements of the group with specific muscle stretching added to their regular training and those.

2. THEORETICAL FRAMEWORK AND LITERATURE

2.1. MYOFASCIAL STRUCTURES

The myofascial system (MS) is essential for the complex structures of movement regulation because it provides tensional support for the human body. The MS is an unbroken continuum that connects the head to the foot anatomically and functionally (20).

2.1.1 FASCIA

The fascia is a large web-like connective tissue that can be observed with the naked eye (11). From head to toe, it provides passive and active support by encasing skeletal muscles, joints, organs, nerves, and vasculature (12). Fascia provides a variety of functions, including providing structural support and stability (11), and allowing the transmission of mechanical forces between muscles (13). Fascia promotes and controls mechanical communication across all tissues by transmitting force through the collagenous network. The MS meridians represent the tensional force transfer in series. In addition, the force distribution flows parallel across the adjacent myofascial tissues (17). The Foundation of Osteopathic Research and Clinical Endorsement (FORCE) group has published several articles that highlight new concepts for a better understanding of the fascia concept, which is any tissue that contains features capable of responding to mechanical stimuli. The fascial continuum is the result of the evolution of the perfect synergy among different tissues, liquids, and solids, capable of supporting, dividing, penetrating, feeding, and connecting all the districts of the body: the epidermis, dermis, fat, blood, lymph, blood, and lymphatic vessels, tissue covering the nervous filaments (endoneurium, perineurium, epineurium), voluntary striated muscle fibers and the tissue covering and permeating it (epimysium, perimysium, endomysium), ligaments, tendons, aponeurosis, cartilage, bones, meninges, involuntary striated musculature, involuntary smooth muscle (all viscera derived from the mesoderm), visceral ligaments, epiploon (small and large), peritoneum, and tongue. The continuum constantly transmits and receives mechano-metabolic information that can influence the shape and function of the entire body." (21,22,23).

2.1.2 STERNOCLEDIOMASTOIDEUS

The SCM has two heads: the medial sternal head, which is rounded and tendinous, and the lateral clavicular head. The sternal head rises posterolaterally from the upper part of the anterior surface of the manubrium sterni. The clavicular head varies in width and ascends almost vertically from the superior surface of the medial third of the clavicle. A triangular interval separates the two heads of origin, corresponding to a surface depression called the lesser supraclavicular fossa. The clavicular head spirals behind the sternal head and combines with its deep surface below the middle of the neck to form a thick, rounded belly as it ascends. A strong tendon links the muscle to the lateral surface of the mastoid process from its apex to its superior border and a thin aponeurosis links it to the lateral half of the superior nuchal line. The clavicular fibers are primarily directed toward the mastoid process, whereas the sternal fibers extend to the occipital bone. The sternocleidomastoid muscle is supplied by the spinal accessory nerve. It also receives proprioceptive innervation from the cervical plexus via the cervical spinal nerve. The sternocleidomastoid muscle is supplied with blood by the branches of the occipital and posterior auricular arteries, which supply the upper part of the muscle. The middle and lower sternocleidomastoid muscles are supplied by muscular branches from the superior thyroid and suprascapular artery (25). Several neck muscles are involved in the movement and balance of the head on the vertebral column, and the SCM plays an important role. The bilateral contraction of the two SCM muscles flexes the cervical region of the spinal column and skull. When functioning unilaterally, each sternocleidomastoid muscle laterally flexes and rotates its head to the opposite side of the contracting muscle (24).

2.1.3 PECTORALIS MAJOR

The pectoralis major muscle originates from the clavicular head, sternum, and costal cartilages of ribs 2–6 and sometimes 1-7 ribs sternocostal head and inserts into the greater tubercle and lateral lip of the intertubercular sulcus of the humerus. As a function, the adducts and medially rotate the arm at the shoulder joint; the clavicular head flexes the arm, and the sternocostal head flexes the extended arm to the side of the trunk by innervating the medial and lateral pectoral nerves (24).

2.1.4 ILIOPSOAS

The psoas major and iliacus muscles share a common insertion (lesser trochanter of femur) and are collectively known as the iliopsoas muscle (24).

2.1.4.1 PSOAS MAJOR

The psoas major is the main supporting guy-wire between the spine and leg, connecting upper to lower, breathing to walking, and functioning in complicated ways with other local muscles to steady different movements (26). The psoas major originates from the transverse processes and bodies of the lumbar vertebrae and is inserted into the lesser trochanter of the femur. Gets Innervated by lumbar spinal nerves L2–L3 (24).

2.1.4.2 ILIACUS

The iliacus is a one-joint flexor of the hip that widens up and laterally from the lesser trochanter to attach along the upper portion of the iliac fossa. The fascia covering the iliacus connects to the fascia on the anterior aspect of the quadratus lumborum (26). The iliacus originates from the iliac fossa and sacrum, and inserts with the psoas major into the lesser trochanter of the femur. Gets are innervated by femoral nerves (24).

2.2 STRETCHING AND PERFORMANCE

Significant research has been conducted on the various factors that influence swimming performance in adults (112). These factors include anthropometric, physiological, and biomechanical parameters, all of which affect swimming performance (113). In this study, multiple parameters were evaluated to assess the performance of the expert swimmers. According to the literature, various methods were employed to evaluate the performance of swimmers, including the examination of height, weight, body mass index, arm length, swimming time, the Wingate anaerobic test (WAnT), muscle strength, core strength, and swimming technique (54, 96, 114, 115).

Flexibility is the degree of movement that can be achieved around a particular joint or a series of joints, and is usually categorized as either static or dynamic (31,32). Enhancing flexibility through stretching is essential for enhancing physical performance. Maintaining good flexibility also helps to avoid musculoskeletal system injuries (30,31,32). Static flexibility is the extent to which a joint can be passively moved to the limits of its range of motion (33). Dynamic flexibility is the extent to which a joint can be moved owing to muscle contraction and may not be an accurate measure of the joint's tightness or looseness (29,30).

It is difficult to differentiate between alterations in stretch tolerance and alterations in muscle stiffness because stretching exercises are likely to cause acute or chronic changes in flexibility (27). However, in a systematic review of the beneficial effects of static stretching on health, static stretching exercises had a positive impact on the health status of various groups. Exercises show potential benefits to human health, regardless of the stretching parameters used. In addition, they are adaptable to individual constraints, relatively simple to perform, and require a low level of strain. Static stretch exercises can serve as a simple and effective tool for improving and maintaining health and increasing satisfaction during activities of daily living (28). In addition, a systematic review and multilevel meta-analysis of 41 studies revealed that regular static stretch exercises have trivial-to-small positive effects on muscle strength and power. Moderate to large increases have been observed in flexibility (35).

2.3 SWIMMING

Swimming is a set of movements performed by a person to move through water over a distance (6). In training and competitions, swimming is defined as swimming certain distances using whole-body muscles with four different styles of swimming techniques (8,7,36).

2.3.1 HISTORY OF SWIMMING

The first information on swimming returned to 9000 BC as a result of archaeological studies. When the findings on cave walls in the Sori Valley of the Libyan Desert are examined, a similar frog-style swimming technique is encountered (5). In Ancient Greek and Roman Civilizations, where primary education was as important as military education, swimming was as important as literacy in both men and women. In Ancient Roman Civilization, swimming pools were built separately from the baths, and it is mentioned in the books that the first heated pool was created by the Roman Gaius Maecenas in the 1st century BC (37). In Ancient Greek Practice, swimming competitions were held occasionally, and an imperial edict was published in the Japanese Empire, which made swimming education compulsory in schools (38,39).

2.3.1.1 WORLDS HISTORY OF SWIMMING

The first sports activities for swimming began with pools opened in London in 1837 (40). The first swimming competitions that took place on an international platform started in London in 1837 and then continued with the 400-meter competition in the swimming championship held in Australia in 1846. With the Metropolitan Swimming Clubs of London, which were established in London in 1869, the first amateur swimming society was established with the Metropolitan Swimming Clubs of London (37, 41). An Englishman named Arthur Trudgeon went to South America in 1860 and learned to swim. When he returned to his country, he taught the European swimmers how to swim. Until Arthur Trudgeon, swimmers in Europe were swimming underwater with their arms crossed in the shape of scissors. Before Arthur Trudgeon taught the stroke, swimming styles were called La Coue, La Marinier, over-arm side stroke, and breaststroke on the back (41).

With the organization of the first modern Olympic Games in 1896, swimming competitions began to officially take place in world history. In 1908, The Fédération internationale de natation (FINA) regulation, which was responsible for organizing water sports competitions in the international arena, began to be taken as a basis (42). With the FINA regulation, it was decided to start measuring the distances of the competitions in meters. First, the backstroke-style swimming technique was added in 1900, and then the breaststroke-style swimming technique was added to the Olympics in 1908. Butterfly-style swimming is the latest technique added to the Olympics. Australian Richmond (Dick) Theophilus Cavill first developed today's freestyle swimming technique and attempted to introduce it to the world. At the 1900 Paris Games, Australian Frederick Lane won the 200 meters freestyle with a time of 2:25.2, and in 1902, Richmond (Dick) Theophilus Cavill of Australia made history as the first person to swim 100 yards in less than one minute (43, 44). FINA officially determines competitions as butterfly, backstroke, breaststroke, and freestyle (40). In the 1912 Olympics, until 1912, female swimmers participated for the first time in competitions in which only men participated (41).

2.3.1.2 TURKEYS HISTORY OF SWIMMING

In Turkey, Mekteb-i Sultani, now known as Galatasaray High School, was founded in 1873. Following the step taken by Galatasaray High School in the name of swimming, swimming in Turkey started in the modern sense in 1910 (41,45).

Between 1932 and 1933, great importance was placed on swimming in Turkey. In Istanbul, Teketof, a famous German trainer, was assigned to teach modern swimming. As a result of modern systematic training, Turkish swimmers Orhan Saka, Halil Dalkum, and Methi Ağaoğlu broke many records that were different from the old records. The first national competition was held with Russia in 1934, and two of our female swimmers were among those who achieved the honor of becoming a national for the first time (5, 45, 46). The first regular race in Turkey was held in Büyükada on September 15, 1923, and Turkey's first Olympic swimming pool opened in 1931 in the Büyükdere district of Istanbul (42). Swimming, which started its activities under the Turkish Aquatic Sports Federation, was established in 1932 under the Turkish Sports Associations Alliance, left the Maritime Federation within the body of the Turkish Sports Association in 1957, and has been operating as a sport branch under the Turkish Swimming Federation (47,48).

2.3.2 SWIMMING STROKES/STYLES

Swimming styles are divided into four as butterfly, backstroke, breaststroke and freestyle swimming technique (36,49,50). Butterfly style swimming technique was first introduced by Henry Myers in 1933 and the technique was officially recognized by FINA and included in the competitions in 1953 (38).

2.3.2.1 FREESTYLE

In the freestyle swimming technique, in which the body is in the prone position in the water, the arms maintain the elbow extension position in the water throughout the technique and alternate between elbow flexion and extension positions outside the water. For the toe-kick technique, the hips are kept in bilateral adduction, the feet are in plantar flexion position throughout the technique, and the knees are constantly moving from full extension to the flexion position at a small angle. Performing lower extremity movements in a bilateral, coordinated, and repetitive manner while maintaining the specified positions constitutes the toe kick technique. To draw the water in the upper extremity, the arms start from the head and perform an ipsilateral shoulder extension movement similar to the letter S through the water, followed by bringing the arm over the head from outside the water. When the arm was above the head, the elbow moved from the full extension position to the 90º flexion position, with scapular retraction movement when the hand was out of the water. From the position where the elbow is in 90º flexion position with scapular retraction, full elbow extension occurs while the hand is on the head (Figure 2.3.2.1). The technique is performed with the head in a fixed position as much as possible, and the number of breaths varies according to the swimming distance and athlete's request (5). The metabolic equivalent of task (MET) value for the freestyle swimming technique was 199.8 ml.kg-1. min-1 (51).

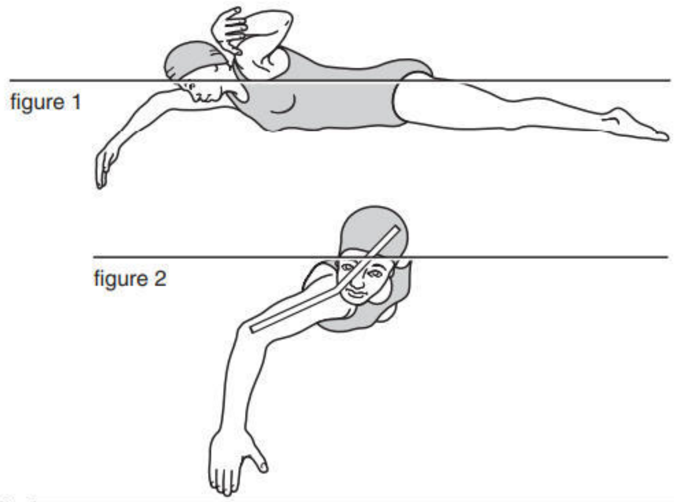


Figure 2.3.2.1 Freestyle

2.3.2.2 BREASTSTROKE

In the breaststroke-style swimming technique, where the body is in the prone position in the water, the lower extremities are not always in the adduction position, unlike in other swimming techniques. In the leg propulsion phase, while the hip and knees take the flexion position, the hip performs an external rotation movement. During the kick, internal rotation and knee extension were performed bilaterally, followed by hip adduction (Figure 2.3.2.2). In the breaststroke-style swimming technique, the feet maintain their neutral position during the stroke and are plantarflexed during the glide phase of the lower extremity. The lower extremities were submerged by using this technique. During each draw in the upper extremity, the head was removed from the water and the breathing process was performed. Following the leg sweep technique, the arms were brought to 90º flexion at the elbows and abduction from the shoulder during the breathing phase of the technique. After the breathing process, the arms are brought bilaterally from the shoulder to adduction and from the forearm to supination, and then from the shoulder to external rotation, from the elbow to extension, and from the forearm to pronation. The arms were brought over the head to pass from the recovery phase of the technique to the glide phase of the arms. Bilateral movement of the lower extremities begins when the arms begin the recovery phase for the breathing phase. In the arm recovery phase, the foot strike movement is performed on the lower extremity to allow sliding movement while the hands are attached to the head. In the breaststroke-style swimming technique, progress is made by sliding in water owing to the force released by the footstroke. In this technique, lower extremity movement is followed by upper extremity movement during coordination. In other techniques, approximately 20 percent of the force for advancement in water is provided by the legs, and this rate reaches approximately 70 percent in breaststroke-style swimming. Leg propulsion is very important in breaststroke-style swimming techniques because 70 percent of the force required for advancement is provided by the lower extremities. Among the four swimming techniques, the breaststroke-style swimming technique is the technique in which coordination and timing are the most important (5,53). The MET value for the breaststroke-swimming technique was 10.3 ml.kg-1. min-1 (51).

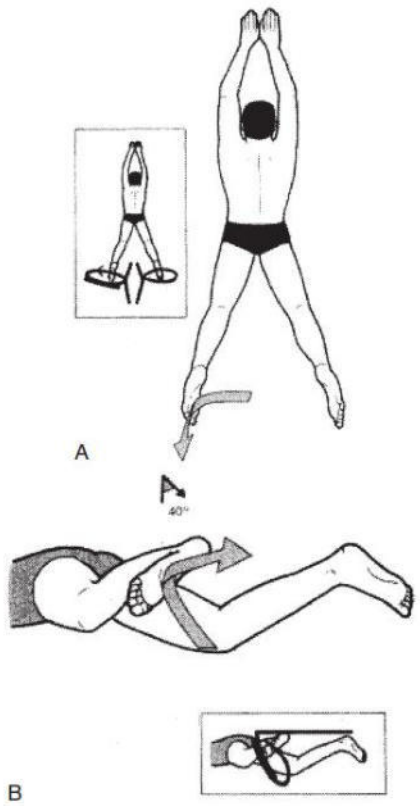


Figure 2.3.2.2 Breaststroke

2.3.2.3 BACKSTROKE

In the supine style swimming technique, the body is in the supine position, the arms alternate between elbow flexion and extension positions in the water throughout the technique, and the elbow takes the full extension position outside the water. Throughout the backstroke kick technique, the hip maintains a bilateral adduction position, and the feet maintain a plantar flexion position, while the knees continuously move from full extension to a small-angle flexion position. The kick technique involves performing lower-extremity movements in a bilateral, coordinated, and repetitive manner while maintaining specified positions. In the technique in which the arms move in opposite directions in the upper extremity, the arm moves over the head, the elbow maintains its full extension position, and the shoulder performs internal rotation. During an arm stroke, the arm above the head comes to the side of the body with adduction and elbow extension following 90º elbow flexion (Figure 2.3.2.3). The technique was performed with the head in as stable a position as possible (5). The mean MET value for the backstroke-swimming technique was 9.5 ml.kg-1. min-1 (51).

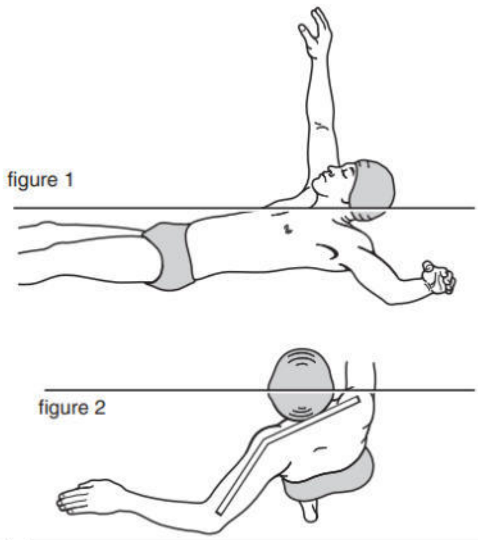


Figure 2.3.2.3 Backstroke

2.3.2.4 BUTTERFLY STROKE

In the butterfly-style swimming technique, in which the body is in the prone position in the water, the arms maintain the elbow extension position throughout the entire technique. In the upper extremity, the arms perform bilateral shoulder extension movements, similar to the letter S, from the water, starting from the top of the head, and the movement is followed by the simultaneous movement of the arms over the head from outside the water (Figure 2.3.2.4). The technique is performed such that the two dolphin movements follow bilateral arm pulls. The head entered the water before the arms, in coordination with the arms, and exited the water before the arms. The number of breaths varies according to the distance swum and athlete's request (5). The MET value for the butterfly-style swimming technique is 13.8 ml.kg-1. min-1 (51).

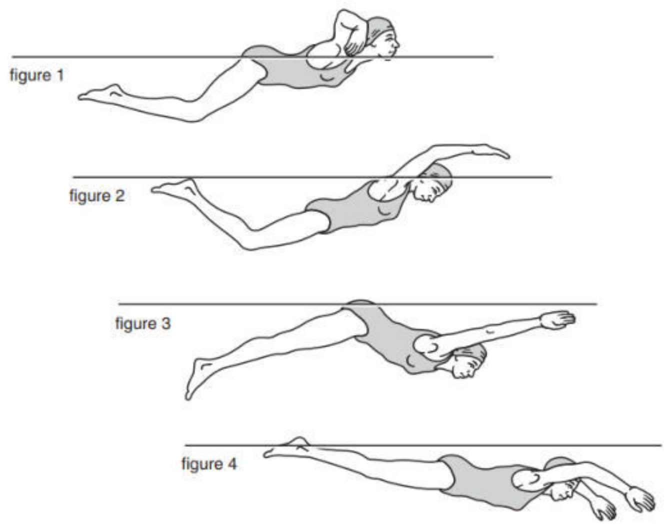


Figure 2.3.2.4 Butterfly Stroke

2.3.3 SWIMMING KINEMATICS AND BIOMECHANICS

Swimming sports competition research, which began in the 1970s, continues today and focuses on the kinematics and biomechanics of swimming styles to improve performance (54,55).

2.3.3.1 SWIMMING KINEMATICS

The kinematics of swimming styles are divided into three categories: stroke cycle (SC) kinematics, extremity kinematics, and center-of-mass kinematics (56).

2.3.3.1.1 STROKE CYCLE KINEMATICS

The variables that depend on this are clean swimming velocity (V), stroke rate (SR), and stroke length (SL). Velocity affected by SR and SL. SL decreases with fatigue, and faster swimmers compensate for this by increasing SR at the end of the race (56,57). In other studies, it was found that for 200m races, the decline in velocity at the end of the race was due to a decrease in SL (58).

As the freestyle swimming technique was the fastest among the four techniques, it had the highest SL and SR. In contrast, the backstroke technique most closely resembled the freestyle swimming technique in terms of speed. For the same SR value as freestyle swimming, the SL value of the backstroke technique was lower; therefore, V also showed a lower value. The method of increasing velocity in the butterfly-style swimming technique involves increasing the SR. The method of increasing V in the frog-style swimming technique, which is the technique in which the lowest SL value is observed, can be achieved by increasing the SR value, as in the butterfly-style swimming technique (63).

The stroke rate was the highest in the last round of competition (64). Considering the SL and SR values according to the distances of competition, as the competition distance increases, there is a conservation in SL value and a decrease in SR and, therefore, V values (65). To compete successfully, a swimmer must have a high SL value so that the V value can be controlled by changes in the SR value (63).

Another variable when examining SC kinematics is the stroke index (SI), which is used to estimate overall swimming efficiency and is calculated by multiplying swimming velocity by the distance per stroke (Ds) (66). SI is used to calculate the efficiency of a swimmer's swimming technique. Among all swimming techniques, the freestyle swimming technique has the highest SI, followed by backstroke, butterfly, and frog-style swimming techniques (67).

2.3.3.1.2 EXTREMITY KINEMATICS

Depends on the SC variables, and SL and SR are affected by the limb kinematics. As upper extremity movements increase, V also increases; therefore, the speed of the upper extremities plays a decisive role in V. While the relative contribution of lower extremity movements to V in the freestyle swimming technique was determined to be 15 percent, the contribution rate of the upper and lower extremities to V in other techniques could not be definitively determined (68).

Trunk rotation movement of the body during breathing was another factor that affected the performance of the freestyle swimming technique (Figure 2.3.3.1.2). The better the swimmer performs the rotation movement, the better the water draw efficiency of the arms (69).

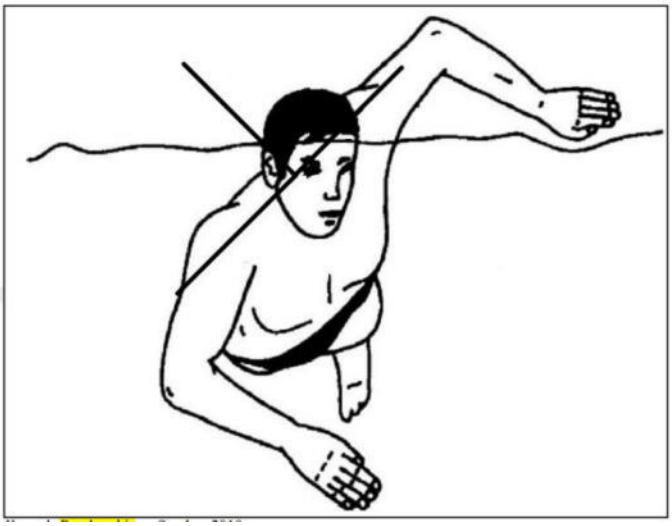


Figure 2.3.3.1.2 Trunk rotation while swimming

In the backstroke-style swimming technique, the better the swimmer performs the streamline position and trunk rotation, the more positively their performance is affected (50,54,70).

The most important factor that determines the quality of performance in the breast stroke-style swimming technique is the timing between movements of the upper and lower extremities (53). High-performance swimmers have an increased SR and SL (71,72).

In the butterfly-style swimming technique, the body angle, the ability of the shoulder to reach extension during the water catch and pull, and the strength of the second dolphin leg stroke are factors that determine the quality of performance. An increase in the angle of the body with the horizontal plane decreases V by increasing the drag force (Fd), which is the water resistance to which the swimmer is exposed. To decrease Fd during the technique, swimmers perform their performances by breathing from the side or without breathing at all at some competition distances (73,74). A swimmer with a higher average swimming velocity tends to have a smaller elbow joint angle during the water withdrawal phase (catch point) (75). When we look at lower-extremity kinematics, the amplitude of the dolphin technical foot strike is reduced and the frequency is increased, thus contributing to the increase in V (67).

In all swimming techniques, V was increased to release more force in the final parts of the water-pull phase (50,76).

2.3.3.1.3 CENTER OF MASS KINEMATICS

The hip and center of mass play an important role in understanding body kinematics; however, they do not represent the same points (59,60). During swimming, the hip undergoes much more velocity change than the center of mass, but some kinematic studies have been carried out over the hip because it is an anatomical point (59). During swimming, the horizontal velocity of the center of mass (dV) of the body never remains constant; it increases and decreases because of limb movements (61,62).

When the swimming speeds of the freestyle and backstroke swimming techniques were examined, similar changes were observed in the dV. dV increased with arm stroke and decreased with kicks in the lower extremities. The reason dV decreases during the kick is the predominance of foot kicks when one arm is at the end of the draft phase and one arm is at the beginning of the draft phase (77).

When we look at the V of the breaststroke swimming technique, dV increases during the sweeping phase of the arms and leg extension in the lower extremities, but reaches a higher value during the leg stroke because 70% of the improvement in the technique is achieved by the movement of the lower extremities (77). Since dV reaches its lowest value in the reaching phase, the swimmer must correctly determine the moment when he will start drawing water (78).

When we look at the V of the butterfly-style swimming technique, dV reaches its highest value at the last moment of the draft phase, when the full force is released, and the lowest value is at the beginning of the draft phase, just after the first dolphin stroke (60).

There are multivariate relationships between dV and V and between dV and the energy consumed during swimming. At the point where dV increased, V and the energy spent swimming also increased. For high-efficiency swimming performance, V should be as high as possible and dV should be as low as possible (62, 79).

2.3.3.2 SWIMMING BIOMECHANICS

Swimming is a sportive branch that is difficult to study because it is performed in water and not on land. In research on swimming and swimmers, performance data are recorded using biosensors placed on the body, and studies are conducted by processing the biosignals obtained through biosensors (55). The factors affecting the swimmer's performance depending on the water are explained by Newton’s second law of motion: the net force acting on an object is equal to the product of mass and acceleration (80,81).

Net force acting on the object;

F = Mass.Acceleration (82)

At the beginning of the competition, the swimmer jumping off the starting block has more acceleration, and this high acceleration increases the net force. From the moment the swimmer first contacts the water, the propulsive force (Fp) provided by the extremities is greater than Fd; thus, the swimmer can continue their performance. Fp increases relative to V, and as V increases, Fd also increases (83).

Equality of forces;

Shown as Fp(v) – Fd(v) = Mass.Velocity (82)

When the swimmer reaches a constant velocity, Fd and Fp become equal and the swimmer's acceleration reaches zero. A swimmer's successful performance lies in their ability to effectively reflect Fp in water by minimizing Fd (76).

To achieve laminar progression, the swimmer must place his/her body in an ellipsoidal shape. Water molecules that hit the swimmer's sports equipment or body during swimming return to their current state and mix with the current in accordance with Newton's Laws of Motion. The turbulent flow that occurs as a result of the impact causes a pressure decrease on the contact surface, and molecules accumulate unevenly behind the swimmer (Figure 2.3.3.2 (A)) (80). The irregular flow behind a swimmer is called an eddy current (84). The upper edge of the turbulent flow, which is in contact with the laminar flow, is called the boundary line, and the more ellipsoidal the swimmer, the more homogeneous the boundary becomes. The homogeneity of the borderline also has a positive effect on V (Figure 2.3.3.2 (B)) (80).

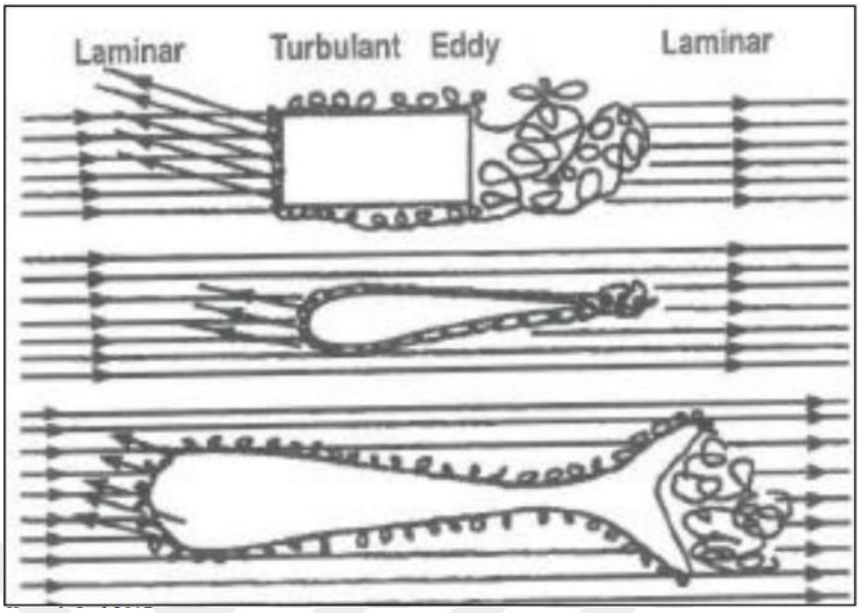


Figure 2.3.3.2 (A) The turbulent flow

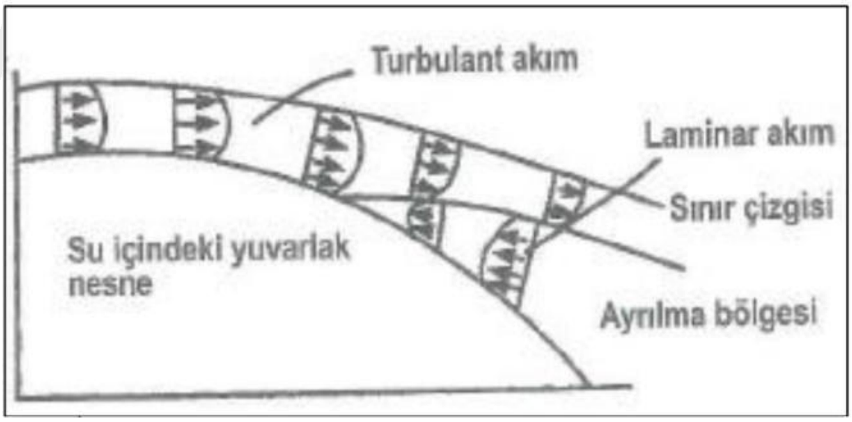


Figure 2.3.3.2 (B) The homogeneity of turbulent flow

2.3.3.2.1 DRAG FORCE

Pioneering studies have shown that reduction in Fd depends on the swimmer's ability to combine a good streamline position with the correct technique (80,82). Studies have found that slender and tall swimmers are more successful at reducing Fd based on their morphological characteristics (85). However, excess body cross-sectional area has no negative effect on swimming performance in swimmers with the same training content (86).

2.3.3.2.2 PROPULSIVE FORCE

Studies on Fp biomechanics were first conducted using theories from 1968 (87). Pushing the water in the caudal direction during the stroke creates a high-pressure area on the ventral side of the hand and a low-pressure area on the dorsum of the hand, creating Fp and progressing in the water (Figure 2.3.3.2.2) (88,89). Performing the stroke by drawing a curved shape, such as the letter S, instead of a straight line, increases the acceleration of Fp (90). The feeling of water gained by increasing experience with training is important for Fp, and one of the most important elements for good competition performance is that the swimmer strokes by feeling water (91). A study of elite swimmers found that the largest hand force occurred on average at 78% of the total stroke time (82).

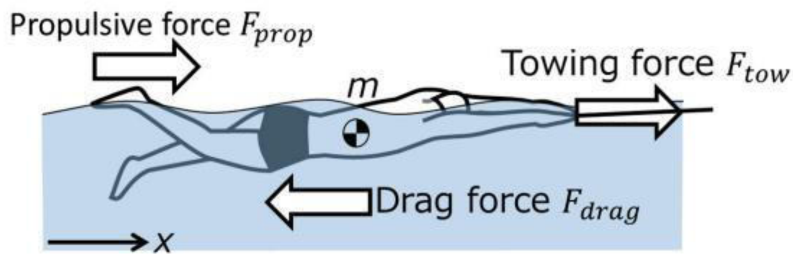


Figure 2.3.3.2.2 Propulsive and other forces during strokes

2.3.3.2.3 FREESTYLE SWIMMING BIOMECHANICS

Since the freestyle swimming technique is the fastest among the four techniques, it is the most preferred technique when measuring time for performance in training (92).

The upper-extremity stroke cycle of this technique consists of five phases (Figure 2.3.3.2.3) (93).

1. **Entry:** Hands enter the water over the head.
2. **Downsweep:** This is the phase where water withdrawal has not yet started and preparation is made.
3. **Insweep:** This is the phase when the water draw reaches the shoulder level.

4. **Outsweep:** In this phase, water is drawn from shoulder level to water level.
5. **Upsweep:** The phase in which the hand is out of the water until the next water entry.

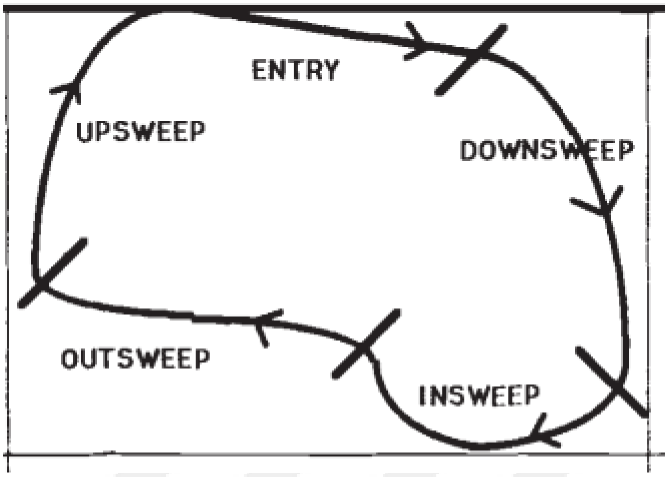


Figure 2.3.3.2.3 The upper extremity stroke cycle of freestyle swimming

In all the techniques, the core acts as a bridge between the lower and upper extremities. In the freestyle swimming technique, the core also allows trunk rotation movements. Throughout the technique, Musculus obliquus externus abdominis, Musculus obliquus internus abdominis, Musculus erector spinae and Musculus multifidi act as agonist muscles in trunk stabilization, flexion, extension, lateral flexion, and rotation (94).

In swimming, the metacarpophalangeal and thumb joints are in an adduction position throughout the entire SC, as the pulls are an important element for progression. The flexor carpi radialis, palmaris longus, flexor carpi ulnaris, flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus muscles serve as agonists for the flexion movement of the wrist, except in the upsweep phase of the SC (94).

2.3.4 SWIMMING PHYSIOLOGY

The performance of a human begins at the cellular level, which means that discussion regarding the physiology of swimming performance must also start at that level. It is important to note that the condition of a swimmer's cells determines the condition of the rest of their bodies. Just as a building's foundation is crucial to its stability, the metabolic processes of a cell are also crucial to a swimmer's ability to perform (95).

At the onset of exercise, the first metabolic pathway provides energy derived from intracellular Adenosinetriphosphate (ATP) and Creatine Phosphate (CP) within the muscle cells. This pathway involves the phosphogens ATP and CP and a single enzyme, creatine kinase, which catalyzes the reaction between the two. A second pathway, referred to as the myokinase system, generates ATP (and an Adenosinemonophosphate (AMP)) from two Adenosinediphosphate (ADP) molecules. It buffers the fall in ATP when energy needs are extreme. Beyond a description of the intermediates and the energetic capacity of the pathway, there is not much to be said about the contribution of immediately available phosphogens. Phosphogen levels increased slightly with training, essentially in proportion to the increase in muscle volume. Estimates of recovery time required for this pathway, given complete exhaustion of the high-energy intermediates, range from early instantaneous to 30s or so (95).

Glycolysis is the second metabolic pathway that metabolizes carbohydrates, and involves 12 enzymes and multiple metabolic intermediates. This pathway breaks down glucose as the fuel substrate, requires no oxygen, and results in the production of ATP and either pyruvate or lactic acid. During prolonged exercise, glycolysis is limited by carbohydrate availability as a source of energy. The carbohydrate substrate is either stored within the muscle cells or transported to the cells via the blood supply. Glucose can be considered a non-oxidative fuel source if the end-products are pyruvate or lactate. Alternatively, glucose can be considered an oxidative fuel source if pyruvate is further metabolized through the Krebs or tricarboxylic acid (TCA) cycle, resulting in the production of oxygen (O), carbon dioxide (CO2), ATP, and heat (95).

In contrast to the other two pathways, aerobic metabolism can continue to produce energy almost indefinitely. It is much more complex than non-oxygen-using pathways and depends on a robust cardiopulmonary system. The TCA cycle exists within the mitochondria rather than within the water-soluble cytosol of the cell. Energy production via this pathway requires oxygen as the final proton and electron acceptor and the electron transport chain (ETC) to phosphorylate ADP. The ETC is located in the inner membrane of the mitochondria. The measurement of oxygen consumption reflects the contribution of this pathway as a source of energy during exercise. The TCA cycle generates nicotinamide adenine dinucleotide + hydrogen (NADH) and carbon dioxide from the available fuel sources, whereas the ETC generates ATP from ADP (by shuttling electrons and protons supplied by NADH) and forms energy, water, and heat as final products. The aerobic pathway begins with Acetyl-coenzyme A (CoA) as the initial substrate. CoA is a cofactor and “universal” acetate carrier. The acetate molecule bound to CoA is formed from metabolic substrates (carbohydrates, proteins, and fats) as follows:

1. Is derived from the 3-carbon pyruvate molecule when decarboxylated by the enzyme pyruvate dehydrogenase
2. Is derived from beta-oxidation of fatty acids
3. The product of deamination or transamination of amino acids.

The function of the TCA cycle can be simplified and described as a pathway involving the production of ATP, CO2, and NADH. The TCA cycle completes the catabolism of glucose, proteins, and fats to simple compounds C02 and water with the assistance of the ETC. The TCA cycle performs the same function for all three primary fuel substrates by catabolizing acetate to COz, ATP, and NADH (95).

3. MATERIAL AND METHODS

3.1. SUBJECTS

This randomized controlled study consisted of 30 master swimmers and was approved by the Yeditepe University Faculty of Health Sciences Ethics Committee (No:202203YO195) (Appendix 1). The study was also registered on ClinicalTrials.gov (NCT05991999). The investigation has been performed following the principles of the Declaration of Helsinki and Good Clinical Practice. The inclusion and exclusion criteria of the study are indicated below.

The inclusion criteria of the study were:

- Participants in the study voluntarily,
- Participants aged 25 to 70,
- Participants must swim at least two days a week.

The exclusion criteria of the study were:

- Presence of chronic disease,
- Participants have undergone surgery in relevant regions in the last 2 years,
- Participants have had injuries in the relevant regions in the last 2 years.

Participants were involved in the study voluntarily. The aim and plan of the study were explained and informed written consent was obtained from each patient (Appendix 2). The study was conducted according to the Declaration of Helsinki. Furthermore, participants were informed they were free to withdraw from the study at any time.

Power analysis was performed to determine the minimum number of participants required for the study using G*Power version 3.1.9.7. According to the results of the power analysis, the number of participants to be included in the study with %95 power with alpha error prob 0.05 and beta 0.05, was determined to be at least 28 individuals.

3.1.1. Flow Chart of the Study Process

The participants were master swimmers who swam in the Yüzme İdman Yurdu Sports Club between January 2023 and March 2023. All swimmers were invited to participate in the study by texting their mobile phones (N=80). We evaluated the eligibility of members who accepted the invitation (n=56). Twenty-six participants were excluded because they did not meet the inclusion criteria. The research group comprised 30 master swimmers. Thirty participants participated in the study in compliance with the inclusion criteria. The participants consisted of master swimmers who trained in their routine and swim for at least two days a week. In the first step, participants were given a brief description of the study's primary purpose, and each swimmer was required to provide an informed online consent form before participating (Appendix 2). Prior to the swimming tests, participants were randomly assigned (using the website tool www.randomizer.org). After they were randomly separated into two groups, each swimmer was informed about the experimental and control groups, whether they were obligated to do so, and how to provide daily feedback to the researchers during the six weeks.

MyotonPRO device measurements were obtained from both groups by applying the myoton device to the same indication point of the two muscles. Tone, Stiffness, Elasticity, Relaxation, Creep values and 800 meter swimming time of the participants were measured and recorded. The exercises have been demonstrated by researchers for three different muscles, and participants have learned about common mistakes they can make at home while doing exercises so that they can avoid them. Additionally, the exercises were sent via video. The experimental group performed exercises every day for 20 seconds, with three sets for both sides. At the end of six weeks, myoton results were obtained from both groups to compare the differences (Figure 3.1.1).

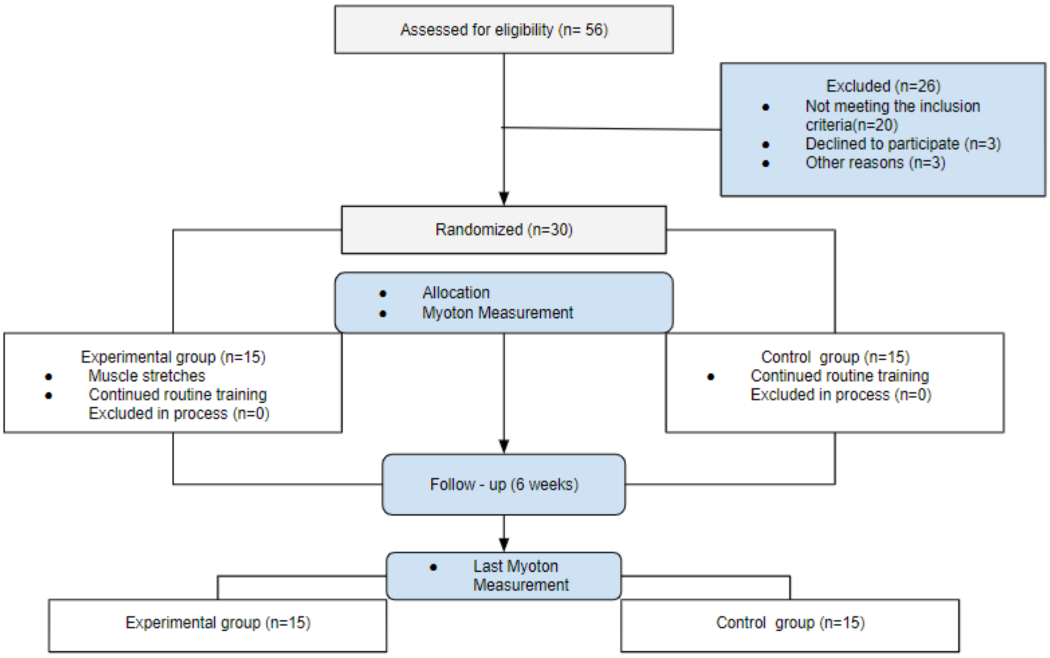


Figure 3.1.1 Flow chart of the study

3.1.2. Study Protocol

The Tone, Stiffness, Elasticity, Relaxation, Creep values of the two muscles were evaluated by measuring them with myoton before the experiment group began their exercises (19). 800-meter swimming performance tests were administered to all swimmers prior to the measurement. Subsequently, the control group just continued their regular training the same as the study group for 6 weeks, while the study group started to do stretch exercises every day for the same amount of time. For both groups, the process lasted for six weeks. At the end of six weeks, performance tests and myoton measurements were performed and analyzed for both groups.

3.2. ASSESSMENT METHODS

3.2.1. Structured Questionnaire

The structured questionnaire prepared by the researcher was sent via Google Forms. The first part of the questionnaire included age, weight, height, body mass index, gender, and chronic diseases to understand the sociodemographic status of the volunteers. In the second part of the questionnaire, swimmers were asked about their history of injury or surgery in the last two years, the sports they do except swimming, how long they have been doing sports, and the frequency of training (Appendix 3).

3.2.2 MyotonPRO Device

The MyotonPRO, which was developed in Tallinn, Estonia, is a device that gives us information about the muscles, tendons, and soft tissues. Understanding the biomechanical features of muscles has recently become more important. The device provides information about the relationship between tonus, elasticity, stiffness, muscle health, and physical condition. The data that the device collected have been given objectively and can be used in the areas of sports rehabilitation, musculoskeletal rehabilitation, neuromuscular control, preventative rehabilitation, etc. (15).

It records the natural oscillations of the muscles, tendons, and soft tissues in the form of an acceleration signal. During the procedure, the tension, viscoelastic properties, and muscle biomechanics were simultaneously recorded. Tissues are classified based on five distinct characteristics: Frequency, Stiffness, Decrement, Relaxation, and Creep. In this study, we use "myoton" to measure the effectiveness of the muscles in all aspects (19).

3.2.2.1 Frequency of Muscle

Muscle tone is determined by the muscle oscillation frequency or frequency of muscle contraction (Hz). The tone of the muscle was evaluated when it was in the resting position. The resting frequency of the device was established at 14.5 Hz. A decrease in muscle regeneration characterizes the inverse relationship between muscle tone and regeneration as muscle tone increases. This decreased regeneration can lead to restricted blood flow and increased intramuscular pressure, causing fatigue and slow muscle regeneration in athletes (116).

3.2.2.2 Stiffness of Muscle

The biomechanical property of a muscle is its stiffness, characterized by its response to contraction or external forces that may cause it to lose its original shape. The concept of dynamic stiffness was created within the program because of the device’s unique application method and technology. The emotional stiffness value for this device was calculated as 250 N/m. When a muscle has high stiffness, it can result in increased energy expenditure during everyday movement (116).

3.2.2.3 Decrement of Muscle

Muscle elasticity is described by a logarithmic reduction in the average amplitude of the tissue. This is related to the dissipation of mechanical energy that arises between the deformation of the tissue and its recovery. It is a biomechanical feature of tissues and is called elasticity. The elasticity of this device was determined to be 1.25. When tissue decrement increases, elasticity decreases. There is an opposite relationship between them (116).

3.2.2.4 Relaxation of Muscle

The Mechanical Stress Relaxation Time (ms) is the duration between displacement from the typical shape of the tissue and its return to its original form. The relaxation value of the device was calculated to be 23.5 ms (116).

3.2.2.5 Creep of Muscle

The creep value for this device was determined to be 1.50, which is the ratio of the deterioration and relaxation times of the tissue in the case of continuous stress, where the tissue regularly stretches over time (116).

3.2.3 800-Meter Swimming Performance Test

We used an 800-meter test to assess the long-term aerobic metabolism performance of athletes. The 800-meter swimming test was performed in freestyle. In the test, the 800-meter swimming times of the participants were measured. The aim was to complete this distance by swimming as soon as possible. Measurements were made in the 40-meter-long pool within the framework of the competition rules without using the jumping stand, with a freestyle swimming technique, and a freestyle flip turn. With the participant starting in the "streamline position," the time on the stopwatch was started, the test was ended with the participant's hand touching the wall, and the time on the stopwatch was recorded as 800 meters of free swimming time. The same procedure was applied twice, with a total interval of six weeks. Measurements taken twice for each participant were recorded as performance test values. During the performance test, the water temperature was measured to be 24 °C, and the air temperature of the test environment was measured to be 26–28 °C. To avoid a negative effect on the test results, the participants were asked not to train for 48 hoursours before the test.

3.3 INTERVENTION

The volunteers who met the inclusion criteria were divided into two groups. The patients were informed about the two different groups, but they were not told which group they belonged to. While the participants in the experimental group performed stretching exercises 7 days a week for 6 weeks, no intervention was performed in the control group.

3.3.1 Sternocleidomastoideus Stretch Exercise

First, we asked the participants to sit in a suitable location. Then, for the left SCM, we instructed him to flex his head laterally to the right, followed by left rotation and extension. We also asked them to stretch their right SCM. We asked the participants to perform each stretch every day of the week, with three repetitions on each side for 20 seconds bilaterally (Figure 3.3.1).

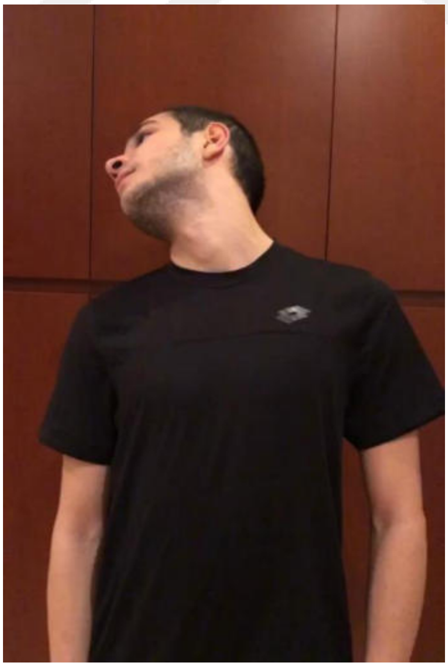


Figure 3.3.1 SCM stretch

3.3.2 Pectoralis Major Stretch Exercise

First, we asked participants to stand in front of a wall. We then placed one hand on the wall to stretch the muscle and asked the participant to push himself forward. We told you not to move your shoulder forward while performing this exercise. We then asked him to repeat this on the other side. We asked the participants to do each stretch every day of the week, with 3 repetitions of each side and 20 seconds bilaterally (Figure 3.3.2).

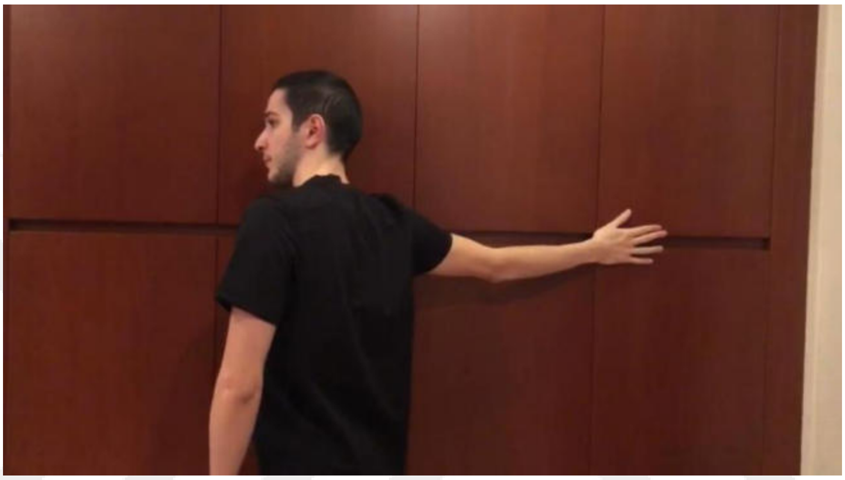


Figure 3.3.2 Pectoralis major stretch

3.3.3 Iliopsoas Stretch Exercise

First, the patient was instructed to stand on the knees. Then, we told her to take one leg forward and stand at 90-90 degrees. In this position, we put her hands on her waist and told her to go forward as far as she could. We asked the participants to do each stretch every day of the week, with 3 repetitions of each side and 20 seconds bilaterally (Figure 3.3.3).

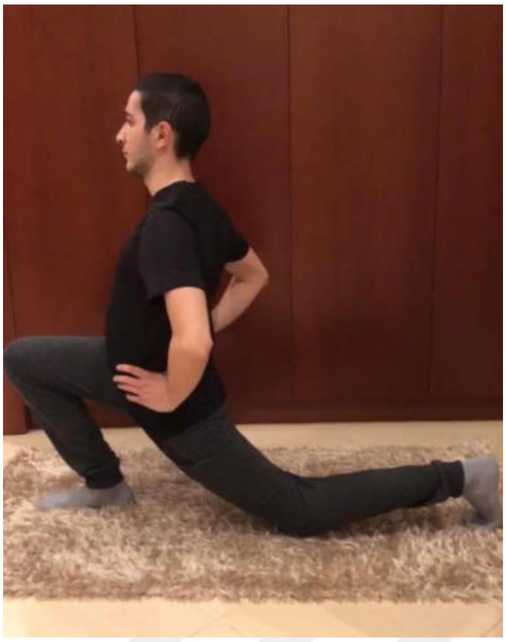
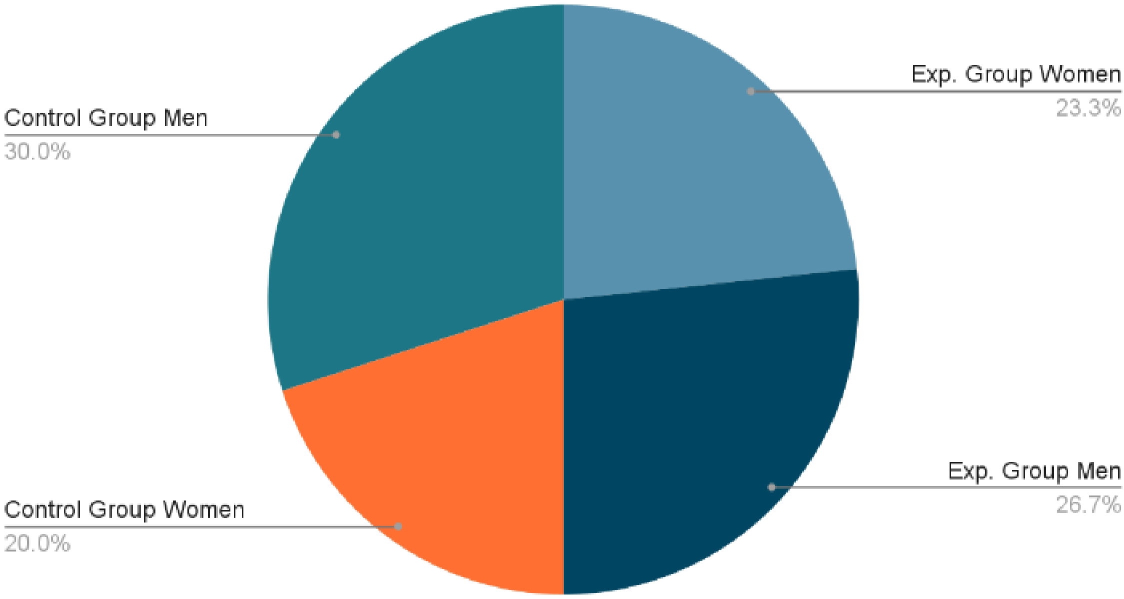


Figure 3.3.3 Iliopsoas stretch

4. RESULTS



4.1. SOCIODEMOGRAPHIC AND BASELINE VARIABLES

Thirty master swimmers (39.03 ± 3.68 age) swimming in Yüzme İdman Yurdu participated in this study. When the two groups were compared, there was no significant difference in terms of basic sociodemographic parameters, age and body mass index (BMI), independent sample t-test or chi-square test results ($p>0.05$) (Table 4.1).

Table 4.1 Comparison of The Baseline Sociodemographic Parameters Between Study Groups

Variables	Experimental Group Mean ± SD	Control Group Mean ± SD	Z	P
Age (years)	38.73 ± 4.09	39.33 ± 3.33	-0.438	0.661
BMI (kg/m²)	23.27 ± 1.34	23.49 ± 1.22	-0.665	0.506

Data expressed as mean ± standard deviation or number (percentage), BMI: Body Mass Index, kg: kilogram, m: meter, kg/m²: kilograms/meter square

An independent sample t-test was used to compare 800-meter degrees and myotone values in the initial study between the two groups. It was shown that there was no statistically significant difference between the data in measurements made from 4 different locations ($p>0.05$) (Table 4.2).

Table 4.2 Comparison of the Results of 800 Meter Degrees and Myotone Values of the Experimental and Control Groups

Variables		Experimental Group	Control Group	Z	P
800 Meter		17.37 ± 3.53	16.29 ± 3.80	-0.684	0.494
SCM Right	**Frequency (Hz)**	11.85 ± 0.86	11.58 ± 0.61	-0.623	0.533
	Stiffness (N/m)	197.80 ± 23.74	196.60 ± 17.58	-0.145	0.884
	Decrement	1.40 ± 0.22	1.37 ± 0.16	-0.457	0.648
	Relaxation (ms)	26.68 ± 2.45	28.12 ± 2.46	-1.142	0.254
	Creep	1.58 ± 0.15	1.68 ± 0.15	-1.287	0.198
SCM Left	**Frequency (Hz)**	12.08 ± 1.72	11.46 ± 0.54	-1.145	0.252
	Stiffness (N/m)	200.13 ± 31.71	196.06 ± 11.47	-0.415	0.678
	Decrement	1.35 ± 0.16	1.31 ± 0.19	-0.830	0.406
	Relaxation (ms)	27.28 ± 3.70	27.87 ± 1.87	-0.041	0.967
	Creep	1.63 ± 0.21	1.64 ± 0.15	-0.561	0.575
Pectoralis Major Right	**Frequency (Hz)**	14.41 ± 1.88	13.68 ± 1.72	-0.975	0.329
	Stiffness (N/m)	244.40 ± 50.28	240.33 ± 35.53	-0.124	0.901
	Decrement	1.31 ± 0.33	1.51 ± 0.41	-1.431	0.152
	Relaxation (ms)	22.34 ± 3.59	23.70 ± 3.74	-0.726	0.468
	Creep	1.34 ± 0.22	1.46 ± 0.23	-1.307	0.191
Pectoralis Major Left	**Frequency (Hz)**	14.88 ± 1.88	14.42 ± 1.88	-0.311	0.756
	Stiffness (N/m)	256.33 ± 32.59	248.00 ± 39.79	-.602	0.547
	Decrement	1.34 ± 0.28	1.50 ± 0.47	-0.477	0.633
	Relaxation (ms)	21.92 ± 3.10	22.65 ± 3.57	-0.228	0.819
	Creep	1.33 ± 0.18	1.32 ± 0.22	-0.851	0.395

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

4.2. CHANGES IN PRIMARY OUTCOMES

A mixed between-subject ANOVA test and Tukey post-hoc were used to analyze within-group changes. In Table 4.3, a statistically significant difference was observed in the 800 meters degrees in the study group after the interventions ($p<0.05$). In Myotone values, a significant difference in relaxation was observed in the measurements made from the left SCM ($p<0.05$) (Table 4.3).

A statistically significant difference was also observed in the control group at 800 meters ($p<0.05$) (Table 4.4). There was no statistically significant difference in Myotone values ($p>0.05$) (Table 4.4).

When the in-group changes of the female participants in the study group were examined, no difference was observed in Myotone values; a statistically significant difference was observed at 800 meters ($p<0.05$) (Table 4.5).

When the in-group changes of the female participants in the control group were examined, no difference was observed in Myotone values; a statistically significant difference was observed at 800 meters ($p<0.05$) (Table 4.6).

When the in-group changes of male participants in the study group were examined, no difference was observed in Myotone values; a statistically significant difference was observed at 800 meters ($p<0.05$) (Table 4.7).

When the in-group changes of male participants in the control group were examined, no difference was observed in Myotone values; a statistically significant difference was observed at 800 meters degrees ($p<0.05$) (Table 4.8).

Table 4.3 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Experimental Group

Variables		Before	After	Z	P
800 Meter		17.37 ± 3.53	16.76 ± 3.30	-3.408	**0.001**
SCM Right	**Frequency (Hz)**	11.85 ± 0.86	12.30 ± 0.92	-1.790	0.073
	Stiffness (N/m)	197.80 ± 23.74	207.46 ± 31.74	-1.847	0.065
	Decrement	1.40 ± 0.22	1.33 ± 0.17	-1.648	0.099
	Relaxation (ms)	26.68 ± 2.45	26.00 ± 2.94	-1.155	0.248
	Creep	1.58 ± 0.15	1.55 ± 0.15	-0.881	0.378
SCM Left	**Frequency (Hz)**	12.08 ± 1.72	12.36 ± 0.95	-1.737	0.082
	Stiffness (N/m)	200.13 ± 31.71	209.33 ± 22.75	-1.644	0.100
	Decrement	1.35 ± 0.16	1.31 ± 0.20	-1.108	0.268
	Relaxation (ms)	27.28 ± 3.70	26.19 ± 2.62	-2.017	**0.044**
	Creep	1.63 ± 0.21	1.57 ± 0.15	-1.962	0.050
Pectoralis Major Right	**Frequency (Hz)**	14.41 ± 1.88	14.31 ± 1.94	-0.220	0.826
	Stiffness (N/m)	244.40 ± 50.28	252.53 ± 36.90	-1.108	0.268
	Decrement	1.31 ± 0.33	1.38 ± 0.28	-1.036	0.300
	Relaxation (ms)	22.34 ± 3.59	22.01 ± 3.91	-0.597	0.551
	Creep	1.34 ± 0.22	1.34 ± 0.23	-0.312	0.755
Pectoralis Major Left	**Frequency (Hz)**	14.88 ± 1.88	14.10 ± 1.28	-1.308	0.191
	Stiffness (N/m)	256.33 ± 32.59	245.80 ± 23.05	-1.413	0.158
	Decrement	1.34 ± 0.28	1.38 ± 0.23	-0.682	0.495
	Relaxation (ms)	21.92 ± 3.10	22.91 ± 2.64	-0.966	0.334
	Creep	1.33 ± 0.18	1.40 ± 0.17	-1.051	0.293

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.4 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Control Group

Variables		Before	After	Z	P
800 Meter		16.29 ± 3.80	15.89 ± 3.67	-3.180	**0.001**
SCM Right	**Frequency (Hz)**	11.58 ± 0.61	11.71 ± 0.86	-0.393	0.695
	Stiffness (N/m)	196.60 ± 17.58	199.06 ± 23.10	-0.455	0.649
	Decrement	1.37 ± 0.165	1.34 ± 0.17	-0.849	0.396
	Relaxation (ms)	28.12 ± 2.46	28.41 ± 2.53	-0.471	0.638
	Creep	1.68 ± 0.15	1.72 ± 0.13	-0.754	0.451
SCM Left	**Frequency (Hz)**	11.46 ± 0.54	11.63 ± 0.59	-1.341	0.180
	Stiffness (N/m)	196.06 ± 11.47	196.93 ± 14.72	-0.085	0.932
	Decrement	1.31 ± 0.19	1.32 ± 0.11	-0.409	0.683
	Relaxation (ms)	27.87 ± 1.87	28.36 ± 2.25	-0.511	0.609
	Creep	1.64 ± 0.15	1.71 ± 0.12	-1.382	0.167
Pectoralis Major Right	**Frequency (Hz)**	13.68 ± 1.72	13.98 ± 1.99	-0.256	0.798
	Stiffness (N/m)	240.33 ± 35.53	249.66 ± 40.06	-1.307	0.191
	Decrement	1.51 ± 0.41	1.48 ± 0.37	-0.171	0.864
	Relaxation (ms)	23.70 ± 3.74	22.63 ± 4.01	-1.224	0.221
	Creep	1.46 ± 0.23	1.38 ± 0.23	-1.728	0.084
Pectoralis Major Left	**Frequency (Hz)**	14.42 ± 1.88	14.08 ± 1.12	-0.841	0.400
	Stiffness (N/m)	248.00 ± 39.79	249.86 ± 30.42	-0.408	0.683
	Decrement	1.50 ± 0.47	1.53 ± 0.40	-0.767	0.443
	Relaxation (ms)	22.65 ± 3.57	22.43 ± 2.74	-0.392	0.695
	Creep	1.32 ± 0.22	1.36 ± 0.16	-1.449	0.147

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.5 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Experimental Group in Female Participants

Variables		Before	After	Z	P
800 Meter		18.18 ± 2.48	17.74 ± 2.64	-2.366	**0.018**
SCM Right	**Frequency (Hz)**	12.01 ± 1.00	12.41 ± 1.08	-1.016	0.310
	Stiffness (N/m)	199.28 ± 34.18	205.42 ± 39.68	-1.014	0.310
	Decrement	1.41 ± 0.31	1.35 ± 0.24	-1.187	0.235
	Relaxation (ms)	26.27 ± 3.09	26.34 ± 3.60	0.000	1.000
	Creep	1.55 ± 0.18	1.57 ± 0.19	-0.169	0.866
SCM Left	**Frequency (Hz)**	12.44 ± 2.48	12.64 ± 1.19	-0.933	0.351
	Stiffness (N/m)	201.71 ± 46.89	211.14 ± 28.70	-1.153	0.249
	Decrement	1.37 ± 0.21	1.32 ± 0.28	-1.185	0.236
	Relaxation (ms)	26.77 ± 5.11	25.72 ± 3.29	-1.183	0.237
	Creep	1.58 ± 0.29	1.54 ± 0.19	-1.101	0.271
Pectoralis Major Right	**Frequency (Hz)**	14.21 ± 2.12	13.67 ± 1.93	-0.676	0.499
	Stiffness (N/m)	232.42 ± 68.02	232.14 ± 34.14	-0.338	0.735
	Decrement	1.19 ± 0.22	1.39 ± 0.15	-1.572	0.116
	Relaxation (ms)	22.68 ± 4.32	24.00 ± 4.25	-0.845	0.398
	Creep	1.34 ± 0.26	1.45 ± 0.25	-1.014	0.310
Pectoralis Major Left	**Frequency (Hz)**	15.47 ± 2.02	14.44 ± 1.70	-1.183	0.237
	Stiffness (N/m)	255.28 ± 44.79	245.57 ± 29.07	-0.676	0.499
	Decrement	1.11 ± 0.16	1.25 ± 0.24	-0.593	0.553
	Relaxation (ms)	21.85 ± 4.27	22.52 ± 3.61	-0.169	0.866
	Creep	1.33 ± 0.25	1.37 ± 0.24	-0.254	0.799

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.6 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Control Group in Female Participants

Variables		Before	After	Z	P
800 Meter		18.15 ± 3.53	17.81 ± 3.54	-2.023	**0.043**
SCM Right	**Frequency (Hz)**	11.58 ± 0.73	11.76 ± 1.18	-0.365	0.715
	Stiffness (N/m)	191.16 ± 22.57	200.66 ± 33.88	-1.214	0.225
	Decrement	1.36 ± 0.16	1.37 ± 0.21	-0.405	0686
	Relaxation (ms)	28.16 ± 2.70	28.45 ± 3.63	-0.544	0.586
	Creep	1.66 ± 0.16	1.72 ± 0.19	-0.674	0.500
SCM Left	**Frequency (Hz)**	11.43 ± 0.70	11.53 ± 0.76	0.000	1.000
	Stiffness (N/m)	194.33 ± 11.91	195.66 ± 21.88	-0.105	0.917
	Decrement	1.41 ± 0.20	1.39 ± 0.12	-0.677	0.498
	Relaxation (ms)	26.93 ± 1.71	28.75 ± 3.20	-1.363	0.173
	Creep	1.60 ± 0.12	1.73 ± 0.18	-1.472	0.141
Pectoralis Major Right	**Frequency (Hz)**	12.991 ± 1.85	14.00 ± 2.63	-1.577	0.115
	Stiffness (N/m)	224.66 ± 37.76	234.33 ± 47.70	-0.734	0.463
	Decrement	1.44 ± 0.34	1.39 ± 0.30	-0.527	0.598
	Relaxation (ms)	26.01 ± 3.81	23.68 ± 5.36	-1.572	0.116
	Creep	1.58 ± 0.25	1.44 ± 0.31	-1.572	0.116
Pectoralis Major Left	**Frequency (Hz)**	14.81 ± 2.79	14.60 ± 1.05	-0.542	0.588
	Stiffness (N/m)	238.83 ± 62.86	235.00 ± 29.25	-0.105	0.917
	Decrement	1.34 ± 0.28	1.35 ± 0.32	-0.105	0.917
	Relaxation (ms)	23.35 ± 5.59	22.35 ± 2.90	-0.135	0.893
	Creep	1.35 ± 0.30	1.34 ± 0.17	-0.943	0.345

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.7 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Experimental Group in Male Participants

Variables		Before	After	Z	P
800 Meter		16.66 ± 4.30	15.90 ± 3.74	-2.521	**0.012**
SCM Right	**Frequency (Hz)**	11.71 ± 0.76	12.20 ± 0.82	-1.185	0.236
	Stiffness (N/m)	196.50 ± 11.01	209.25 ± 25.65	-1.540	0.123
	Decrement	1.40 ± 0.13	1.31 ± 0.11	-1.400	0.161
	Relaxation (ms)	27.05 ± 1.87	25.71 ± 2.44	-1.590	0.112
	Creep	1.61 ± 0.12	1.54 ± 0.13	-1.472	0.141
SCM Left	**Frequency (Hz)**	11.76 ± 0.65	12.11 ± 0.66	-1.278	0.201
	Stiffness (N/m)	198.75 ± 11.00	207.75 ± 17.97	-1.183	0.237
	Decrement	1.33 ± 0.12	1.31 ± 0.14	-0.280	0.779
	Relaxation (ms)	27.73 ± 2.11	26.60 ± 2.01	-1.614	0.106
	Creep	1.67 ± 0.13	1.60 ± 0.11	-1.682	0.092
Pectoralis Major Right	**Frequency (Hz)**	14.58 ± 1.76	14.87 ± 1.88	-0.339	0.735
	Stiffness (N/m)	254.87 ± 28.65	270.37 ± 30.73	-1.192	0.233
	Decrement	1.41 ± 0.39	1.37 ± 0.36	0.000	1.000
	Relaxation (ms)	22.05 ± 3.09	20.27 ± 2.79	-1.893	0.058
	Creep	1.34 ± 0.19	1.24 ± 0.16	-1.612	0.107
Pectoralis Major Left	**Frequency (Hz)**	14.37 ± 1.72	13.81 ± 0.75	-0.986	0.324
	Stiffness (N/m)	257.25 ± 20.07	246.00 ± 18.40	-1.693	0.090
	Decrement	1.54 ± 0.20	1.50 ± 0.15	-0.491	0.623
	Relaxation (ms)	21.97 ± 1.89	23.25 ± 1.57	-1.542	0.123
	Creep	1.34 ± 0.12	1.43 ± 0.09	-1.682	0.092

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.8 In-Group Changes in 800 Meter Degrees and Myotone Values on the Before and After Treatment in Control Group in Male Participants

Variables		Before	After	Z	P
800 Meter		15.06 ± 3.64	14.62 ± 3.35	-2.521	**0.012**
SCM Right	**Frequency (Hz)**	11.57 ± 0.56	11.67 ± 0.65	-0.491	0.624
	Stiffness (N/m)	200.22 ± 13.63	198.00 ± 14.61	-0.423	0.673
	Decrement	1.38 ± 0.17	1.31 ± 0.16	-1.368	0.171
	Relaxation (ms)	28.10 ± 2.46	28.38 ± 1.73	-0.296	0.767
	Creep	1.70 ± 0.15	1.71 ± 0.09	-0.296	0.767
SCM Left	**Frequency (Hz)**	11.48 ± 0.45	11.70 ± 0.49	-1.786	0.074
	Stiffness (N/m)	197.22 ± 11.75	197.77 ± 8.82	0.000	1.000
	Decrement	1.25 ± 0.16	1.27 ± 0.07	-0.830	0.407
	Relaxation (ms)	28.50 ± 1.79	28.10 ± 1.50	-0.593	0.553
	Creep	1.67 ± 0.16	1.70 ± 0.08	-0.350	0.726
Pectoralis Major Right	**Frequency (Hz)**	14.20 ± 1.51	13.97 ± 1.60	-1.007	0.314
	Stiffness (N/m)	250.77 ± 31.79	259.88 ± 33.06	-1.127	0.260
	Decrement	1.55 ± 0.47	1.54 ± 0.42	-0.533	0.594
	Relaxation (ms)	22.15 ± 2.95	21.93 ± 2.97	-0.560	0.575
	Creep	1.39 ± 0.19	1.34 ± 0.17	-0.911	0.362
Pectoralis Major Left	**Frequency (Hz)**	14.15 ± 1.04	13.74 ± 1.08	-0.702	0.483
	Stiffness (N/m)	254.11 ± 14.00	259.77 ± 28.45	-0.981	0.326
	Decrement	1.60 ± 0.56	1.65 ± 0.42	-0.889	0.374
	Relaxation (ms)	22.18 ± 1.50	22.48 ± 2.80	-0.676	0.499
	Creep	1.31 ± 0.16	1.38 ± 0.16	-0.593	0.553

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

When the differences between the control and experimental groups are examined in Table 4.9, there is no statistical difference in 800 meters degrees and Myotone values.

In Table 4.10, when the differences between the control and experimental groups in women are examined, there is no statistical difference in 800 meters degrees and Myotone values.

When the differences between the control and experimental groups in men in Table 4.11 are examined, there is no statistical difference in 800 meters degrees and Myotone values.

Considering the differences between men and women in the study group in Table 4.12, no statistical difference was observed in 800 meters degrees and Myotone values.

Considering the differences between men and women in the control group in Table 4.13, no statistical difference was observed in 800 meters degrees and Myotone values.

Table 4.9 Comparison of 800 Meter Degrees and Myotone Values Between The Experimental and Control Group

Variables		Experimental Group Δ	Control Group Δ	Z	P
800 Meter		0.61 ± 0.55	0.40 ± 0.39	1.471	0.235
SCM Right	**Frequency (Hz)**	0.44 ± 0.86	0.13 ± 0.81	1.050	0.314
	Stiffness (N/m)	9.66 ± 16.73	2.46 ± 15.55	1.489	0.212
	Decrement	0.07 ± 0.15	0.03 ± 0.14	0.597	0.446
	Relaxation (ms)	0.68 ± 2.16	0.28 ± 2.71	1.166	0.289
	Creep	0.02 ± 0.14	0.03 ± 0.17	1.103	0.303
SCM Left	**Frequency (Hz)**	0.28 ± 1.46	0.16 ± 0.42	0.083	0.775
	Stiffness (N/m)	9.20 ± 25.75	0.86 ± 10.79	1.335	0.258
	Decrement	0.03 ± 0.13	0.00 ± 0.13	0.712	0.406
	Relaxation (ms)	1.09 ± 3.01	0.48 ± 2.84	2.180	0.151
	Creep	0.05 ± 0.17	0.06 ± 0.19	3.486	0.072
Pectoralis Major Right	**Frequency (Hz)**	0.10 ± 2.02	0.30 ± 1.50	0.376	0.545
	Stiffness (N/m)	8.13 ± 47.32	9.33 ± 22.13	0.008	0.930
	Decrement	0.07 ± 0.35	0.03 ± 0.28	0.777	0.386
	Relaxation (ms)	0.33 ± 4.08	1.06 ± 2.85	0.325	0.573
	Creep	0.00 ± 0.26	0.08 ± 0.17	1.144	0.294
Pectoralis Major Left	**Frequency (Hz)**	0.78 ± 1.76	0.33 ± 1.96	0.429	0.518
	Stiffness (N/m)	10.53 ± 26.07	1.86 ± 51.12	0.700	0.410
	Decrement	0.04 ± 0.27	0.03 ± 0.28	0.014	0.908
	Relaxation (ms)	0.99 ± 3.65	0.22 ± 4.44	0.666	0.421
	Creep	0.06 ± 0.23	0.04 ± 0.26	0.077	0.784

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.10 Comparison of 800 Meter Degrees and Myotone Values Between The Experimental and Control Group in Female Participants

Variables		Experimental Group Δ	Control Group Δ	Z	P
800 Meter		0.44 ± 0.43	0.34 ± 0.34	0.219	0.649
SCM Right	**Frequency (Hz)**	0.40 ± 0.75	0.18 ± 0.85	0.236	0.637
	Stiffness (N/m)	6.14 ± 16.46	9.50 ± 18.87	0.118	0.738
	Decrement	0.06 ± 0.13	0.01 ± 0.15	0.998	0.339
	Relaxation (ms)	0.07 ± 1.98	0.28 ± 3.21	0.021	0.887
	Creep	0.01 ± 0.14	0.06 ± 0.20	0.227	0.643
SCM Left	**Frequency (Hz)**	0.20 ± 2.10	0.10 ± 0.59	0.013	0.913
	Stiffness (N/m)	9.42 ± 33.36	1.33 ± 13.27	0.308	0.590
	Decrement	0.05 ± 0.12	0.01 ± 0.14	0.334	0.575
	Relaxation (ms)	1.04 ± 4.12	1.81 ± 3.09	1.938	0.191
	Creep	0.04 ± 0.24	0.13 ± 0.17	2.134	0.172
Pectoralis Major Right	**Frequency (Hz)**	0.54 ± 2.28	1.08 ± 1.31	2.356	0.153
	Stiffness (N/m)	0.28 ± 63.09	9.66 ± 20.93	0.135	0.720
	Decrement	0.19 ± 0.34	0.05 ± 0.20	2.453	0.146
	Relaxation (ms)	1.31 ± 4.98	2.33 ± 3.44	2.268	0.160
	Creep	0.11 ± 0.33	0.14 ± 0.19	2.686	0.130
Pectoralis Major Left	**Frequency (Hz)**	1.02 ± 2.27	0.21 ± 2.99	0.308	0.590
	Stiffness (N/m)	9.71 ± 35.87	3.83 ± 74.51	0.035	0.856
	Decrement	0.14 ± 0.30	0.00 ± 0.19	0.878	0.369
	Relaxation (ms)	0.67 ± 5.17	1.00 ± 6.28	0.277	0.609
	Creep	0.04 ± 0.33	0.00 ± 0.37	0.059	0.812

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.11 Comparison of 800 Meter Degrees and Myotone Values Between The Experimental and Control Group in Male Participants

Variables		Experimental Group Δ	Control Group Δ	Z	P
800 Meter		0.76 ± 0.63	0.44 ± 0.43	1.520	0.237
SCM Right	**Frequency (Hz)**	0.48 ± 1.00	0.10 ± 0.82	0.763	0.396
	Stiffness (N/m)	12.75 ± 17.44	2.22 ± 11.78	4.391	0.054
	Decrement	0.08 ± 0.19	0.06 ± 0.14	0.081	0.779
	Relaxation (ms)	1.33 ± 2.21	0.28 ± 2.52	1.966	0.181
	Creep	0.07 ± 0.14	0.01 ± 0.17	1.186	0.293
SCM Left	**Frequency (Hz)**	0.35 ± 0.69	0.21 ± 0.29	0.303	0.590
	Stiffness (N/m)	9.00 ± 19.30	0.55 ± 9.67	1.349	0.264
	Decrement	0.01 ± 0.15	0.01 ± 0.14	0.280	0.605
	Relaxation (ms)	1.13 ± 1.91	0.40 ± 2.43	0.475	0.501
	Creep	0.06 ± 0.09	0.02 ± 0.20	1.464	0.245
Pectoralis Major Right	**Frequency (Hz)**	0.28 ± 1.84	0.22 ± 1.45	0.405	0.534
	Stiffness (N/m)	15.50 ± 30.55	9.11 ± 24.15	0.231	0.637
	Decrement	0.03 ± 0.34	0.01 ± 0.33	0.020	0.890
	Relaxation (ms)	1.77 ± 2.64	0.22 ± 2.19	1.755	0.205
	Creep	0.09 ± 0.16	0.04 ± 0.15	0.360	0.557
Pectoralis Major Left	**Frequency (Hz)**	0.56 ± 1.27	0.41 ± 1.07	0.070	0.795
	Stiffness (N/m)	11.25 ± 15.98	5.66 ± 32.61	1.766	0.204
	Decrement	0.03 ± 0.23	0.05 ± 0.34	0.387	0.543
	Relaxation (ms)	1.27 ± 1.90	0.30 ± 3.03	0.610	0.447
	Creep	0.08 ± 0.12	0.07 ± 0.18	0.039	0.847

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.12 Comparison of 800 Meter Degrees and Myotone Values Between Female and Male Participants in Experimental Group

Variables		Women Δ	Men Δ	Z	P
800 Meter		0.44 ± 0.43	0.76 ± 0.63	1.281	0.278
SCM Right	**Frequency (Hz)**	0.40 ± 0.75	0.48 ± 1.00	0.036	0.853
	Stiffness (N/m)	6.14 ± 16.46	12.75 ± 17.44	0.564	0.466
	Decrement	0.06 ± 0.13	0.08 ± 0.19	0.103	0.753
	Relaxation (ms)	0.07 ± 1.98	1.33 ± 2.21	1.662	0.220
	Creep	0.01 ± 0.14	0.07 ± 0.14	1.431	0.253
SCM Left	**Frequency (Hz)**	0.20 ± 2.10	0.35 ± 0.69	0.037	0.851
	Stiffness (N/m)	9.42 ± 33.36	9.00 ± 19.30	0.001	0.976
	Decrement	0.05 ± 0.12	0.01 ± 0.15	0.290	0.600
	Relaxation (ms)	1.04 ± 4.12	1.13 ± 1.91	0.003	0.954
	Creep	0.04 ± 0.24	0.06 ± 0.09	0.089	0.771
Pectoralis Major Right	**Frequency (Hz)**	0.54 ± 2.28	0.28 ± 1.84	0.609	0.449
	Stiffness (N/m)	0.28 ± 63.09	15.50 ± 30.55	0.398	0.539
	Decrement	0.19 ± 0.34	0.03 ± 0.34	1.755	0.208
	Relaxation (ms)	1.31 ± 4.98	1.77 ± 2.64	2.339	0.150
	Creep	0.11 ± 0.33	0.09 ± 0.16	2.400	0.145
Pectoralis Major Left	**Frequency (Hz)**	1.02 ± 2.27	0.56 ± 1.27	0.248	0.627
	Stiffness (N/m)	9.71 ± 35.87	11.25 ± 15.98	0.012	0.914
	Decrement	0.14 ± 0.30	0.03 ± 0.23	1.522	0.239
	Relaxation (ms)	0.67 ± 5.17	1.27 ± 1.90	0.095	0.763
	Creep	0.04 ± 0.33	0.08 ± 0.12	0.110	0.745

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

Table 4.13 Comparison of 800 Meter Degrees and Myotone Values Between Female and Male in Control Group

Variables		Women Δ	Men Δ	Z	P
800 Meter		0.34 ± 0.34	0.44 ± 0.43	0.229	0.640
SCM Right	**Frequency (Hz)**	0.18 ± 0.85	0.10 ± 0.82	0.035	0.854
	Stiffness (N/m)	9.50 ± 18.87	2.22 ± 11.78	2.223	0.160
	Decrement	0.01 ± 0.15	0.06 ± 0.14	1.156	0.302
	Relaxation (ms)	0.28 ± 3.21	0.28 ± 2.52	0.000	0.997
	Creep	0.06 ± 0.20	0.01 ± 0.17	0.282	0.604
SCM Left	**Frequency (Hz)**	0.10 ± 0.59	0.21 ± 0.29	0.232	0.638
	Stiffness (N/m)	1.33 ± 13.27	0.55 ± 9.67	0.017	0.897
	Decrement	0.01 ± 0.14	0.01 ± 0.14	0.204	0.659
	Relaxation (ms)	1.81 ± 3.09	0.40 ± 2.43	2.414	0.144
	Creep	0.13 ± 0.17	0.02 ± 0.20	1.073	0.319
Pectoralis Major Right	**Frequency (Hz)**	1.08 ± 1.31	0.22 ± 1.45	3.108	0.101
	Stiffness (N/m)	9.66 ± 20.93	9.11 ± 24.15	0.002	0.964
	Decrement	0.05 ± 0.20	0.01 ± 0.33	0.069	0.797
	Relaxation (ms)	2.33 ± 3.44	0.22 ± 2.19	2.133	0.168
	Creep	0.14 ± 0.19	0.04 ± 0.15	1.125	0.308
Pectoralis Major Left	**Frequency (Hz)**	0.21 ± 2.99	0.41 ± 1.07	0.033	0.859
	Stiffness (N/m)	3.83 ± 74.51	5.66 ± 32.61	0.116	0.738
	Decrement	0.00 ± 0.19	0.05 ± 0.34	0.117	0.738
	Relaxation (ms)	1.00 ± 6.28	0.30 ± 3.03	0.292	0.598
	Creep	0.00 ± 0.37	0.07 ± 0.18	0.270	0.612

Data expressed as mean ± standard deviation or number (percentage), SCM: Sternocleidomastoid, Hz: Hertz, N/m: Newton/mass, ms: milliseconds.

5. DISCUSSION

While the effects of stretching exercises on land performance have been studied in several studies, their impact on swimming performance has not been thoroughly examined, especially with master swimmers (97,98,99,100,101).

The main purpose of this study was to investigate the effects of static stretch of the sternocleidomastoid, pectoralis major, and iliopsoas muscles on 800 m swimming performance among master swimmers and to compare these results with the data obtained from the study.

Tate et al. examined swimming performance from an artistic perspective. They Investigated the influence of music on swimming performance and enjoyment using SwiMP3, a device that delivers music via bone conduction. The study found statistically significant improvements in swimming performance times in both 50m and 800m trials with the use of music. However, there was no significant improvement in physical enjoyment. This study suggests that bone-conducted music can positively influence the performance of competitive adult swimmers (102). Apart from the results of these studies, we used stretching for a long time period and measure 800m swimming time to compare the performance results.

Muscle stiffness is a key component of sports performance (103). Some studies have revealed that stretching applications require repetitive muscle contractions. Consequently, it may increase muscle fatigue, which may negatively affect athletic performance (104,105). Another study found a correlation between muscle fatigue and stiffness (106). These two factors were proportional to each other. In terms of health outcomes, competitive swimming has been found to have positive effects on various aspects of master swimmers' health. Potdevin et al. found that compared to the general population, master swimmers involved in national championships have lower rates of obesity, improved lung function, and more favorable scores for various subscales of the 36-Item Short Form Survey (SF-36), a measure of health-related quality of life (107). Stretch exercises can also have a significant effect on master swimmers by reducing unwanted adaptation. One study found that female swimmers with reduced shoulder range of motion (ROM) may experience a decrease in stroke length and increased shoulder load. However, it is important to note that stretching may aggravate shoulder symptoms. Therefore, caution should be exercised when evaluating potential benefits of shoulder elevator stretching. In this study, the age group of master swimmers was 27% of the total participants, and range of motion (ROM), strength, pectoral muscle length, core endurance, and scapular dyskinesis were assessed (108). Another study evaluated the correlation between anaerobic upper-body performance and swimming achievement in the sprint disciplines of high-level swimmers. The participants were 52 swimmers from the Bulgarian Youth National Swimming Team:15 girls with an average age of 15.5 ± 1.46 years and 37 boys with an average age of 15.9 ± 1.29 years. They recorded the official results of the swimmers at 50, 100, and 200 m freestyle events during their main competitions, which were held no later than 2 weeks after the WAnT date. The specialized software they used automatically calculated many basic and derivative parameters, in their study such as Peak Power, Relative Peak Power, Average Power, Relative Average Power, Minimum Power, Relative Minimum Power, Power Drop, Relative Power Drop, Power Drop, Total work. The mean values of all tested parameters, except age, differed significantly between sexes. The WAnT test parameters correlated significantly with swimming achievement, with the highest correlation observed between the average power and 50 m freestyle for both sexes (109). Compared to their study, we found it more appropriate to measure the time duration due to their energy system usage and quantity of swimming. We used 800 m swimming time as the performance criterion. Exercises were administered more frequently, and lower extremity stretch exercises were performed but could not be measured with Myoton because of the depth of the muscle location.

Another study has examined the relationship between age and swimming time. Swimmers 70 years and older, and to compare this relationship to one based on “United States Masters Swimming” swimming times for swimmers of all ages. The age of the swimmers ranged from 19 to 96 years. Swimming times were recorded for 223 swimmers (99 females and 124 males). A total of 487 swimming times were retrieved, including 239 for females and 248 for males. For the portion of the dataset restricted to older swimmers, the ages ranged from 70 to 96 years. Swimming times were recorded for 43 swimmers (16 female and 27 male). A total of 128 swimming times were retrieved, including59 for females and 69 for males. The fastest time were 15.70 minute and slowest was 41.50 minute (110). We invited 80 swimmers; 56 accepted our invitation and volunteered to participate in our study. 30 of them met the inclusion criteria (13 female and 17 male). Unlike the participants in these studies, our participants were individuals aged 25–70 years old.

In a study of Olympic swimmers, researchers compared the variability and progression of performance times of the US and Australian Olympic swimmers in competitions leading up to and including the Olympics. In total, 676 performances were analyzed over a 12-month period, leading up to and including the Olympics. The study period included three major swimming competitions. In the swimming program, there were 13 individual events for both the male and female swimmers. Two swimmers from each nation (USA and Australia) were entered into each event. The freestyle events were 50 m, 100 m, 200 m, 400 m, and 800 m (females only) and 1500 m (males only); there were also two backstroke, breaststroke, and butterfly events over 100 m and 200 m, and 200-m and 400-m individual medley events. Both nations showed similar improvements from heat to finals; the mean for all swimmers was 1.2% (95% confidence limits 1.1 to 1.3%). The improvement averaged over all swimmers was 0.9% (95% confidence limits 0.6 to 1.2%) and was similar for both nations. However, US swimmers showed a greater improvement between the finals of these two competitions than Australian swimmers (a difference of 0.5%; 95% confidence limits 70.2 to 1.1%). Surprisingly, there was little improvement in performance from the finals of the Trials to the finals of the Olympics, although US swimmers made a slightly larger gain (0.2%) than Australians (0.1%). The results of the present study indicate that an improvement of approximately 1.0–1.4 % in performance time for elite swimmers is necessary to account for both progression and variability in the pre-Olympic year (111). Compared to this study, our participants showed a similar result in terms of improvement, but their average age was higher, and the level of performance differed significantly.

This study has some limitations. Limitations were:

- The exercises in this study were not performed in the presence of a physiotherapist; therefore, the study group could not be observed.
- Failure to measure the iliopsoas muscle with the Myoton device despite stretching.
- The pool, which had a length of 20 m, differed from the standard pool.

- The fact that only time was taken as a performance criterion and more detailed biomechanical measurements could not be performed.
- The swimmers were not asked about their sense of performance.

In summary, stretch exercises can have a positive impact on master swimmers by improving their range of motion, performance, and overall health outcomes. In our study, the results did not show any statistically significant difference between the data in measurements made from four different locations, possibly because of the unmeasured but stretched myofascial structures or side effects that occurred but were not found by researchers. Further research is needed to better understand the relationship between longer periods of stretch exercises with higher frequency and structural changes in the body that affect swimming performance, biomechanical basis, and swimming training volume in master swimmers.

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Conflict of interests

The author declares no conflict of interest.

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APPENDIX 1: ETHICAL COMMITTEE APPROVAL

YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No 2.0
13.02.2022
Sayfa 1 / 2

KARAR FORMU

15.03.2022

ETİK KURUL BİLGİLERİ	Etik Kurulun Adı	Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
	Açık Adres	Yeditepe Üniversitesi Kayışdağı Kampüsü, Tıp-Mühendislik Binası, Sağlık Bilimleri Enstitüsü, İnönü Mah. Kayışdağı Cad. 326A, 26 Ağustos Yerleşimi 34755 Ataşehir, İstanbul
	İnternet Sayfası	http://goetik.yeditepe.edu.tr/
	Telefon	0216 578 00 00
	E-posta	goetik@yeditepe.edu.tr

DEĞERLENDİRİLEN BELGELER	Islak imzalı başvuru dosyası, CD'si ve elektronik başvuru	☒
	Araştırma başlığı ve araştırmacıların isimleri	☒
	Başvuru dilekçesi	☒
	Başvuru Formu- Araştırmanın;	☒
	• Niteliği	☒
	• Önemi ve özgün değeri	☒
	• Amaç ve hedefleri	☒
	• Yöntemi	☒
	• Yönetimi	☒
	• Yaygın etkisi	☒
	• Araştırma bütçesi (Mevcutsa)	☒
	• Süresi ve uygunluğu (Zaman cetveli)	☒
	• Kaynakları	☒
	Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)	☒
	Taahhütname-1 Araştırmanın yapılacağı kurumdan izin alma sorumluluğunun araştırmacılara ait olduğuna dair taahhüt	☒
	Taahhütname-2 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt	☒
	Taahhütname-3 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt	☒
	Taahhütname-4 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt	☒
	Taahhütname-5 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt	☒
	Taahhütname-6 Milli Eğitim Bakanlığı Araştırma Uygulama İzinleri konulu yazının okunmasına dair taahhüt	☒
	Araştırmacıların her birisine ait özgeçmiş formu	☒
	Ek belgeler (Varsa kullanılan ölçek izinleri vb.)	☒

KARAR BİLGİLERİ	Başvuru Numarası	202203YO195
	Toplantı Tarihi	11.03.2022
	Toplantı Yeri	Çevirim içi (Google Meet)
	Karar No	10

Araştırmanın Başlığı	Pektoralis majör, Sternokleidomastoid ve İliopsoas kaslarının gerilmesinin master yüzücülerde 800 metre yüzme performansı üzerine etkisi
Araştırmacılar	Fzt.Şafak ÖZSÖNMEZ,Dr.Öğr.Üyesi Feyza Şule BADILLI HANTAL,Dr.Öğr.Üyesi Elif DEVELİ

BAŞVURU NUMARASI: 202203YO195

15.03.2022

KARAR

☒ **KABUL**	☐ **RET** ☐ *KAPSAM DIŞI (GİRİŞİMSEL)* ☐ *BİLİMSEL VE/VEYA ETİK KURALLARA AYKIRI* ☐ *BİR SORUMLU ARAŞTIRMACININ (TEZ İSE DANIŞMAN), BİR TOPLANTIYA* ***İKİ (2) ADETTEN FAZLA ÇALIŞMA BAŞVURUSUNDA*** *BULUNMASI* ☐ *KURUM İÇİ BAŞVURULARINDA* ***KURUMSAL E-POSTA HESABI*** *İLE GİRİŞ YAPILMAMIŞ OLMASI* ☐ *ŞARTLI KABULDE BELİRTİLEN REVİZYONLARIN ZAMANINDA VE/VEYA İSTENİLDİĞİ ŞEKİLDE YAPILMAMIŞ OLMASI*

Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu adına
Prof.Dr.Didem Özdemir ÖZENEN
Başkan

Araştırmanın Başlığı	Pektoralis majör, Sternokleidomastoid ve İliopsoas kaslarının gerilmesinin master yüzücülerde 800 metre yüzme performansı üzerine etkisi
Araştırmacılar	Fzt.Şafak ÖZSÖNMEZ,Dr.Öğr.Üyesi Feyza Şule BADILLI HANTAL,Dr.Öğr.Üyesi Elif DEVELİ

APPENDIX 2: INFORMED WRITTEN CONSENT

YEDİTEPE ÜNİVERSİTESİ

EK 1. BİLGİLENDİRİLMİŞ OLUR FORMU

Araştırmanın Adı: Pektoralis majör, Sternokleidomastoid ve İliopsoas kaslarının gerilmesinin master yüzücülerde 800 metre yüzme performansı üzerine etkisi.

Sayın Katılımcı,

Yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunmaktasınız. Çalışmaya katılıp katılmama kararı tamamen size aittir. Katılmak isteyip istemediğinize karar vermeden önce araştırmanın neden yapıldığını, bilgilerinizin nasıl kullanılacağını, çalışmanın neler içerdiğini, olası yararları ve risklerini ya da rahatsızlık verebilecek yönlerini anlamanız önemlidir. Lütfen aşağıdaki bilgileri dikkatlice okumak için zaman ayırınız. Sorularınız olursa sorunuz ve açık yanıtlar isteyiniz.

Bu araştırma ile germe egzersizlerinin 800 metre serbest stil yüzme performansı üzerine etkisinin araştırılması amaçlanmıştır. 800 metre süre alımı kronometre ile yapılacaktır. Ek olarak sizlerin fiziksel aktivite düzeyinizi belirlemek ve eski yaralanma ya da ameliyat geçmişinizi öğrenmek amacıyla belirlediğimiz anketleri doldurmanız istenecektir. Araştırma için Yeditepe Üniversitesi'nden izin alınmıştır. Araştırmaya sizin dışınızda 27 kişi katılacaktır. Sizden bu çalışmaya 6 hafta (haftada her gün 6 dakika) ayırmanız istenecektir. Bunun size ve yakınlarınıza hiçbir zararı olmayacaktır. Çalışmaya katılmakta parasal yük altına girmeyeceksiniz ve size de herhangi bir ödeme yapılmayacaktır.

Bu araştırmaya katılıp katılmamakta tümüyle özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Araştırmaya katılmayı istemezseniz burada size verilen hizmet olumu veya olumsuz şekilde etkilenmeyecektir. Gerekli gördüğü takdirde araştırmanın herhangi bir kısmında katılımcı araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir, gizlilik kurallarına uyulmak kaydıyla sunulabilir ve yayınlanabilir.

Araştırma ile ilgili daha fazla bilgiye ihtiyaç duyarsanız araştırma yürütücüsüne numaralı telefondan

Yukarıda yer alan ve araştırmaya başlanmadan önce katılımcılara verilmesi gereken bilgileri içeren metni okudum (ya da sözlü dinledim). Araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uymak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim.

Katılımcı;	Araştırma Yürütücüsü;
İmza/Tarih:	İmza/Tarih:
Adı-Soyadı:	Adı-Soyadı:
Adres:	Adres:
Telefon No:	Telefon No:

Tanık:

İmza/Tarih:	Ad-Soyadı:
Adres:	Telefon No:

APPENDIX 3: STRUCTURED QUESTIONNAIRE

DEMOGRAFİK DEĞERLENDİRME FORMU

Tarih: …../…../20…..

1. Ad Soyad:
2. Telefon:
3. Doğum Tarihi:
4. Cinsiyet: ( ) Kadın ( ) Erkek
5. Boy (cm): ....
6. Kilo (kg): ....
7. BKI (kg)/m²): ....
8. Kronik bir hastalığınız var mı? ( ) Var ( ) Yok
9. Kronik bir hastalığınız varsa lütfen belirtiniz…………………………..........................
10. Son 2 yıl içerisinde aşağıdaki bölgelerden geçirilmiş herhangi bir yaralanma öykünüz var mı? (Birden fazla şık seçebilirsiniz.)

( ) Boyun

( ) Omuz

( ) Gövde

( ) Kalça

( ) Diz

( ) Ayak

( ) Ayak bileği

( ) Yaralanma öyküm yok

11. Lütfen yaralanma öykünüzü/öykülerinizi kısaca açıklayınız.

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

12. Son 2 yıl içerisinde aşağıdaki bölgelerden geçirilmiş herhangi bir ameliyat öykünüz varsa lütfen işaretleyiniz. (Birden fazla şık seçebilirsiniz.)

( ) Boyun

( ) Omuz

( ) Gövde

( ) Kalça

( ) Diz

( ) Ayak

( ) Ayak bileği

( ) Ameliyat öyküm yok

13. Lütfen ameliyat öykünüzü/öykülerinizi kısaca açıklayınız.

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

14. Düzenli yaptığınız spor var mı? ( ) Evet ( ) Hayır

15. Lütfen düzenli yaptığınız sporun adını belirtiniz………………………….

16. Kaç senedir bu sporu yapmaktasınız?

( ) 1 yıldan az.

( ) 1-1.5 yıldır

( ) 1.5-2 yıldır.

( ) 2-2.5 yıldır.

( ) 2.5-3 yıldır.

( ) 3 yıldan fazla.

17. Haftalık antrenman sıklığınız nedir?

( ) 1 gün/hafta

( ) 2 -3 gün/haftada

( ) 4-5 gün/hafta

( ) Haftada 5 günden fazla.

( ) ……gün/haftada çift antrenman yapıyorum.

18. Yaptığınız antrenman ortalama kaç dakika sürüyor?

( ) 30 – 60 dk.

( ) 60 – 90 dk.

( ) 90 – 120 dk.

( ) 120 dk.'den fazla.

APPENDIX 4: CURRICULUM VITAE

Kişisel Bilgiler

Adı	Şafak	**Soyadı**	Özsönmez

Oğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora			
Yüksek Lisans			
Lisans	Fizyoterapi ve Rehabilitasyon	**Yeditepe Üniversitesi**	2020
Lise	Matematik-Fen	**Fen Bilimleri Temel Anadolu Lisesi**	2016

Bildiği Yabancı Dilleri	**Seviye**
Ingilizce	Çok iyi

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	**Süre (Yıl - Yıl)**
Fizyoterapist	LifeOn Concept	2020 - 2023

Bilgisayar Bilgisi

Program	**Kullanma becerisi**
Microsoft Office	Iyi

*Çok iyi, iyi, orta, zayıf olarak değerlendirin

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

Diğer dergilerde yayınlanan makaleler

Uluslararası bilimsel toplantılarda sunulan ve bildiri kitabında (*Proceedings*) basılan bildiriler

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)
