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EXERCISE & HEALTH

“The development of Aquaticity through water game activities in school children”

by

Danae Varveri MSc

Supervisory Team:
Giorgos K. Sakkas PhD
Christina Karatzaferi PhD
Elizana Pollatou PhD

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“Some people love the ocean. Some people fear it. I love it, hate it, fear it, respect it, resent it, cherish it, loathe it, and frequently curse it. It brings out the best in me and sometimes the worst.”

Roz Savage

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While my name may be alone on the front cover of this thesis, I am by no means its sole contributor. Rather, there are a number of people behind this piece of work who deserve to be both acknowledged and thanked here: committed and generous supervisors; kind participants; inspiring aquatic athletes, patient friends and most of all fantastically supportive children.

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'This PhD study is dedicated to all who love and respect the water element'.

Danae

Abstract

Introduction: This PhD thesis is an integrated approach to 'Human Aquaticity'. Until recently the term has been used empirically among swimmers and aquatic coaches, to describe how 'comfortable', 'efficient', or 'successful' an athlete interacts with the water element while in free diving, aquaticity often refers to the diver's ability to achieve amazing depths and mental focus underwater. To the best of our knowledge, a part of this thesis there were no scientific evidence or reports that deal with the aspect of 'Human Aquaticity'.

Aims: The aims of the current PhD research project were to define the term "Aquaticity", to develop a test for assessing the levels of aquaticity in humans and to investigate whether aquaticity could be improved by implementing an intervention training program.

Study Design and Methods: The current thesis is composed of three studies:

<u>Study 1</u>: The aim of the first study was to define the term "aquaticity", present the factors that describe it and reveal the form in which it presents itself in today's society, in order to become a distinct scientific field of study. A systematic review of the literature has been conducted using anecdotal reports from the internet and forums as well as scientific articles and books from databases on issues related to aquatic sports.

<u>Study 2</u>: The second study aimed to develop a scientific instrument to evaluate aquaticity levels in humans. We developed and validated an aquaticity assessment test (AAT) for the evaluation of human physical adequacy in the water. Forty-six volunteers (25M/21F; 20±8 years,) participated and performed 10 easy-to-administer and practical aquatic tasks. Group A was formed by 36 elite athletes (M/F 20/16, 24.7±10yrs) from two sports categories depending on their affinity to the water environment: terrestrial (wrestling, cycling, dancing) and aquatic (swimming, synchronized swimming, free diving) sports. Group B was formed by 10 non-athlete participants (5M/5F, 14.4±1.4yrs) and was assessed by two independent evaluators. Participants in Group A performed the aquatic tasks once to develop the final AAT items and cutoffs. Participants in Group B performed the aquatic tasks twice on different days to assess repeatability.

<u>Study 3</u>: The aim of the 3rd study was to assess whether aquaticity levels could be improved by the implementation of a specific to aquaticity training program compared

to the classical swimming training used in all aquatic sports. Twenty high school students (8M/12F, 16.5±0.7) participated in the study after obtaining parental consent. Participants were screened for their aquaticity levels using the Aquaticity Assessment Test (AAT) and were randomly divided into two groups: Group A was the “Swimming” intervention group (4M/6F, 16.3±0.8) and completed a classical swimming training program, while Group B was the “Aquaticity” intervention group (4M/6F, 16.8±0.5) and completed the aquaticity intervention program. Both interventions lasted for two months (3 workouts/ per week, lasting 60 min per session) while participants assessed before and after the training period using the same set up and evaluators.

Results: In the current PhD thesis all 3 aims were achieved.

Study 1: For study 1, the proposed definition of the term aquaticity was *“Aquaticity is the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. The level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element. The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water’’*. The development of knowledge regarding the aquatic environment leads humans to an improved state of aquaticity. The study showed four components of human aquaticity: 1) Physical conditioning, optimization of swimming technique; 2) Psychological and emotional conditioning; 3) Breath-hold capacity (apnea) and diving ability; and 4) Anthropometric characteristics.

Study 2: The second study demonstrated, that AAT differentiated successfully all the aquatic from the terrestrial sports’ participants, as well as identified participants with high (≥43.3), medium (from 23.8 to 43.2) and low (≤23.7) aquaticity levels and therefore low physical adequacy in the water (and increased risk). Further repeatability and reliability analyses showed that the AAT is repeatable and reliable with a very small margin of error between different measurement’s days and different examiners. The AAT was composed of 10 tasks related to the four recognized components of human aquaticity. Each task can be graded from 0 to 5 (with 0.5 step increments) with the later score implying excellent performance in the particular task. The highest overall score that can be achieved by a single person is 50 points.

Study 3: In the third study, data showed that Aquaticity score was increased in both groups by 13% and 27% in Group A and Group B respectively ($p<0.01$). The magnitude of change in aquaticity score was 2 folds higher in the Group B compared to Group A (p=0.001) while the Group A (swimming), improved significantly the 7 out of 10 tasks of the AAT compared the pre values ($p<0.05$) and Group B (aquaticity) improved significantly 10 out of 10. Delta changes between the two groups was statistically significant in 5 out of 10 tasks (tasks 2, 3, 7, 9, 10) implying again higher magnitude of improvements in the aquaticity intervention group compare to swimming group.

Discussion: Throughout the PhD thesis, it has been demonstrated scientifically, that "Aquaticity" is a distinct scientific field of study and would allow its assessment as another parameter of human performance. The Aquaticity Assessment Test (AAT) is the first available validated test to assess a human's aquaticity levels and contains tasks that can be performed easily by everybody independently from fitness level or existing familiarity to the water. It seems that aquaticity can be trained and improved not only by classical swimming training but significantly more by specific aquaticity training. Aquaticity training is effective and easy to implement in any participant while could be an alternative way of exercise that prepares athletes for all aquatic sport as well as people that need to reach a specific level of aquaticity in order to participate in certain type of aquatic activities. Future research is needed in order to assess whether the levels of aquaticity could be used as prognostic risk factor for people prone to drown accidents.

Περίληψη

Εισαγωγή: Αυτή η διδακτορική διατριβή αποτελεί μια ολοκληρωμένη προσέγγιση για το θέμα της «Ανθρώπινης Υδροβιότητας». Μέχρι πρόσφατα, ο όρος υδροβιότητα χρησιμοποιούταν εμπειρικά, από κολυμβητές και προπονητές του υγρού στίβου και των θαλάσσιων αθλημάτων για να περιγράψουν χαρακτηριστικά όπως «άνεση» «απόδοση», «πλευστότητα» και «ηρεμία» μέσα στο νερό ενώ για τους ελεύθερους δύτες ο όρος «υδροβιότητα» αναφέρεται στην ικανότητα του δύτη να καταδυθεί σε μεγάλο βάθος και να έχει ψυχική ηρεμία και συγκέντρωση την ώρα της προσπάθειας. Εκτός από την παρούσα μεταπτυχιακή διατριβή, δεν υπάρχουν άλλα επιστημονικά στοιχεία και άρθρα που να εξετάζουν το θέμα της ανθρώπινης υδροβιότητας.

Σκοποί: Οι σκοποί της παρούσας διδακτορικής διατριβής ήταν, να προσδιορισθεί ο όρος " Υδροβιότητα ", να αναπτυχθεί ένα τεστ για την αξιολόγηση των επιπέδων υδροβιότητας στους ανθρώπους και να διερευνηθεί κατά πόσον η υδροβιότητα, μπορεί να βελτιωθεί με την εφαρμογή ενός προγράμματος παρέμβασης.

Σχεδιασμός Μελέτης και Μέθοδοι Έρευνας : Η παρούσα διατριβή αποτελείται από τρεις επιμέρους μελέτες:

<u>Μελέτη 1:</u> Ο σκοπός της πρώτης μελέτης ήταν να προσδιορίσει τον όρο "Υδροβιότητα", να παρουσιάσει τους παράγοντες που την περιγράφουν και να αποκαλύψει τη μορφή με την οποία παρουσιάζεται στη σημερινή κοινωνία, προκειμένου να αποτελέσει έναν ξεχωριστό επιστημονικό κλάδο έρευνας της ανθρώπινης απόδοσης. Διεξήχθη μια συστηματική ανασκόπηση της βιβλιογραφίας με τη χρήση αναφορών από το διαδίκτυο και τα φόρουμ, καθώς και από επιστημονικά άρθρα και βιβλία από τις βάσεις δεδομένων για θέματα που σχετίζονται με τα θαλάσσια σπορ και τον υγρό στίβο.

<u>Μελέτη 2</u> : Η δεύτερη μελέτη είχε στόχο να αναπτύξει ένα επιστημονικό εργαλείο για την αξιολόγηση των επιπέδων υδροβιότητας στον άνθρωπο. Σε αυτή την έρευνα συμμετείχαν σαράντα έξι εθελοντές (25M / 21F ? 20 ± 8 έτη), οι οποίοι εκτέλεσαν 10 υδρόβιες δοκιμασίες. Η Ομάδα Α αποτελούνταν από 36 αθλητές (Α/Θ 20/16 , 24.7 ± 10χρόνια) από δύο κατηγορίες αθλημάτων - ανάλογα με τη συγγένειά τους με το υδάτινο περιβάλλον: αθλήματα ξηράς (πάλη, ποδηλασία, χορός) και τα υδρόβια (κολύμβηση, συγχρονισμένη κολύμβηση, ελεύθερη κατάδυση).

Την Ομάδα Β αποτελούσαν 10 συμμετέχοντες, που δεν ήταν αθλητές (5Α/5Θ, 14,4 ± 1.4χρόνια) και αξιολογήθηκαν από δύο ανεξάρτητους εξεταστές. Οι συμμετέχοντες στην Ομάδα Α αξιολογήθηκαν μία φορά για να αναπτύξουν τα τελικά στοιχεία του τεστ (ΑΑΤ) ενώ οι συμμετέχοντες στην Ομάδα Β εκτέλεσαν το τεστ δύο φορές σε δύο διαφορετικές ημέρες για την αξιολόγηση της επαναληψιμότητας της μεθόδου.

Μελέτη 3: Ο σκοπός της 3ης μελέτης ήταν να αξιολογήσει εάν το επίπεδο της υδροβιότητας μπορεί να βελτιωθεί. Αυτό πραγματοποιήθηκε με την εφαρμογή ενός πρωτοποριακού προγράμματος παρέμβασης, εξειδικευμένο για την ανάπτυξη της Υδροβιότητας, σε σύγκριση με ένα πρόγραμμα κλασσικής κολύμβησης. Είκοσι μαθητές γυμνασίου (8Α/12Θ, 16.5 ± 0.7χρόνια) συμμετείχαν στη μελέτη μετά από γονική συναίνεση. Οι συμμετέχοντες αξιολογήθηκαν για τα επίπεδα υδροβιότητας τους - χρησιμοποιώντας το τεστ αξιολόγησης (ΑΑΤ) και χωρίστηκαν τυχαία σε δύο ομάδες: Η πρώτη ομάδα παρέμβασης, ήταν η ομάδα της κολύμβησης (Ομάδα Α- Κολύμβηση) (4Α/6Θ, 16,3 ± 0,8χρόνια) και ολοκλήρωσε ένα πρόγραμμα κλασσικής κολύμβησης ενώ η δεύτερη ομάδα, ήταν η ομάδα της υδροβιότητας (Ομάδα Β- Υδροβιότητα) (4Α/6Θ, 16,8 ± 0,5χρόνια) και ολοκλήρωσε το πρόγραμμα ανάπτυξης της Υδροβιότητας. Και οι δύο παρεμβάσεις είχαν διάρκεια δύο μήνες (3 προπονήσεις /εβδομάδα, διάρκειας 60 λεπτών ανά συνεδρία), ενώ οι συμμετέχοντες αξιολογήθηκαν πριν και μετά την περίοδο παρέμβασης, χρησιμοποιώντας το ίδιο πρωτόκολλο αξιολόγησης.

Αποτελέσματα : Στην παρούσα διδακτορική διατριβή επιτεύχθηκαν όλοι οι στόχοι.

Μελέτη 1: Σύμφωνα με την πρώτη μελέτη, ο προτεινόμενος ορισμός του όρου υδροβιότητα είναι « Η Υδροβιότητα, είναι η ικανότητα ενός χερσαίου οργανισμού να μπορεί να λειτουργήσει και να εξοικειωθεί στο υδάτινο περιβάλλον. Το επίπεδο της υδροβιότητας εξαρτάται από την ψυχική και σωματική κατάσταση του ανθρώπου και μπορεί να βελτιωθεί με την συχνή έκθεση στο υγρό στοιχείο. Το ιδανικό/μέγιστο επίπεδο της υδροβιότητας επιτυγχάνεται με την ενεργοποίηση του καταδυτικού αντανακλαστικού, όταν το ανθρώπινο σώμα είναι εντελώς βυθισμένο στο νερό". Η ανάπτυξη των γνώσεων σχετικά με το υδάτινο περιβάλλον οδηγεί τους ανθρώπους σε ένα ανεπτυγμένο επίπεδο Υδροβιότητας. Η μελέτη έδειξε τέσσερις παράγοντες που παίζουν καθοριστικό ρόλο στην ανθρώπινη Υδροβιότητα: 1) φυσική επάρκεια στο νερό –βέλτιστη κολυμβητική τεχνική, 2) ψυχολογική και συναισθηματική κατάσταση, 3) ικανότητα άπνοιας και κατάδυσης και 4) ανθρωπομετρικά χαρακτηριστικά.

Μελέτη 2: Η δεύτερη μελέτη κατέδειξε ότι το εργαλείο αξιολόγησης της Υδροβιότητας (AAT), μπορεί να ξεχωρίσει με επιτυχία τους συμμετέχοντες από τα αθλήματα της ξηράς με εκείνους από τα αθλήματα του νερού. Επίσης μπορεί να προσδιορίσει το επίπεδο Υδροβιότητας σε υψηλό (≥43.3), μέσο (23,8 έως 43,2) και χαμηλό (≤23.7). Το χαμηλό επίπεδο αποδεικνύει τη χαμηλή σωματική επάρκεια στο νερό και ως εκ τούτου αυξημένο κίνδυνο για ατυχήματα πνιγμού. Περαιτέρω, οι αναλύσεις για την επαναληψιμότητα και την αξιοπιστία του τεστ (AAT), έδειξαν ότι το τεστ αποτελεί ένα αξιόπιστο εργαλείο καθώς υπήρξε μόνο ένα πολύ μικρό περιθώριο σφάλματος μεταξύ των διαφορετικών εξεταστών και ημερών αξιολόγησης. Το τεστ Υδροβιότητας (AAT) αποτελείται από 10 δοκιμασίες που σχετίζονται με τις τέσσερις αναγνωρισμένες συνιστώσες της ανθρώπινης υδροβιότητας. Κάθε δοκιμασία μπορεί να βαθμολογηθεί από 0-5 (με προσαυξήσεις 0,5 ανά βήμα). Η υψηλότερη συνολική βαθμολογία που μπορεί να επιτευχθεί από ένα εξεταζόμενο είναι οι 50 μονάδες (μονάδες υδροβιότητας).

Μελέτη 3: Στην τρίτη μελέτη, τα δεδομένα έδειξαν ότι το επίπεδο υδροβιότητας, αυξήθηκε και στις δύο ομάδες κατά 13 % και 27 % στην ομάδα Α (κολύμβηση) και ομάδα Β (υδροβιότητα) αντίστοιχα ($p<0,01$). Το μέγεθος όμως της βελτίωσης στη βαθμολογία της Υδροβιότητας ήταν 2 φορές υψηλότερη στην ομάδα Β σε σύγκριση με την Α ομάδα ($p = 0,001$). Επίσης η Ομάδα Α, βελτίωσε σημαντικά τις 7 από τις 10 δοκιμασίες του τεστ σε σύγκριση με τις αρχικές τιμές ($p < 0,05$) και η Ομάδα Β βελτιώθηκε σημαντικά 10 στις 10 δοκιμασίες. Οι διαφορές στα επίπεδα βελτίωσης μεταξύ των δύο ομάδων ήταν στατιστικά σημαντική σε 5 από τις 10 δοκιμασίες (δοκιμασίες 2,3,7,9,10) που σημαίνει και πάλι υψηλότερο μέγεθος των βελτιώσεων στην ομάδα υδροβιότητας σε σύγκριση με την ομάδα κολύμβησης.

Συζήτηση: Κατά τη διάρκεια της παρούσας διδακτορικής διατριβής, προσπαθήσαμε να αποδείξουμε επιστημονικά ότι η «Υδροβιότητα» αποτελεί ένα ξεχωριστό επιστημονικό πεδίο μελέτης και αποτελεί μια ακόμη παράμετρο της ανθρώπινης απόδοσης. Το τεστ της Υδροβιότητας (AAT) αποτελεί το πρώτο επιστημονικό εργαλείο για την αξιολόγηση των επιπέδων της ανθρώπινης υδροβιότητας και αποτελείται από εύκολες δοκιμασίες που μπορούν να εκτελεστούν από τον καθένα, ανεξάρτητα από το επίπεδο της φυσικής κατάστασης ή την εξοικείωσή του με το νερό. Φαίνεται ότι η Υδροβιότητα μπορεί να προπονηθεί και να βελτιωθεί όχι μόνο από ένα πρόγραμμα της κλασικής κολύμβησης αλλά σημαντικά περισσότερο από ένα εξειδικευμένο πρόγραμμα Υδροβιότητας. Το πρόγραμμα Υδροβιότητας. είναι αποτελεσματικό και εύκολο να εφαρμοστεί σε κάθε συμμετέχοντα, ενώ θα μπορούσε να είναι ένας εναλλακτικός τρόπος άσκησης που προετοιμάζει αθλητές για όλα τα υδρόβια αθλήματα. Μελλοντική έρευνα είναι αναγκαία προκειμένου να εκτιμηθεί κατά πόσον τα επίπεδα της υδροβιότητας θα μπορούσαν να χρησιμοποιηθούν ως προγνωστικός παράγοντας κινδύνου σε περιπτώσεις αποφυγής πνιγμών και άλλων ατυχημάτων που σχετίζονται με το υγρό στοιχείο.

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AAT	Aquaticity Assessment Test	21
AAH	Aquatic Ape Hypothesis	30
AIDA	Association Internationale pour le Development de l’Apnee	63
CMAS	World Confederation of Underwater Activities	63
PADI	Professional Association of diving Instructors	67
M/F	Males/Females	93
AU	Aquaticity Units	105

Introduction

Since time immemorial, humans have been attracted by water. We are inspired by the sea, hearing it, smelling it in the air, playing in it, walking next to it, painting it, surfing, swimming or diving in it and creating arts and lasting memories along its edge. Indeed, throughout history, we can see our deep connection to water described in art, sport, science and poetry. Water can give us energy, whether it's hydraulic, hydration, the tonic effect of cold water splashed on the face, or the mental refreshment that comes from the gentle, rhythmic sensation of hearing waves lapping a shore. Immersion in warm water has been used for millennia to restore the body as well as the mind.

Moreover, human survival depends on water's unique chemical and physical properties, since without it basic physical processes would be impossible. Human cells need water to survive, while none of the essential physical functions, such as breathing, digestion, or muscle movement could take place without water. Most importantly, 70 percent of the human body is made up of water. When it comes to human babies, it is known that a three-day old fetus is 97% water, while at eight months the fetus is 81% water. At the same time, more than 70 percent of Earth is covered in water, since ocean water covers nearly a great percent of its surface and fresh waters in lakes and rivers cover less than 1%. Water on Earth occurs as liquid, ice and gas making water an element that sustains and nurtures plants, animals and humans. Water makes Earth, "the water planet", a perfect match for life in general [1].

But Water, not only sustains the physical body, there is so much else that human do with it. Humans have discovered new lands through boating and sailing activities, and created extreme performances in sports within water such as in swimming, free diving, fin swimming, wind surfing etc. Ice and snow is also used in ice skating, ice hockey, skiing and snowboarding. e.t.c.

In recent years the study of human performance in the different water sports has been growing in a rapid rate. Most researches have been conducted in the field of classical swimming, where new world records are very popular specially during the Olympic Games. There is now a considerable body of research which suggests the factors that play a crucial role to a swimmer's performance [2].

Classical Swimming is a technique driven sport. Any discussion about a swimmer's elite performance should rest on a prior understanding of the basic principles of hydrodynamics and bioengineering. The result of efficient and fast propulsion of human body through water, comes from the combination of both technique and training methods [2, 3].

The goal of a competitive swimmer is to travel a given distance- at the surface of water- in minimum amount of time. Swimming technique emerged as an area of interest through this body of research. Data show that, there are two basic hydrodynamic principles that seem to apply equally to swimming, whether for fun or for a competition: streamlining and sculling. If these two principles can be mastered, they generally will lead to successful swimming. Elite swimmers, though, apply advance stroke technique and momentum, that leads to efficient gliding and graceful swimming [4].

In this research there has been also much interest, in the advance water skills that can be developed in sports like synchronized swimming, water polo and life guarding.

The advance skills that can be developed at water surface demand, essential feeling of the water, that means: ability to maintain a hands-free vertical position, support the body in reverse vertical positions, performing various sculling techniques, breath holding control and also combination of movement patterns depending on the activity's objective. For example, synchronized swimming includes surface water skills, all combined in a routine. In this sport there's technique, and then there's the creative part [5-7].

While in water polo, swimmers combine water skills for game strategies, that include offence and defense actions. A water polo competitive performance, also includes, various ball handling drills (passing, shouting etc) in combination with zig-zag swimming, stop and go drills, strength, stamina and game intelligence.

Another very demanding activity at water surface, is lifesaving. Lifeguards demonstrate various combinations of water skills, to help drowning victims. During a rescue there are various unpredictable factors, that might set lifeguard's life into danger. There are multiple rescue techniques, so a lifeguard can develop the ability to evaluate risk and finding solutions.

Immersing deeper under the surface, humans have to adjust to even more physical laws and experience an altered state of consciousness. Human adaptation underwater is both conscious and unconscious. In this research, we studied competitive free divers performance, Sea-population's extreme water adaptions and deep scuba divers psychological and mental challenges into the deep ocean [7-10].

In free diving sport, competitive free-divers can achieve very low heart rates during the dive. But they do so, in part, by seizing willful control of the autonomic system through proxy variables, specifically emotional states. They don't just benefit from the 'dive reflex'; they drive a "consciousness control of their autonomic function" to get more out of the dive reflex than just the 10-25% reduction in heart rate that most of the people would get (if they don't panic, in which case they might not even get that). In other words, in free diving the diving reflex (DR), has to be shaped and elaborated - it has to be cultivated into a skill.

Underwater the movement patterns are different than swimming at surface. The move of the diver should be slow and as efficient as possible. The more the diver thrashes and the harder he works, the faster he'll convert the oxygen to carbon dioxide [11-13].

In the field of underwater senses adaptation, Anna Gislen and her team studied a population of sea gypsies, called the Moken, that live in the archipelago of Burma, in Southeast Asia, and is adapted to improved underwater vision (Gislen et al., 2003). As it is commonly known, humans are poorly adapted for underwater vision, given that in air. The researchers have found that the improved underwater vision of the Moken children was not the result of better contrast sensitivity in general, but rather that they have learned to control their accommodation underwater, due to their dependence on it for survival. Experiments showed that, through training, underwater vision can be improved in all children even though unfamiliar to the water.

Underwater, we experience an altered state of consciousness - an altered state of mind. Based on NASA Extreme Environmental Mission Operations project, known as NEEMO, scientists have dedicated a lot of time in the study of scuba divers psychosocial characteristics which allows them to live and work in one of the most extreme environments available on earth: the ocean [8]. These researchers agree that divers must undergo a significant process of psycho-physiological adaptation, in order to remain underwater and remain useful, without causing problems to their health and to the mission. Divers are expected to perform effectively in stressful and emergency conditions, demonstrating confidence, ease, security and emotional stability. In addition, divers must have enough emotional control to respond calmly to the environmental circumstances and the psycho-physiological conditions of immersion [14, 15]. NASA scientists have concluded that there is an obvious association between performance in water environment and emotional stability. However, there is a scientific gap in research in aspects related to human's ability to connect to the water element.

Taking into account the results of previous research concerning human performance in, on and under the water, it becomes apparent that humans have to face different physical laws in the multiple water layers (on the surface, sallow and deep) that leads to different body and senses adaptation.

It has been noted that elite athletes in swimming and polo, despite their rigorous and constant training, are unable to dive into deep water zones of -20 to -30 meters depth. Moreover, extreme mono fin divers that have conquer depth, breath holding diving and living into extreme environments cannot perform as good without equipment, while many cannot even float efficiently. Maybe the most important question still is why trained swimmers could have a drown accident in their effort to help others during a sea rescue, meaning essentially that they fail to respond successfully to an emergency in water, even though they admittedly possess excellent buoyancy and thrusting skills in water [16].

No matter how good the swimming technique is, or how deep can one dive or even how long can one hold his breath, still the sense of panic when in the water could challenge many aquatic sportsmen. These data help us go beyond the question of how fast we can swim indicating a gap in researches in the approach of the relationship between humans and water and the effects on aspects related to human adaptability in the aquatic environment.

This research aims to study human's adaptation ability and performance in water. Its goal is to bridge the gap between knowledge and abilities that humans can develop in water. This study also offers a new approach for aquatic adaptability that humans can experience and aspires to offer some answers to questions concerning our existence in the aquatic environment. In other words, we suggest that water harmonization can be shaped, elaborated and cultivated into a skill.

This research attempts to explore the term "aquaticity" by looking into the meaning, recognize its characteristics and possibilities of the term aquaticity for human' performance, using scientific methodology. Through our research, it became apparent that, while the term aquaticity is largely ignored by scholars and academic publications, popular sports culture and the diving community use the term on a regular basis, in order to describe the comfort, the efficiency and the feeling of success athletes feel, when immersed under water. Its constant mention by coaches, trainers and athletes involved in all kinds of water sports, forces us to acknowledge its existence and investigate further its characteristics and possibilities. Moreover, as water activities are frequently used in special needs education and rehabilitation/therapy settings, it became evident that there is a need to address and investigate the term in a scientific manner.

Aims – Significance

The aims of the current PhD research thesis are:

1. To define the term "aquaticity", present the factors that describe it and reveal the form in which it presents itself in today's society.
2. To develop a scientific instrument to evaluate aquaticity levels in humans.
3. To assess whether aquaticity levels can be improved by the implementation of a specific to aquaticity training program compared to the classical swimming training.

Our effort to clarify and define the term "aquaticity" is important because the definition of the term" aquaticity" will help it to become a distinct scientific field of study as another parameter of human performance in water. In other words, we propose that the term "Aquaticity" should be included in sport terminology as another parameter of human performance. Human contact with the water element seems to promote not only the physical wellbeing, but also the psychological and emotional health. The development of aquaticity could promote lifelong exercise in the water, the development of environmental awareness and the desire for creative expression. However, it is essential to be able not only to define Aquaticity but also to assess it, in order to use it as a safety tool for excluding people with very low aquaticity levels from tasks that may endanger them through an abrupt exposure to water and thus carry a high probability of a drowning accident. The levels of aquaticity could also be used as a tool for generally assessing competence for activities and tasks that require high physical adequacy to the water. Consequently, the development of an education program in aquaticity for children seems necessary, since it could contribute towards the development of physical skills, knowledge and psychological balance.

Literature Review

Relation human-water

Water Planet.

The Earth is characterized as “the water planet”, since ocean water covers nearly 71 percent of its surface and fresh waters in lakes and rivers cover less than 1%. Water on the Earth’s surface occurs as liquid, ice and gas, with thick ice sheets and glaciers covering its Polar Regions and higher mountains and clouds masking about half of its surface most of the time. Furthermore, volcanic eruptions are constantly drawing water and gases to the surface, extracting it from rocks situated deep under the Earth’s surface. Water is of vital importance to the survival of both the Earth’s flora and fauna. Plants, animals and human beings need water in order to sustain all physiological processes necessary to their survival, including the control of the body’s temperature in humans and animals. Therefore, it comes as no surprise that areas that receive adequate rain or oceans harbor an abundance of life, while deserts are bare and desolate places [17].

Physiology Review

Water in the human body.

Apart from being essential to life, water is a substance of great importance and unexpected properties, since it is the only inorganic liquid that occurs naturally on Earth and the only chemical compound that occurs naturally in all three physical states, liquid, gas and solid. When looked in closely, water has the highest specific heat of any common substance, 1 calorie/gm °C= 4.186 J/gm °C. This means that it provides stability of temperature for the land masses it surrounds and a stable temperature for the human body, since it operates as an effective cooling agent. Water’s high heat of vaporization makes it, also, an effective coolant for the human body, through the process of evaporation and perspiration, broadening the range of temperatures in which the human body can survive [18].

In physiology, body water represents the water content of an animal body that is contained in the tissues, the blood, the bones and elsewhere. The amount of water that is present in the human body is substantial, both in terms of weight and volume, since it ranges from 50 to 75%. There are variations to the percentage of water present, due to age, gender and fitness level, since fatty tissue contains less water than lean tissue. Generally, however, the average adult human body is 50-60% water, while the average adult female body is 55% water, given that women have naturally more fatty tissue than men. At the same time, overweight men and women appear to have more water in their bodies than their lean counterparts. When it comes to human babies, it is known that a three-day old fetus is 97% water, while at eight months the fetus is 81% water. As we can see, there is a much higher percentage of water in infants –typically around 75-78%- which drops to 65% when they reach one year of age. There are other factors that control the body's quantity of water, such as individuals' hydration levels, since it is known that when thirsty, people lose around 2-3% of their body's water, resulting in impaired mental and physical performance [19].

Embryology

Psychobiology of the amniotic environment.

Water constitutes a basic element of the amniotic fluid and therefore is closely related to notions of life, fertility and motherhood in many different cultures and religions. Material evidence has given rise to the idea that this fluid constitutes the first real environment in which a fetus lives and acts. There are many studies that confirm the notion that in amniotic fluid the fetus essentially starts the formation of its character, its memories and intelligence. The fluid appears to be the first mean that facilitates the learning and acknowledging process, since in it, fetuses experience sounds, smells, tastes and emotions. Urinoterapy and staminal cells sampling reveals how amniotic fluid can be considered as an additional therapeutic resource [20] [21]. Scientists are proving the existence of intelligent life in the womb [22]. At nine weeks, the embryo's ballooning brain allows it to bend its body, hiccup, and react to loud sounds. At week ten, it moves its arms, "breathes" amniotic fluid in and out, opens its jaw, and stretches. Before the first trimester is over, it yawns, sucks, and swallows as well as feels and smells. The fetus savors its mother's meals, first picking up the food tastes of a culture in the womb. By the end of the second trimester, it can hear and can distinguish between the voice of Mom and that of a stranger, and respond to a familiar story read to it. Toward the end of pregnancy, it can see. Just as adults do, the fetus experiences the rapid eye movement sleep of dreams [23-26].

Fetal taste

By 13 to 15 weeks a fetus' taste buds resemble those of a mature adult. Doctors believe that the amniotic fluid that surrounds the fetus can smell strongly of all the essences from a mother's diet. It is yet unknown whether fetuses can taste these flavors, but scientists have found that a 33-week-old preemie will suck harder on a sweetened nipple than on a plain rubber one. Finally, during the last trimester, the fetus is swallowing up amniotic fluid to a liter a day [27].

Fetal hearing

It has been proven that even premature babies that enter the world at 24 or 25 weeks, respond to sounds. This proves that fetuses' auditory apparatus have been functioning in the womb. Fetal heart rate, also, has been known to slow down, when the mother's voice is audible, proving that the fetus not only hears and recognizes the sound, but is, also, calmed by it [21, 28].

Fetal vision

Vision is the last sense to develop. A very premature infant can see light and shape; researchers presume that a fetus has the same ability. Japanese scientists have even reported a distinct fetal reaction to flashes of light shined on the mother's belly [21].

Birth: A bridge from Aquatic environment to the terrestrial life

Neonate Physiology

Birth is an important physical challenge and it represents the transition from life in the amniotic fluid to the terrestrial life. The changes that occur to the pulmonary, cardiovascular, gastrointestinal, urinary systems and the thermoregulation enhance this transition and they should take place within the first few minutes after the birth of an infant.

Pulmonary system

The neonate's lungs are filled with fluid and they have no part in the breathing process. In utero, this liquid constitutes part of the amniotic fluid. The inhibition of any breathing movements from the part of the neonate eliminates the possibility of inhalation of meconium that was possibly excreted by the infant's gastrointestinal system into the amniotic fluid. Also, the continuing excretions of the cellular epithelium prevent the entry of meconium in the cells. The embryonic excretion of the surfactant is increased during the last trimester and it constitutes an indication of the ability of survival outside the uterus [29].

Cardiovascular neonate adjustments

During birth, the blood flow to the placenta stops and the blood flow to the lungs increases. The beginning of the breathing process is vital to the infant's survival. The breathing process cannot take place in the placenta, given that the neonate's lungs are filled with the fluid produced by the excretions of the cellular epithelium. During birth, the first breath is stimulated by exterior sensory stimuli due to the skin's coldness and the pressure release caused by the birth. Breathing is stimulated further by hypoxia and hypercapnia, a reflex of the breathing control system that continues to work lifelong. The liquid found within the lungs resists the entry of air during inhalation. Due to that, the very first breath the infant takes requires approximately 60 mmHg of pleural pressure. The breaths that follow require less pressure, given that the fluid is resorbed through the epitheliums. Inhalation creates an interface area between air and water with a surface of high stress to the lungs.

After birth, the exchange of air must take place in the lungs. The expansion of the neonate's lungs during birth permits the exchange of O_2. The lungs' expansion allows the alveolar ventilation and relieves the infant from hypoxic pulmonary constriction.

The reduced resistance of the pulmonary vessels permits the flow of the pulmonary artery to go through the lungs. The combination of ventilation and perfusion is achieved within the first few minutes of an infant's life.

In utero, mothers provide a stable environment for the embryo's growth. The placenta is the main source for the supply of nutritional elements and the exchange of air. The thermoregulation is controlled by the mother. The production of hormones from the mother and the placenta constitute the main source of stimuli control for the embryo. After birth, the neonate is expected to assume an independent existence. The exchange of air should be facilitated by the neonatal lungs. The nutritional elements that exist in the infant's body should sustain it, until breastfeeding commences. The neonate's thermo-regulative processes become functional within the first few days of the infant's life [30].

The Aquatic Instinct after birth

The skills of human babies and toddlers in aquatic settings surpass those of other terrestrial animals, such as the apes, and are an indication that specific innate templates are activated for adapting to an aquatic condition. The aquatic innate reflexes of newborns, such as floating, controlling breathing underwater, diving and playing in and near water, are unique to features that only human's possess, compared to terrestrial animals.

According to various researches, early swimming not only makes babies aquatic, but it also increases their locomotion, independence and ability to cope with unfamiliar circumstances. Babies and toddlers exhibit a natural ease with water as soon as four months or less has passed after the day they are born, indicating that there is a fixed innate 'neural template' that is activated during this sensitive period of their lives. Even though, unlike other terrestrial animals, human babies are unable to walk or swim the first eight months of their lives, nevertheless, their adaptation to water is remarkable, functioning various aquatic activities that some link to quicker development than other terrestrial animals. Therefore, by displaying the ability to float, swim and dive in the first months of their birth, human babies and toddlers are proof of a successful aquatic adaptation, while their semi-aquatic abilities have shown to be the reason for their advanced mental and emotional development, compared to other terrestrial animals [31, 32].

Historical Review

The Aquatic Ape Hypothesis

The Aquatic Ape Hypothesis (AAH), is a theory that claims that the evolutionary ancestors of modern humans spent a long period of time adapting to a semi-aquatic existence. This idea was first put forward by the German pathologist Max Westenhofer in 1942, in which he claimed that returned to land in recent times and a number of traits that today exist in humans derived from a fully aquatic existence in the open seas (the aquatile man theory). The same hypothesis can be found, also, in Sir Alister Hardy's writings, who, since 1930, claimed that humans is possible to have ancestors more aquatic than previously imagined.

In an article published in 1960 in the New Scientist, Sir Alister Hardy argued that a branch of primitive hominoids was forced by competition from life in the trees near the sea-shores, where they had to hunt for food in the shallow waters off the coast. Sir Hardy believes that the same group of hominoids was later forced into water, as was the case with many other terrestrial animals. Sir A.Hardy's suggestions were further developed by Elaine Morgan in 1972, who pointed out various human features or abilities, such as hairless skin or human babies' ability to swim or hold their breath underwater, as evidence of a semi-aquatic existence.

The 1987 symposium held in Valkenburg dismissed most of these claims, but the discussions on the validity of the theory has given birth to a growing body of supporters of the AAH, who argued that these protohumans have spent time either wading, swimming or diving on the shores of alkaline or saline waters and that many of the features that distinguish humans from other animals emerged because humans have returned to terrestrial life, before becoming fully adapted to the aquatic environment.

The theory kept gaining supporters and in later years, Algis Kuliukas coined the term 'water hypothesis of human evolution' in order to represent the diversity of hypothesis available on the issue. Despite their differences, the supporters of such hypothesis claim that specific features in hominin evolution present an interesting alternative to conventional explanations of human evolution. For them various traits shared by all humans can be seen as adaptations to an aquatic environment. For example, bipedalism is a very useful trait in water, since it allows for deeper wading, offers balance and blood circulation and reduces strain on the back and knees. Also, the elongation of the lower limbs helps improve swimming speed and the hairlessness of human skin as well as the position of the human larynx are very common traits of aquatic mammals. Finally, humans have greater control over their breathing, compared to other terrestrial animals.

Scientists, such as biochemist Stephen Cunnane and his team, also claim that other characteristics, such as the complexity of the human brain, point towards the theory of an aquatic existence, since human diet apparently depended on the consumption of micronutrients and macronutrients, found in fish, shell-fish and other sea foods. Moreover, human babies' inability to walk upright before they are one-year-old, like many terrestrial animals, and their ability to swim along their mother, when still newborns, also points towards the AA Hypothesis. Finally, for many, humans' habitat and behavior, for instance the tendency to live in large groups near coastal regions, river valleys, lakes and seashores, as well as their bathing habits, all point towards a semi-aquatic existence.

Despite the evidence presented above, the scientific community refused to fully accept the Aquatic Ape Hypothesis, claiming that AAH's attempts to explain human evolution as a single cause mechanism is not well supported by the evolutionary fossil record and therefore, is internally inconsistent, weak and lacking in complexity, compared to the terrestrial hypothesis. To the critics, there is no single accepted explanation for human features such as bipedalism or hairlessness, since most of these features are connected to skeletal adaptations and changes in the shape of the skeleton and soft tissues. Furthermore, the position of the larynx can be seen in other terrestrial animals and it can be seen as an adaptation for the improvement of vocalization for humans. Moreover, critics also point out that the complexity and size of the human brain can be seen in later years (genus Homo) and the inclusion of sea foods in human diet can be explained through consumption of hunted or scavenged animal brains, rich in DHA. Finally, critics argue that even though human infants are well adapted to water, they are always in danger of drawing, when parted from their mothers. Overall, the scientific community sees the AAH as a popular rather than s scientific hypothesis [33-40].

Mythology

Water, humans and the sacred

Water and the begging of life

Water is a primordial element which underlays creation myths and stories around the world. In the Egyptian Heliopolitan creation story, the sun-god Atum (Re) reposed in the primordial ocean (Nun), while in Assyro-Babylonian mythology, first the gods and subsequently all beings arose from the fusion of salt water (Tiamat) and sweet water (Apsu). Similar tales can be found in Greek Mythology and philosophy, especially in the work of Homer, Hesiod, Athenagoras and Plato.

For Homer, everything was divine in origin, since, at the beginning there was Oceanus and Tethys, from whom all gods originated (Illiad, XIV, 201). Centuries later, Plato also, adopts Homer's views on the begging of all life, naming Oceanus and Tethys as the parents of gods and humans, alike. Hesiod (700 BC), also, talked about the importance of water for the beginning and sustenance of life in his account of cosmogony and theogony. He begins his account with Chaos, as the originator of life, in which one finds water, watery vapors, fire, rivers and the void. Hesiod also mentions Ocean as the first god to begin wedding rituals and gives a detailed account of the birth of the sea, the rivers, the nymphs and the sea gods.

Similarly, the Orphic theogony, elements of which influenced the Greek religious way of life, starts with the Night, from which Uranus and Earth originated and Ocean and Tethys followed. Athenagoras also mentions that water was the main element giving origin to mud, from which Khronos Heracles was generated, the creator of Uranus and Earth from whom all gods and humans originate. Orphism developed in Greece from the sixth century BC and continued down to the fourth century ac, and represents an important step in Greek culture, since it introduced the idea of the divine into man. The idea of reincarnation gave birth to the rituals that will assist the separation of the spirit from the body, during death.

In Greek mythology, the dead cross a river and they have to drink fresh water from the lake of Mnemosyne, in order to proceed. Similarly, for Homer water was a lustral element to be used during the preparation of the last trip after death. In his writings, corpses were washed with water, the dead body was cleansed and at the end of the ceremony, all participants cleaned their hands with water. Water was also used for ablution before banquets, weddings, delivery and during all kinds of religious ceremonies, in order for people to introduce themselves clean to the divinity. Cleaning was preliminary to any ritual activity including initiation ceremonies and in ancient Greece, there were terracotta basins found in private homes [41, 42].

All the above show that water was an important element in Ancient Greece that connected humans and gods. This connection, as well as the beginning of life through water, was also highlighted in other mythologies around the world. For example, the holy books of the Hindus explain that all the inhabitants of the earth emerged from the primordial sea. Moreover, at the beginning of the Judeo-Christian story of creation, the spirit of God is described as stirring above the waters, and a few lines later, God creates a firmament in the midst of the waters to divide the waters (Genesis 1:1-6). Finally, in the Koran one can read the words: *We have created every living thing from water.*

Gods and divinities of the water- The Greek and Celtic Mythologies

Water divinities of various kinds appear in the mythologies of many cultures. The Celtic mythology is full of water gods and goddesses, as well as references that highlight the importance and sacredness of water. On Celtic inscriptions a river name is prefixed by some divine epithet--dea, augusta. There are references of people expressing their gratitude for benefits received from the divinity or the river itself. Moreover, on Celtic inscriptions, one can find names such as Bormanus, Bormo or Borvo, Danuvius (the Danube), and Luxovius as names of river or fountain gods. At the same time, in Celtic mythology goddesses are more numerous--Acionna, Aventia, Bormana, Brixia, Carpundia, Clutoida, Divona, Sirona, Ura--well-nymphs; and Icauna (the Yonne), Matrona, and Sequana (the Seine)--river-goddesses. In addition, personal names, like Dubrogenos (son of the Dubron), Enigenus (son of the Aenus), and the belief of Virdumarus, indicate that river-divinities might have amours with mortals and gave birth to children called by their names [43].

Furthermore, in Celtic mythology, the name of the water-divinity was sometimes given to the place of his or her cult, or to the towns which sprang up on the banks of rivers. Many towns (e.g. Divonne or Dyonne, etc.) have names derived from a common Celtic river name Deuona, meaning "divine." This name in various forms is found all over the Celtic area, and there is little doubt that the Celts named river after river by the name of the same divinity, believing that each new river was a part of his or her kingdom.

Also, just as in the Hindu sacred books, the waters are seen as mothers and therefore sources of fertility. The Celtic mother-rivers were probably goddesses, akin to the Matres, givers of plenty and fertility. In Gaul, Sirona, a river-goddess, is represented like the Matres. Moreover, gods like Grannos, Borvo, and others, are seen to preside over healing springs, and they are usually associated with goddesses, as their husbands or sons. But as the goddesses are more numerous, and as most Celtic river names are feminine, female divinities of rivers and springs are of greater importance, especially as their cult was connected with fertility. The gods, fewer in number, were all equated with Apollo, but the goddesses were not merged by the Romans into the personality of one goddess, since they themselves had their groups of river-goddesses, Nymphs and Naiads [44, 45].

Before the Roman conquest, the Celtic cult of water-divinities and their connection with humans, probably formed a large part of the popular religion of Gaul. Thermal springs had also their genii, and they were appropriated by the Romans, so that the local gods now shared their healing powers with Apollo, Esculapius, and the Nymphs. Thus every spring, every woodland brook, every river in glen or valley, the cataract and the lake, were haunted by divine beings, mainly thought of as beautiful females with whom the Matres were undoubtedly associated. Tales claim that these deities revealed themselves to their worshippers. When paganism had passed away, these creatures remained as fées or fairies that haunt the springs, wells or rivers, and are still seen by the romantics.

Similar to Celtic mythology’s account of the deities of the water are the accounts of sea gods and water deities found in Greek mythology. The ancient Greeks had a large number of sea deities and Greek cities were always located near the Mediterranean coastline from the Hellenic homeland to Asia Minor, Libya, Sicily and Southern Italy. The range of Greek sea gods range from an Olympian god to heroic mortals, chthonic nymphs, trickster-figures, and monsters. In Greek mythology, Oceanus and Tethys are the father and mother of the gods in the Iliad and in Orpheus's song in Book I of the Argonautica, the sea-nymph Eurynome is named as the first queen of the gods, wife of the ocean-born giant Ophion. The Greeks, also, consider many rivers to be Oceanus and Tethys’ offsprings, like Achelous, the river god who wrestled against Heracles for the hand of Deianira, in the shape of a bull. In Greek mythology, these gods and deities play a vital role and their fate is always intertwined with that of major gods and humans.

However, the best known sea god of the Greek mythology is Poseidon. He was the great Olympian god of the sea, rivers, flood and drought, earthquakes, and horses and was depicted as a mature man of sturdy build with a dark beard, and holding a trident. His name seems to be connected with potos, pontos and potamos, according to which he is the god of the fluid element. He was a son of Cronos and Rhea and Zeus, Hades, Hera, Hestia and Demeter were his brothers and sisters. His palace was in the depth of the sea near Aegae in Euboea, where he kept his horses with brazen hoofs and golden manes. With these horses he rides in a chariot over the waves of the sea, which become smooth as he approaches, and the monsters of the deep recognized him and played around his chariot. Being the ruler of the sea, he is described as gathering clouds and calling forth storms, but at the same he has it in his power to grant a successful voyage and save those who are in danger, and all other marine divinities are subject to him. As the sea surrounds and holds the earth, he himself is described as the god who holds the earth and has it in his power to shake the earth. He is mentioned by a variety of surnames, either in allusion to the many legends related about him, or to his nature as the god of the sea. His worship extended over all Greece and southern Italy, but he was more especially revered in Peloponnesus and in the Ionic coast towns [46].

Sacred rivers, springs and wells all over the world.

The identification of the sources of rivers, streams, springs, and wells as sacred is very ancient, since in mythologies from around the world, these places are the dwelling place of supernatural beings. The wells or streams were often claimed to offer healing to the injured and cure to the sick and they quickly came to be regarded as sacred shrines. The Roman philosopher Seneca declared that where a spring rises or water flows we ought to build altars and offer sacrifices. Even within the Judeo-Christian tradition, which avoids any direct links with nature and its elements, there are numerous examples of sacred springs or wells, and rivers, which have acquired sacredness through connection with a significant or miraculous event.

In general, springs and wells with healing waters acquired a special sacred significance throughout the world since ancient times. For example, the water of the River Jordan is sacred because Jesus Christ was baptized in it by Saint John the Baptist and since then, the Christian view water as a symbol of grace, using it for baptisms to this day.

Similarly, in the New Testament, St. John describes the pool of Bethesda in Jerusalem, surrounded by five covered colonnades, where a great number of disabled people used to lie waiting to be the first to enter the pool, when the water was stirred. Moreover, in the mid-19th century, soon after Bernadette's vision of the Virgin Mary, the water issuing from the grotto at Lourdes began to bring about cures in people and the spring was designated a place of miracles. Moreover, sources of bubbled forth mineral water were also regarded as healing and in later years they became baths and spas. For example, the hot mineral springs at Bath in England were already being used 7000 years ago by the Celts, who established a shrine there dedicated to Sulis, and later the Romans built on the same spot a temple to Sulis Minerva and renamed the town Aquae Sulis.

In ancient times, wells or streams were also oracular. For example, Pausanias (VII, 21. 11) reports that a sacred stream in front of the sanctuary of Demeter at Patras served as an accurate form of divination by using a mirror. Similarly, the Celts respected natural springs of water for their sacred and medicinal value and many holy wells were later Christianized through rededication to a saint. This practice of venerating sacred wells continued into the Christian era in the West, though they were now referred to as wishing wells [19].

Moreover, wells and springs were often associated with a god or goddess and the sacred water dispensed there was believed to be capable to ensure life, health, and abundance. For example, the Babylonian moon goddess, Ishtar, was associated with sacred springs, and her temples were often situated in natural grottoes. Also, the Ancient Greeks used to build shrines and erect artificial basins and place icons of the deity or deities near springs considered to be sacred. Moreover, both the Celts and the Romans thought goddesses and nymphs were connected with certain rivers, springs, and wells and, often the rivers were named after the goddess, such as the Shannon River, after Sinann, and the Boyne, after Boann, in Ireland. Finally, in 1963, at the Gallo-Roman Fontes Sequanae sanctuary at the source of the Seine, 200 wooden figures carved to represent all or part of the human body, were excavated, indicating that the goddess of the sacred spring was believed capable of curing a whole range of infirmities.

All the above indicate that humans harbor a profound faith in the sacredness of water. Water is also one of the four elements possessing fundamental characteristics. In many cultures, water appears as a reflection or an image of the soul. In Japan, in particular, water prefigures the purity and pliant simplicity of life, since it can be both calm and animated. Japanese temples have ponds full of unruffled water and waterfalls are places of worship. Similarly, the lotus-stream of the Buddha or Boddhisattva rises up from the waters of the soul, in the same way the spirit, illumined by knowledge, frees itself from passive existence. Finally, in India, the sacred River Ganges embodies for Hindus the water of life and bathing in it helps humans free themselves from sin, achieving inward purification. Moreover, the source of the Ganges lies in the Himalayas, the mountains of the Gods, and therefore its water is considered to be directly descendent from Heaven [47].

Last but not least, springs and wells also took the form of sacred fountains which were claimed to be the Fountain of Youth or the Fountain of Immortality or the Well of Knowledge. A Fountain of Youth was believed to exist in the newly-discovered Americas, and the Spanish conquistador Ponce de Léon set out in 1513 on an expedition to find it in Florida. Similarly, according to Wang Chia, writing in the Chin Dynasty (265-420 CE), the water of the fountain at Pon Lai in China was believed to confer a thousand lives on those who drink it. A similar reputation was also attached to the springs of Mount Lao Shan [48].

Aquatic Rehabilitation

Definition and historical perspective

Aquatic rehabilitation is a rather modern term and it stands for a medical rationale or a set of clinical procedures that use water's properties in order to restore physical mobility and physiologic activity through water immersion. The term's history is better linked to the history of water's healing powers, which dates back to ancient times. It is considered to be an evolution of hydrotherapy, as far as its scientific treatment methodology is concerned, and it is viewed by many as beneficial for the treatment of a great variety of rehabilitative problems and conditions

The use of water for healing purposes is present in many primitive civilizations, such as those of Greece, Rome, Persia and Egypt. The introduction of drugs, however, managed to gain ground over water therapy, until the 18th century, when scientific interest in water therapy becomes apparent through a series of scientific articles. By the 1900's hydrotherapy was established as part of the medical mainstream, especially in the treatment of orthopedic disorders in Europe and Japan. In the 19th century, the

Vincent Priessnitz foundation had brought the use of water in medicine to the forefront and in 1911; Dr Charles Leroy Lowman was using therapeutic tubs to treat patients with cerebral palsy and spastic conditions [47, 49, 50]

Many mostly American universities and hospitals adopted various methods of aquatic healing, among them the Massachusetts Department of Mental Disease, the Saratoga and Hot Springs Arkansas spas, as well as the National Foundation for Infantile Paralysis. Nowadays, water as a means of healing and rehabilitation is internationally accepted by the scientific and medical community, since it was found to offer various benefits for the body.

The Physical properties of water and their therapeutic aspects

Water is considered to be an ideal treatment medium for various conditions, such as neuromuscular reduction and strengthening, reduction of pain, inflammation and muscle spasm, increase of the range of motion, as well as reduction of stress on the body, when full weight bearing is not indicated. The contributing factors that allow water to do all that are buoyancy, specific gravity, hydrostatic pressure, viscosity and thermodynamics.

Buoyancy is perhaps the most important aspect of the aquatic environment, since it provides for weight relief and a reduction in the gravitation forces that act on the musculoskeletal system. Buoyancy, with the help of floating devices in some cases, decreases the compression stress on weight bearing joints, bones and muscles and promotes this way a more effective pain-free exercise of the muscles and joints [51] [52].

Moreover, any object that is located below the surface of the water is subjected to an additional pressure, known as hydrostatic pressure. This type of pressure varies with depth and is exerted on all surfaces of the body in water, causing gas and fluid to be displaced on lower pressure areas. Consequently, a person standing in water feels an enhanced compression on his body, acting inwards and upwards, as fluids are displaced from the lower extremities into the lymphatic drainage system and back toward the central cavity, working against blood’s tendency to pool in the lower extremities. This very movement of fluids may benefit patients with circulatory problems and swelling around the joints and tissues, since it increases cardiac output and reduces peripheral resistance and edema. Additionally, hydrostatic pressure may be an ideal form of exercise, since it promotes equal resistance to all muscle groups and enhances stability, offering patients more strength and improved flexibility [53-55].

Lastly, viscosity is closely related to water's ability to act as a variable accommodating resistance that occurs between the molecules of a liquid, determine its thickness and ability to flow. Therefore, the higher the viscosity, the greater the resistance. In this light, the element of viscosity is of great importance to the rehabilitation process, since it allows for a natural resistance of the body moves through water, approximating the muscular force exerted and reducing the possibility of exceeding tissue tolerances that could lead to injuries. Finally, strengthening exercises performed in water can be designed in a way that closely matches functional movement, providing this way neuromuscular adaptation similar to that of daily life [54, 56, 57].

Water Sports and Development of Human potentials in the water

Water has always been a source of fascination for humans. Some prefer the feel and sensation of calm waters, while others opt for the big waves. The deep blue ocean or the swallow water fun and sea life colors, the thrill of adventure, racing or competition makes water the ideal medium for sports and activities. People experience an adrenaline rush and enjoy it to the core. With water sports there is never a dull moment. Both, physical exertion and mental stimulation can be attained in the water. That is why, in recent years, the list of available water sports is ever growing. There is a variety of individual and team water sports on offer that can be enjoyed by people in a recreational or competitive way. Water sports are activities, that involve bodies of water and can be played in, on, or under water, based on the relation of the human body to the water element [58].

Sports at water surface

In these sports, human body is immersed at water surface -while breathing process is regularly stimulated (inhalation airways out of the water and exhalation in the water through the mouth or nose). They are performed in 1 atm ambient pressure, except if they take place in altitude. This category of water sports can be divided in Olympic water sports, recreational sports and rescue swimming.

The Olympic Water Sports are swimming, synchronized swimming**,** diving, water polo, open water swimming, Olympic Triathlon, Modern Pedathlon. Some of the sports include only one part related to water such as a triathlon, pedathlon and diving [59].

Olympic Water Sports

Swimming

Human swimming is the self-propulsion of a person through water or another liquid, usually for the purpose of recreation, sport, exercise, or survival. Locomotion is achieved through coordinated movement of the limbs, the body, or both, synchronized by the breathing process.

Swimming is one of the top activities around the globe and in some countries swimming lessons are part of children's educational curriculum.

As a formalized sport, swimming is part of our everyday culture and it features in local, national and international competitions, including every modern summer Olympics, which occurs every four years

Its history dates back to prehistoric times, since its earliest recording dates back to the Stone Age, as seen in paintings from around 10,000 years ago. Written references of swimming date from 2000 B.C., including those found in the Gilgamesh, the Illiad, the Odyssey, the Bible, Beowulf and the Quran. The first swimming book was written in 1538 by Nikolaus Wynmann, a German professor of languages, titled *The Swimmer or A Dialogue on the Art of Swimming* (*Der Schwimmer oder ein Zweigespräch über die Schwimmkunst*) [60].

In 1828, St George's Baths, the first indoor swimming pool for the public was opened and in the 1830's, swimming emerged as a competitive sport in England. By 1837, there were six artificial swimming pools in London and the National Swimming Society was holding swim competitions regularly. In 1880, the first national governing body was formed, named the Amateur Swimming Society and in 1873. Competitive swimming became particularly popular in the late century, as swimming times have dropped over the years, due to better training techniques and new developments. The foundation of FINA in 1908 signaled the commencement of recording the first official world records in swimming

Records can be set in long course (50 meters) or short course (25 meters) swimming pools. FINA recognizes world records in the following events for both men and women.

Freestyle: 50m,100m,200m,400m,800m,1500m

Backstroke:50m,100m,200m

Breaststroke:50m,100m,200m

Butterfly:50m,100m,200m

Individual medley:100m (short course only), 200m,400m

Relays:4×50m freestyle relay (short course only), 4×100m freestyle, 4×200m freestyle,4×50m medley relay (short course only), 4×100m medley,4×50m mixed freestyle (short course only), 4×100m mixed freestyle, 4×50m mixed medley (short course only), 4×100m mixed medley.

Swimming Styles- Strokes

Swimming can be undertaken using a wide range of different styles, known as 'strokes,' that are used for different purposes, or to distinguish between classes in competitive swimming. Regardless of their style or purpose, most strokes involve synchronized breathing, rhythmic and coordinated movements of all major body parts, such as the torso, hands, feet and head. It is also possible to adapt strokes to avoid using parts of the body, either to isolate certain body parts, such as swimming with arms only or legs. Such strokes are usually used in training or exercise or in the case of paralympians [56].

It is not necessary to use a defined stroke for propulsion through the water, and untrained swimmers may use a “doggy paddle” of arm and leg movements, similar to the way four-legged animals swim. There are four main strokes used in competition and recreation swimming: the front crawl, the breaststroke, the backstroke and the butterfly. Competitive swimming in Europe started around 1800, mostly using the breaststroke [61].

Other strokes exist for specific purposes, such as training or rescue. There are several stroke styles**:** **Front crawl** is the fastest style and **dolphin crawl** is similar to front crawl. The **catch up stroke** is a variation of the front crawl, where one arm always rests at the front, while the other performs one cycle. **The head-high crawl** is similar to the front crawl, only that the head is above the water. It is usually used in water polo and by lifeguards to save victims in sight. Trudgen is also similar to the front crawl, except that it is swum with scissors kicks. Trudgen swimming style, also, includes the double trudgen and the double trudgen crawl.

The butterfly-stroke is another swimming style, performed face down in the water, where the legs perform a dolphin kick and the arms move together in a forward “circle”. The butterfly stroke was developed in the 1930s and was considered a variant of the breaststroke until it was accepted as a separate style in 1952. There is, also, the slow butterfly, which is similar to butterfly, but with an extended gliding phase. There are plenty variations of butterfly - usually performed for training reasons - such as arms butterfly move and legs use the flutter kick or whip kick [62].

Breaststroke, also, is a swimming style performed face down in the water, without rotating the torso and the arms staying underwater and moving synchronously, while the legs perform whip-kick. Similar to breaststroke is the inverted breaststroke. **The backstroke** of back crawl is similar to the front crawl, only that it is done while lying on the back. As a swimming style, it also includes the elementary backstroke, the inverted butterfly and the back double trugend.

The **sidestroke** is a different swimming style, during which the body is on the side and the water is pulled as if with a rope, while the arms are going out and stopping in the middle and the legs are performing scissors kick sideways. Similar to sidestroke is the lifesaving stroke, while another well-known swimming style is the combat sidestroke, used by USA Navy SEALs

Dog paddle is a common swimming style used by many, where the face is over the water and paddling is used with alternate hands. The human stroke is similar to the dog puddle, but the hands reach out more and pull farther down. The **survival travel stroke** is an alternating underwater arm stroke, where one cycle serves for propulsion and the other for lift to the surface. that is very slow but sustainable. The breast feet first strokes require for the legs to be extended and the arms to be used in a pushing, flapping, clapping or uplifting motion.

Other swimming styles include snookering (using a snorkel, mask and fins), **finswimming** (using fins), that also include **flutter back finning**, feet first swimming and an arm and a leg finswimming, the **corkscrew swimming**, which involves a constant rotation of the swimmer and is used for training purposes, underwater swimming, which involves any style of swimming underwater, gliding, where the swimmer is stretch with the arms to the front and the feet to the back to minimize resistance and allow the swimmer to glide and the turtle stroke, where the swimmer extents the right arm and pulls after pushing with the left leg and then the opposite limbs repeat the process. Finally, there is the **oarstroke or moth stroke**, which consists of the opposite motions, used to perform the butterfly stroke and was developed for recreational purposes [56, 63].

Lifesaving strokes

Special purpose styles were, also, developed for certain situations. For instance, **Lifesaving approach stroke** (also known as *head-up front crawl*): it is developed similar to the front crawl, but with the eyes to the front above the water level, such as to observe the surroundings as for example a swimmer in distress or a ball. The **pushing rescue stroke** serves to assist a tired swimmer, while he lies on the back and the rescuer swims a breaststroke kick and pushes against the soles of the tired swimmer.

Similarly, the **pulling rescue stroke** serves the same purpose, with both swimmers laying on their back and the rescuer grabbing the swimmer by the armpits, while swimming.

The extended arm tow involves the rescuer holding the head of the swimmer with a straight arm, while swimming to shore and variations of the same swimming styles are the vice grip turn and trawl for injured swimmers, the clothes swimming, when the swimmer is clothed, and the rescue tube swimming, when the lifeguard pulls a flotation device, when approaching the swimmer in distress.

Moreover, in life-threatening situations, humans' employ different swimming styles, developed out of necessity for survival. One of those styles is the **survival floating** (dead man float or drown proofing) where the swimmer is lying on the prone and stays afloat with minimal leg movement. Back floating is very similar, with the exception that the swimmer is on his back. **Treading water** is another style used, where the swimmer is head up and feet down in the water and uses different kicks and hand movements to stay afloat. **Sculling**, also, is a swimming style used in surf lifesaving, water polo and synchronized swimming, during which the swimmer uses the figure 8 movement of the hands for forward motion or upward lift. Finally, there is the **turtle float and the jellyfish float**, where, for the first, the knees are raised to the chest and encircled by the arms, while for the second, the ankles are held by the hands [64].

An important premise of swimming is the body's natural buoyancy. The body's ability to stay afloat is caused by its relative density, which is, on average, 0.98 compared to water. Buoyancy, however, differs according to body composition and the salinity of water. Since the human body is slightly less dense than water, swimming is considered to be a 'low-impact' type of activity, compared to land activities, such as running. On the other hand, the density and viscosity of the water create resistance for objects moving through water and those wishing to swim faster will have to either increase the power of their strokes or reduce their water resistance, by having a horizontal water position, rolling the body in order to reduce its breadth in water and extending the arms as far as possible [54, 56]

Human performance in competitive swimming

The science that studies the movement of bodies within water is called hydrodynamics and the science of competitive swimming is concerned with the factors that affect fast movement of the human body in water. Bioengineering is the science that applies the laws of engineering to living things and its subject could be the movement humans make, when in water and therefore, the science of propulsion of human body through water is the combination of both hydrodynamics and bioengineering. Any discussion about a swimmer's hydrodynamics should rest on a prior understanding of the basic principles of bioengineering.

The goal of a competitive swimmer is to travel a given distance in the minimum amount of time. Performance in competitive swimming is most simply described as a function of balance between propulsive and resistive forces that are encountered over a given distance. Muscle strength is also an important component of success in competitive swimming. The ability to express high power in swimming specific movements, bears a very close relationship to swimming performance. The swimmer who possesses both a high maximal power output and the capacity to sustain a high percentage of this maximal power over a distance has the greatest advantage [65].

Competitive swimming is a technique driven sport. Swimming skill is related to propulsive efficiency. According to the researches, following points show are important for swimming skill: a. sculling hand actions are used by skilled swimmers, b. diagonal pulling pattern allow straight forward propulsion through the combination of lift and drag force, c. a pulse of propulsive force is created within an isolated pulling area in each stroke, d. within any sample of swimmers, there is a range of efficient propulsive styles each suited to the individual attributes of a given swimmer e. It has been suggested that increased joint flexibility enables the swimmer to achieve a greater range of motion during the arm stroke.

Swimmers, in order to achieve a better performance and to concur a new world record, should take also advantage of the technical parts used in competitive swimming, such as: starting, turning, swimming and finishing. Each part's contribution to the overall performance of the athlete depends on the length required to be covered by every sport. According to the researches, a swimmer's performance at a 50 or 100m swimming contest depends on his performance during the start of a race, which is the time elapsing between the starting signal and the time that the athlete's head reaches 10 meters [56, 64, 66, 67].

Body Composition and Anthropometric Considerations

Swimming sports emphasize and reward upper extremity strength. Generally, the aquatic athletes have wide shoulders and have relatively large muscle mass, especially in their middle and upper bodies. Moreover, elite swimmers tend to have longer arms and larger hand surface areas. Based on biomechanical description, certain anthropometric variables can influence performance capacity.

If we examine different swimming style athletes, we will find that freestyle sprinters and backstrokers are the tallest and heaviest (greater muscle mass), with the breaststrokers being the shortest. Studies upon the differences in body dimensions between elite and sub-elite swimmers in order to determine how these differences related to performance, show that changes in drag forces because of changes in body configuration are not the reason for better swimming performance. It is rather the better application of this effective forces during swimming that helps improve performance [68-72].

Body fat Considerations

The percentage of body fat on both elite male and female swimmers appears to be lower than the percentage of the average population (approximately 15% to 20% body fat for males, 20% to 25% body fat for females). However, low percentage of body fat appears to have little effect on swimming performance. Although there appears to be an ideal range of body fat percentage for swimmers, there is no support for use of a single "ideal" value [63, 73, 74].

Water Polo

Water Polo is a team sport played in water. This sport is very energetic and involves a full body workout, as players must swim and defend the ball as well as try to score in the opponent's goal. It's a lot more like handball played in the water rather than polo. This sport is very intense and competitive, with a lot of strategies and techniques involved in gameplay.

The history of this game as a team sport began in late 19th century in England and Scotland, when William Wilson devised the first set of rules for a team game in water, in order to combat the public's boredom with the swimming carnivals. Today, the game is considered to be one of the most physically demanding team games, in which players are required to cover up to three kilometers in the pool during the one-hour game. The game is now played in more than 100 countries and is one of the longest-standing team sports in the Olympic Games, since it was first introduced as one in Paris in 1900. Players of water polo use specific swimming techniques, such as eggbeater kicks and the water polo stroke, to help them perform better [75].

The eggbeater kick

The **eggbeater kick** is a hands-free form of treading water that allows the swimmer to remain vertical. This form provides continuous support because there is no break in the kick and it propels swimmers in an upward direction and allows them to freely use their hands, remain stable in the water without swaying, maintain a constant vertical position and conserve energy. The swimmer rotates his or her legs circularly while keeping their feet arched and angled, causing water above their foot to move faster than the water under their foot. Due to Bernoulli's principle, the faster-moving water has a lower pressure than the slower-moving water. This difference in pressure between the moving water and the surrounding water creates a force, propelling the swimmer upwards. The faster the swimmer's feet move, the more upward propulsion he or she receives. In water polo players need to perfect the eggbeater kick in order to be successful, so their hands can be free to shoot, pass, dribble and control the ball. Especially Goalkeepers must be able to do this as they need to have the power to get to the ball [76].

Long swimming stroke- water polo stroke

Physiologically- the polo stroke is a shorter jab stroke with much wider entry angles. With backstroke the head is much higher and the arms don't usually (shouldn't!) reach behind the head.

Water Polo training **increases aerobic ability** and give a participant significantly **more leg strength**. Due to its demanding and competitive nature as a team sport, water polo helps athletes to **build endurance and strength**, since they swim for approximately 4 miles per game and are required to use constantly many muscle groups, in order to stay afloat. During training and games, the arms and legs of players are also strengthened, since they are always in motion. It, also, constitutes **a great cardiovascular workout**, offering flexibility and agility to the human body. Water polo is considered to be a sport for any age, since water polo training is less stressful on the joints and muscles of older people than the more high-impact, non-aquatic sports like jogging [64, 77, 78].

Synchronized swimming

Synchronized swimming is considered to be a combination of swimming, gymnastics and ballet. As an olympic sport, it consists of either solos, duets, trios, combos or teams, performing synchronized routines in the water, accompanied by music.

The sport’s history dates back to 1933, when Katherine Whitney Curtis organized a show called "The Kay Curtis Modern Mermaids," for the World Exhibition in Chicago, in which the term synchronized swimming was first used. This type of rhythmic swimming became well-known in 1968 and synchronized swimming became officially recognized by FINA as the fourth water sport next to swimming, platform diving and water polo. In 1984 it became an official Olympic sport.

Advance water skills

Synchronized swimming demands advanced water skills, essential feeling of the water and requires great strength, endurance, flexibility, grace, artistry and precise timing, as well as exceptional breath control when upside down underwater. Synchronized swimming includes **water skills** such **as sculls, eggbeater kick, lifts, positions** and all these are combined in a routine. In fact, sculls are an essential part of synchronized swimming and they include support scull, standard scull, torpedo scull, split-arm scull and paddle scull. The eggbeater kick is also an essential skill of synchronized swimming, since it allows for stability and height above the water, while leaving the hands free to perform strokes and ‘boosts’. An average eggbeater height is usually around chest level. Moreover, the eggbeater kick allows the swimmers to lift teammates out of the water. The lifts can be performed only by well-trained and experienced swimmers and there are several types of lifts used, such as platform lift, the stack lift and the throw lift. Eggbeating for a considerable period is also referred to as an "aquabob" and is used to build propulsion under water prior to a boost or pop-up [7, 79, 80].

Routines- a combination of advance water skills

Routines are composed of "hybrids" (leg movements) and arm or stroke sections. They often incorporate lifts or throws, an impressive move in which a group of swimmers lift or throw another swimmer out of the water. Swimmers are synchronized both to each other and to the music. During a routine swimmer can never use the bottom of the pool for support, but rather depend on sculling motions with the arms, and eggbeater kick to keep afloat. After the performance, the swimmers are judged and scored on their performance based on technical merit and artistic impression. Technical skill, patterns, expression, and synchronization are all critical to achieving a high score.

Furthermore, during their routines, swimmers use various positions. There are hundreds of different regular positions that can be used to create seemingly infinite combinations. Among the most basic and commonly used ones are the back layout (floating body, rigid, while sculling under the hips), the front layout (swimmer on his/her stomach, sculling by his/her chest), sailboat/bent knee (knee bent and toe touching the inside of other leg), the ballet leg (one leg perpendicular to the body, the other parallel), the flamingo (bottom leg pulled into the chest and shin touching the knee of the vertical leg), the vertical (body completely straight upside down and perpendicular to the surface), the crane (leg vertical in a 90-degree angle or "L" shape), the bent knee (one leg remains vertical while the other leg bends so its toe is touching the knee of the vertical leg), the split position (one leg is stretched forward along the surface and the other extended back), the knight (the legs are flat on the surface, and the body is arched so that the head is vertically in line with the hips) and finally the side fishtail (one leg remains vertical, while the other is extended out to the side parallel to the water, creating a side "Y" position) [15, 81].

Diving and Synchronized diving off springboards or off platforms

Diving is both a recognized sport and a favorite recreational activity for people. Cliff diving is one form where divers jump off cliffs or rocks in freshwater or salt water. It is fun to just dive off a high cliff into the calm waters below. A World Series Cliff Diving Competition is held every year. The height from which divers plunged into the waters below was 85 feet –equal to jumping off an eight-story building. Avid cliff divers travel the world in search of exotic locations to experience the thrill. Olympic Diving is the sport of jumping and falling into water from a platform or springboard, usually while performing acrobatics. It has been a popular pastime across the globe for many years but the first diving competitions were held in England in the 1880's and synchronized diving became an Olympic sport in 2000. As a method of exercise, diving has been used by gymnasts since the early 19^{th} century in Germany and Sweden. In England, the practice of high diving became very popular and in 1893 the first diving stages were erected at a height of 15 feet at the Highgate Ponds, where the first world championship took place in 1895 (National Graceful Diving Competition).

Diving and Swimming Technique

Although the global governing body of diving is FINA, which also governs swimming, synchronize swimming, water polo and open water swimming, the sport of Diving does not have the same contact with the water as the other aquatic sports have. The competitors must possess both the skills of gymnasts and dancers, such as strength, flexibility, kinesthetic judgment and air awareness. When competing, divers are required to fulfill established requirements, including somersaults and twists, and have high acrobatic and coordination skills to perform complex dives. They must, also, feel comfortable in deep water and have the ability to swim. The entry is the only phase during the dive that the diver's body immerses into the water. During the entry the rules state that the diver's body should be vertical, an almost impossible task that forces divers to create the illusion of being vertical, especially with rapidly rotating multiple somersault movements. One technique is to allow the upper body to enter slightly short of vertical so that the continuing rotation leaves the final impression of the legs entering vertically. Another is to use "entry save" movements of scooping the upper body underwater in the direction of rotation so as to counteract the rotation of the legs. Athletes hit the water at speeds of up to 40mph, with supreme acrobatic and coordination skills required to perform the complex dives. The rules state that is important the **amount of splash created by the entry to the water** (how the diver hits the water). The arms must be beside the body for feet-first dives, which are typically competed only on the 1m springboard and only at fairly low levels of competition, and extended forwards in line for "head-first" dives, which are much more common competitively. It used to be common for the hands to be interlocked with the fingers extended towards the water, but a different technique has become favoured during the last few decades. Now the usual practice is for one hand to grasp the other with palms down to strike the water with a flat surface. This creates a vacuum between the hands, arms and head which, with a vertical entry, will pull down and under any splash until deep enough to have minimal effect on the surface of the water (the so-called "rip entry"). Once a diver is completely under the water they may choose to roll or scoop in the same direction their dive was rotating to pull their legs into a more vertical position [58].

The Olympic Triathlon

The Olympic Triathlon is a multi-sport event that requires the completion of three continuous and sequential endurance events. The word "triathlon" is of Greek origin from τρεις or treis (three) and αθλος or athlos (contest). It consists of a combination of swimming, cycling and running and it requires great physical fitness and endurance. Triathletes compete for fastest overall course completion time and the sport was recently included in the Olympics.

The first modern swim/bike/run event to be called a 'triathlon' was conceived and directed by Jack Johnstone and Don Shanahan, members of the San Diego Track Club, and was held at Mission Bay, San Diego, California on September 25, 1974. The first modern long-distance triathlon event was the Hawaiian Ironman Triathlon. It included a swim of 2.4 miles (3.9 km), a bike ride of 112 miles (180 km), and a marathon run of 26.219 miles (42.195 km). The sport made its debut on the Olympic program at the Sydney Games in 2000 over the Olympic Distance (swim: 1,500 m (1,600 yd) – bike: 40 km (24.9 mi) – run: 10 km (6.2 mi) [82].

Triathlon and swimming technique

Triathletes usually swim in open-waters and swimming is only one part of the race they participate. Many triathletes often use their legs less vigorously and more carefully than other swimmers, conserving their leg muscles for the cycle and run to follow. They altered swim strokes to compensate for turbulent, aerated water and to conserve energy for a long swim, while others employ drafting or dolphin kicking and diving to make headway against waves or body surfing to take advantage of a wave's energy and speed up their swim. They must, also, swim sometimes with a raised head above water, in order to spot landmarks or buoys that mark their course. Moreover, open water swim areas are often cold and wearing a wetsuit provides a competitive advantage. Due to that, specialized triathlon wetsuits have been developed in a variety of styles to match the conditions of the water [64, 83].

Modern pentathlon

The modern pentathlon is an Olympic sport that comprises five events: fencing, 200 m freestyle swimming in a pool, show jumping, and a final combined event of pistol shooting, and a 3200 m cross-country run. It is a variation of the Ancient pentathlon and it focuses on skills that were essential to a 19th century soldier, such as shooting, swimming, fencing, equestrianism and cross country running. The sport has been a core sport of the Olympic Games since 1912, and since 1949 an annual World Championship has been held [84].

Rescue swimming

Rescue swimming and lifeguard saving water techniques are performed at the surface of the water as well.as underwater. Each type of rescue technique requires great swimming and advance water skills because several factors are involved in a rescue case.

Lifesaving Swimming Sport

Lifesaving is the act involving rescue and first aid. Lifeguard techniques are mainly developed and used in rescue situations, where first aid is needed. Lifesaving could involve dangerous situations in water and aquatic rescue of people in need, but it, also, include ice rescue, flood and river rescue, pool rescue and other emergency services. Finally, it can, also, be a type of sport, in which lifesavers compete with each other in speed and team work.

Lifesaving sport has grown in popularity around the world. The sport consists of a series of competitions with the intent to further develop and demonstrate lifesaving skills, fitness and motivation. It is a sport that can be played in indoors swimming pools or on the beaches and is one of the few sports that have a humanitarian purpose, since this type of sport was primarily developed in order to maintain and improve people's essential physical and mental skills necessary to save lives in an aquatic environment. Competitive lifesaving is carried out widely in the UK, with clubs including Derby Phoenix Lifesaving and Crawley. Competitions at university level are organized through BULSCA. Lifesaving has progressed significantly becoming a modern and widely known sport and occupation.

Furthermore, rescue swimming is swimming with the goal to rescue other swimmers. The term rescue swimmer may be applied to any number of water rescue professionals, in coast guards and militaries operating around the world. The purpose of their training is to acquire the necessary skills for entering the water and assisting survivors in distress. Training programs for rescue swimming can be found in various countries, such as Canada, Denmark and the USA. These training programs teach future lifeguards essential swimming styles, such as the eggbeater kick, that help them to rescue drowning victims [85].

Recreational Sports

There are a number of recreational sports practiced around the world.

Among them, snorkeling is a popular one and so is aqua aerobics. The first is a practice of swimming at the surface (typically of the sea) with the aid of a mask, fins and snorkel. Aqua aerobics, is a form of exercise performed in shallow water by all age groups.

Aqua aerobic

Aqua aerobic has become a preferable form of exercise for many, since it exercises the body in a much more enjoyable and safe way, reducing the risk of injury to muscles and joints and preventing overheating of the body. Aquaerobic focuses on buoyancy, balance and streamlining of the body in water and apart from its beneficial results for the body in both healthy and injured people, it can also serve as the first step to swimming lessons and a way to help hydrophobics overcome their fear of water [86].

Water sports on water surface

Surface water sports are very popular and even though the human body does not come in contact with water, since they are performed atop a body of water. There is an endless list of surface water sports available for people, such as speed boat water sports, which includes sports such as racing, freestyle tricks for recreation, water skiing, barefoot skiing, boating and boat racing, as well as cable skiing and rowing (usually on rivers, lakes or the ocean). There are, also, water board sports and sports by wind acting. Water board sports are sports that are performed with some sort of board as the primary equipment on a variety of terrains, such as flat water or big waves and air. Kite boating, kitesurfing, skim boarding, skurfing and surfing are only a few of the water sports that belong to this category [58].

Windsurfing

Windsurfing is a surface water sport that combines element of surfing and sailing. This sport involves travel over water on a small 2-4.7 miter board using wind for propulsion in combination with a single sail. The sail is connected to the board by a flexible joint. The sport is a hybrid between sailing and surfing. The sail board might be considered the most minimalistic version of the modern sailboat, with the major exception that steering is accomplished by the rider tilting the mast and sailor, when planning, carving the board, rather than with a rudder. Windsurfing can be said to straddle both the laid-back culture of surf sports and the more rules-based environment of sailing. A windsurfer offers experiences that are outside the scope of any other sailing craft design. Windsurfers can perform jumps, inverted loops, spinning maneuvers, and other “freestyle” moves that cannot be matched by any sailboat. The boom of the 1980s led windsurfing to be recognized as an Olympic sport in 1984 [87].

Team Water Sports on water

There are various team sports that take place on the water’s surface that are, also, well-liked by many people around the world and attract the attention of large crowds. These water sports relay on teamwork, synchronization of movements, balance, energy and joint effort in order for the teams to be successful. Rafting is a famous leisure sport found in this category, it is a river sport that is considered to be slightly dangerous, depending on the location and the water’s current speed. Rowing is, also, a river team sport, in which athletes compete in boats on rivers, lakes, or the ocean, depending on the type of race. The force of the athletes on the oar blades of the boat while rowing, work against the water forces to propel the boat forward. It is played for both competitive and recreational purposes, and is one of the oldest sports to be included in the Olympics. Another team sport found in this category is Yachting sailing or Yacht racing.

Sailing: Traveling in the open sea

Sailing has played an important role in the development of civilization as we know it, since it offered humanity a greater mobility than travel over land, whether for trade, transport or warfare, and the capacity for fishing. Representations of ships under sail date back to 5000 BC, while advances in sailing technology from the Middle Ages onward allowed Arab, Chinese, Indian and European explorers to make longer voyages into regions with extreme weather and climatic conditions. From the 15th century onwards, sailing contributed to the exploration of the world, since European ships went further north, stayed longer on the Grand Banks and in the Gulf of St. Lawrence, and eventually began to explore the Pacific Northwest and the Western Arctic.

All around the world, sailing is enjoyed both as a recreational activity and as a sport. Recreational sailing or yachting can be divided into racing and cruising. Cruising can include extended offshore and ocean-crossing trips, coastal sailing within sight of land, and day sailing. Those who like traveling by sea and great adventurous, sailing is a fascinating sport that requires experience in varying wind and sea conditions, as well as knowledge concerning sailboats themselves and an understanding of one's surroundings.

Sailing offers to those who love it many advantages that the land cannot afford them. Most long-distance sailors claim that being in the open sea has helped them get rid of the excessive noise of the city-life, sharpened their senses and become more receptive to feelings and sounds of nature and especially the sea. In particular, Josha Slocum, who was the first man to sail single-handedly around the world, mentions in his 1900 *Sailing Alone Around the World* book that a special boned is created between the sailor, his boat and the sea, when one travels alone in the open sea.

Stephen J Bryant, owner, skipper and creator of websites that provide pilotage information for small craft Mariners planning on visiting ports, also mentions that boats to sailors are like living human beings with different characters and characteristics, that speak to you and guide you in the open sea, allowing you to see, hear and experience things you would normally ignore.

Freedom is a concept that most people think when they experience sailing. With the wind at the sails and the ability to go anywhere the heart desires without the distractions of cell phones, work, bills, traffic, clocks, etc. sailing is liberation at its finest [88].

Under Water Sports

There are, also, a number of competitive or recreational sports that people enjoy under water. In fact, underwater sports are considered by many as fun-filled, stress-relievers that help people relax and rejuvenate. Snorkeling and recreational diving are among the most well-known and loved of the underwater sports, that are usually on offer in many places of rare natural beauty. Recreational diving or sport diving, in particular, is a type of sport that relates to snorkeling and underwater hunting and uses SCUBA equipment for the purpose of leisure and enjoyment.

Before the development of scuba equipment and wetsuits, recreational underwater excursions were limited by the amount of breath that could be held. The invention of the aqualung in 1943 by Jacques-Yves Cousteau and the wetsuit in 1952 by University of California, Berkeley physicist, Hugh Bradner, and its development over subsequent years, led to a revolution in recreational diving. Even though, for much of the 1950s and early 1960s, recreational scuba diving was a sport limited to those who were skilled and able to afford the equipment, the sport's popularity forced manufacturers to produce easy to use and affordable equipment, accessible to everybody. The developments in SCUBA technology increased the safety, comfort and convenience of the gear encouraging more people to train and use it.

In the 1950s, navies and other organizations performing professional diving were the only providers of diver training only to professionals. The first scuba diving school was created in France with the purpose of training the owners of the Jacques Yves Cousteau and Emile Gagnan designed double hose scuba. After that, many more scuba diving schools started to offer training to those who were interested to learn, such as the Melbourne City Baths, the Scripps Institution of Oceanography (1952), the British Underwater Centre (1953) and the Los Angeles County Underwater Instructor Certification Course (1954). Professional instruction started in 1959 when the non-profit NAUI was formed, which later effectively was split to form the for-profit PADI in 1966. Today, PADI alone issues approximately 950,000 diving certifications a year.

Even though diving is now a favorite recreational sport for the public and despite the developments in scuba technology and safety measures available, recreational diving depths are limited to a maximum of between 30 and 40 meters, beyond which a variety of safety issues- such as oxygen toxicity and nitrogen narcosis- make it unsafe to dive using recreation diving equipment and practices. There are many diving activities which need further training than that provided by the initial courses. Among them are altitude diving, Cave diving, Deep diving, Drift diving, Dry suit, Ice diving, Identifying and surveying sea life and freshwater life, Maritime archeology or Underwater archeology, Night diving, Rebreather, Rescue Diver, Side mount diving, Underwater navigation, Underwater search and recovery, Underwater videography, Wreck diving, Nitrox diving and Underwater photography[59].

Competitive underwater sports

Underwater sports are a group of competitive sports that are conducted in open water, lakes or artificial aquatic environments, using one or a combination of underwater diving techniques, such as snorkeling or scuba, diving masks, fins or mono-fins, weights and nose-clip. This type of sport includes, fin-swimming, free-diving, spearfishing and underwater target shooting, the aquathlon underwater football, underwater hockey, underwater ice hockey, underwater orienteering, underwater rugby.

Aquathlon

The Aquathlon or underwater wrestling is an underwater sport where two competitors wearing masks and fins wrestle underwater in an attempt to remove a ribbon from each other's ankle band in order to win the bout. The wrestling match takes place in a 5-metre square ring within a swimming pool, and is made up of three 30-second rounds, with a fourth round played in the event of a tie. The sport was created and developed during the years 1980 to 1982 by Igor Ostrovsky, an underwater sports coach at the Moscow Technological Institute and it was first introduced in April 1982 in Moscow. The first International Competition was held during August 1993 in Moscow and three years later the International Aquathlon Association (IAA) was established. The sport was officially recognized by the Confédération Mondiale des Activités Subaquatiques (CMAS) in 2008 [59].

Fin- swimming

Fin-swimming was developed in Europe during the 1950s, when Luigi Ferraro, an Italian diving pioneer, organized the first fin-swimming competition in the sea. The first competition was then held in the Soviet Union during 1958 and in 1969, the first European Fin-swimming Championship was held in Locarno, Switzerland. Finally, the first World Championships were held in Hanover, Germany during 1976 followed by the inclusion of the sport in the inaugural World Games in Santa Clara, California, USA during 1981. In the 1970’s, the arrival of the monofin replaced the bi-fins and this revolutionized the sport, since it offered the opportunity for a much improved performance. The main appeal of monofin swimming is the speed that a swimmer can reach. The world record time for the 50 m in fin swimming has approximately 50% increase in speed over classical swimming.

Fin-swimming is well-liked by many, since fin-swimmers are not required to be good swimmer, in order to participate in it [89]

Free diving

From Origins to Modern Times

Free diving is as ancient as humanity itself and is considered to be based on old subconscious reflexes written in the Homo Sapiens genome. Apnea has become a synonym for free diving in athletic terminology and it means diving on one breath of air, without using equipment. Even though free diving is seen as a natural and serene way to explore the ocean, apnea is not an easy task to achieve, since it requires training, having the right mood and knowing the limits of your body and mind.

In 1960 a scientific theory labeled *The Aquatic Ape Hypothesis* was published by the late Sir Alister Hardy to mixed reviews. Sir Alister Hardy claimed in his paper that humans had primate ancestors more aquatic that previously imagined, basing his claim on studies of human lack of fur and its replacement by a layer of insulating sub skin fat, similar to that of marine mammals. According to this theory, therefore, swimming and diving was a key feature of the Homo family.

Indeed, free diving as an activity seems to be as ancient as humanity itself, since free diving dates back to at least 5.400 B.C. Archaeological evidence that would confirm the presence of free diving in ancient times can be found in a Scandinavian Stone Age culture, called Ertebolle, a culture of shell fishing divers. Proof is also present in other parts of the world, in the *Mesopotamian* and *Egyptian* civilizations dating back to 4.500 and 3.200 years B.C. respectively. Moreover, the legendary philosopher *Aristotle* is the first to document the common problems associated with diving while it is believed that *Alexander the Great* used divers during his military campaigns. In addition, in the *Roman Empire* existed a war unit called "Urniatores" that were assigned the recovering of lost anchors, the removal of underwater barricades and other sub aquatic war tasks.

Finally, in Asia and across the Middle Eastern, Indian and Pacific oceans, the desire for pearls and other aquatic goods lead to the increase of free diving activities over the centuries. A particularly famous –even today- free diving tradition is that of the *Amas*. This extraordinary tradition involves mostly Japanese and Korean women, aged 17 to 50 years of age, who use rocks to plunge to the bottom of the sea, where they pick up shells and sea weeds in water barely over 10 degrees Celsius.

There are, also, various legends about free diving, circulating in later times. For instance, in 1913, the Italian naval flag ship “La Regina Margherita” lost its anchor off the Greek island Karpathos and offered a reward for its retrieval. For the task a 35-year-old sponge diver from nearby Symi was recruited, who, despite the fact that he suffered from lung emphysema, smoked extensively and was part deaf, he managed to salvage the anchor from 88 meters depth. His diving technique involved the use of a heavy stone called ‘skandalopetra’ and frees diving up to three minutes at a time. This legend was seen by many as an exaggeration, but in 2001, the Italian Navy confirmed most of the reports[90].

The modern sport of free diving, however, was founded by the Italian fighter pilot and avid spear fisher Raimond Bucher, who, for a lavish bet of 50.000 lire, reached a depth of 30 meters on a breath hold in a spot outside Naples. Ennio Falco broke Bucher’s record two years later, creating the grounds for a competitive sport and attracting even more free divers to Italy. By 1962, Enzo Maiorca monopolized the scene of competitive free diving, establishing it as a competitive sport around the world. Maiorca was the first to reach and breach the fateful 50 meters barrier in 1962, despite warnings from scientists that beyond that mark, the human lungs would collapse from the pressure. Maiorca enjoyed the first place in free diving for 25 years, until Frenchman Jacques Mayol was introduced in 1966. Mayol introduced the use of yoga and meditation to free diving and went on to breach the 100 meters free diving mark and achieve eleven world records. Their sportive rivalry was immortalized in the heavily fictionalized depiction of the two divers in *Luc Besson*’s 1988 famous motion picture The Big Blue [91, 92].

A very influential figure of free diving, the American Robert ‘Bob’ Croft, was also introduced around the same time. Croft, a USA Navy submarine personel trainer, was the first to free dive beyond the 70 meters and the first to use lung packing, known as the Glossopharyngeal Breathing Technique. The 1943 invention of the aqualung had lead scuba diving to overrun free diving, both professionally and leisurely but in the 1960’s, women such as Giliana Treleani and Evelyn Patterson had gone beyond the 30 meters depth. In fact, two of Enzo Maiorca’s daughters took up records in the late

1970's, reigniting interest in the sport of competitive free diving and opening up the way for divers such as Angela Bandini and Debora Andollo to break the 107 meters depth record of Jacques Mayol [91].

The recent history of free diving

Most of the free diving activities were suspended by CMAS in the 1960's, after a combination of medical and safety concerns were raised. Despite the suspension, free divers continued to dive and in the 1980's a new fierce rivalry was born between two free divers: the Italian Umberto Pelizzari and the Cuban Francisco Rodriguez, who, fully equipped with modern tools and equipment excelled in the category now called No Limit, taking it into the meters 110, 120, 130 and beyond. In 1990, Roland Specker, a free diver from France, met free diver Claude Chapuis from Nice and decided to organize clinics in order to attract more people to free diving and to create proper regulations for the sport's world records. Eventually, the two of them with the help of others created the Association Intrenationale pour le Development de l'Apnee (AIDA), with Specker being its first president. AIDA quickly recognized several records and they became the reference for free diving.

AIDA and CMAS's differences created a climate of political volatility in the field of competitive free diving, with AIDA's world record's regulations winning ground. Through the early 1990's, Chapuis had organized small competitions between free divers and the idea of a world championship was born. The 1st AIDA World Championship was held in Nice in October 1996 while 1997 was a transition year for free diving, with several free divers creating their own groups in their countries.

Despite the differences, the 2nd AIDA World Championship was held in Sardinia in 1998 and was hosted by Umberto Pelizzari. 28 countries participated and the event received praise for its organization. The interest sparked by free diving lead to the suggestion of many new competitive disciplines in the field. A pool training discipline, that was later labeled Static Apnea, was gaining some recognition, enough to motivate AIDA to keep distinctions between depth records set in sea and fresh water and between short and long pool records in the new discipline called Dynamic Apnea.

By the mid 1990's the static and dynamic disciplines received a lot of attention, mainly due to Frenchman Andy Le Sauce, who held the first place for five consecutive years in both static and dynamic Apnea. At the end of this decade, AIDA became AIDA

International and free diving enjoyed an explosion in numbers of registered athletes and competitions, developments in regulations and increased interest by the media. Around that time, also, free divers kept pushing the limits of breath holding diving, with Umberto Pellizzari becoming the first to reach 150 meters in No Limit and the first to reach 80 meters in Constant Weight.

In 2000 a new format of competition has emerged. AIDA organized the World Cup and in an effort to reduce criticism for blackouts and sambas, kept the team format. Unfortunately, the three competitions that were held had limited success and many expressed the desire to see more individual events worldwide. Over the years that followed, even more local clubs started organizing individual pool competitions and in 2005 the 1st AIDA Individual World Championship was held in Renens, Switzerland. In this event, many great athletes surpassed the 200 meters depth in dynamic and 8 minutes in static, while Natalia Molchanova set three new world records. Molchanova went on to claim the gold in the Constant Weight discipline a week later.

Throughout the 2000's, AIDA administered competitions all over the world almost on a weekly basis, gaining recognition and supporters. In 2007, AIDA launched new guidelines for sled diving and great free divers such as Herbert Nitsch and Sara Campbell broke new deep diving world records. By 2008, AIDA has officiated 204 world records and presented 156 world championship medals, introducing new and talented athletes from all over the globe, such as William Winram, Dave Mullins, Ant Williams, Elisabeth Kristoffersen and Karla Fabrio. Today, free divers seem to defy science by holding their breath for more than 10 minutes, swimming further than 250 meters in length and going beyond 200 meters in depth, all on a single breath of air, making clear to the world that the aquatic potential of humans knows no limits [66].

Safety and human breath-hold diving

Free diving has often been linked to various physiological reactions, limitations and pathophysiological mechanisms, since it claimed the life of many divers over the years. It is true that the human body faces many challenges when in deep water, such as hypertension, bradycardia, compression of the lungs, intrapulmonary hemorrhage, edema and the effects of glossopharyngeal insufflations and exsufflation. While this is true, the current free diving world records mentioned above and the quest for even further performance enhancements by free divers indicate that humans are able to overcome the challenges presented by diving in great depths. Moreover, a closer look into mortality figures reveal that free diving has claimed the lives of mainly less well-trained recreational divers and competitive spear fishermen, who fall victim to hypoxia [25, 93].

Humans performance in Apnea and the diving reflex

Human 'adaptation' to water is both conscious and unconscious. The diving reflex in humans is characterized by breath-holding, slowing of the heart rate, a decrease in cardiac output with sympathetic mediated peripheral vasoconstriction, an increase in mean arterial blood pressure and splenic contraction. Blood is re-directed to more vital organs (heart, brain and lung) while at the peripheral level poor irrigation of tissues manifests as lactate accumulation. A simultaneous splenic contraction is also observed which indeed increases the static apnea duration and helps in further resurgence of red blood cells in the blood circulation. These phenomena also exist during repeated episodes of dynamic apnea. Diving reflex is firstly triggered by breath-holding and is augmented further by immersion of the face into cold water.

All these modifications allow economizing of the oxygen stores for the breath-hold diver. When we hold our breath, the body slowly converts the oxygen our bodies store in our lungs and blood into carbon dioxide. Levels of oxygen decrease (to hypoxia), and carbon dioxide increases (to hypercapnia). As our body wants to breathe a powerful involuntary mechanism overrides voluntary breath-holding and causes the breath that defines the 'breakpoint'. The occurrence of the breakpoint breath appears to be caused by neurological and respiratory reflexes [91].

Based on neurological researches, the central nervous system begins to try to restart respiration, including through the diaphragm, before the impetus to breathe becomes almost irresistible to an untrained breath holder. In a competitive static apnea event, in which divers hold their breaths in stationary positions, competitive breath holders can last five to eleven minutes as the body puts into place a range of survival responses and competitors learn to make the most of the oxygen they've got. Scientist have found, that most divers experience involuntary contractions of the diaphragm several minutes during the duration of a breath hold. Elite apneist are able to continue to hold their breath even though the nervous system sought to reinitiate breathing. During a breath hold, the brain is still connected to oxygen stores in the lungs and the body quickly starts making adjustments to stretch this oxygen store last as long as possible.

Studies also show that the central respiratory rhythm, an autonomic rhythm like the cardiac rhythm, persists during a breath hold, even though voluntary breath holding suppresses it active expression. This means that breath-holders are not so much stopping their breathing voluntarily as they are holding their chests open and resisting the respiratory rhythm. The respiratory rhythm intensifies during the breath hold, even causing more widespread respiratory-anticipating reactions like 'tracheal tugging' in the lead up to the break point.

When we hold our breath, we are not so much 'running out of air' as we are fighting powerful impulses to breath when we don't really need the oxygen yet. Breath holding is the active over-coming of automatic processes by conscious suppression. In other words, exceptionally long breath holding requires that a person learns to resist powerful involuntary reflexes, especially spasms in the diaphragm as it attempts to contract in order to re-initiate breathing.

Competitive free divers are able to experience and enjoy the whole underwater swimming, by stopping the airway voluntarily and close the glottis muscularly. In other words, they have cultivated and developed the skill of involuntary breathing. A diver can make the last breath last, through a range of techniques, which help to stretch the oxygen supply [94].

Before entering the water:

In competitive free diving, almost all athletes employ "lung packing" in the water prior to submersion. 'Lung packing' or hyper-inflating the lungs to some degree (not to dizziness) before diving is discouraged for a number of reasons, but it can put more air into the lungs to start with, boost the blood oxygen level in the blood slightly, and – most importantly and dangerously – suppress the level of carbon dioxide in the body. With less carbon dioxide, a diver's breathing reflex is going to be delayed, but this may also be the reason that free diving participants pass out with some frequency; they run low on oxygen before carbon dioxide levels get high enough to prompt breathing

The simplest way to make the breath-hold last, is to do as little as possible and to stay calm. The record for stationary breath-holding is much longer than the record for any dynamic activity. In addition, the calmer a diver can stay, the more he will suppress his heart rate, decreasing the speed at which the body runs through its oxygen supply. humans can make use of breath holding and the dive reflex, when they need to relax because, the heart rate drops and a feeling of peace and relaxation comes.

The human dive reflex, can increase with training. A trained diver's heart rate can drop profoundly during a dive [97]. Over time and repeated dives, the divers' bodies adapt to diving. Human respiratory system may have 'plasticity' at a number of different levels, from autonomic behavioral adaptations (breathing differently), to structural changes that affect lung volume, and even to biochemical shifts, such as changes to red blood cells. Adaptation can occur through 'modifications to the gas exchanger, respiratory pigments, respiratory muscles, and the neural control systems responsible for ventilating the gas exchanger.

Researches on veteran divers have shown, that the dive reflex becomes exaggerated: bradycardia increases so that heart rates become abnormally low, and the divers' responses to hypercapnia (high carbon dioxide levels) become blunted. Trained free divers are able to absorb almost twice as much carbon dioxide into the blood before needing to breathe. According to Ferretti and Costa (2003), similar ventilatory responses have been found in synchronized swimmers, underwater hockey players, submarine escape tower trainers, and Royal Navy divers. Since the increase in carbon dioxide levels is the primary stimulant to breathe, the ability to tolerate higher levels of CO_2 in the blood (hypercapnia) would allow divers to avoid gasping in conditions that would be hard to resist for normal individuals

The condition of hypercapnia that was maintained during most of the dive, which could even lead to a reversal of pulmonary carbon dioxide transfer, would compel the diver to resist the drive to breathe elicited by the stimulation of central and peripheral chemoreceptors. This opposition would be facilitated by the observed blunted ventilatory response to carbon dioxide. Carbon dioxide sensitivity could be a primary determinant of the breath-hold duration, at least in professional divers. It is noteworthy that also diving mammals, which are frequently exposed to high arterial PO_2 and PCO_2 values, are characterized by blunted ventilator responses to carbon dioxide compared with non-diving mammals of similar size [95].

During breath-holding, oxygen stores reduce and the body starts diverting blood from hands and feet to the vital organs. Human bodies have a way to compensate. Underwater pressure constricts the spleen, squeezing out extra hemoglobin, the protein in red corpuscles that carry oxygen around the body.

Competitive free-divers can achieve very low heart rates. But they do so, in part, by seizing willful control of the autonomic system through proxy variables, specifically emotional states. They don't just benefit from the 'dive reflex'; they drive a consciousness-to-emotion-down-to-autonomic chain to get more out of the dive reflex than just the 10-25% reduction in heart rate that most of the people would get (if they don't panic, in which case they might not even get that).

William Trubridge, for example, like many competitive free divers, uses meditative and mind-body techniques borrowed from yoga. Other divers use pre-dive routines, to relax their chest and air gulping. That is, the 'reflex' can be elaborated into a well-schooled top-down technique for self-management that ends up exerting control over autonomic systems like the cardio-pulmonary system [94, 96].

Thermoregulatory Response

Water immersion causes a shift in body fluids, which in turn is affected by body position before entering the water and after immersion. Also, the depth of immersion can cause a shift. Another thing that affects body fluids is the water's temperature that also affects heat exchange. Fluid in the body is shifted during water immersion because of a "relief" of the gravitational effects placed on the body, making, for example, a 70-kg swimmer weigh about 10 kg in water

Moreover, the transition from standing on land to supine immersion in the water triggers a renal diuresis and subsequent hemoconcentration and that is why many swimmers may feel an urge to urinate not long after entering the water.

In swimming, despite the fact that metabolic rates are increased to similar levels, evaporation is stopped by the surrounding water and convection is main cause of heat loss. Activity level influences thermoregulation in water, and subsequently thermal comfort. In swimming competitions governed by Federation International Natation Amateur (FINA) regulations the water temperature does not fall below the range of 25 to 27°C.

In contrast, swimming training often presents a thermoregulatory problem, mainly because working at high intensities for long periods of time produces high body heat. For instance, when entering the water, the skin temperature is in equilibrium with the water's temperature but if the water is below 33 to 34°C (thermoneutrality), and the swimmers are at a low level of energy expenditure, they become hypothermic after prolonged immersion. The core temperature is significantly elevated during high-volume swimming training and they found an increase in core temperature (1" to 2°C) in swimmers completing workouts of 8,000 to 10,000 m in length [97-99][97].

Extreme adaption in gold water

Spending a lot of time in water can cause a lot of problems to the human body's ability to maintain a constant temperature. The thermal conductivity of water is twenty-five times greater than air (Reilly and Waterhouse 2005), so being submerged in water below body temperature can quickly lead to hypothermia. Despite that fact, Korean divers are known to spend hours in the water at 10 degrees Celsius in January, conditions that quickly lead to hypothermia, without wearing insulated gear.

In fact, during the coldest seasons, an elevation in their basal metabolic level—an incredibly rare seasonal variation in human metabolism—left them unable to eat enough to keep from slowly losing weight. In addition, it was observed that the divers' vascular systems appeared to adapt, restricting heat loss from blood vessels near the skin by constricting them below the level of obese individuals. This way, their skin became cool to the touch but without showing signs of the shiver response, because such a thing would have sped up the body's radiation of heat.

Moreover, studies have also found that adaptation to cold has also been found in Australian aborigines, who sleep nearly naked in the cold, in trained Arctic scuba divers, even when they wore wetsuits and in Canadian fishermen, who repeatedly immerse their hands in water at 9-10 degrees. On the other hand, however, the adoption of wetsuits by the Ama has led to a decrease in their bodily adaptation to cold-water resistance [100, 101].

Underwater Vision

In the field of underwater vision, Anna Gislen's work has produced some very interesting results. As it is commonly known, humans are poorly adapted for underwater vision, given that in air, the curved corneal surface accounts for two-thirds of the eye's refractive power and this is lost when air is replaced by water. Therefore, if a human is immerged in water, the image that the eye can see becomes severely blurred and defocused. Anna Gislen and her team studied a population of sea gypsies, called the

Moken, that live in the archipelago of Burma, in Southeast Asia, and are suspected of being adapted for improved underwater vision.

Indeed, Gislen and her team (2003) tested the visual acuity of six Moken children to that of 28 European children in various experiments. The results of those tests shown that, even though on dry land both the Moken and the European children appear to have similar abilities of accommodative range, when underwater, the Moken children were able to constrict their pupils considerably, compared to their European counterparts (Moken children, 1.96 ±0.05mm, n=6, European children, 2.50 ±0.05, n=15, Mann-Whitney, $p<0.001$). Gislen et. Al (2003) concluded that the underwater acuity of Moken children is roughly twice as good as those of the European children while the amount of accommodation necessary is about 15-16 D, which is the reported limit of accommodation for children of that age. Most importantly Gislen believe that the Moken children's ability to see clearly underwater is something they have learn to do, due to their extensive use of their eyes underwater to gather food, and therefore, it should be possible for all human beings to learn to see better underwater.

To that effect, in 2005, Gislen, Warrant, Dacke and Kröger tested their theory about underwater vision, by examining more closely the Moken children's contrast sensitivity, while, at the same time, training European children in underwater activities, in order to determine whether their underwater vision could improve. The researchers have found that the improved underwater vision of the Moken children was not the result of better contrast sensitivity in general, but rather that they have learned to control their accommodation underwater, due to their dependence on it for survival. This argument was further supported by the results the researchers obtained, through the training of the European children in underwater activities over the course of one month.

In particular, Gislen prepared and realized a one-month intense underwater activities course (11 sessions) for a group of European children, in order to improve their underwater vision. When, after a four-month period of no underwater training, the underwater vision of the group was tested, the results have shown that the European children had improved their underwater vision and appeared to have distinct bursts of pupil constriction. Furthermore, eight months after the initial underwater training, the group of children was tested once more in similar conditions to the ones the Moken children are used to, and the results verified completely Gislen's initial hypothesis: that, through training, the European children can and have attained the same underwater acuity as the Moken children [100, 101].

Underwater hearing

Hearing is the sense of detecting. When we are hearing sounds, it means that we are receiving information about the environment from vibratory movement communicated through a medium such as air, water or ground.

According to a research by U.S. Navy, human beings possess the ability to hear far higher pitched sounds when underwater than they can while on terra firma and that happens by "hearing" with their bones rather than through the normal pathways of hearing.

As it is widely known, through normal pathways, human hearing differs above and below water. That practically means that humans only hear between 20 and 20,000 hertz through the air, while their hearing threshold and the ability to localize sound sources are reduced underwater, in which the speed of sound is faster than in air. On land, humans hear through air conduction. Sound pressure waves cause tiny disturbances in the air that travel into the ear canal and vibrate the ear drum, which is connected to the three smallest bones in the body, the ossicles of the middle ear. The ossicles are connected to the cochlea, which is filled with fluid and contains "hair cells," or tiny protrusions that also move, stimulating the auditory nerve, which sends signals to the brain.

Underwater, hearing, however, appears to depend on differences in amplitude detected by bone conduction. The U.S. Navy researchers claim that underwater humans can catch sounds all the way up to 200,000 hertz when submerged. According to them, that is possible because underwater, humans don't hear using the normal channels. Sound lateralization on land is largely explained by the mechanisms of interaural intensity differences and interaural temporal or phase differences. During submersion, these differences are largely lost due to the increase in underwater sound velocity and cancellation of the head's acoustic shadow effect because of the similarity between the impedance of the skull and the surrounding water. The study found that humans hear through bone conduction, which bypasses the outer ear and the ossicles of the middle ear and sound comes through the mastoid, or the bone you can feel if you put your fingers behind the ear. This way, the human ear can actually receive sounds at frequencies way higher than most people would have expected [102].

Extreme scuba diver's adaptation in the underwater environment

It is commonly accepted that the underwater environment often creates added stressors for divers, mainly due to its differences from the terrestrial environments. These stressors can be structural, such as the exposure to high pressure, environmental, such as the variations of temperature and visibility, physiological, such as the toxicity of breathing gases or psychological, such as changes in anxiety and sensory stimulation. Therefore, many researchers agree that divers must undergo a significant process of psycho-physiological adaptation, in order to remain underwater and remain useful, without causing problems to their health [103].

This set of physical, medical and psychological characteristics are of great importance in scientific and operational diving, since divers must overcome underwater stressors in order to successfully adapt to such unusual conditions. And while the physical aspect of this adaptation has been in the center of scientific research, nowadays more and more studies in the field focus on the psychological approach to adaptation in such environments, in order to analyze the relationship of the dispositional traits of divers with their underwater performance and adaptation [104].

Scientists argue that intelligence and personality play an important role in every professional field, since they operate as predictors for a person’s ability to solve problems and perform in a satisfactory and responsible manner, even when the situation becomes unpredictable. Equally, divers are expected to perform effectively in stressful and emergency conditions, demonstrating confidence, ease, security and emotional stability. In addition, divers must have enough emotional control to respond calmly to the environmental circumstances and the psycho-physiological conditions of immersion

Since anxiety, stress and performance seem to be of importance in the diving field, where often errors can cause a high level of risk, it comes as no surprise that an interest in the empirical analyses of intellectual capacity and personality traits and their relationship with performance during training of divers is evident in studies in the field. To that effect, initial studies on the validity of psychological test in Spanish and Australian divers have shown that intellectual ability and personality traits were significantly correlated to the results obtained in diving courses, while numerous other studies have focused on typical traits of divers and their correlation with the decision to become a diver, as well as the success in diving courses.

Moreover, with regard to underwater performance, the results have confirmed the predictive power of intellectual capacity, reasoning, emotional stability, emotional control and facilitating anxiety with a positive sign of their coefficients and a negative sign of emotional sensitivity. Finally, the results have indicated that for underwater adaptation, emotional stability, emotional hardness, facilitating anxiety, intellectual capacity and emotional control constitute the most important predictors [104].

NASA studies show that the traits associated with the dimensions of adaptability and emotional stability may be useful predicting diving performance and adaptation to the environmental and operational conditions of diving. NASA and the Psychosocial Characteristics of Optimum Performance in Isolated and Confined Environments Space is considered to be an extremely inhospitable and unusual place for humans, since it presents unique challenges and extreme environments, compared to terrestrial conditions. In order for astronauts to be prepared for these extreme environments, NASA introduces them to NASA Extreme Environmental Mission Operations project, known as NEEMO, which allows them to live and work in one of the most extreme environments available on earth: the ocean. During this program, crew members, called aquanauts, live in the world's only undersea laboratory, which is located 3.5 miles off the cost of Key Largo, where most of the underwater activities are accomplished by traditional scuba diving [104, 105].

Apart from the training for space travelling and landing, the program focusses heavily on the physiological and psychological health of the aquanauts, since they have to spent long periods of time in an extreme environment of physical and psychological isolation, such as the floor of the Atlantic Ocean. Therefore, it comes as no surprise that NASA scientists have dedicated a lot of time in the study of psychosocial characteristics and their correlation with people's performance in isolated and confined environments.

NASA scientists have concluded that there is an obvious association between performance in extreme environments and emotional stability and age, education and socioeconomic and civilian status, marital status and enjoyment and awe of the environment. As far as crew homogeneity is concerned –which is considered to be another variable for performance- the studies have shown that it closely correlates with demographic characteristics, culture and personality. As far as personality is concerned, the results has shown that there is a link between performance in extreme environments and education/socioeconomic status, introvert personality and high need for achievement and high motivation [8].

For the most part, NASA in the review it has published pointed out that there are certain psychosocial characteristics that can be related to performance under any and extreme environmental or occupational settings. In particular, the results of various studies have shown that individuals who are older, more experienced and emotionally mature, highly motivated, socially adept, skillful in exercising leadership, satisfied with their jobs, highly productive and exhibit few symptoms of depression and anxiety and rely on social support networks to cope with stress are more likely to perform well under any conditions. Moreover, NASA's review of researches also pointed out that some not so desirable characteristics, such as being unmarried, having an introvert personality, not being particularly conscientious or open to experience, not expressing one's emotion or possessing a capacity for self-reflection, having little interest in leisure activities and needing little sympathy from others are uniquely suited characteristics for individuals living in isolated and confined environments [106].

The importance of Aquaticity

Aquaticity has significant, real-world applications—for sports, education, rehabilitation, creativity, childhood development, water safety, environmental awareness, and treatment of aqua phobia, addiction, trauma and more. Most of all, it can lead to a deeper understanding of who we are and how our bodies, minds and emotions are shaped by our interaction with the most prevalent substance on our planet- the water. This study offers new proposals for aquatic adaptability that humans can experience.

An aquaticity program promotes skills for the physical body, such as propulsion in and underwater, multiple body positions developing coordination, apnea ability, buoyancy, balance, strength, stamina and more. For the mental development, an aquaticity program is enriched with various challenges that enchase intelligence in the water, which is the ability to solve abstract problems and to learn. This is considered as the set of necessary skills for performing satisfactorily in various professional fields as lifeguards, scuba divers and free divers. A higher intellectual capacity enables a better understanding of the environment and also favors the ability to apply the available resources to achieve a suitable level of performance and adaptation to new situations. Furthermore, the measure of intellectual capacity is an appropriate technique for identifying individuals who can adapt to a changing and unpredictable environment such as the underwater one.

Good performance and adaptation requires coping with stressful situations, applying skills and resources at appropriate times, and reacting appropriately to emergency situations. The aquaticity program refers also in "water and our emotions". The contact with the water environment plays a vital role in human's physical and mental health. In the water, we-experience feelings of calmness free from tensions, a return to our origins. That means the feelings of safety and peace that we had in the womb of our mother before our birth. Our mind can reach harmony with archetypal sensations of quiet and pleasure only in water. This is the way to explain the possibility to feel beautiful sensations and really deep inner peace, experiences during immersion in liquid elements. Never the less aquaticity skills focus also, on Self-control in the water and develop functional responses to the demands of the aquatic environment. This can help panic reactions to be avoided.

Aquaticity and pedagogy

The issue of safety in water is a major concern for both children and adults. Aquaticity skills contribute greatly to the ability to survive in water, since they are closely linked with lifeguard training techniques and skills which, when acquired, could open up a lot of safe recreational opportunities for people, such as surfing, kayaking and boat fishing. Teaching children to feel comfortable when in water offers them valuable lessons for both the independence and self-confidence. In particular, aquaticity programs offer propulsion, floating, coordination and senses adaptation skills to children. Moreover, aquaticity challenges is a great way for them to get a lot of sensory input, since the constant sensation of water decreases tactile sensitivity and provides proprioceptive input of the body that strengthens body awareness and position in space. Lastly, all the above help children negotiate water emotional stability, safety and prepares them for most of the challenging situations that they may encounter in water.

Research Paper 1: Aquaticity: a discussion of the term and of how it applies to humans

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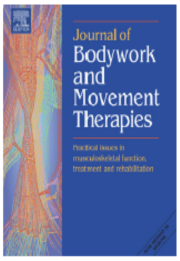

SYSTEMATIC REVIEW

Aquaticity: A discussion of the term and of how it applies to humans

Danae Varveri, MSc, Christina Karatzaferi, PhD, Elizana Pollatou, PhD, Giorgos K. Sakkas, PhD*

School of Physical Education and Sport Sciences, Department of Sport Science, LIVE Laboratory, University of Thessaly, Karies, Trikala GR42100, Greece

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ABSTRACT

The relationship between humans and water and the effects on aspects related to human performance has never been studied. The aim for the current systematic review is to attempt to define the term “aquaticity”, present the factors that describe it and reveal the form in which it presents itself in today’s society, in order to become a distinct scientific field of study. A systematic review of the literature has been conducted using anecdotal reports from the internet and forums as well as scientific articles and books from databases on issues related to aquatic sports.

To the best of our knowledge there are no scientific articles dealing with human’s aquaticity. In the current systematic review, four factors have been recognized that are closely related to human aquaticity. Those are related to physical condition in the water, to apnea and ability to immerse, to mental health and to parameters related to body composition.

According to our findings, “Aquaticity is the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. The level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element”. The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water. The development of knowledge regarding the aquatic environment leads humans to an improved state of aquaticity.

Key words: swimming, education, diving, aquatics, safety, water sports, therapy

Introduction

The aim of the current article is to attempt to discuss and define the term *aquaticity*, as it applies to humans, present the factors that characterize it and reveal the form in which it presents itself in today's society, in order to become a distinct scientific field of study that would allow its assessment as another parameter of human performance. One of the main difficulties of the subject is the term itself. To our knowledge, aquaticity, when used, describes the 'level' of being aquatic [107]. While missing in formal dictionaries it is a term frequently used in many biological disciplines and variable contexts. For example in ecology, aquaticity levels could range from 1 (truly aquatic species) to 8 (brackish water or salty marches species) – but the meaning of the term there is restricted in the evaluation of 'affinity' of an organism to water [108]. In sports coaching, trainers empirically evaluate children's aquaticity (for example when selecting 'talented' children for water sports) as ability to perform inside or underwater [109]. In rehabilitation, physiotherapists evaluate how 'comfortable' a patient may be in water. While in diving, aquaticity refers strictly to a diver's ability for optimal underwater performance (a culmination of efficacious and thus safe underwater movement) [92, 110, 111].

Based on the literature, popular sports culture and our interactions with the diving community it became clear that while aquaticity is indeed a term used among divers, swimmers, to describe how 'comfortable', 'efficient', or 'successful' is one athlete during water immersion etc, aquaticity has not been clearly defined in the scientific literature nor is it used to scientifically describe 'ability in water'. This poses a problem as often coaches, trainers and athletes refer to *levels* of aquaticity expressed through their empirical observations or expressions of personal experiences [112]. Moreover, as water activities are used in special needs education and rehabilitation/therapy settings, it became evident that there is a need to address the term and place it in a scientific context – that is the purpose of this article.

The benefit will be that a basis will be set for describing ‘ability in water’ and that will allow for devising a test to objectively evaluate it, and thus support the needs of various populations engaged in water activities. Indeed an aquaticity test has been developed and validated in healthy individuals by our group [113].

Aquaticity does not describe a ‘vague’ relationship between humans and water. We propose that it is a performance attribute that can be evaluated and improved upon with various interventions. Our aim is to clarify and define the term as “a water performance” attribute the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. If such a goal would be achieved then not only communication among sport scientists, coaches, physical therapists, and water safety educators will be greatly improved – but also communication among other disciplines such as biologists, physiologists and anthropologists.

Methods

In our effort to investigate the term aquaticity and its characteristics, we have conducted a search using electronic databases, scientific articles and books on aquatic sports.

A search in the electronic databases such the Google, Yahoo, Answers.com, Ask.com and Bing reveal that the term aquaticity in Greek – (υδροβιότητα) appears mainly in websites that related to free-diving and scuba diving, as well as websites that contain information about underwater fishing (spear fishing). In addition, a search of the equivalent English term was conducted (i.e. aquaticity), however, we came across various statements made by free diving athletes, who present their own perspective on aquaticity, based on their personal experiences and long-term participation in water sports. Scientific databases such as the PubMed, the scopus and the sciencedirect were also used for additional information on the subject of aquaticity in humans. Furthermore, our methodology extended to the review of books, scientific articles and studies on various sports that take place on, in and under the surface of water. The following key terms where used during our extensive search: swimming abilities, aquatics, synchronized swimming advanced water skills, water confidence, mindful swimming, aquatic brain, talent swimmers, factors influencing success in swimming performance, apnea, free diving, diving response (depth, temperature etc), special adaptations (water vision, navigation etc.) of Ama Japanese divers, Moken (sea people), body shape & composition, water dance, benefits of water exercise, aqua-phobia, fluidity, sailing, surfing, human amphibious.

Results and Discussion

Results from the most popular internet search engine with the term 'aquaticity' resulted about 2735'hits' (google) mostly in diving/sports pages with aquaticity being referred to as 'ability or comfort in water'. More restricted search among available scholarly work resulted in 20 results (Google scholar). In Greek the equivalent term is "υδροβιότητα" which gives over 971 hits in Greek, again with relation to diving and water activities. A related term is hydrobiosis (υδροβίωση) which has a clear biological meaning (= ability of an organism to live/thrive underwater). The term, "hydrobiosis", appears in ~4700 hits in general search and ~446 hits in academic search (Google scholar). No scientific articles have been found under the subject of Aquaticity or similar terminology when PubMed or other scientific data bases were used.

Definition of Aquaticity: why "introduce" a new term?

Aquaticity offers the characteristics that mammals need in order to function within water. The meaning of the term ***aquaticity*** is closely related to life itself, given the fact that human beings spend the first 9 months of their lives within the amniotic sac, surrounded by the amniotic fluid.

Subtypes of aquaticity

The way that humans interact with water varies. A person's ability in water with no equipment support, could be called '*physical aquaticity'*. However, using swimming equipment, rafts or boats is a prerequisite for many activities and of course a person's interaction with the water element is largely altered as compared to the case of no equipment use. This types of a person's ability in water, could be called '*technical aquaticity*' while when a person uses rafts and boats etc could be called '*interactive aquaticity*'.

To explain further the need to introduce subtypes of aquaticity, one can empirically understand that the aquaticity of sailing (an overwater activity) with the aquaticity of free diving (underwater) activity can differ by many degrees. As overwater activity such as sailing may require only some of the elements that may constitute 'aquaticity' even though most sailors argue that they 'read the water' and have a 'connection' with it. Moreover, there is the interaction of the sailor with the boat to consider, a mechanical aid that allows the traversing of the liquid surface, which complicates the evaluation.

Still, one could evaluate a yachtman's physical aquaticity levels and propose measures to improved it if found 'under par' for the requirements of safe sailing (in case of an accident). We view physical aquaticity as a factor of human performance that can be measured and assessed in all sports.

How is aquaticity gained?

According to anecdotal reports, unpublished personal notes and common sense, a good level of aquaticity is achieved through frequent contact with the water environment [110]. A high level of physical aquaticity gives humans better balance, breathing control, motor skill, sufficient propulsion, fluidity of movement and confidence.

Characteristics of aquaticity

In order to decode the term ***aquaticity***, the main characteristics should first be examined. To the best of our knowledge and judging from the few bibliographical references available, there are no scientific articles dealing with this issue. So far the majority of the scientific articles dealing with water activities, aim mainly to locate and investigate isolated parameters related to the performance of humans in the water. In order to define the term aquaticity, we studied activities that take place on the surface of water (i.e. sailing), activities and sports that take place in water (i.e. swimming and synchronized swimming) as well as these activities that take place under the surface of water (i.e. free-diving). We also examined studies investigating the special adaptations occurred (water vision, navigation) after exposure in various sports [114] and in various marine populations, such as the Ama and Moken female divers [101].

<u>Aquaticity in sailing</u>**:** The ability to cruise and navigate demands an in-depth knowledge of the special characteristics of water and air, but also a strong will and focus of mind. The available literature on Olympic Sailing Classes highlights the importance of

physical fitness in the racing performance of individuals during single or consecutive sailing races especially during bad weather conditions, where the yachtsman's stamina and endurance plays a crucial role in his racing performance [115].

Aquaticity in classic swimming: Aquaticity requires a smooth flow of movements when in water and it is achieved through the learning of swimming skills and the person's familiarization with the liquid element [116]. According to Australia's national organization for the teaching of swimming and water safety (www.austswim.com.au), aquatic activities for people should begin when they are still infants by taking baby swimming lessons. Contact with water seems to promote physical and mental health, while, at the same time, it contributes to the formation of an emotional bond between humans and the liquid element. The main goal of acquiring water skills is initially the acquisition of a feeling of safety and water confidence, while later is to progress to efficiency of movement. The swimming ability of a human being is directly linked to his/her aquaticity, since swimming is defined as the movement the body makes when floating in water. Moreover, in order for someone to acquire these swimming abilities, it is necessary to start by achieving balance in the water, the ability to propel in the water efficiently and finally, a last stage of swimming abilities is learning and applying the techniques of the four available swimming styles [117].

Aquaticity in synchronized swimming: In synchronized swimming a much more complex set of water skills is required, since it is considered to be one of the most difficult and demanding of the water sports [7]. Synchronized swimming combines swimming with aerobics and dance routines with breath hold apneas, facilitated by a nose clip, while the athletes should also have excellent swimming skills, a sense of balance and orientation in water, precision in movement and a sense of time and rhythm. It is evident that synchronized swimmers, unlike their classical swimming peers, are obliged to develop a much more adaptation to the liquid element, due to the demands of their sport, compared to the other water activities.

Aquaticity in free-diving: During free diving (diving on a single breath), the human body adapts to the increases of the hydrostatic pressure and the temperature changes. This adaptation is called ‘diving response’ and it includes physical and psychological adjustments [118, 119].

World record holders in free diving argue that the secret for someone to achieve total immersion and infiltration to the aquatic environment is aquaticity, meaning the physical and mental harmonization with the liquid element that can allow one to reveal the remarkable abilities that the human body possesses, when in water [101]. An excellent swimming technique, especially for torso and leg movements, seems imperative. For example Umberto Pelizzari, the well-known free-diving trainer and founder of one of the biggest academies of free-diving, in his book entitled ‘The Manual of Freediving’, mentions that classical swimming improves aquaticity dramatically and that is the reason why he opted to include it on all the available free-diving courses he offers [91].

Aquaticity of pearl gatherers: The adaptations to the aquatic environment developed by populations such as the Japanese female divers Ama and the sea gypsies Moken in South Asia are impressive. Gilsen and her colleagues [100] studied the underwater vision of Moken children, and they found that Moken children have 50% more precise underwater vision and increased focus abilities compared to the children of a similar age in the general population. These abilities are not innate but they can be developed, since they are compatible to the lifestyle of the people that belong to the Moken tribe. Moreover, according to various studies, the Bajan divers in Philippines and the Ama female divers in Korea and Japan have developed a strong diving reflex through which the heartbeat is significantly decreased and therefore a longer period of apnea is achieved [120, 121].

Components of aquaticity

Based on the above, *four factors* have been proposed by us to play an important role in human *aquaticity* and they are listed below.

1. Physical conditioning, optimization of swimming technique

The development of a good physical condition when in water (i.e. endurance, strength, speed) promotes the feeling of security and independence. The optimization of the swimming technique promotes, also, the perfection of the stroke and the control against the aquatic environment (i.e. balance, resistance and response to hydrostatic pressure), the different sensations (hearing, vision) and the development of special water skills (navigation, floatation, hydrodynamic position) [122].

2. Psychological and Emotional Conditioning

Jacques Mayol – known from the “Big Blue” movie - said that the level of relaxation when the body is immersed in the liquid element it is proportional to the degree of aquaticity of the individual [123]. The emotional relationship with the aquatic environment can be developed through activities related to water, even when they do not involve immersion of the face or the body into the water. Nevertheless, the liquid element could also cause negative feelings that can prevent joy and pleasure leading to panic and frustration, such as aquaphobia [124]. The total control over mind and body in the aquatic environment is part of the special adjustments a diver has to make, when he or she is in a high pressure and low visibility environment [125].

3. Breath-hold capacity (apnea) and diving ability

The ability to hold one's breath and stay underwater is an important factor of aquaticity [95]. Competitive divers can hold their breath more than 8 minutes while diving academies require a static (no movement) breath hold capacity of 2 minute, and a dynamic apnea (underwater swimming) of 25 meters for budding 1 stage trainees. This affects also how deep one may go, although there is no linear relationship between static apnea and depth of dive [126].

4. Anthropometric Characteristics

Performance can also be dictated by body composition and other anthropometric characteristics such as the length of limbs, the vital capacity of the lungs, size of the spleen and the bone mineral density [126]. All of these parameters play a significant role in swimming, and are thus important also for underwater activities, since they determine the buoyancy, the propulsion, the speed and apnea ability of humans in water [127]. Those variables could also play an important role in the process of acquiring aquaticity.

Practical Application

Definition of aquaticity: To the best of our knowledge, this is the first attempt to define the term aquaticity and to assess the potential parameters that seem to affect its level. After investigating scientific evidence and anecdotal reports we have concluded that ***"Aquaticity is the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. The level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element and instruction".***

Conclusions

Aquaticity is a physical capacity/ability that humans develop from a young age, when they come in contact with the water element. The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water [128]. Contact with the liquid element can be achieved in many different ways through various activities either recreational or professional. Human contact with the water element seems to promote not only the physical wellbeing, but also the psychological and emotional health. The development of aquaticity could promote lifelong exercise in the water, the development of environmental awareness and the desire for creative expression. Consequently, the development of an education program in aquaticity for children seems necessary, since it could contribute towards the development of physical skills, knowledge and psychological balance.

Research Paper 2: Developing and testing an instrument to assess aquaticity in humans

Authors: Danae Varveri PhD, Andreas D. Flouris PhD, Nikitas Smirnios BSc, Elizana Pollatou PhD, Christina Karatzaferi PhD, Giorgos K. Sakkas PhD

Affiliation: School of Physical Education and Sport Science, University of Thessaly, Trikala, Greece

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Abstract

We developed and validated an aquaticity assessment test (AAT) for the evaluation of human physical adequacy in the water. Forty-six volunteers (25M/21F; 20±8 years,) participated and performed 10 easy-to-administer and practical aquatic tasks. Group A was formed by 36 elite athletes (M/F 20/16, 24.7±10yrs) from two sports categories depending on their affinity to the water environment: terrestrial (wrestling, cycling, dancing) and aquatic (swimming, synchronized swimming, free diving) sports. Group B was formed by 10 non-athlete participants (5M/5F, 14.4±1.4yrs) and was assessed by two independent evaluators. Participants in Group A performed the aquatic tasks once to develop the final AAT items and cutoffs. Participants in Group B performed the aquatic tasks twice on different days to assess repeatability. Factor analysis recommended all 10 aquatic tasks to be included in the final AAT, resulting in scores ranging from 9.5-49.5. The AAT scores were statistically different between the terrestrial and the aquatic sports' participants ($p<0.001$). The duration of the test was 25 minutes from the time of water entry. Receiver operating characteristics curve analyses demonstrated that the cutoffs for low and high aquaticity levels in this sample were ≤23.7 and ≥43.3, respectively. Reliability analyses demonstrated that the aquaticity scores obtained on different days and by different examiners highly correlated ($p<0.001$) and were not significantly different ($p>0.05$). The AAT appears to be a valid and reliable tool for the evaluation of human physical adequacy in the water. It is an easy and user-friendly test which can be performed in any swimming pool without a need for highly trained staff and specialized equipment, however more research needs to be done in order to be applied in other population group.

Introduction

We recently proposed that aquaticity is a performance attribute that can be evaluated and improved upon with various interventions. We provided a definition to facilitate a departure from empirical and anecdotal approaches to 'ability in water' and move towards the scientific development of the concept: *"Aquaticity is the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. The level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element and instruction*" [129].

Aquaticity is a capacity that humans develop ideally from a young age, by coming in frequent contact with the water element but also later in life through various aquatic activities and participation in aquatic sports [129]. The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water [128]. Human contact with water seems to promote not only physical wellbeing, but also psychological and emotional health [130-132]. The development of aquaticity since it's related to water contact and relaxation could promote a healthier lifestyle including lifelong exercise, leading to the development of environmental awareness and the desire for creative expression.

In various sports, coaches and trainers empirically evaluate athlete's aquaticity (for example when selecting 'talents' for water sports) examining their 'ability' to perform exercise in the water or underwater [109] . In water rehabilitation, physiotherapists evaluate how 'comfortable' a patient may be in water using their own personal criteria and experience. In addition, in lifeguard academies, teachers and trainers use only physical fitness tests for assessing lifeguards' skills before their graduation, while in military schools water skills and performance are important entry criteria for enrollment.

Even though “Aquaticity” was only recently defined by our group [129] many water sport professionals such as coaches, trainers and athletes refer to *levels* of aquaticity expressed through their empirical observations or expressions of personal experiences [112]. Moreover, given that water activities are increasingly being used in special needs education and rehabilitation settings, there is a pressing need for a scientific instrument to assess the levels of aquaticity and to allow the scientific health-allied community to set up norms and standards. To the best of our knowledge there is currently no physical adequacy assessment test to evaluate the aquaticity levels in humans. The aims of the current study were: 1) to develop an aquaticity assessment test (AAT), 2) to determine the validity of the AAT towards correctly identifying individuals with variable aquaticity levels, and 3) to assess the reliability of the proposed AAT.

Materials and Methods

Ethics Statement

The study was conducted according to the principles expressed in the Declaration of Helsinki and was approved by the University of Thessaly Ethics Committee (protocol no.518-29/03/2012).

Participants

A total of 46 subjects (25M/21F, 22.6±10) gave consent to participate in this study. In the case of a minor's consent the guardian's consent was also secured. Thirty six subjects (Group A) were elite athletes (20M/16F, 24.7±10yrs) and were recruited from two different sports categories, depending on their affinity to the water environment, such as terrestrial (wrestling, cycling, ballet dancing) and aquatic (swimming, synchronized swimming, free diving) sports, 6 from each sport. The remaining 10 participants (5M/5F, 14.4±1.4yrs) (Group B) were healthy volunteers with no systematic participation in an organized exercise training program more than one time per week, which served as the validation group for the validity and repeatability assessment. All subjects were assessed in the same 25 m heated pool. None of the terrestrial sports participants had ever been trained in the water apart of recreational swimming that could take place every summer excluding any underwater activities such as spearfishing or scuba diving.

Experimental Protocol

In order to develop and validate the aquaticity test, the participants were divided in two groups: Group A was composed of 36 elite athletes from 6 different sports. Group B was composed of 10 healthy individuals who were evaluated on two different days concurrently by two independent examiners, one week apart and served as "the validation" group.

Participants were assessed in a series of aquatic tasks related to their ability in the water while examiners were scoring each task using specific written instructions. In the Group B, the test was repeated after one week using the same setting and examiners. Group A was used for assessing the characteristics related to Sensitivity and Specificity of the aquaticity test. Group B was used for assessing the validity and repeatability of the designed test.

Development of the Aquaticity Assessment Test

We used 10 aquatic tasks addressing the following four components of human aquaticity: 1) Physical conditioning, optimization of swimming technique; 2) Psychological and emotional conditioning; 3) Breath-hold capacity (apnea) and diving ability; and 4) Anthropometric characteristics, as proposed by our group [129].

Table 1. Description and components of the Aquaticity Assessment Test.

Tasks	Description
1. Surface buoyancy and balance	Maintain a supine and prone floating position.
2. Breathing control	Showing capacity of exhaling inside the water rhythmically.
3. Underwater hydrodynamic position	Under water gliding with push start from the wall, maintain hydrodynamic position.
4. Surface freestyle swimming technique	Swimming technique assessment for 25m
5. Physical fitness adequacy in the water	Continuous swimming for 5 min using any type of swimming style
6. Treading water	Keeping the head out of the water while maintain a vertical position.
7. Underwater senses - vision	Using no goggles recognize various shapes, colors and complete a dexterity task
8. Underwater senses - hearing	Recognize sounds, direction of sound and number of sound stimuli.
9. Underwater swimming – Dynamic Apnea	Underwater breath hold swimming for the longest possible distance
10. Expiratory diving	Voluntary sinking while exhaling

The 10 tasks required to be completed by the participants during assessment are described in Table 1. The tasks were selected based on the literature and the authors' own experience on children and adult, recreational and competitive swimming and diving training. A critical prerequisite for task selection was to require inexpensive and easy to use equipment or no equipment at all. The tasks assessed the following parameters: 1) Surface buoyancy and balance, 2) Breathing control, 3) Underwater hydrodynamic position, 4) Surface freestyle swimming technique, 5) Physical fitness in water (5 min continuous swimming), 6) Treading water 7) Underwater vision, 8) Underwater hearing, 9) Underwater breath hold swimming and 10) Expiratory – breath out diving. Each task was scored from 0 (fail) to 5 (excellent). For each task, participants could achieve a score from 0 to 4.5 depending on the level of adequacy they demonstrated. To achieve the excellent score (5 points), a participant had to complete a variation of the task with advanced complexity, after one-minute break. Examiners assigned points (with 0.5 step increments) based on fidelity of performance to instructions given, repetitions achieved, time of sustained performance etc. (Appendix 1 & 2). Given that all participants from Group B were assessed by two independent evaluators, the final score for each item was calculated as the average score of the two evaluators. The highest overall score that could be achieved by a single subject was 50 points while the duration of the testing was approximately 25 minutes from the time of entering the water. Between the tasks there was a minimum of 2 minutes break.

Equipment

The equipment used to implement the aquaticity testing was: a training swimming pool, depth greater than 2m; floatation aids such as kickboard, foam noodles and pull boys; whistle and timers; a metallic stick object to be used for generating the underwater sounds (e.g. nocking the handle of the pool ladder); waterproof piece of cardboard with pictures of geometrical shapes for water vision; 7 donut- shaped weights and a thin rope to put through the weights; an 1m piece of thin white rope (5mm diameter) with 7 knots and one standard size latex balloon (28cm/11”).

Statistical Analysis

Three data analyses were conducted, each addressing one of the purposes of the study. The first data analysis aimed at developing the aquaticity test based on the aforementioned 10 aquatic tasks related to physical adequacy in the water. For this purpose, we conducted a principal factor analysis to examine possible factor structures and identify specific items to perhaps create a shorter version of the aquaticity test reflecting the main sources of physical adequacy in the water. The suitability of the data for structure detection was assessed using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO), indicating the proportion of variance in the variables that may be caused by underlying factors (>0.5 values suggest that the factor analysis results are useful), and Bartlett's test of sphericity, which tests the relationships between the variables and, hence, the suitability for structure detection ($p<0.05$ values suggest that the factor analysis results are useful). An eigenvalue >1 was used as an *a priori* criterion to determine the number of factors to be extracted from the data. Generally, factor loadings of $r\geq0.7$ are considered high, while loadings of $r\leq0.4$ are considered low [133, 134]. To ensure a minimum of moderate-level factor loading, we excluded items that loaded with $r<0.6$ on any factor.

The aim of the second data analysis was to determine the validity of the aquaticity test towards identifying individuals with physical adequacy in the water. A Receiver Operating Characteristics (ROC) curve analysis was used to define the cutoff point for low levels of aquaticity using the aforementioned Aquaticity Task 6 (treading water) as a reference standard. Task 6 was considered the one with the most physiological contribution to physical adequacy in the water, as it is related to maintaining a vertical floating position once in the water and it is used in all surviving courses. This is because the ability to maintain the head above the water's surface is essential for avoiding inhalation of water [135]. Therefore, Task 6 was considered as the most appropriate to define the LOW limit of aquaticity in order to ensure safety. For this purpose, a positive detection for low aquaticity (LOW) was assigned to individuals with an Aquaticity Task 6 score of ≤1, while a negative detection for low aquaticity was assigned to individuals with an Aquaticity Task 6 score of >1. Thereafter, a second ROC curve analysis was used to define the cutoff point for high levels of aquaticity using the aforementioned “sports category” [i.e., terrestrial (wrestling, cycling, dancing) or aquatic (swimming, synchronized swimming, free diving)] as a reference standard. For this purpose, a positive detection for high aquaticity (HIGH) was assigned to individuals participating in aquatic sports, while a negative detection for high aquaticity was assigned to individuals participating in terrestrial sports. The area under the ROC curve was estimated using the Delong non-parametric method [136, 137]. Calculated sensitivity and specificity with corresponding 95% confidence intervals (CI95%) were used to determine cutoff points that would allow a correct detection for LOW and HIGH. Sensitivity in the two ROC curve analyses was defined as the proportion of individuals detected as LOW using the ROC results with an Aquaticity Task 6 score of ≤1, or the proportion of individuals not detected as HIGH using the ROC results of those who participated in terrestrial sports. Specificity in the two ROC curve analyses was defined as the proportion of individuals detected as “disease” free (i.e., not LOW) using the ROC results with an Aquaticity Task 6 score of >1, as well as the proportion of individuals detected as HIGH using the ROC results of those who participated in aquatic sports. Cohen’s Kappa statistic was used to evaluate the agreement between test detection and the reference standard tests (i.e., Aquaticity Task 6 score in ROC curve analysis 1 and sports category in ROC curve analysis 2).

The aim of the third data analysis was to assess the reliability of the aquaticity test using data from the Group B of 10 healthy participants who were evaluated by two independent examiners on two different days, one week apart. For this purpose, the two aquaticity tests for each of these participants were randomly termed Day 1 and Day 2. As previously suggested [138-140], reliability was assessed using correlation coefficients between different days, intraclass correlation coefficients between different examiners, and univariate analysis of variance to determine the effect of different days and examiners. Thereafter, 95% limits of agreement and percent coefficient of variation were used to quantify the amount of test-retest and examiner-induced error. Data were analyzed with SPSS (version 19, SPSS Inc., Chicago, Illinois) and NCSS 2007 (Number Cruncher Statistical Systems, Utah, USA) statistical software packages. The level of significance was set at $p<0.05$.

RESULTS

A Post hoc power analysis revealed that a sample size of 3 would give actual power of 98% and effect size of 4.61 to detect differences between the low and the high aquaticity group. Analyses suggested that all ten tasks tested were necessary for the Aquaticity Assessment Test (AAT), see below. The description and the characteristics of the AAT are presented in Table 1 while participants' basic characteristics are presented in Table 2.

Table 2: Basic characteristics of the participants

Groups	N	Gender	BMI	Age
Martial Arts Group (terrestrial)	6	5 M/1 F	24.8± 2.3	32.4± 12.6
Cycling Group (terrestrial)	6	5 M/1 F	23.5± 4.5	18.33± 6.2
Dancing Group (terrestrial)	6	0 M/6 F	20.0± 1.1	29.83± 5.3
Swimming Group (aquatic)	6	5 M/1 F	22.3± 1.0	16.33± 0.8
Freediving Group (aquatic)	6	5 M/1 F	23.6± 2.6	37.17± 6.8
Synchronized swimming Group (aquatic)	6	0 M/6 F	20.8± 0.9	15.67± 0.8
Validation Group (sedentary)	10	5 M/5 F	20.0± 2.9	14.4± 1.4

The AAT was easy to perform independently from the fitness level of the participants and it lasted for approximately 25 minutes from the time of water entry. Both examiners and examinees did not report any difficulties related to the scoring or how to perform the specific tasks. No adverse events were reported during or after the participants' assessment. Aquaticity scores (reported as aquaticity units – AU) among the various groups are reported in Table 3.

Table 3: Aquaticity score among groups. AU: Aquaticity Units

Variable	Martial Arts	Cycling	Dancing	Swimming	Freediving	Synchronized Swimming
Aquaticity score (AU)	24.5±6.9	25.0± 4.0	13.1± 3.4	45.2± 1.7	47.7± 1.5	46.7± 0.5
(95%CI)	(21.5-27.6)	(21.9-28.0)	(10.0- 16.1)	(42.1-48.3)	(44.7-50.7)	(43.7- 49.8)

Aquaticity score was statistically different between the aquatic and terrestrial sports' participants ($p<0.001$). More specifically, the Dancing group had the lower aquaticity score and differed statistically from the rest of the groups, while Martial Arts and Cycling groups differed statistically only from all aquatic sports ($p<0.001$). Finally, the aquaticity score among the three aquatic sports groups (Swimming, Freediving and Synchronized swimming) did not differ statistically ($p>0.05$).

Aquaticity Test Development (analysis 1)

The required factoring criteria were satisfied (KMO=0.89; Bartlett's test χ^2=713.1; $p<0.001$). Factor analysis of the initial 10 aquatic tasks relating to physical adequacy in the water suggested that one factor explained 88% of the variance (factor loadings from each item appear in Table 4). It became clear, therefore, that the final aquaticity test must contain all 10 aquatic tasks used (see Table 4). The obtainable score range for the aquaticity was 9.5 to 49.5, with higher numbers reflecting greater physical adequacy in the water.

Table 4. Factor loadings for the 10 tasks of the aquaticity test

Task	**Factor Loadings**
Aquaticity Task 1	0.656
Aquaticity Task 2	0.875
Aquaticity Task 3	0.951
Aquaticity Task 4	0.921
Aquaticity Task 5	0.837
Aquaticity Task 6	0.841
Aquaticity Task 7	0.903
Aquaticity Task 8	0.904
Aquaticity Task 9	0.973
Aquaticity Task 10	0.936

Validity assessment (analysis 2)

The first ROC curve analyses revealed that the most appropriate cutoffs for LOW was "23.7" aquaticity units (AU). Relevant univariate statistics and ROC curve analyses for the designated cutoff appear in Table 5.

Table 5. Results for ROC curve and McNemar Chi-Square analyses for the designated cutoffs for the LOW and HIGH aquaticity test cutoffs.

	SE±CI95%	SP±CI95%	PPV±CI95%	NPV±CI95%	LR±CI95%	AUC±SE
LOW	1.00±0.00	0.73±0.15	0.25±0.24	1.00±0.00	3.67±0.15	0.98±0.04*
HIGH	1.00±0.00	0.94±0.11	0.95±0.10	1.00±0.00	18.00±0.11	1.00±0.00*

*Note: * = AUC test statistically significant (p<0.05) from 0.5 (i.e., no detective ability). Key: ROC=receiver operating characteristics; SE=sensitivity; SP=specificity; PPV=positive predicted value; NPV=negative predicted value; LR=likelihood ratio; AUC=area under the ROC curve; CI95%=95% confidence interval; SE=standard error.*

The Aquaticity Task 6 results suggested that 3 individuals demonstrated limited physical adequacy in the water. The LOW cutoff in the aquaticity test was able to detect all of these individuals. Cohen's Kappa statistic demonstrated significant agreement with the Aquaticity Task 6 results (z=2.56, p=0.010).

The second ROC curve analyses revealed that the most appropriate cutoffs for HIGH aquaticity was "43.3" AU. Relevant univariate statistics and ROC curve analyses for the designated cutoff appear in Table 5. The Sports Category suggested that 18 individuals participated in aquatic sports while the HIGH cutoff in the aquaticity test was able to detect all of these individuals. Cohen's Kappa statistic demonstrated significant agreement with the Sports Category results (z=5.67, p<0.001).

Reliability assessment (analysis 3)

The test scores of Day 1 and Day 2 were highly correlated (r=0.993, p<0.001). Moreover, the scores of Examiner 1 and Examiner 2 were highly correlated (intraclass correlation coefficient = 1.000, p<0.001). Univariate analysis of variance demonstrated no statistically significant differences between days (p=0.594) or examiners (p=0.990) as well as no statistically significant day*examiner interaction (p=0.970). The 95% limits of agreement for different days were 1.055±1.44, indicating that a score of 30 on one day can be as high as 32.5 or as low as 29.61 on another day. The corresponding percent coefficient of variation for different days was 2.04%, indicating that a score of 30 on one day can be as high as 30.611 or as low as 29.39 on another day. On the other hand, the 95% limits of agreement for different examiners were 0.025±0.50, indicating that a score of 30 could be as high as 30.53 by one examiner or as low as 29.52 by another examiner. The corresponding percent coefficient of variation for different examiners was 0.71%, indicating that a score of 30 could be as high as 30.21 or as low as 29.79 between examiners.

Discussion

The present study demonstrated that the Aquaticity Assessment Test (AAT) appears to be a valid and reliable assessment tool for evaluating human aquaticity levels. An aquaticity score higher than 43.3 AU can accurately detect high aquaticity levels while a score below 23.7 AU can detect low levels of aquaticity and therefore low physical adequacy in the water (and increased risk). The AAT is composed of ten aquatic tasks assessing physical adequacy parameters in the water. It is an easy and user-friendly test, lasting for 25 min and it can be performed in any swimming pool without the need of highly trained staff or specialized equipment.

To our knowledge this is the first scientifically tested method created to assess aquaticity levels in humans. The AAT is composed of 10 tasks related to the four recognized components of human aquaticity [129]. Each task can be graded from 0 to 5 (with 0.5 step increments) with the later score implying excellent performance in the particular task. The highest overall score that can be achieved by a single person is 50 points.

The characteristics assessed by the AAT are presented in Table 1. Surface buoyancy, balance and relaxation (task 1) are indices of comfort and efficiency [55] and are related to a human's adaptability to water. Similarly, controlling inspiration and expiration in and out of the water (task 2) reflect the level of breathing control and provides evidence of relaxation for activities under water since face immersion has been shown to activate the diving reflex and induce bradycardia [141]. The ability of underwater orientation and positioning and the capacity for controlling and correcting the hydrodynamic status of the body (task 3) are key parameters for efficient movement [142, 143]. The level of technical skills in crawl swimming (task 4) is an objective index of advanced water adaptation and the capacity of elite swimming performance [143, 144], while the distance covered when continuously swimming for 5 min (task 5) independently from the style of swimming, reflects fitness level [145]. The ability to maintain a vertical floating position inside the water (task 6) keeping the head above water level (Treading water) is a very important survival skill [135] since failure to maintain this position for a certain amount of time could have serious life threatening consequences. The abilities to see (task 7) and hear (task 8) underwater are related to chronic adaptations to the water environment [101, 102] and are important features of professional divers' training related to performance and safety issues. The ability to perform a dynamic apnea for 25 m (task 9) reflects general physical adequacy in the water but more strongly breath-hold diving ability [146]. Moreover diving after voluntary expiration (task 10), near to the functional residual capacity of the lung, requires a good level of familiarization with underwater activities [147].

The AAT differentiated successfully all the aquatic from the terrestrial sports' participants as well as identified participants with high (≥43.3), medium (from 23.8 to 43.2) and low (≤23.7) aquaticity levels. Indeed, ROC curve analyses revealed that the sensitivity of the AAT to detect high aquaticity level participants was 100% (all athletes with high aquaticity level were detected) while the specificity was 94% (6% chance to false positive identify high aquaticity level). Similarly, for the low aquaticity level participants the sensitivity and the specificity were 100% and 73% respectively showing that the AAT was sensitive and specific in the whole range of values. Factor analysis revealed that all 10 tasks were important for composing the total aquaticity score (Table 4). The AAT measured scores ranging from 9.5 (very low aquaticity level) to 49.5 (very high aquaticity levels). The 6 different groups of athletes had significant differences in aquaticity scores with dancers and free divers reporting the lowest and highest values respectively. These findings were in accordance to the general notion that terrestrial sports' athletes are spending less time in water compared to aquatic sports' athletes however the fact that some of the terrestrial sports' athletes could have a natural talent for water sports cannot be eliminated. In fact, there were athletes with medium levels of aquaticity even though they belonged to terrestrial sports. However, the majority of the low scorers came from athletes from the dancing group. On the other hand, the highest scorers came from the free-diving group in accordance to the notion that such athletes need to excel in underwater activities.

Further repeatability and reliability analyses showed that the AAT is repeatable and reliable with a very small margin of error between different measurement days and different examiners. This is very crucial for the applicability of the test to various populations by different professionals ranging from coaches and lifeguards to rehabilitation and military staff.

There are two important factors that highlight the future impact of developing the AAT. The first is based on the fact that the test is sensitive and specific enough to distinguish participants with high levels of aquaticity from those with medium level and therefore could be used as a test for 'talent identification' for aquatic sports such as swimming, polo and synchronized swimming. This may prove very important since the tests that are used until now are based solely on anthropometric or specific performance characteristics excluding thus other contributing factors that characterize "elite water athletes". The second is based on the ability of the test to distinguish the low aquaticity level participants.

If the AAT was to be adopted for water safety screening the result might be to minimize the possibility of an accident or drowning death. Until now, the usual approach to assess the level of 'ability' in the water prior to actual participation to various water activities (from recreation, to training to rehabilitation) was limited to questions such as "can you swim?" or "get into the water and show me what you can do" with answers and reactions varying vastly. Such an 'empirical' approach relies heavily on the examiners' experience. An inexperienced instructor might easily overestimate the abilities of a novice person. Such an overestimation could lead to a near-drowning accident with a significant impact on the mental status of the participant since it could lead to aquaphobia, a type of anxiety disorder [124].

Another potential use of the AAT could be for assessing the aquaticity levels of military and safety personnel including helicopter and airplane crews, oil rig, coast guard and lifeguarding staff as well as special forces and rescue teams, or any professional working in close proximity to the open water. The use of a medium aquaticity score as part of the essential criteria for the entry in military academies or other training schools could eliminate military basic training attrition rates (drop outs) and could save money and lives.

In the current study some potential weaknesses have been recognized that need to be acknowledged. Firstly, our study examined the aquaticity levels from only six different sports, three terrestrial and three aquatic ones, selected as representative of popular non-team sports and the test showed high reliability. Future work should be expanded in other sports and different age groups since the people participated in Group B were adolescents and aged-matched with Group A. Another possible limitation of the study is the fact that the test has been constructed for and performed in a pool, which is a highly controlled environment and has not been applied in the open sea environment where buoyancy and other parameters could have affected the final outcome. We selected the swimming pool environment as the most commonly available to aquatic development and rehabilitation activities. Indeed, a future study performed at the sea environment might reveal other aspects to be considered in the assessment of aquaticity (such as cold tolerance, orientation etc.). Finally, the age of the participants was limited to the late twenties since we focused in competitive athletes and therefore the applicability of our test to middle age or elderly people might be limited, despite the careful selection of activities. It is important that future research should test the AAT in various populations including those who might be most likely to require water rehabilitation.

Future research is needed to investigate whether an aquaticity intervention program could improve the aquaticity score in various populations and whether such a program can be used for the improvement of physical and mental health related quality of life. With the creation of AAT we now have a tool that will support future efforts for the development of water based interventions for sport, professional and health applications.

In conclusion, to our knowledge, the Aquaticity Assessment Test (AAT) is the first available validated test to assess a human's aquaticity levels. The AAT contains tasks that can be performed easily by everybody independently from fitness level or existing familiarity to the water. The AAT can be used as a tool for talent identification in aquatic sports. Moreover, the AAT can be used as a safety tool for excluding people with very low aquaticity levels from tasks that may endanger them through an abrupt exposure to water and thus carry a high probability of a drowning accident. The AAT could also be used as a tool for generally assessing competence for activities and tasks that require high physical adequacy to the water.

Research Paper 3: Aquatic exercise training for improving aquaticity levels in humans. A randomized control study.

Authors: Danae Varveri MSc, Christina Karatzaferi PhD, Elizana Pollatou PhD, Andreas D. Flouris PhD, Giorgos K. Sakkas PhD

Affiliation: School of Physical Education and Sport Science, University of Thessaly

Abstract

Aquaticity is an important parameter of human aquatic performance, however until recently this aspect did not receive the appropriate attention from the scientific community mainly due to the fact that coaches and trainers have been using their own empirical assessment. Our group recently defined aquaticity as well as developed and validated an instrument to assess aquaticity levels in humans. So far, due to the lack of scientific knowledge, no attempts have been made to assess or improve aquaticity in humans. The aim of the current study was to assess whether aquaticity levels could be improved by the implementation of a specific to aquaticity training program compared to the classical swimming training used in all aquatic sports. Twenty high school students (8M/12F, 16.5±0.7) participated in the study after obtaining parental consent. The study was approved by the local ethic committee. Participants were screened for their aquaticity levels using the Aquaticity Assessment Test (AAT) and were randomly divided into two groups: Group A was the "Swimming" intervention group (4M/6F, 16.3±0.8) and completed a classical swimming training program, while Group B was the "Aquaticity" intervention group (4M/6F, 16.8±0.5) and completed the aquaticity intervention program. Both interventions lasted for two months (3 workouts/ per week, lasting 60 min per session) while participants assessed before and after the training period using the same set up and evaluators. Aquaticity score was increased in both groups by 13% and 27% in Group A and Group B respectively ($p<0.01$). The magnitude of change in aquaticity score was 2 folds higher in the Group B compared to Group A ($p=0.001$). The Group A (swimming), improved significantly the 7 out of 10 tasks of the AAT compared the pre values ($p<0.05$) while Group B (aquaticity) improved significantly 10 out of 10. Delta change between the two groups was statistically significant in 5 out of 10 tasks (tasks 2, 3, 7, 9, 10) implying again higher magnitude of

improvements in the aquaticity intervention group compare to swimming group. Aquaticity is another parameter of human performance, that can be trained and improved by classical swimming training in agreement to anecdotal reports, but significantly more by specific aquaticity training. Aquaticity enhance training programs could become an integrated aquatic method for the development of human's aquatic education and safety as part of the overall aquatic performance.

Introduction

We recently provided a definition to the concept of Aquaticity as the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. We concluded that the level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element and instruction [129]. Even though aquaticity has been an important parameter of aquatic human performance for many years, in various sports, coaches and trainers empirically evaluate athlete's aquaticity by visually examining their 'ability' to perform exercise in the water or underwater [109] or in the area of water rehabilitation, physiotherapists evaluate how 'comfortable' a patient may be in water using their own personal criteria and experience. This is also the case in lifeguard academies where teachers and trainers use only non-specific physical fitness tests for assessing lifeguards' skills before their graduation, while in military schools water skills and performance are important entry criteria for enrollment. Only recently our group has developed and validated an aquaticity assessment test (AAT) for the evaluation of human physical adequacy in the water [148]. The AAT appears to be a valid and reliable tool for the evaluation of human physical adequacy in the water while it is an easy and user-friendly test which can be performed in any swimming pool without a need for highly trained staff and specialized equipment. Until now, the accurate assessment of aquaticity levels was not possible and therefore any attempt to assess or improve it was not possible or scientifically accepted. Due to that now no attempt has been made so far to present an integrated aquatic program that will embrace aquaticity. Anecdotal reports from coaches support the notion that classical swimming training can improve aquaticity levels however there are no scientific evidence or validated methodology has been used to support such statements. The aim of the current study was to assess whether aquaticity levels could be improved by the implementation of a classical swimming training program and whether a specific to aquaticity training program could result in a larger magnitude of changes compared to the gold standard approach.

Materials and Methods

Ethics Statement

Study approval was obtained from the University of Thessaly Research Ethics Committee and the Athens College private school internal affairs office. Information letters and consent forms requesting parental permission were sent to potential participants' homes while those who returned signed were screened for the eligibility criteria.

Participants:

Twenty high school students (8M/12F, 16.5±0.7) were screened for the current study. Medical clearance was obtained for all participants including full cardiological assessment and dermatological examination (required by the pool safety regulations). Inclusion criteria were: parental consent, attending high school classes, ability to swim or float for 25 meters using any style and medical clearance. Exclusion criteria were aquaphobia, inability to float or infection and musculoskeletal injuries interfering with the swimming activities. Participants were screened for their aquaticity levels using the Aquaticity Assessment Test (AAT) as described previously [148] and randomly divided into two groups matching carefully age, gender and aquaticity score. Group A was the "Swimming" intervention group while Group B was the "Aquaticity" intervention group.

Study design

The participants of the current study participated in a two months intervention program using classical swimming or aquaticity training. The Group A (Classical swimming group) was consisted of 10 subjects (4M/6F, 16.3±0.8) and participated in a classical swimming training program lasting for 60 min per session, 3 workouts/ per week for two months. The Group B (Aquaticity group) consisted of 10 subjects (4M/6F, 16.8±0.5) and participated in the aquaticity intervention program lasting for 60 per session, 3 workouts/ per week for two months. Participants were re-assessed after the 2 months training period using the same set up and evaluators. All training sessions were supervised by the same instructor taking place on separate days and times for each group.

Aquaticity Assessment Test

The AAT is composed of 10 tasks required to be completed by the participants during the assessment. The tasks assessed the following parameters : 1) Surface buoyancy and balance, 2) Breathing control, 3) Underwater hydrodynamic position, 4) Surface freestyle swimming technique, 5) Physical fitness in water (5 min continuous swimming), 6) Treading water 7) Underwater vision, 8) Underwater hearing, 9) Underwater breath hold swimming and 10) Expiratory – breath out diving. Each task was scored from 0 (fail) to 5 (excellent). For each task, participants could achieve a score from 0 to 4.5 depending on the level of adequacy they demonstrated. To achieve the excellent score (5 points), a participant had to complete a variation of the task with advanced complexity, after one-minute break. Examiners assigned points (with 0.5 step increments) based on fidelity of performance to instructions given, repetitions achieved, time of sustained performance etc. The highest overall score that could be achieved by a single subject is 50 points.

Facilities

The both intervention programs were held in the swimming center "Alexandra Prokopiou" in Athens College private school in Athens, Greece. The data analysis carried out at the LIVE Laboratory at the School of Physical Education and Sport Science, at the University of Thessaly, Greece.

Intervention

Training details are summarized in Appendix 5.

Group A - Classical Swimming Group

The participants in Group A followed a classical swimming training program using modern training methods that are used in competitive swimming and they are based on both hydrodynamics and bioengineering studies [149]. Competitive swimming is a technique driven sport and each session prepares the participant for the best swimming performance- speed and technique perfection- of the four competitive swimming strokes (freestyle, backstroke, breaststroke and butterfly) [61]. The aim of the swimming training program (as any swimming training program at this level) was the development of aerobic and anaerobic capacity, so that eventually the participants can cover racing distances at maximum speed. In addition, the training program was also aimed to develop hydrodynamic body position, strong kicking action and quality stroke mechanics, that will allow more efficient propulsion and performance. Therefore, the drill progressions start with the basics and link to full movement through repeated instructions and visual feedback. Since the goal of a competitive swimmer is to travel a given distance in the minimum amount of time, we worked on starts, turns and finishes. Each part's contribution to the overall performance of the athlete depends on the length required to be covered by every swim event. The percentage of varying training intensities when averaged out is: aerobic training 60%, aerobic/anaerobic 20%, in water strength training 15% and anaerobic lactic 5% [61]. Each training session was composed by warm up, main sets and cool down. The total swimming distance covered in each session was approximately 2000-2500m depending on the training objectives (Appendix 5).

Group B- Aquaticity Group

The participants in Group B followed the Aquaticity intervention program. The Aquaticity intervention program, is free from competitive strategies and aims to human's water adaptation. The participants in Group B were trained both at the surface and underwater. The goal of the aquaticity training program was to enhance the participant's perception and interaction with the liquid environment.

The Aquaticity training program included:

1. Physical efficiency (both on the surface and underwater)

Physical efficiency was developed through five training methods: aerobic, anaerobic, endurance, hypoxic and hypercapnic [149]. In order the participants to develop physical efficiency in the water, the Aquaticity Program applied various stimuli including:

a) Continuous swimming (aerobic ability) similarly to the swimming group

b) Endurance training (pulling, sculling, scooping, kicking, egg-beater, underwater sprints with fins, buddy exercises) [76, 150]

c) Navigation (combined multiple movement patterns in all directions) including training through different water layers (swallow, middle, deep) and interchanging directions (forward-back, left-right) in combination with advance rotations, somersaults, vertical jumps and reverse vertical sculls [150, 151]

d) Underwater training, where participants were training underwater. This type of training is based on freedivers training methods which include hypoxic and hypercapnic stimulus during static and dynamic apneas. During hypoxic training the participants developed tolerance in low levels of O_2 and during hypercapnic training participants developed tolerance in high levels of CO_2. None of the participants were forced to hold their breath more than they felt comfortable [152].

2. Technique development skills- multiple movement patterns

In this program different kind of propulsion skills (strokes, kicks, sculling and egg beater) are taught and practiced, extending the participant's movement pattern in all directions (horizontally and vertically, reverse vertically) and through different body positions (prone, sideward, backwards, by rotating or performing somersaults) [150]. To enhance the swimming technique, special sculling drills were added so the participants could learn to "feel" the mass of the water. The feel of the water refers to the participant's intuitive ability to effectively handle the water. This mean the sense of touch in every stroke and the sensation of moving pressure that leads to advance stroke technique and greater expertise [149]. That way the participant learns to find lines to travel in the water with less resistance.

3. Emotional control - relaxation

When immersing in the water, especially underwater, humans can experience feelings of panic or to harmony depending their previous experience[153]. Through the aquaticity training the participants had to develop skills to activate the positive stimulus and sensory functions underwater [104]. This has achieved by training the following skills:

a) Relaxation techniques in the water by practicing breathing cycles. Relaxation in the water is an ability that humans can develop. First step is conscious breathing. The participants developed proper breathing preparation before every breath hold session (static or dynamic apnea). Second step is diaphragmatic breathing. This deep breathing is marked by expansion of the abdomen rather than the chest when breathing. The participants become aware of their body and its reactions to breathing and apnea.

b) Senses training by practicing underwater vision and hearing ability. Various underwater vision challenges (without goggles) aimed to develop conscious vision, the participant's ability, to estimate the size and distance of immersed objects. Based on experiments by Gislen and colleagues [101], underwater vision can be developed by specific training. Underwater hearing aimed to develop the participants sense of detecting the underwater sounds.

c) Mental control and conscious thinking underwater [154]. The participants came through mind challenges during underwater mind games. This was completely something new to them and aimed to helped them to develop awareness, teamwork, concentration and confidence.

The percentage of varying training stimulus when average out in terms of the intervention training program was aerobic stimulus- tempo continuous swimming 20%, hypoxic & hypercapnic stimulus – static and dynamic apnea 30%, in water strength training 10%, technique drills 30%, and mind training 10%.

Each training session was composed by warm up, main sets and cool down. The total swimming distance covered in each session was approximately 1600m depending on the training objectives (Appendix 5).

Statistical analysis

Two data analysis were conducted, each addressing one of the purposes of the study. The first data analysis aimed at compare Aquaticity test score between Group A and Group B at baseline and before and after the intervention period (Pre and Post). For comparing the differences between groups an independent t-test was used while differences within groups assessing pre and post values were assessed using a paired t-test. Second data analysis was conducted within groups and between the ten tasks performed from the two groups pre and post intervention using a paired t-test while Delta changes were compared using an independent t-test. The results are expressed as mean ± SD. All the statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 18.0, Chicago III). Differences were considered significant when $p \leq 0.05$.

Results

Participants' basic characteristics are presented in Table 1.

Table 1. Basic characteristics of the participants divided in two groups. *BMI: Body Mass Index. * Differences between the two groups. Data are Mean ± SD.*

Parameters	**Group A (Swimming)**	**Group B (Aquaticity)**	**P value**
N	10	10	-
Gender (M/F)	4/6	4/6	-
Age (yrs)	16.3±0.8	16.8±0.5	0.105
Height (cm)	167±0.1	174±0.1	**0.030***
Weight (kg)	60±6.9	70±11.9	**0.033***
BMI (kg/m^2)	21.4±1.1	22.9±2.2	0.072
Aquaticity (AU)	29.1±3.3	27.1±3.8	0.239

Briefly, participants were matched for gender, age and aquaticity levels before the randomization process. Even though height and weight differ statistically, BMI did not show any statistical differences between the two groups.

Changes in Aquaticity score before and after the 2 months intervention program are presented in Table 2.

Table 2. Changes in Aquaticity score before and after the 2 months intervention.

Intervention	Group A (Swimming)	Group B (Aquaticity)	P value*
Pre Training	29.13 ± 3.27#	27.17 ± 3.89#	0.239
Post Training	32.8 ± 2.28	34.08 ± 2.6	0.257
Delta Change (%)	-3.67 ± 1.33 (-13.23 ± 6.88%)	-6.91 ± 2.14 (-26.6 ± 10.40%)#	**0.001** **0.004**

* Differences between the two groups. # Differences within groups (Pre vs Post), p,0.01. Data are Mean ± SD.

Aquaticity score improved by 13.23% and 26.6% in the swimming (group a) and aquaticity (group B) team respectively ($p<0.01$) with no statistical differences between the two groups in post training measurements. However, the Delta change differences in aquaticity score was 2 folds increased in the Aquaticity group compared to Swimming one ($p=0.001$) (Table 2) implying higher magnitude of improvement in the aquaticity group.

Individual task's aquaticity score before and after the 2 months intervention training is presented in Table 3. In Group A (swimming), 7 out of 10 tasks were improved significantly compared the pre values ($p<0.05$) while in Group B (aquaticity) 10 out of 10 shown significant improvements compared to pre training values. Interestingly, the magnitude of change (Delta change) between the two groups was statistically significant in 5 out of 10 tasks (tasks 2, 3, 7, 9, 10) implying again higher magnitude of improvements in the aquaticity intervention group compare to swimming group where only task 5 has shown larger magnitude of change compare to aquaticity one (Table 3).

Table 3. Individual Task's Aquaticity score before and after the 2 months intervention.

Tasks	Group A Pre	Group A Post	P value*	Group B Pre	Group B Post	P value*
Task 1 **Δ change (%)**	3.05±0.59	3.50±0.52 16.78±16.01	**0.004**	3.45±0.64	4.3±0.25 27.61±18.54	**0.001**
Task 2 **Δ change (%)**	3.80±0.42	4.10±0.21 9.16±13.72	**0.050**	3.50±0.66	4.3±0.34 25.27±15.28#	**0.001**
Task 3 **Δ change (%)**	3.20±0.25	4.00±0.00 25.71±9.83	**0.001**	2.85±0.66	4.15±0.33 50.41±24.91#	**0.001**
Task 4 **Δ change (%)**	3.55±0.43	4.20±0.25 19.28±9.72	**0.001**	3.25±0.42	3.65±0.47 13.09±15.27	**0.022**
Task 5 **Δ change (%)**	3.50±0.40	4.0±0.40 14.46±1.70#	**0.001**	3.05±0.49	3.25±0.35 7.66±9.94	**0.037**
Task 6 **Δ change (%)**	3.20±0.78	3.30±0.82 3.33±10.54	0.343	3.40±0.51	3.80±4.22 13.33±17.21	**0.037**
Task 7 **Δ change (%)**	3.2±0.26	3.5±0.00 8.33±8.78	**0.015**	2.6±0.45	3.55±0.15 39.76±21.60#	**0.001**
Task 8 **Δ change (%)**	2.95±0.68	3.30±0.48 15.33±21.49	**0.045**	2.85±0.24	3.70±0.48 30.66±20.41	**0.001**
Task 9 **Δ change (%)**	2.08±0.30	2.2±0.26 7.01±14.77	0.239	1.62±0.38	2.18±0.25 38.92±24.97#	**0.001**
Task 10 **Δ change (%)**	0.55±0.15	0.70±0.25 30.00±48.30	0.081	0.60±0.21	1.20±0.42 100.00±0,00#	**0.001**

* Differences within group (Pre vs Post). # Differences between Delta Changes $p \leq 0.01$.

Discussion

This is the first study to address the aspect of "Training Human Aquaticity" and how it can be developed using a structured training program in confined waters. The current study has shown that aquaticity score has been improved by 2 folds more when a structured - specific to aquaticity training - is implemented compared to classical swimming in naïve to swimming training participants. This is the first study to show that aquaticity score can also be improved by the classical swimming training (13%) however is much more less comparted to specific training (27%).

The aquaticity score was acquired using the Aquaticity Assessment Test recently developed by our group [148]. Briefly the test is composed of 10 tasks that assess various aspects of human's aquaticity as it has been presented recently [129]. In Group A where classical swimming training was used as an intervention, 3 out of 10 tasks did not change after the intervention program. More specific, task 6 is related to treading water exercise which is mainly used in specific aquatic sports like water polo, synchronized swimming and in lifeguarding activities for maintaining a hands free support of the body, by holding a vertical and stable position [76, 151]. This type of exercise is not commonly trained in classical swimming training since it has no use in any of the competitive styles. In contrast task 6 was significantly improved in Group B however the magnitude of change did not differ between the two groups mainly due to a large range of values among the participants. Similarly, task 9 which is related to breath holding underwater swimming did not improve in Group A after the classical swimming training. Underwater swimming is a common type of training in freediving and synchronized swimming and not in classical swimming and therefore it was expected to see no changes in this group [150, 152, 153]. In contrast, Group B showed almost 40% improvements after the aquaticity training and statistically significant differences in the magnitude of change between the two groups. Since aquaticity is related to underwater performance and ability to relax underwater [129] it is expected that breath hold activities will be incorporated in the aquaticity training and therefore to be improved after the intervention training period. Finally, task 10 which includes a voluntary exhalation and unsupported sinking in the bottom of the pool and it is considered one of the most difficult exercises to be completed from an untrained swimmer, did not change after the conventional swimming training while improved 100% in Group B. This is expected since this type of exercises are taking place only in competitive free diving training since they promote relaxation under water and improve lung functionality simulating deep diving activities [153].

Regarding the magnitude of changes (Delta changes) between the two groups, it is significant to denote that task 5 which is related to physical fitness adequacy in swimming and included a 5 min continue swimming was higher in Group A compared to Group B. This is expected since classical swimming training is based in swimming long distances and improving fitness levels while in aquaticity training is only one out of ten parameters contributing to the total aquaticity score. In Group B where aquaticity specific training was applied for two months showed larger improvements in tasks 2,3,7,9 and 10 compared to Group A (Table 3). More specific, task 2 is related to breathing control which is trained in both classical swimming and in our aquaticity training however the magnitude of changes after the intervention period was much higher in Group B possibly due to the fact that aquaticity training is specifically trained breathing relaxation techniques. Task 3 is related to underwater hydrodynamic position which is an important characteristic of competitive swimming and it was expected to be more improved in Group A. Interestingly, the magnitude of change was higher in Group B in contrast to our assumptions possibly due to the fact that classical swimming train hydrodynamic position only as part of the moment after turns and not as a single skill and capacity. On the other hand Task 7 is related to underwater vision which is a very distinct ability that can be trained and improved by frequent exposure to the water without googles or mask [101]. This ability was improved in Group B more than in Group A due to the fact that classical swimming uses google for training eliminating any training effect in this capability compared to Group B where participants were exercised specifically. Similarly Tasks 9 & 10 are improved more in Group B compared to Group A as it has been discussed above.

In the current study some potential weaknesses have been recognized that need to be acknowledged. Firstly, the number of participants per group was limited to 10. A larger number of participants could have shed more light in the explanation of these findings. In addition, the study had only two groups for comparison. Additional groups from other aquatic sports such as synchronized swimming or freediving could have helped us explain better our findings.

In conclusions, aquaticity is another parameter of human performance that can be trained and improved not only by classical swimming training but significantly more by specific aquaticity training. Aquaticity training is effective and easy to implement in any participant. Aquaticity training could be an alternative way of exercise that prepares athletes for all aquatic sport as well as people that need to reach a specific level of aquaticity in order to participate in certain type of aquatic activities.

Discussion

This PhD Thesis, is a modest contribution to the ongoing discussions about "Human Aquaticity". We proposed that aquaticity is a performance attribute that can be evaluated and improved upon with various interventions. We provided a definition to facilitate a departure from empirical and anecdotal approaches to 'ability in water' and move towards the scientific development of the concept Aquaticity. We concluded that "*Aquaticity is the capacity of a terrestrial mammalian organism to function and habitualise in the aquatic environment. The level of aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element and instruction*". Based on our research, four factors have been proposed by us to play an important role in human aquaticity: physical condition in the water, apnea and ability to immerse, mental health and parameters related to body composition.

In our effort to evaluate human's Aquaticity, we created and validated an Aquaticity Assessment Test (AAT). To our knowledge this is the first scientifically tested method created to assess aquaticity levels in humans. The AAT differentiated successfully all the aquatic from the terrestrial sports' participants as well as identified participants with high (≥43.3), medium (from 23.8 to 43.2) and low (≤23.7) aquaticity levels. The AAT is composed of 10 tasks related to the four recognized components of human aquaticity. Each task can be graded from 0 to 5 (with 0.5 step increments) with the later score implying excellent performance in the particular task. The highest overall score that can be achieved by a single person is 50 points.

This research also addressed the aspect of "Training Human Aquaticity" and how it can be developed using a structured training program in confined waters. The findings showed that, aquaticity is another parameter of human performance and that it can be trained and improved by classical swimming training, but significantly more by specific aquaticity training. The current study has shown that aquaticity score has been improved by 2 folds more when a structured - specific to aquaticity training - is implemented compared to classical swimming in naïve to swimming training participants. This is the first study to show that aquaticity score can also be improved by the classical swimming training (13%) however is much more less comparted to specific training (27%).

Aquaticity enhance-training programs and could become an integrated aquatic method for the development of human's aquatic education and safety as part of the overall aquatic performance.

In the current research some potential weaknesses have been recognized that need to be acknowledged. Firstly, our study concerning the AAT (paper 2), examined the aquaticity levels from only six different sports, three terrestrial and three aquatic ones, selected as representative of popular non-team sports and the test showed high reliability. Future work should be expanded in other sports and future research should test the AAT in various populations. Another possible limitation of the study is the fact that AAT has been constructed and performed in a pool, which is a highly controlled environment and has not been applied in the open sea environment where buoyancy and other parameters could have affected the final outcome. We selected the swimming pool environment as the most commonly available to aquatic development and rehabilitation activities. Indeed, a future study performed at the sea environment might reveal other aspects to be considered in the assessment of aquaticity (such as cold tolerance, orientation etc). In the Intervention study (paper 3) some potential weaknesses have been recognized that need to be acknowledged too. Firstly, the number of participants per group was limited to 10. A larger number of participants could have shed more light in the explanation of these findings. In addition, the study had only two groups for comparison. Additional groups from other aquatic sports such as synchronized swimming or freediving could have helped us explain better our findings.

Future research is needed to investigate whether an aquaticity intervention program could improve the aquaticity score in various populations and whether such a program can be used for the improvement of physical and mental health related quality of life. With the creation of AAT we now have a tool that will support future efforts for the development of water based interventions for sport, professional and health applications.

Conclusions

From the research that has been carried out, it is possible to conclude that Aquaticity is a physical capacity/ability that humans develop from a young age, when they come in contact with the water element. The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water. The findings have clearly shown that the Aquaticity Assessment Test evaluates human's level of Aquaticity and can detect high and low levels of aquaticity and therefore low physical adequacy in the water (and increased risk). The AAT contains tasks that can be performed easily by everybody independently from fitness level or existing familiarity to the water.

Aquaticity as another parameter of human performance, can be trained and improved not only by classical swimming training but significantly more by specific aquaticity training. Aquaticity training is effective and easy to implement in any participant.

Aquaticity Assessment Test and Aquaticity Development Program, can play a vital role in water safety, in education, in competitive water performance (perfection), in military training, in rehabilitation, in treatment of aqua phobia, as a long life activity and as an aging fitness approach. Most of all, it can lead to a deeper understanding of who we are and how our bodies, minds and emotions are shaped by our interaction with the most prevalent substance on our planet- the water.

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Appendix

Appendix 1: Bioethics Approval

ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ
ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ

Εσωτερική Επιτροπή Δεοντολογίας

Τρίκαλα: 29 /03 /2012
Αριθμ. Πρωτ.: 518

Αίτηση Εξέτασης της πρότασης για διεξαγωγή Έρευνας με τίτλο: "Η ανάπτυξη της Υδροβιότητας με μουσικοκινητικές δραστηριότητες σε παιδιά σχολικής ηλικίας"

Επιστημονικώς υπεύθυνος-η / επιβλέπων-ουσα: Ελιζάνα Πολάτου
Ιδιότητα: Επίκουρη Καθηγήτρια
Ίδρυμα: Πανεπιστήμιο Θεσσαλίας
Τμήμα: ΤΕΦΑΑ

Επιστημονικώς υπεύθυνος-η / επιβλέπων-ουσα: Δρ. Γεώργιος Σακκάς
Ιδιότητα: Ερευνητής Δ', Κλινικής Εργοφυσιολογίας
Ίδρυμα: ΚΕΤΕΑΘ
Τμήμα: ΙΣΑΑ

Κύριος ερευνητής-τρια / φοιτητής-τρια: Δανάη Βαρβέρη
Πρόγραμμα Σπουδών: Διδακτορικό Πρόγραμμα Σπουδών
Ίδρυμα: Πανεπιστήμιο Θεσσαλίας
Τμήμα: ΤΕΦΑΑ

Η προτεινόμενη έρευνα θα είναι:

Ερευνητικό πρόγραμμα ☐ **Διδακτορική διατριβή X** Διπλωματική εργασία ☐ Ανεξάρτητη έρευνα ☐

Τηλ. επικοινωνίας: 2431-500-911
Email επικοινωνίας: gsakkas@med.uth.gr

Η Εσωτερική Επιτροπή Δεοντολογίας του Τ.Ε.Φ.Α.Α., Πανεπιστημίου Θεσσαλίας μετά την υπ. Αριθμ. 3-3/22-2-2012 συνεδρίαση της εγκρίνει τη διεξαγωγή της προτεινόμενης έρευνας.

Ο Πρόεδρος της
Εσωτερικής Επιτροπής
Δεοντολογίας – ΤΕΦΑΑ

Τσιόκανος Αθανάσιος
Αναπληρωτής Καθηγητής

Appendix 2: Consent Form

ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ
ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ

Έντυπο συναίνεσης δοκιμαζόμενου σε ερευνητική εργασία

Τίτλος Ερευνητικής Εργασίας: "Η ανάπτυξη της Υδροβιότητας μέσα από παιγνιώδεις δραστηριότητες στο νερό σε παιδιά σχολικής ηλικίας."

Επιστημονικός Υπεύθυνος: Επίκουρος Καθηγητής Γεώργιος Σακκάς

Ερευνητές: Δανάη Βαρβέρη BSc, MSc (698-66-300-30)

Σκοπός της ερευνητικής εργασίας

Ο σκοπός της παρούσας μελέτης είναι να προσδιορίσει την Υδροβιότητα καθώς και να δημιουργήσει ένα εργαλείο αξιολόγησης της για παιδιά σχολικής ηλικίας. Δευτερεύων σκοπός της έρευνας είναι η δημιουργία και εφαρμογή ενός εκπαιδευτικού προγράμματος ανάπτυξης της Υδροβιότητας, που θα ενισχύει το κλασσικό πρόγραμμα κολύμβησης και θα αναπτύσσει το συναισθηματικό δεσμό των παιδιών με το υγρό στοιχείο. Τα παιδιά θα έρθουν σε επαφή με το νερό μέσα από μουσικοκινητικές δραστηριότητες (με τη χρήση υδρόφωνου) και με σκοπό να προσαρμόσουν τις αισθήσεις τους (αφή , όραση, ακοή) μέσα στο υδάτινο περιβάλλον. Με αυτό τον τρόπο θα νιώσουν ασφάλεια, θα διασκεδάσουν και θα αναπτύξουν κινητικές δεξιότητες χωρίς την πίεση αθλητικών επιδόσεων.

Διαδικασία

Αρχικά θα χρειαστεί να αξιολογηθεί ο δείκτης Υδροβιότητας των μαθητών σύμφωνα με μια δοκιμασία αξιολόγησης Υδροβιότητας. Η αξιολόγηση θα γίνεται ατομικά και θα διαρκεί 15 λεπτά για κάθε μαθητή. Τα αποτελέσματα θ' ανακοινωθούν μόνο στο δοκιμαζόμενο και στους γονείς του. Έπειτα οι μαθητές θα χωριστούν σε δύο ομάδες (με τυχαία επιλογή) ανάλογα με το πρόγραμμα παρέμβασης: στην Ομάδα Α (ομάδα κλασσικής κολύμβησης) και στην Ομάδα Β (ομάδα Υδροβιότητας). Οι δύο ομάδες θα παρακολουθήσουν διαφορετικά αθλητικά πρόγραμμα που θα έχει όμως την ίδια διάρκεια (1 ώρα από 3 φορές την εβδομάδα για 2 μήνες).

Η Ομάδα Α θα προπονηθεί στην κλασσική κολύμβηση σύμφωνα με τις σύγχρονες μεθόδους προπόνησης. Στόχος είναι η βελτίωση της τεχνικής στα 4 στιλ κολύμβησης (ελεύθερο, ύπτιο, πρόσθιο, πεταλούδα), στις στροφές και στις εκκινήσεις. Δεύτερος στόχος είναι η βελτίωση της αθλητικής επίδοσης και αυτό θ' αξιολογηθεί με χρονομέτρηση στα 50μ, σε δύο κολυμβητικά στιλ. Κατά συνέπεια οι μαθητές που θα συμμετάσχουν στην Ομάδα Α, θα αξιολογηθούν στην τεχνική και θα χρονομετρηθούν μία φορά πριν την έναρξη του προγράμματος και μία στο τέλος. Η συνολική απόσταση που θα διανύουν οι μαθητές σε κάθε προπόνηση θα κυμαίνεται από 2200-3000 μέτρα ανάλογα με τον προπονητικό στόχο. Η κάθε προπονητική μονάδα θα αποτελείται από την προθέρμανση, το κυρίως μέρος και την αποθεραπεία. Ο εξοπλισμός που θα χρησιμοποιηθεί είναι οι σανίδες τα βαρελάκια, τα χεράκια και τα πέδιλα.

Η Ομάδα Β θα παρακολουθήσει το πρόγραμμα ανάπτυξης της Υδροβιότητας. Στόχος του προγράμματος είναι οι μαθητές να γνωρίσουν τις διαφορές που έχει το ξηρό και το υγρό περιβάλλον και να έρθουν σε επαφή με τις δυνατότητες που έχει το ανθρώπινο σώμα υποβρυχίως. Να μάθουν επίσης νέα στιλ προώθησης όπως πλάγιο κολύμπι, πόλο, σκάλινγκ και ν' αναπτύξουν την ικανότητα χαλάρωσης και βύθισης. Τοποθετώντας επίσης το σώμα τους, εκτός από πρόσθια και ύπτια θέση που έχουν διδαχτεί στην κλασσική κολύμβηση, σε πλάγια, όρθια και κατακόρυφη θέση, θ' αναπτύξουν νευρομυικό έλεγχο, προσανατολισμό και κιναίσθηση στο νερό.

Το πρόγραμμα Ανάπτυξης της Υδροβιότητας θα χρησιμοποιήσει Υδρόφωνο, έτσι ώστε η μουσική να συνοδεύει με έμμεσο ή άμεσο τρόπο τις ασκήσεις που θα εκτελούν οι μαθητές. Η μουσική θα χρησιμοποιηθεί ως κίνητρο για τη μεγαλύτερη παραμονή του σώματος υποβρυχίως με σκοπό την εξοικείωση των μαθητών με τις τεχνικές κατάδυσης και άπνοιας. Η συνολική απόσταση που θα διανύουν οι μαθητές στην επιφάνεια ή υποβρυχίως θα κυμαίνεται από 1200-1500μ. Προπονητικός στόχος είναι η άθληση και η διασκέδαση χωρίς την πίεση της αθλητικής επίδοσης. Απώτερος στόχος είναι οι μαθητές μέχρι το τέλος του προγράμματος να έχουν αναπτύξει ένα ιδιαίτερο δεσμό με το υγρό στοιχείο και να εκτελούν δεξιότητες στο νερό που δεν γνώριζαν ή δεν μπορούσαν πριν. Ο εξοπλισμός που θα χρησιμοποιηθεί είναι, υδρόφωνο, βυθιζόμενα στεφάνια και αντικείμενα, σκοινί/δισκάκι/ταμπελάκια, βυθιζόμενη μπασκέτα και μπάλα. Η κάθε προπονητική μονάδα θα περιλαμβάνει την προθέρμανση, το κυρίως μέρος και την αποθεραπεία.

Κίνδυνοι και ενοχλήσεις

Η άσκηση στο νερό αποτελεί ιδανική μορφή άθλησης λόγω έλλειψης της βαρύτητας και μη καταπόνησης των αρθρώσεων.

Οι δοκιμαζόμενοι μπορεί να αντιμετωπίσουν κάποια ενόχληση στα μάτια λόγω της χλωρίωσης του νερού, όμως αυτό μπορεί να αποφευχθεί με τη χρήση ειδικών γυαλιών κολύμβησης.

Η θερμοκρασία του νερού θα είναι στους 27 βαθμούς κελσίου, που είναι ιδανική για το ανθρώπινο σώμα όταν ασκείται στο νερό.

Η καθαριότητα του κολυμβητικού κέντρου είναι σχολαστική κι έτσι οι πιθανότητες να κολλήσουν τα παιδιά μυρμηγκιές ή μυκητιάσεις ελαχιστοποιούνται.

Όλοι οι μαθητές θα κυκλοφορούν με ειδικές σαγιονάρες στο χώρο του κολυμβητηρίου, θα φορούν ειδικό σκουφάκι κολύμβησης και θα κάνουν ντουζ πριν μπουν στο νερό.

Βασικός κανόνας για να μην κινδυνέψουν οι μαθητές κατά την διάρκεια της άθλησης στο νερό είναι να μην έχουν φάει 2 ώρες πριν την προπόνηση.

Στο κολυμβητήριο υπάρχουν όλα τα σωστικά μέσα και όλες οι δραστηριότητες γίνονται πάντα υπό την παρουσία Ναυαγοσώστη.

Προσδοκώμενες ωφέλειες

Με το εργαλείο αξιολόγησης της Υδροβιότητας, τα παιδιά και οι γονείς τους, θα μπορέσουν να γνωρίσουν την ικανότητα προσαρμογής του δοκιμαζόμενου στο νερό.

Οι μαθητές που θα συμμετέχουν στην Ομάδα Α (ομάδα κλασσικής κολύμβησης),θα βελτιώσουν την τεχνική τους στα 4 στιλ (ελεύθερο, ύπτιο, πρόσθιο, πεταλούδα), στις στροφές και στις εκκινήσεις. Προπονητικός στόχος είναι οι δοκιμαζόμενοι να βελτιώσουν και την αθλητική τους επίδοση σε δύο διαφορετικά στιλ και σε απόσταση 50μ.

Οι μαθητές που θα συμμετέχουν στην Ομάδα Β (ομάδα Υδροβιότητας) θα αναπτύξουν προχωρημένες δεξιότητες στο νερό, θα εκπαιδευτούν σε τεχνικές και στιλ κολύμβησης που δεν εφαρμόζονται στην κλασσική κολύμβηση. Με τη συμμετοχή τους σ' αυτό το ερευνητικό πρόγραμμα τα παιδιά θα γυμναστούν, θα διασκεδάσουν και θα εξερευνήσουν τις ικανότητες που έχει το σώμα τους στο νερό.

Στη δεύτερη ομάδα θα χρησιμοποιήσουμε τη μουσική ως εκπαιδευτικό μέσον και ως μέσον έμπνευσης και έκφρασης. Θα ενεργοποιηθεί επίσης ο συναισθηματικός κόσμος του παιδιού και η φαντασία τους σε συνδυασμό με τη σωματική άσκηση. Η μουσική στο νερό αποτελεί μία ενδιαφέρουσα και νέα εμπειρία καθώς η πλειοψηφία των μαθητών δεν έχουν ακούσει μουσική υποβρυχίως.

Δημοσίευση δεδομένων – αποτελεσμάτων

Η συμμετοχή σας στην έρευνα συνεπάγεται ότι συμφωνείτε με την μελλοντική δημοσίευση των αποτελεσμάτων της, με την προϋπόθεση ότι οι πληροφορίες θα είναι ανώνυμες και δε θα αποκαλυφθούν τα ονόματα των συμμετεχόντων. Τα δεδομένα που θα συγκεντρωθούν θα κωδικοποιηθούν με αριθμό, ώστε το όνομα σας δε θα φαίνεται πουθενά.

Πληροφορίες

Μη διστάσετε να κάνετε ερωτήσεις γύρω από το σκοπό ή την διαδικασία της εργασίας. Αν έχετε οποιαδήποτε αμφιβολία ή ερώτηση ζητήστε μας να σας δώσουμε διευκρινίσεις.

Δανάη Βαρβέρη: 698-66-300-30

Γεώργιος Σακκάς: 697-85-091-02

Ελευθερία συναίνεσης

Η συμμετοχή σας στην εργασία είναι εθελοντική. Είστε ελεύθερος-η να μην συναινέσετε ή να διακόψετε τη συμμετοχή σας όποτε το επιθυμείτε.

Δήλωση συναίνεσης

Διάβασα το έντυπο αυτό και κατανοώ τις διαδικασίες που θα ακολουθήσω. Συναινώ να συμμετάσχω στην ερευνητική εργασία.

Ημερομηνία: __/__/__

Ονοματεπώνυμο και
υπογραφή συμμετέχοντος

Υπογραφή ερευνητή

Ονοματεπώνυμο και
υπογραφή παρατηρητή

Ονοματεπώνυμο και

υπογραφή γονέα ή κηδεμόνα

Appendix 3: General Health Questionnaire

Ερωτηματολόγιο Γενικής Υγείας
GHQ-30

Παρακαλούμε διάβασε τα παρακάτω προσεκτικά:
Θα θέλαμε να ξέρουμε αν έχετε κάποια ενοχλήματα και γενικά πως ήταν η υγεία σας τις τελευταίες εβδομάδες. Παρακαλούμε να απαντήσετε σε ΟΛΕΣ τις ερωτήσεις στις σελίδες που ακολουθούν.
Σημειώστε με ☒ το πλαίσιο που περιγράφει καλύτερα την απάντησή σας.
Προσέξτε, θέλουμε να ξέρουμε τα τωρινά και πρόσφατα ενοχλήματα σας και όχι εκείνα που είχατε στο παρελθόν.
Έχει σημασία να προσπαθήσετε να απαντήσετε σε ΟΛΕΣ τις ερωτήσεις.
Ευχαριστούμε πολύ για την συνεργασία σας.

ΤΟΝ ΤΕΛΕΥΤΑΙΟ ΚΑΙΡΟ:

1. Τα καταφέρνεις να συγκεντρωθείς σε οτιδήποτε κάνεις;

Καλύτερα απ' ότι συνήθως ☐	Το ίδιο όπως συνήθως ☐	Λιγότερο απ' ότι συνήθως ☐	Πολύ λιγότερο απ' ότι συνήθως ☐

2. Έχεις ξαγρυπνήσει πολλές φορές επειδή ήσουν ανήσυχος/η;

Καθόλου ☐	Όχι περισσότερο απ' ότι συνήθως ☐	Μάλλον περισσότερο απ' ότι συνήθως ☐	Πολύ περισσότερο απ' ότι συνήθως ☐

3. Έχεις περάσει ανήσυχες και ταραγμένες νύχτες;

Καθόλου ☐	Όχι περισσότερο απ' ότι συνήθως ☐	Μάλλον περισσότερο απ' ότι συνήθως ☐	Πολύ περισσότερο απ' ότι συνήθως ☐

4. Έχεις καταφέρει να είσαι δραστήριος/α και πάντα απασχολημένος/η;

Περισσότερο απ' ότι συνήθως ☐	Το ίδιο όπως συνήθως ☐	Μάλλον λιγότερο απ' ότι συνήθως ☐	Πολύ λιγότερο απ' ότι συνήθως ☐

5. Βγαίνεις από το σπίτι σου όπως συνήθως;

Περισσότερο απ' ότι συνήθως ☐	Ίδια όπως συνήθως ☐	Λιγότερο απ' ότι συνήθως ☐	Πολύ λιγότερο απ' ότι συνήθως ☐

6. Τα καταφέρνεις τόσο καλά όσο θα κατάφερναν οι περισσότεροι άνθρωποι αν ήταν στη θέση σου;

Καλύτερα από τους περισσότερους ☐	Περίπου το ίδιο ☐	Μάλλον όχι τόσο καλά ☐	Πολύ χειρότερα ☐

1

7. Έχεις αισθανθεί πως σε γενικές γραμμές τα καταφέρνεις καλά;

Καλύτερα απ' ότι συνήθως	☐	Περίπου το ίδιο	☐	Χειρότερα απ' ότι συνήθως	☐	Πολύ χειρότερα	☐

8. Είσαι ικανοποιημένος/η με τον τρόπο που εκτελείς τις δουλειές σου;

Περισσότερο ικανοποιημένος/η	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο ικανοποιημένος/η	☐	Πολύ λιγότερο ικανοποιημένος/η	☐

9. Μπορείς να νιώσεις ζεστασιά και στοργή γι' αυτούς που είναι κοντά σου;

Καλύτερα απ' ότι συνήθως	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

10. Βρίσκεις ότι σου είναι εύκολο να τα πας καλά με τους άλλους ανθρώπους;

Καλύτερα απ' ότι συνήθως	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

11. Έχεις ξοδέψει αρκετό χρόνο για κουβεντολόι με τους άλλους ανθρώπους;

Περισσότερο χρόνο απ' ότι συνήθως	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο χρόνο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

12. Έχεις αισθανθεί πως παίζεις χρήσιμο ρόλο σε ότι γίνεται γύρω σου;

Περισσότερο απ' ότι συνήθως	☐	Το ίδιο όπως συνήθως	☐	Λιγότερο χρήσιμο απ' ότι συνήθως	☐	Πολύ λιγότερο χρήσιμο απ' ότι συνήθως	☐

13. Έχεις αισθανθεί ικανός/η να παίρνεις αποφάσεις για διάφορα θέματα;

Περισσότερο απ' ότι συνήθως	☐	Το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο ικανός/ή	☐

14. Έχεις αισθανθεί να βρίσκεσαι συνεχώς κάτω από πίεση;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

15. Έχεις αισθανθεί πως δεν θα μπορούσες να ξεπεράσεις τις δυσκολίες σου;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

16. Βρίσκεις πως η ζωή είναι ένας συνεχής αγώνας;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

17. Μπορείς να χαρείς τις συνηθισμένες καθημερινές δραστηριότητες σου;

Περισσότερο απ' ότι συνήθως	☐	Το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

18. Παίρνεις τα πράγματα βαριά;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

19. Φοβάσαι ή πανικοβάλλεσαι χωρίς σοβαρό λόγο;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

20. Τα καταφέρνεις να δεις και να αντιμετωπίσεις τα προβλήματα σου;

Περισσότερο απ' ότι συνήθως	☐	Το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

21. Αισθάνεσαι πως δεν αντέχεις άλλο;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

22. Αισθάνεσαι δυστυχισμένος/η και μελαγχολικός/η;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

23. Έχεις χάσει την εμπιστοσύνη στον εαυτό σου;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

24. Σκέφτεσαι πως δεν αξίζεις τίποτα;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

25. Έχεις αισθανθεί πως η ζωή είναι χωρίς καμία ελπίδα;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

26. Αισθάνεσαι αισιόδοξος/η για το μέλλον σου;

Περισσότερο απ' ότι συνήθως	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο ελπίδα	☐

3

27. Σε γενικές γραμμές αισθάνεσαι ευτυχισμένος/η;

Περισσότερο απ' ότι συνήθως	☐	Περίπου το ίδιο όπως συνήθως	☐	Λιγότερο απ' ότι συνήθως	☐	Πολύ λιγότερο απ' ότι συνήθως	☐

28. Αισθάνεσαι συνεχώς νευρικός/η και σε υπερδιέγερση;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

29. Έχεις αισθανθεί ότι δεν αξίζει κανείς να ζει;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

30. Βρήκες μερικές φορές ότι δεν μπορούσες να κάνεις τίποτα γιατί τα νεύρα σου ήταν σε άσχημη κατάστασή;

Καθόλου	☐	Όχι περισσότερο απ' ότι συνήθως	☐	Μάλλον περισσότερο απ' ότι συνήθως	☐	Πολύ περισσότερο απ' ότι συνήθως	☐

Appendix 4: Copyright Statement

Υπεύθυνη Δήλωση

Η κάτωθι υπογεγραμμένη NAME μεταπτυχιακή/ος φοιτήτρια/ης του Προγράμματος Μεταπτυχιακών Σπουδών «ΑΣΚΗΣΗ ΚΑΙ ΥΓΕΙΑ» του Τμήματος Επιστήμης Φυσικής Αγωγής και Αθλητισμού του Πανεπιστημίου Θεσσαλίας

δηλώνω υπεύθυνα ότι αποδέχομαι τους παρακάτω όρους που αφορούν

(α) στα πνευματικά δικαιώματα της Μεταπτυχιακής Διπλωματικής Εργασίας (ΜΔΕ) μου με τίτλο «Η επίδραση της μυικής κόπωσης στην νευρομυική δραστηριότητα κατά τη διάρκεια του ύπνου»

(β) στη διαχείριση των ερευνητικών δεδομένων που θα συλλέξω στην πορεία εκπόνησής της:

1. Τα πνευματικά δικαιώματα του τόμου της μεταπτυχιακής διατριβής που θα προκύψει θα ανήκουν σε μένα. Θα ακολουθήσω τις οδηγίες συγγραφής, εκτύπωσης και κατάθεσης αντιτύπων της διατριβής στα ανάλογα αποθετήρια (σε έντυπη ή/και σε ηλεκτρονική μορφή).

2. Η διαχείριση των δεδομένων της διατριβής ανήκει από κοινού σε εμένα και στον/στην πρώτο επιβλέποντα -ουσα καθηγητή -τριας.

3. Οποιαδήποτε επιστημονική δημοσίευση ή ανακοίνωση (αναρτημένη ή προφορική), ή αναφορά που προέρχεται από το υλικό/δεδομένα της εργασίας αυτής θα γίνεται με συγγραφείς εμένα τον ίδιο, τον/την κύριο-α επιβλέποντα -ουσα ή και άλλους ερευνητές (όπως πχ μέλους –ών της τριμελούς συμβουλευτικής επιτροπής), ανάλογα με τη συμβολή τους στην έρευνα ή στη συγγραφή των ερευνητικών εργασιών.

4. Η σειρά των ονομάτων στις επιστημονικές δημοσιεύσεις ή επιστημονικές ανακοινώσεις θα αποφασίζεται από κοινού από εμένα και τον/την κύριο -α επιβλέποντα -ουσα της εργασίας, πριν αρχίσει η εκπόνησή της. Η απόφαση αυτή θα πιστοποιηθεί εγγράφως μεταξύ εμού και του/της κ. επιβλέποντα -ουσας.

Τέλος, δηλώνω ότι γνωρίζω τους κανόνες περί λογοκλοπής και πνευματικής ιδιοκτησίας και ότι θα τους τηρώ απαρέγκλιτα καθ' όλη τη διάρκεια της φοίτησης και κάλυψης των εκπαιδευτικών υποχρεώσεων που προκύπτουν από το ΠΜΣ/τμήμα, αλλά και των διαδικασιών δημοσίευσης που θα προκύψουν μετά την ολοκλήρωση των σπουδών μου.

Ημερομηνία

Η δηλούσα/ων

ονομα

Appendix 5: Group A and Group B training Logs

Table 4. Classical Swimming Group A - Training Log

Macro cycle details :	Macro cycle 1, week 1-8	Macro cycle 1, week 1-8	Macro cycle 1, week 1-8
Day and date :	**Mondays**, October- November 2014	**Wednesdays**, October- November 2014	**Fridays,** October- November 2014
Time:	**16.00- 17.00**	**16.00- 17.00**	**16.00- 17.00**
Pool length:	25m / Pool depth: 1.60- 2.85m	25m / Pool depth: 1.60- 2.85m	25m / Pool depth: 1.60- 2.85m
Water Temperature:	27 C	27 C	27 C
Workout number:	1st , 4th , 7th , 10th , 13th , 16th , 19th , 22nd	2nd , 5th , 8th , 11th , 14th , 17th , 20th , 23nd	3rd , 6th , 9th , 12th , 16th , 19th ,21st , 24nd
Length of session:	2500 meters	2000 meters	2200 meters
Training Zone:	Aerobic training zone (A3 aerobic stimulus to increase aerobic capacity/tempo)	Aerobic / Anaerobic Lactic	Anaerobic endurance

Training aims :	Aerobic development, Stroke technique enhancement-drill progressions for all four competitive strokes, develop core elements of body strength and control, enchase the feel of the water, kick and pull training.	Resistance training, develop core body strength and stability, kick and pull training to increase stroking power and short sprints.	technique development (stroke efficiency, hydrodynamic body position, develop the feel of the water, momentum, gliding, body roll).
Heart rate:	120- 160 bpm	120- 185 bpm	120- 190 bpm
Effort:	up to 70%	up to 85%	up to 90%
Perceived exertion:	Comfortable and Somewhat uncomfortable	Fast but comfortable (short sprints)	hard work
Equipment:		hand paddles, fins	
Warm-up:	15 min 600 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally.	15 min 600 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally. Warm-up allow oxygen consumption mechanisms to respond faster, increases blood flow, stretches the	15 min 600 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally. Warm-up allow oxygen consumption

	Warm-up allow oxygen consumption mechanisms to respond faster, increases blood flow, stretches the joints and muscles increasing the range of motion and sense of pace.	joints and muscles increasing the range of motion and sense of pace, HR 50 BBM. Drills: low intensity swim 200 m FS (rest 15sec), 200m IM kick development -count the number of kicks done every 50m (rest 15sec), 200m personal stroke- negative split.	mechanisms to respond faster, increases blood flow, stretches the joints and muscles increasing the range of motion and sense of pace, HR 50 BBM. Drills: low intensity swim 200 m FS (rest 15sec), 4* 100m progression drills in all four strokes (rest 15sec).
Main Set:	40 min 1400 m Objectives: volume- speed combination [(i) improving aerobic capacity, aerobic muscular endurance and (ii) improving anaerobic muscular endurance] , improve fitness and efficiency on taking fewer strokes per length of the pool 1.4* 200 m FS on 3.00 min, with bilateral breathing (the	40 min 1000 m Objectives: (i)._Build resistance kick/ speed kick with fins/ technique -based pulling /and resistance pull training. (ii)Develop pure speed • 4* 100m FS swimming with paddles on a 1.10 min send off. • 8* 50m main stroke kick with fins, negative split. • 16* 25m maximum speed (1 FS/ 1 personal stroke) rest 1.30 min.	40 min 1200 m Objectives: teaching swimmer to relax when swimming at speed and learn efficient coordination, develops muscle strength, fast shape ring effect rapid improvement **a.** 2* 200m **b.** 4* 100m **c.** 8* 50m FS, fast swimming 160-190 bpm (rest 30sec)

	2^{nd} and the 4^{th} breathing every three, five, seven). 2.pyramid 25m, 50m, 75m, 100m, 75m, 50m, 25m (25m BF, 50m BK, 75m BS, 100m IM). 3.8 * 50 m on a 1.05 min send-off , personal stroke.		
Secondary Set:	work on turns for all strokes <u>Objectives:</u> develop technique points (approach towards the wall, fast turn or rotation if it is two handed touch, dynamic push off and exploding through the knees and hips to maintain streamlined position from the arms through to the pointed toes, hydrodynamic head position, fast & vigorous dolphin kicks	work on starts for all strokes <u>Objectives:</u> development of grab starts and backstroke start.	work on finishes for all strokes and relay takeovers <u>Objectives:</u> development of finishes.

	ensuring maintenance underwater streamlined position, practice turn both ways L&R).		
Cool-down:	5 min, 200m Swim- down, any stroke Objectives: Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.	5 min, 200m Swim- down (HR at 50 BBM) objectives: Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.	5 min, 200m Swim- down **objectives:** Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.

Table 5. Aquaticity Development Group B - Training Log

Macro cycle details :	Macro cycle 1, week 1-8
Day and date :	**Mondays**, October- November 2014
Time:	**17.00- 18.00**
Pool:	6 lanes/ length 25m/ depth 1.60- 2.85m
Workout number:	1st , 4th , 7th , 10th , 13th , 16th , 19th , 22nd
Length of session:	1600 meters
Training Zone:	Aerobic training zone (A3 aerobic stimulus to increase aerobic capacity/tempo)
Training aims :	**a.** Physical efficiency in the water **b**. Technique development in different swimming strokes: FS, BK, BS, BF, side stroke, lifeguard stroke, underwater swimming-pull down breaststroke, dolphin kick **c**. Underwater training: breath hold ability, underwater buoyancy, Dyn no-fins (underwater swimming-pull down breaststroke), underwater push-off from the wall, hydrodynamic position and gliding **d**. Relaxation techniques development: low heart beats, positive stimulus, preparation for breath holding
Heart rate:	120- 175 bpm

Effort:	up to 70%
Perceived exertion:	Comfortable and Somewhat uncomfortable
Warm-up:	10 min 400 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally. Warm-up allow oxygen consumption mechanisms to respond faster, increases blood flow, stretches the joints and muscles increasing the range of motion and sense of pace. Drills: continuous swim 400m [200 m FS (rest 15sec), 200m any stroke] (rest 2min)
Main Set:	40 min 1000 m Objectives: **a**. Technique development in different swimming strokes: FS, BK, BS, BF, side stroke, lifeguard stroke, dolphin kick, balance development in side and supine body position, streamling, **b**. Underwater swimming ability: breath holding technique, underwater buoyancy, pull down breaststroke, underwater push-off from the wall and maintain a hydrodynamic position to achieve efficient gliding Drills: **a**. 4* 100m side body position swimming [100m side stroke (left and right), 100m lifeguard side stroke (back hand- straight up), 100m side stroke with sessors kick, 100m butterfly kicks on side (left & right)]

	4* 100m supine body position [100m on supine position BS kick, 100m supine position sculling with the head/scaling with the legs, 100m balance swimming FS kick- hands straight up over the water - both palms together] **b**. 16 * 25m dynamic apnea progressions [4* max gliding distance after push – off from the wall, 4*12.5 m Dyn no-fins (rest 45sec) swimming-pull down breaststroke, 4* 12.5m dyn only BS kick, 4* 12.5m dyn only arm stroke] rest: 12.5m swim-down + 15sec.
Secondary Set:	drills on the same spot -at the maximum Depth of the pool - 10 min Objectives: Relaxation Technique, breathing control, static apnea, uw buoyancy control Drills: **1**. a. Supine floating positions, b. Hanging apnea skills **2**. Preparation and diaphragmatic breathing, static apnea 2min **3**. Static apnea 6 sets [3sets on floating position, 3 sets on underwater position -at max depth of the pool] 5 min
Cool-down:	100m Swim- down any stroke Objectives: Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.

Table 6. Aquaticity Development Group B - Training Log

Macro cycle details :	Macro cycle 1, week 1-8
Day and date :	**Wednesdays**, October- November 2014
Time:	**17.00- 18.00**
Pool:	6 lanes/ length 25m/ depth 1.60- 2.85m
Workout number:	2nd , 5th , 8th , 11th , 14th , 17th , 20th , 23nd
Length of session:	1500 meters
Training Zone:	Aerobic / Anaerobic Lactic
Training aims :	**a**. Development of strength and endurance in the water: Develop elements of different movement pattern, for body strength and control in the water (swimming, sculling, scooping, kicking, egg-beater, underwater swimming, underwater navigation) **b**. Physical efficiency in the water **c**. Navigation: zic- zac swim, stop and go, swim-dive- swim **d**. Buoyancy training: on the same spot (back layout with or without scull, side layout, tub and tuck, rolls, oyster, water wheel, logroll)
Heart rate:	120- 175 bpm

Effort:	up to 80%
Perceived exertion:	Comfortable and uncomfortable
Warm-up:	10 min 400 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally. Warm-up allow oxygen consumption mechanisms to respond faster, increases blood flow, stretches the joints and muscles increasing the range of motion and sense of pace. Drills: continuous swim 200 m FS (rest 15sec), 200m kicking with no kickboard- any kick style (rest 15")
Main Set:	40 min 800 m Objectives: Develop various movement patterns, develop core strength and stability, buoyancy control Drills: On the same spot and during distance swimming: sculling/scooping/ BS kicking/ egg-beater/ turns, somersaults and rotations/ Reverse vertical sculls/ jump turns **Vertical positions on the same spot:** 2 * 30sec/rest 15sec 1. egg- beater on the same spot 3. Vertical BS kick – hands above the head 5. Flat sculling position to butterfly-turn and streamlined position (L&R)

	7. Flat Sculling position to backstroke-turn and finishing on the back in a streamlined position 9. Front and back somersault with a tight tuck 11. Reverse vertical sculls 13. Vertical push offs- streamline Jumps + turns (FS/BK) 15. Water wheel *** vertical kicking, the arms are held in a streamlined position out of the water- if possible** **Distance swimming + different movement pattern**: 2* 50m/rest 15sec 2. egg- beater distance swim: prone and supine position (double arm sweep in, sweep out) 4. BS kick distance swim: prone and supine position 6. Head first horizontal scull on back/ Sculling with legs leading 8. Short swim distance- both high velocity + changing directions (L& R/ F&B) - intense bursts of activity, lasting less than 15 seconds-followed by recovery (lower-intensity swim) (head-high FS) 10. Scooping-A clean catch and ability of hold the water, helps to maximize stroke efficiency. (Propeller- face remains on surface) supine position <u>Buddy-Up Partner Exercises:</u> Entry-Approach the partner at 25m distance point-Tow back 12. Giant Stride entry - approaching the partner performing head high breaststroke - Towing (Kickback, Inverted Breastroke Kick with two Arms) 14. Grab start entry - approach FS no breath – towing back eggbeater kick

	16. Entry- duck dive – approach the partner underwater- tow back side stroke
Secondary Set:	Team Work / Body& Mind challenge: ability to act-finding solutions in the water environment Objectives: Developing psychological and emotional conditioning in the water, concentration, independence, increases senses of awareness. Enhances the participant to perform determination and will of power under unexpected and difficult conditions. Emotional stability & mind challenge Drill: 5 min, Relay 2 teams- 50 m - swimming with eyes in darkness- requires a pair of goggles that have been blacked out, tempo swimming any stroke
Cool-down:	5 min, 250m Swim- down , any stroke Objectives: Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.

Table 7. Aquaticity Development Group B - Training Log (Day 3)

Macro cycle details :	Macro cycle 1, week 1-8
Day and date :	**Fridays,** October- November 2014
Time:	**17.00- 18.00**
Pool:	6 lanes/ length 25m/ depth 1.60- 2.85m
Workout number:	3rd , 6th , 9th , 12th , 16th , 19th ,21st , 24nd
Length of session:	1600 meters
Training Zone:	Anaerobic endurance
Training aims :	**a**. Physical efficiency in the water **b**. Underwater intensive training: breath hold ability, underwater buoyancy, Dyn with fins **c**. Senses adaptation-Mind tasks- Team work Heart rate: 120- 200 bpm Effort: up to 90% Perceived exertion: Uncomfortable
Heart rate:	120- 190 bpm
Effort:	up to 90%

Perceived exertion:	Uncomfortable
Warm-up:	10 min 400 m Objectives: Necessary prelude to all physical activities. Warming-up helps participants to prepare both physiologically and mentally. Warm-up allow oxygen consumption mechanisms to respond faster, increases blood flow, stretches the joints and muscles increasing the range of motion and sense of pace. Drills: continuous swim 400m FS (rest 2min)
Main Set:	40 min 800 m Objectives: **Combination surface and underwater swimming (with fins)- Hypercapnic training (increased levels of CO2) -hydrodynamic position (head & body)- surface breathing preparation – recovery breathing- Diving Reflex training** Drills: 4* 50m [25m FS with fins/25m UW FS kick] rest 30sec 4* 50m [25m BF with fins/25m BF kick] rest 30sec 4* 25m Static Apnea 10sec/ UW FS kick rest 1min (whistle sign) 4* 25m UW BF kick/ Static Apnea 10sec (or count to 10) rest 1min 8* 25m UW sprint any stroke (with or without fins) rest 1.5 min
Secondary Set:	Underwater vision and underwater hearing development, mind challenges (at max depth of the pool) 10 min

	<u>Objectives:</u> Dive technique, Apnea ability, underwater buoyancy control, Senses adaptation (vision& hearing). Mind tasks (water intelligence), develop underwater awareness <u>Drills</u>: no swimming goggles, no fins • Underwater Game: 2 teams (Sharks & Fishes), pool point: Swallow & Deep/2 lanes • Challenges(tasks): 2 shallow & 2 deep • Equipment: 2 Underwater Writing Dive Slates + pencils, 40 glass marbles, 2 padlocks and multiple keys [one lock find the right key], 7 waterproof plastic cards [picture 1 fruit + 1 number], 1 iron stick (for tapping sounds), stopwatch • Wins: The team that completes all 4 tasks [best time and less mistakes] • Starting the game: both teams at the middle of the pool lane **1**. Heads underwater- "**Find the number of ladder tapping beats to follow the right direction"** to start the game (ex. 5 is to the Right/ 6 to the Left side of the pool length) Every team announces the number of the beats, right answer starts from the deep tasks, wrong answer starts from shallow tasks. *Score: correct direction/ 5 points/ If a team starts to the opposite side -5 points off at the final score **Deep Challenges:** **2**. "Draw **& Write - underwater**", one UW dive slate (for every team), is immersed in the max depth of the pool (-2.80 m), all players have to draw a triangle & a circle inside and under the draw have to write the name of the team (Sharks or Fishes). Score: all draws & names clear, full 5 points. Drawn mindlessly -0,5 each doodle & careless handwriting -0,5 each scribble.

	3. “Find **the right key! one lock multiple keys**”. At the deep side of the pool (-2,40m) *shallower depth* than task 2a, one padlock for each team is immersed and one key per player. Each participant dives, chooses one key and tries to unlock the padlock. When that is achieved the team continuous to the next challenge. Score: time oriented score **Swallow Challenges:** **4**. “**Match the cards”** (depth – 2.00m). One card is placed out of the water (showing one fruit and one number), this is the same card for both teams. Participants have to dive and pick from 7 cards, that are immersed in every lane, the one that shows the same picture. Score: time oriented score **5**. “Yellow **glass marbles**”, at the shallowest side of the pool (-1.60m), 20 colored glass marbles are immersed in the bottom of every lane. Every participant has to find one yellow marble and place it at the deck. Score: **5** if all team members find the yellow marble, -1 point for every missing marble.
Cool-down:	100m Swim- down any stroke objectives: Permits faster recovery instead of simply stopping, by removing carbon dioxide from muscles and delivering oxygen to them at a faster rate. The rate of lactic acid removal increases through a mechanism called the muscle pump.

Appendix 6: Aquaticity Assessment Test

Aquaticity Assessment Test – AAT

Scoring Sheet

1. Surface Buoyancy and Balance

Description: The participant should take:

(a) a supine floating position for 30'' and switch to (b) a prone position for 15'', after the sound of the whistle.

Score:

1. Fails to perform the task	**0 points**
- Performs only (a), with assistance	**0.5**
2. Performs (a) and (b), with assistance for less time	**1**
- Performs (a) and (b), with assistance for the total time	**1.5**
3. Performs (a), without assistance, but immerses face	**2**
- Performs (a) and (b), without assistance, for less time	**2.5**
4. Performs (a) and (b), total time with limp movements	**3**
- Performs the task without limp movements, for less time in (a) or (b)	**3.5**
5. Performs the task successfully	**4**
- Performs No 6 for less than the time required	**4.5**
Pause and reassessment of the participant	
6. Buoyancy and balance at a supine floating position, with the body maintaining an aligned position and the arms stretched above the head for 30''. With the blow of the whistle, the participant must switch to a prone floating position for 20'' with his limbs outstretched (no limb movements)	5

Key points: explain to the participant to perform the task with less limb movements possible and at part (a), face should be clearly out of the water, breathing normally. The task should be performed at the maximum depth of the pool so in that case the legs don't touch the bottom of the pool.

2. Breathing control with head in and out of the water

Description: The participant should inhale through the mouth; immerse the head underwater and exhale through the mouth and nose, calmly and slowly, while repeating this circle of breathing for 10 times, rhythmically. The exhalation should be extended and last approximately twice as long as the inhalation.

Score:

1. Fails to perform the task	**0 Points**
- Tries to perform the task, but the head stays completely above the surface, the water doesn't go higher than the chest, doesn't feel safe	**0.5**

2. Performs the task, manages to get the mouth under water and blow bubbles, eyes, nose and ears above water, doesn't want nostrils to touch the water surface **1**

- Face is immersed, but not the whole head, ears above, tries to perform a circular breathing, not proper way-holds breath **1.5**

3. The head is immersed in water but inhales and exhales in an erratic, nervous and intermittent manner for less than 10 times, can't perform rhythmically submerge and emerge of the head. **2**

- Performs 10 intermittent breathing circles with erratic and fast exhales **2.5**

4. Performs rhythmic breathing for less than 10 times **3**

- Performs circular breathing 10 times, can't perform long exhalation **3.5**

5. Performs circular breathing 10 times, body and mind shift into the breathing process automatically, exhalation lasts twice as long as the inhalation. **4**

- Tried and failed to perform (6) **4.5**

Pause and reassessment of the participant

6. The participant must immerse underwater, lying on back at the bottom of the pool (1.5 to 2.00m depth), looking towards to the surface and to exhale in a constant, calm manner through the nose **5**

3. Hydrodynamic position & Gliding

Description: The participant must perform an underwater glide by pushing off the pool's wall on one breath, in order to gather speed and distance without any stroke or kicks. The body must hold a stable prone streamlined hydrodynamic position (from the arms through to the pointed toes). The head should be between the arms, neither too high nor too low. The direction should be straight maintaining the same depth until resurfacing. (Approximately -1 m below the surface, this an ideal traveling depth)

Score:

1. Does not perform the task **0**

- Performs the task at the surface with assistance, head out of the water **0.5**

2. Performs the task at the water's surface with assistance while only the face submerses **1**

- Performs the task without assistance but at surface, face immerses, not efficient start (a) and without strong push off (b) and thrust gliding or hydrodynamic position **1.5**

3. Performs the task by forceful diving or having a rigid rather than hydrodynamic body position/creating turbulence and ripples/ without thrust gliding, body immerses little above the surface can't stay underwater **2**

- Performs the task by totally immersing underwater, after the push off makes strokes, kicks or dolphin moves **2.5**

4. Performs the task underwater without a dynamic push off, nor a hydrodynamic position-hands are not stretched above the head, head is too high, does not achieve speed and distance underwater 3

- Performs the task underwater, not proper push off and despite maintaining a streamlined position there isn't a straight direction of the thrust **3.5**

5. Performs the task with efficient start, dynamic push off, body maintains streamlined, hydrodynamic head position, thrusting forward without creating turbulence, efficient gliding, maintaining depth and straight direction **4**

-Tried and failed to complete task No 6 **4.5**

Pause and reassessment of the participant

6.Performs the task by rotating around the long body axis (body rotation), without movement of the limbs **5**

4. **Surface Swimming-Front crawl technique assessment**

Description: The participant will be evaluated in crawl swimming technique for 25m, breathing should be bilateral every 5 strokes. If the participant doesn't know what is "crawl", explain the basic points of this challenge. Perform a continuous alternate overarm swimming with less strokes possible, in a prone body streamline position, breathing twisting the head sideways with the rhythm of five strokes-breathing

Score:

1. Does not perform the task **0 points**

- Performs the task with assistance, head out of the water no crawl swimming **0.5**

2. Performs the task without assistance but with a jerky swimming style, keeps head completely above water, forceful motions, no streamlining- nor an over arm swimming (body position, breathing, kicking mistakes) **1**

- Performs an alternate overarm stroke, no coordination, lacked continuity, arms fly round and round in a flurry of wild splashing, legs kick using a deep knee-bend – breaststroke kick or scissors kick, cannot produce efficient propulsion, head above the water **1.5**

3. Performs the task, the breathing process is erratic, head burrows in the water, mouth is shut- fails to exhale when face submerses. The head lifts and turns from left to right side with an intense rhythm, legs perform freestyle or frog kicks, turbulence is created **2**

- Performs the task, breathing sideways making breathing mistakes (turning face to soon or too late, lifts head, returns head slowly), unable to control breathing and arm movement, wasteful muscular activity, poor propulsive action **2.5**

4. Performs the task by breathing sideways but makes stroke and kicking mistakes. During recovery phase the elbow is down or the arm maintains in an extended position, kicking is too deep or too high **3**

- Performs the task making arm stroke mistakes during recovery or entry, uses too much effort, swings the arm over the water low and wide, not efficient body position might wiggle down the pool like a snake **3.5**

5. Performs the task without extending fully the arm forward in entry, poor body roll movement, cannot perform alternate breathing every 5 strokes **4**

- Performs the task with efficient crawl technique and alternate breathing every 5 strokes, but there is no easy gliding, needs to develop prolonged momentum (by accurate timing arm strokes and streamlining body alignments throughout stroke sequence) **4.5**

6. Elite performance, prolonged momentum, breathing every 5 strokes **5**

5. **Physical efficiency in water**

Description: Continuous swimming for 5', using any swimming stroke.

Score:

1. Does not perform the task **0 points**

- Performs the task with assistance for less than 100m **0.5**

2. Performs the task with assistance for > 100 m **1**

- Performs the task without assistance for less than 100	**1.5**
3. Up to 100m without assistance	**2**
- Up to 150m	**2.5**
4. Up to 200 m	**3**
- Up to 250 m	**3.5**
5. Up to 300 m	**4**
- Up to 400m	**4.5**
6. Up to 450m	**5**

6. Treading water, egg bitter kick

Description: The participant will perform treading water kicks. The head should be clearly above the water, body vertical to the surface in a sitting position. The participants need to perform treading water exercise for (a) 30'' with the arms in the water. After the blow of the whistle (b) for 15''must raise one arm high, with the elbow above water- next to the ear, and after the blow of the whistle (c) must raise also the other arm high for another 15''. The participants must stay as higher above the water as possible for the overall task time (60'').

Score:

1. Fails to perform the task	**0**
2. Performs the task for less than 30''	**1**
3. Performs the task for 30", only first part	**2**
4. Performs the task for 45'' and with one arm raised	**3**
5. Performs the exercise for 60''with both arms raised and held behind the head, the water's surface reaching up to the neck and beyond i.e. the chin, nose, mouth	**4**
6. performs the exercise successfully and the water's surface is near the shoulders and below (chest, ribcage)	**5**

7. Underwater vision

Description: The participant without the help of any swimming goggles or masks should perform the following tasks

(a) recognize a drawn object (color and shape), the picture will be situated 1m deep underwater

(b) count the knots on a piece of rope 1m long without touching the rope

(c) find and position 7 small weights through a rope that are immersed between 1-2m depth.

Score:

1. Does not perform the task	**0 points**
2. Fails to recognize all the elements requested in part (a)	**0.5**
3. Performs part (a) successfully after two attempts	**1**
4. Performs part (a) successfully after one attempt	**1.5**
5. Fails to count all the knots in part (b)	**2**

6. Succeeds in counting all the knots after two attempts	**2.5**
7. Succeeds in counting all the knots after one attempt	**3**
8. Fails to position all the weights through the rope	**3.5**
9. Performs part (c) successfully after 3 attempts	**4**
10. Performs part (c) successfully after 2 attempts	**4.5**
11. Performs part (c) successfully after one attempt	**5**

8. Underwater hearing

Description: The participant will be positioned in the middle of the pool with the head immersed in the water, without having eye contact with the available sound sources. The ears of the participants should be inside the water. The examiner (right ladder) and his assistant (left ladder) generate sounds, by hitting on the two different ladders available on opposite sides of the swimming pool. The participant should answer the following questions:

(a). "How many sounds did you hear overall?"

(b). "From which direction?" (Sound direction) meaning from which ladder

(c). "In what order?", for example: 3 sounds from the right ladder I heard 2 while from the left ladder I heard one.

Score:

1. Does not immerse the head under water	**0 points**
2. Immerses the head, gives wrong answers in all parts after two attempts	**1**
3. Answers correctly on 1 part with 2 attempts	**2**
4. Answers correctly on 2 parts after two attempts	**3**
5. Answers all the questions correctly with 2 attempts	**4**
6. Answers all the questions correctly with 1 attempt	**5**

9. Dynamic Apnea

Description: Perform underwater swimming using breath-hold apnea for the longest possible distance (max 25m), without the use of the necessary equipment to regulate underwater buoyancy, neither swimming fins.

Score:

1. Does not perform the task	**0**
2. Fails to immerse totally under water and performs the task or part of it on the surface **0.5** points are subtracted from the total score	

Scores will follow the formula: [distance in meters] /[10 *2] (e.g. 12/10=1,2*2=2,4 points)

10. Adjustment to hydrostatic pressure

Description: The participant must take a deep breath through the mouth, inflate a balloon with only one exhale and afterwards should dive in the pool's maximum depth (2-3m) and lay on his/her back at the bottom of the pool for 30''.

Score:

1. Fails to perform the task	**0 points**
2. Dive in the pool but resurfaces immediately	**0.5**
3. Dive at ½ of the pool's maximum depth (1-1.5m)	**1**
4. Dive at 2/3 of the pool's maximum depth (2-2.5m)	**2**
5. Touches the bottom of the pool, does not lay and immediately resurfaces	**3**
6. Laid on the back but for less than 30''	**4**
7. Performs the task successfully	**5**

Total Score Calculation:

Sum all the individual scores in order to obtain the **Total Aquaticity Score**. The range is between 0-50 aquaticity units.

Appendix 6: Instruction for the examiners of the Aquaticity Assessment Test

Instructions for the AAT examiners

1. Surface Buoyancy and Balance

In this test we assess the participant's ability to float and balance at the water's surface. The participant should maintain a horizontal body position performing both supine and prone flotation. In order to maintain streamline body position, it is possible to perform compensatory arms and legs movements, without great movement achieved. The participant must remain calm, on the same spot, without creating great undulation, noise and intense limbs movement. During the supine flotation the airways (mouth & nose) should be continuously above water, while assuming the prone position, part of the participant's back side should be above water, floating.

<u>Description</u>: The participant should take:

(a) a supine floating position for 30'' and switch to

(b) a prone position for 15'', after a whistle sound.

Score:

1. Fails to perform the task **0 points**

The participant refuses to get in the water or is in the water but doesn't want to perform the task even with assistance (signs of fear).

- Performs only (a), with assistance **0.5**

The participant performs the part (a) of the task using a noodle or board (floating aid), looks stressed or unhappy.

2. Performs (a) and (b), with assistance for less time **1**

The participant performs the task, but still is not independent in the water, has a lot of muscle tense, not feeling safe in the deep water

- Performs (a) and (b), with assistance for the total time **1.5**

The participant cannot float independent, though, reacts positive to instructions, signs of enjoyment

3. Performs (a), without assistance, but immerses face **2**

The participant performs the part (a) independently but immerses the face (mouth and nose) continuously, no buoyancy control, no body alignment

- Performs (a) and (b), without assistance, for less time **2.5**

The participant performs the task (a & b) independently, performs intense limb movements and waves, splashes around, doesn't complete the required time.

4. Performs (a) and (b), total time with limp movements **3**

The participant manages to complete the required time, but performing intense and strong limb movements, hips are immersed, no streamline position, there is an obvious muscle tension all over the body.

- Performs the task without limp movements, for less time in (a) or (b) 3.5

The participant assumes a horizontal body position, the arms and legs are possibly spreader open like a starfish, chest and head are floating upwards, breathing is freely regulated. The participant should look relaxed. Despite that, fails to complete the task on one or both floating positions within the allocated timeframe. The participant is very close at completing successfully the task for the required time

5. Performs the task successfully 4

The participant performs the task effortless. Performs both floating positions, assuming and maintaining streamline body position, without limb movements.

- Performs No 6 for less than the time required 4.5

The participant tries to perform the task but fails to assume straight extension of arms and legs, doesn't have yet excellent surface buoyancy control

Pause and reassessment of the participant

6. **Buoyancy and balance at a supine floating position**, with the body maintaining an aligned position and the arms stretched above the head for 30''. With the blow of the whistle, the participant must switch to a prone floating position for 20'' with his limbs outstretched (no limb movements) **5**

Full marks are given to those that perform a perfect floatation, with complete body control and stability, excellent balance at surface and harmonization with the water. For a successful fully horizontal body position, the position of the head, hips and limbs plays a crucial part. All parts should be aligned on the water's surface. The participant should be able to perform the floatation task perfectly and with ease.

2. Breathing control with head in and out of the water

In this task we assess breathing control (rhythm and relaxation) when in water, in a standing or haging position next to the pool wall. The participant should support him/herself on the wall, so as to help concentrate on breathing process. The body should be in an upward position, parallel to the wall. The inhalation should be performed by using only the mouth and the exhalation by using the mouth or the nose or both. The exhalation should be relaxed and extended, longer than inhalation.

During the exhalation, the air should slide out of the airways and not forced out. The participant should avoid trying to hold the breath, and the exhalation should start immediately after immersion in the water, while as soon as the head surfaces, inhalation should begin, avoiding any attempts to exhale. An impression of relaxation and calmness should be given during breathing regulation.

<u>Description</u>: The participant should inhale through the mouth; immerse the head underwater and exhale through the mouth and nose, calmly and slowly, while repeating this circle of breathing for 10 times, rhythmically. The exhalation should be extended and last approximately twice as long as the inhalation.

Score:

1. Fails to perform the task

The participant refuses to get in the water or is in the water but doesn't want to perform the task even with assistance, probably has fear of the water. **0 points**

- Tries to perform the task, but the head stays completely above the surface, the water doesn't go higher than the chest, doesn't feel safe 0.5

It is obvious, the participant doesn't like the face being in contact with water, afraid to immerse the nose, eyes, ears etc. Look stresses, doesn't react positive to instructions, blows air on water creating a small crater on its surface.

2. Performs the task, manages to get the mouth under water and blow bubbles, eyes, nose and ears above water, doesn't want nostrils to touch the water surface 1

Fear to immerse the face, reacts to instructions by scooping up water with the hands and apply it to the face, no immersion of the face

- Face is immersed, but not the whole head, ears above, tries to perform a circular breathing, not proper way-holds breath 1.5

The participant reacts better in the instructions, though doesn't like to be underwater completely, doesn't exhale fully, tries to catch the breath

3. The head is immersed in water but inhales and exhales in an erratic, nervous and intermittent manner for less than 10 times, can't perform rhythmically submerge and emerge of the head. 2

The participant immerses the head in and out in without clear distinction between the inhalation and exhalation phases. The cycle of breathing is not automatically yet.

- Performs 10 intermittent breathing circles with erratic and fast exhales 2.5

The participant fails to extend the exhalation, holds the breath momentarily and then exhales. Tries to maintain breathing in control but has trouble doing so. Seems stressed, breathing is not conscious yet

4. Performs rhythmic breathing for less than 10 times 3

Can't keep a proper pattern when submerge and emerge of the head, stops often

- Performs circular breathing 10 times, can't perform long exhalation 3.5

Manages to perform 10 breathing patterns, seems in control but can't stay long while exhaling, not excellent breathing control

5. Performs circular breathing 10 times, body and mind shift into the breathing process automatically, exhalation lasts twice as long as the inhalation. 4

The participant performs successfully the task, looking at ease and feeling comfortable, almost like he/she is able to complete infinite circles of breathing

- Tried and failed to perform (6) 4.5

The participant sits at the bottom, can't lay back and face upwards, no underwater buoyancy control

Pause and reassessment of the participant

6. The participant must immerse underwater, lying on back at the bottom of the pool (1.5 to 2.00m depth), looking towards to the surface and to exhale in a constant, calm manner through the nose 5

Elite performance, doesn't need a nose clip to perform a supine position, excellent buoyancy control.

3. Hydrodynamic position & Gliding

In this task we assess the ability of the participant to acquire a hydrodynamic position in order to overcome water resistances (frontal resistance, friction and turbulence) and achieve high gliding capacity.

The participant will have to thrust away from the pool's wall using feet, knees and hips power. After the push off should maintain a hydrodynamic body position from arms through the toes. Stay underwater at same depth for the whole duration of the gliding.

Description: The participant must perform an underwater glide by pushing off the pool's wall on one breath, in order to gather speed and distance without any stroke or kicks. The body must hold a stable prone streamlined hydrodynamic position (from the arms through to the pointed toes). The head should be between the arms, neither too high nor too low. The direction should be straight maintaining the same depth until resurfacing. (Approximately -1 m below the surface, this an ideal traveling depth)

1. Does not perform the task 0 points

The participant refuses to perform the task, refuses to immerse into the water or is in the water but refuses to move away from the pool's wall.

- Performs the task at the surface with assistance, head out of the water 0.5

The participant performs the task using a floating board or with the trainer's help, holds the head above water, seems very stressed, not safe in the water

2. Performs the task at the water's surface with assistance while only the face submerses 1

The participant performs the task using a floating aid or with the trainer's help, reacts positive in the instructions but still has tense and anxiety.

- Performs the task without assistance but at surface, face immerses, not efficient start (a) and without strong push off (b) and thrust gliding or hydrodynamic position 1.5

The participant performs the task on the water's surface without any help, does not place both the feet on the wall is unable to forcefully push off, does not have a hydrodynamic position and as a result water resistance is increased, prohibiting him/her from gathering distance and gliding.

3. Performs the task by forceful diving or having a rigid rather than hydrodynamic body position/creating turbulence and ripples/ without thrust gliding, body immerses little above the surface can't stay underwater 2

The participant is stressfully immersed, pushing off the wall upwards towards the surface, without having a hydrodynamic body position and as a result increasing water resistance and creating turbulence and ripples.

- Performs the task by totally immersing underwater, after the push off makes strokes, kicks or dolphin moves 2.5

The participant performs the task immersed underwater, pushing off the wall without an efficient thrust that will propel him/her in a straight line, performing volatile and ergogenic movements with arms and legs.

4. Performs the task underwater without a dynamic push off, nor a hydrodynamic position-hands are not stretched above the head, head is too high, does not achieve speed and distance underwater 3

The participant is calmly immersed underwater, placing the feet deeply enough for the push off. The knees are not bent correctly, resulting in an inefficient push off from the pool's wall. Fails to assume a hydrodynamic body position. Joint flexibility is lacking and is unable to place the arms stretch out above the head.

- Performs the task underwater, not proper push off and despite maintaining a streamlined position there isn't a straight direction of the thrust 3.5

The participant fails to maintain depth and a straight forward direction during the glide. The feet are placed too deep. Body is streamlined, though head is too high

5. Performs the task with efficient start, dynamic push off, body maintains streamlined, hydrodynamic head position, thrusting forward without creating turbulence, efficient gliding, maintaining depth and straight direction 4

Excellent performance of gliding, with an ease, achieving a long glide. The participant looks like comfortable and in harmony with water

-Tried and failed to complete task No 6 4.5

The participant performs the glide rotating but fails to stay underwater or moves limbs to aid gliding

Pause and reassessment of the participant

6. Performs the task by rotating around the long body axis (body rotation), without movement of the limbs 5

Elite performance, the participatn holds a hydrodynamic body position and has a completely straight course. No turbulence or water resistance. No limbs movements. The gliding is harmonious; the depth is maintained throughout the task.

4. Surface Swimming-Front crawl technique assessment

During this task we evaluate the level of technique in the basic stroke of classical swimming, the front crawl (Freestyle). Front crawl is the first style to be taught in swimming lessons; it is easy also to be evaluated from examiners that have not practiced butterfly or other more technical strokes. The examiner should pay attention to following points:

- Body position: stability, streamline, balance equally on both sides
- Leg efficient kicking: amount of bent at knees
- Breathing process: bilateral, right timing- head turn synchronized with arm action
- Hand wrist action: on entry, on catch, on pull
- Elbow up: on pull and recovery
- Body roll: Shoulder rotation and hip rotation
- Prolonged momentum and gliding: forward extension of each arm as it enters

Description:

The participant will be evaluated in crawl swimming technique for 25m, breathing should be bilateral every 5 strokes. If the participant doesn't know what is "crawl", explain the basic points of this challenge". "Perform a continuous alternate overarm swimming with less strokes possible, in a prone body streamline position, breathing twisting the head sideways with the rhythm of five strokes-breathing.

1. Does not perform the task 0

The participant refuses to perform the task, refuses to immerse into the water or is in the water but refuses to move away from the pool's wall.

- Performs the task with assistance, head out of the water no crawl swimming 0.5

The participant needs floating aids, not independent and safe in the water.

2. Performs the task without assistance but with a jerky swimming style, keeps head completely above water, forceful motions, no streamlining- nor an over arm swimming (body position, breathing, kicking mistakes) 1

The participant floats independent but seems that he/she is not actually safe in the water. Probably water that splashes into the face will disturb and irritate the participant.

- Performs an alternate overarm stroke, no coordination, lacked continuity, arms fly round and round in a flurry of wild splashing, legs kick using a deep knee-bend – breaststroke kick or scissors kick, cannot produce efficient propulsion, head above the water 1.5

The participant probably performs his own style, splashes water with nervous movements. Puts too much effort.

3. Performs the task, the breathing process is erratic, head burrows in the water, mouth is shut- fails to exhale when face submerses. The head lifts and turns from left to right side with an intense rhyt hm, legs perform freestyle or frog kicks, turbulence is created 2

The participant splashes with the hands and feet, bents the knee and the foot is completely out of the water. The swimmer is totally unbalanced in the water. No breathing technique and right timing with the arm action

- Performs the task, breathing sideways making breathing mistakes (turning face to soon or too late, lifts head, returns head slowly), unable to control breathing and arm movement, wasteful muscular activity, poor propulsive action 2.5

The participant turns the face too soon to breath or too late, lifts the head or returns the head too slowly. This causes body position mistakes, horizontal alignment that increases resistance. The arm-stroke technique is not proper during all phases.

4. Performs the task by breathing sideways but makes stroke and kicking mistakes. During recovery phase the elbow is down or the arm maintains in an extended position, kicking is too deep or too high 3

The participant has pure propel technique swings the arm over the water low and wide, during entry pushes water forward. The strokes are not symmetrical and that blocks the alternate breathing. The kicking is too deep or bends the legs too much.

- Performs the task making arm stroke mistakes during recovery or entry, uses too much effort, swings the arm over the water low and wide, not efficient body position might wiggle down the pool like a snake 3.5

The participant doesn't have a stable body position, during the armstroke- drops the elbow and slides the hand out to the side too much or too little. Recovers the arm too wide or pushes water during insweep.

5. Performs the task without extending fully the arm forward in entry, poor body roll movement, cannot perform alternate breathing every 5 strokes 4

The participant makes his entry too close to his head and then immediately drives the arm forward and down to catch. This decelerates forward speed.

- Performs the task with efficient crawl technique and alternate breathing every 5 strokes, but there is no easy gliding, needs to develop prolonged momentum (by accurate timing arm strokes and streamlining body alignments throughout stroke sequence) 4.5

The participant's swimming seems off balance, doesn't extends efficient the entry arm to preserve momentum and the opposite arm doesn't pull, so there is no body roll or body rotation gets out of synch with stroking movements.

6. Elite performance, prolonged momentum, breathing every 5 strokes 5

Perfection, efficient stroke technique with minimum resistance. Beautiful gliding and momentum. The swimmer has an easy run through the water that produces graceful action, harmony.

5. Physical efficiency in water

In this test we assess the participant's fitness levels by assessing the ability to swim for a long distance. We only assess the participant's endurance as he/she moves in water. We measure the distance he/she has traveled, using any swimming style he/she chooses, and we are using the scoring guidelines that follow to grade him/her.

Description: (Performed as the last task). Continuous swimming for 5', using any swimming stroke.

Score:

1. **Does not perform the task 0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water, stressed and unhappy

-Performs the task with assistance for less than 100m 0.5

The participant needs the help of a couch or uses board/noodle, experiences anxiety and sees the pool like an "ocean"

2. **Performs the task with assistance for > 100 m 1**

The participant needs assistant but is more relaxed and enjoys being there, reacts positive to instructions.

-Performs the task without assistance for less than 100 1.5

The participant splashes around; swims disorientated, hold the line often, and puts too much energy and power, not safe to swim in the open sea.

3. **Up to 100m without assistance 2**

The participant changes swimming styles, stops to rest often, doesn't have streamline body position and probably can't perform breathing process in the water. Not safe to swim in the open sea.

Up to 150m 2.5

The participant stops many times, not efficient technique, not a particular swimming style, not safe to swim in the open sea.

4. **Up to 200 m 3**

The participant swims continuously; changes swim styles, swims slow.

Up to 250 m 3.5

The participant swims continuously, doesn't have efficient technique and propulsion, though he/she could be independent in the open sea.

5. **Up to 300 m 4**

The participant swims with efficient technique, not with gliding, probably swims breaststroke, or other slow stroke.

Up to 400m 4.5

Efficient swimming technique, not prolonged momentum and gliding

6. **Up to 450m 5**

Elite Performance

6. Treading water, egg bitter kick

The egg-bitter is an auxiliary kick that is mainly used as a way to help swimmers retain a vertical body position and to move forward. The body holds a vertical position, and the head stays above water, while the body's spine is vertical to the water's surface. The swimmer's legs must be bent and his/her knees looking outwards. The participant should look like he/she is sitting on a chair; with his/her legs spread open. The movement of the legs should only involve the knees and lower limbs. One foot should perform a circular clockwise movement, while the other a counterclockwise movement. The hands are used to support the body, pressing continually on the water's surface. The movement of the hands resembles that of a car's wipers and is performed with bent elbows, especially using the forearm and palm, sideways and away from the body.

Description: The participant will perform treading water kicks. The head should be clearly above the water, body vertical to the surface in a sitting position. The participants need to perform treading water exercise for (a) 30'' with the arms in the water. After the blow of the whistle (b) for 15''must raise one arm high, with the elbow above water- next to the ear, and after the blow of the whistle (c) must raise also the other arm high for another 15''. The participants must stay as higher above the water as possible for the overall task time (60'').

Score:

1. **Fails to perform the task** **0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water, stressed and unhappy face

2**. Performs the task for less than 30''** **1**

The participant fails to keep his/her head above water, is sinking, his/her feet are not moving properly, splashing the water stretched out vertically, as in freestyle swimming or a different style, without effective power. The participant leans his/her head backwards and holds his/her face above water, while he/she struggles to hold the rest of his/her body in a vertical position. He/she performs in an unsteady, erratic way, using his/her limbs.

3. **Performs the task for 30", only first part** **2**

The participant holds his/her head upwards and above water, but performs with intense movements the limbs and an ineffective way of movement, as far as his/her feet are concerned. The arm and leg movements are energy wasteful and he/she appears nervous and clumsy in his/her movements, without any harmony or fluidity.

4**. Performs the task for 45'' and with one arm raised** **3**

The participant cannot hold his/her arm stretched above his/her head, the elbow touches the water or is located inches from the water's surface. The participant holds one hand stretched upwards but fails to maintain both arms together above his/her head.

5. **Performs the exercise for 60''with both arms raised and held behind the head, the water's surface reaching up to the neck and beyond i.e. the chin, nose, mouth** **4**

The participant performs the task but seems tired at the end of the required time, seems that couldn't hold longer

6. performs the exercise successfully and the water's surface is near the shoulders and below (chest, ribcage) **5**

Elite performance**.** The participant perfectly executes the technique of the task, his/her arms are raised together above the head and his/her chest is located above the water. He/she appears to easily hold his/her body's position steady in water.

7. Underwater vision

In this task we assess the participant's ease when asked to see underwater without the aid of a swimming mask or goggles.

Description: The participant without the help of any swimming goggles or masks should perform the following tasks

(a) recognize a drawn object (color and shape), the picture will be situated 1m deep underwater

(b) count the knots on a piece of rope 1m long without touching the rope

(c) find and position 7 small weights through a rope that are immersed between 1-2m depth.

Score:

1. Does not perform the task **0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water, stressed and unhappy face

2. Fails to recognize all the elements requested in part (a) **0.5**

When in water, the participant tries to perform the task but fails to keep his/her eyes open underwater.

3. Performs part (a) successfully after two attempts **1**

4. Performs part (a) successfully after one attempt **1.5**

5. Fails to count all the knots in part (b) **2**

6. Succeeds in counting all the knots after two attempts **2.5**

7. Succeeds in counting all the knots after one attempt **3**

8. Fails to position all the weights through the rope **3.5**

9. Performs part (c) successfully after 3 attempts **4**

10. Performs part (c) successfully after 2 attempts **4.5**

11. Performs part (c) successfully after one attempt **5**

8. Underwater hearing

In this task we assess the participant's reaction to sound stimuli, when he/she is submerged in water.

Description: The participant will be positioned in the middle of the pool with the head immersed in the water, without having eye contact with the available sound sources. The ears of the participants should be inside the water. The examiner (right ladder) and his assistant (left ladder) generate sounds, by hitting on the two different ladders available on opposite sides of the swimming pool. The participant should answer the following questions:

(a). “How many sounds did you hear overall?”

(b). “From which direction?” (Sound direction) meaning from which ladder

(c). “In what order?”, for example: 3 sounds from the right ladder I heard 2 while from the left ladder I heard one.

Score:

1. Does not immerse the head under water **0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water and stressed.

2. Immerses the head, gives wrong answers in all parts after two attempts **1**

3. Answers correctly on 1 part with 2 attempts **2**

4. Answers correctly on 2 parts after two attempts **3**

5. Answers all the questions correctly with 2 attempts **4**

6. Answers all the questions correctly with 1 attempt **5**

9. Dynamic Apnea

In this task we evaluate the participant’s efficiency performing underwater swimming. Without the use of fins and paddles (googles and nose clips are allowed) the participant should swim underwater and voluntarily hold his/her breath by pushing off the wall of the pool and swim constantly for max of 25m.

Description: Perform underwater swimming using breath-hold apnea for the longest possible distance (max 25m), without the use of the necessary equipment to regulate underwater buoyancy, neither swimming fins.

Score:

1. Does not perform the task **0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water and stressed.

2. Fails to immerse totally under water or performs part of the task on the surface 0.5 points are subtracted from the total score

The participant can’t maintain buoyancy.

Scores will follow the formula: [distance in meters] /[10 *2] (e.g. 12/10=1,2*2=2,4 points)

10. Adjustment to hydrostatic pressure

Description: The participant must take a deep breath through the mouth, inflate a balloon with only one exhale and afterwards should dive in the pool’s maximum depth (2-3m) and lay on his/her back at the bottom of the pool for 30’’. The balloon is one standard size latex balloon of 28cm/11”.

Score:

1. Fails to perform the task **0 points**

The participant refuses to get in the water or he/she is in the water but doesn't want to perform the task even with assistance. Probably feels fear of water.

2. Dive in the pool but resurfaces immediately **0.5**

3. Dive at ½ of the pool's maximum depth (1-1.5m) **1**

4. Dive at 2/3 of the pool's maximum depth (2-2.5m) **2**

5. Touches the bottom of the pool, does not lay and immediately resurfaces without staying underwater **3**

6. Laid on the back but for less than 30'' **4**

7. Performs the task successfully **5**

Total Score Calculation:

Sum all the individual scores in order to obtain the **Total Aquaticity Score**. The range is between 0-50 aquaticity units.

Appendix 7: Aquaticity Assessment Test tools used

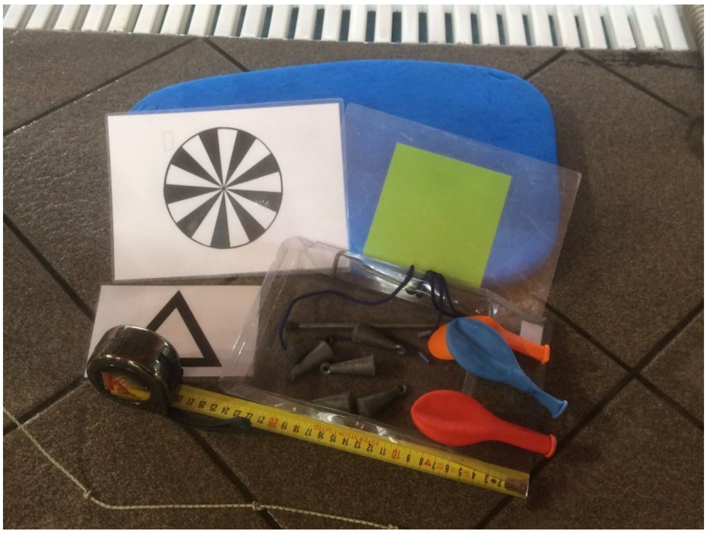

Photo 1: AAT- equipment: floating board, stop watch, whistle, measure, plastic cards, balloon, metallic stick, 7 donut- shaped weights & line rope, rope for knots

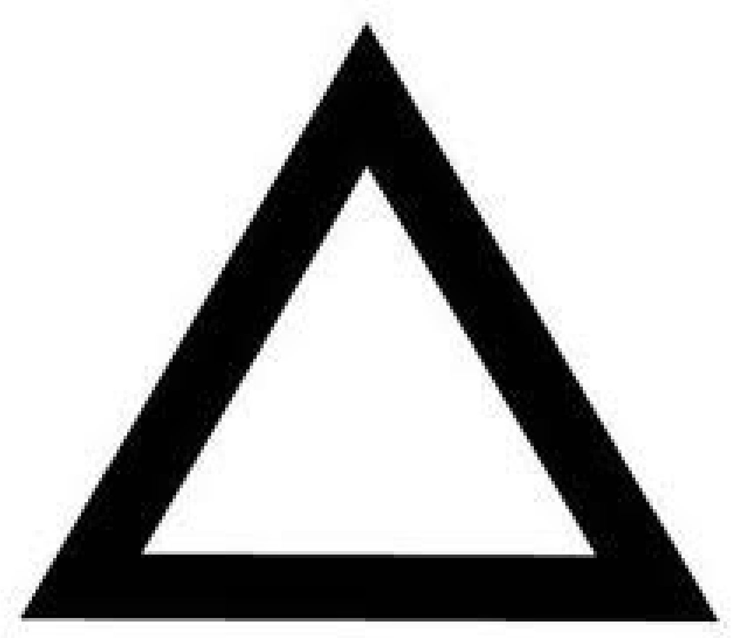

Photo 2: Waterproof piece of plastic card with pictures of geometrical shape for underwater vision task, black white triangle

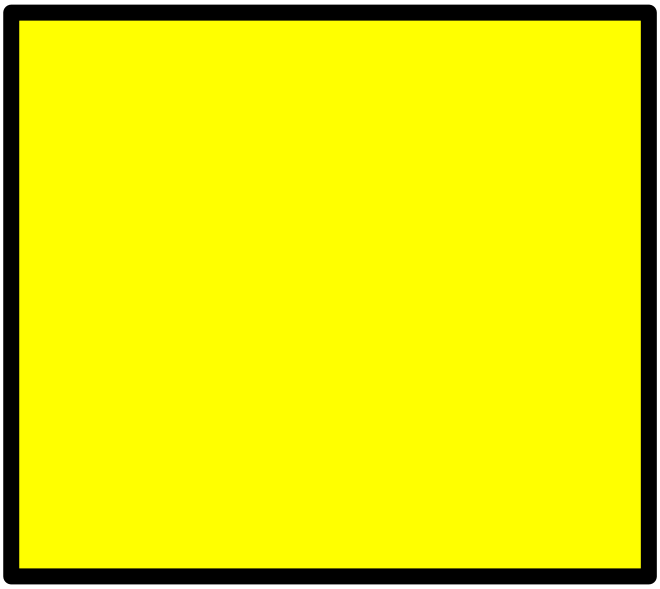

Photo 3: Waterproof piece of plastic card with pictures of geometrical shape for underwater vision task, black yellow square

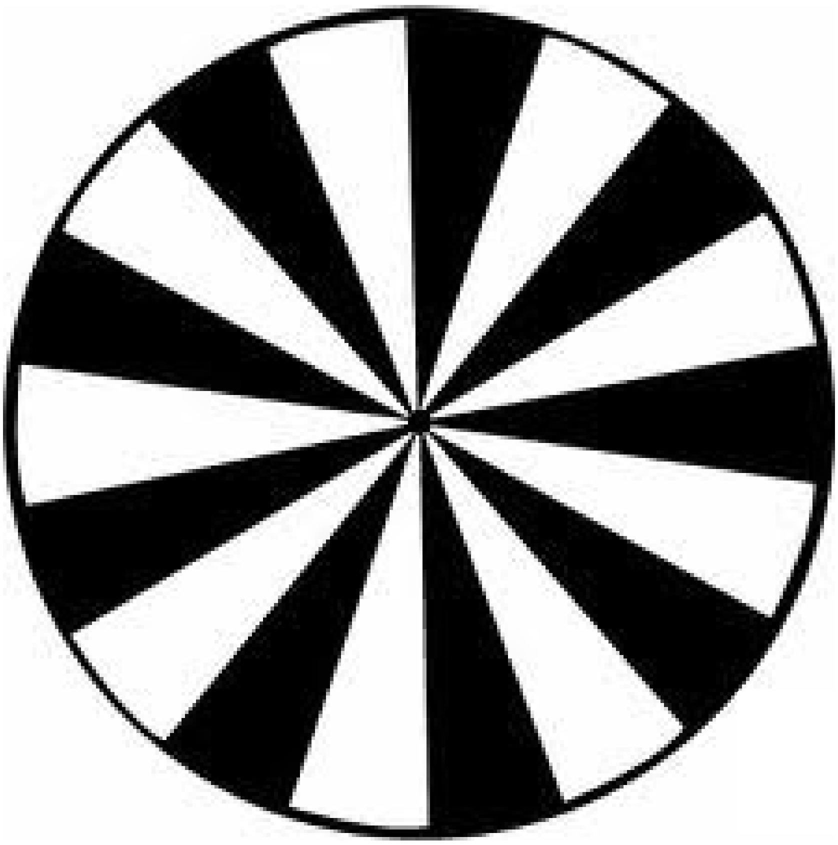

Photo 4: Waterproof piece of plastic card with pictures of geometrical shape for underwater vision task, black white circle

Appendix 8: Aquaticity Assessment Test photos

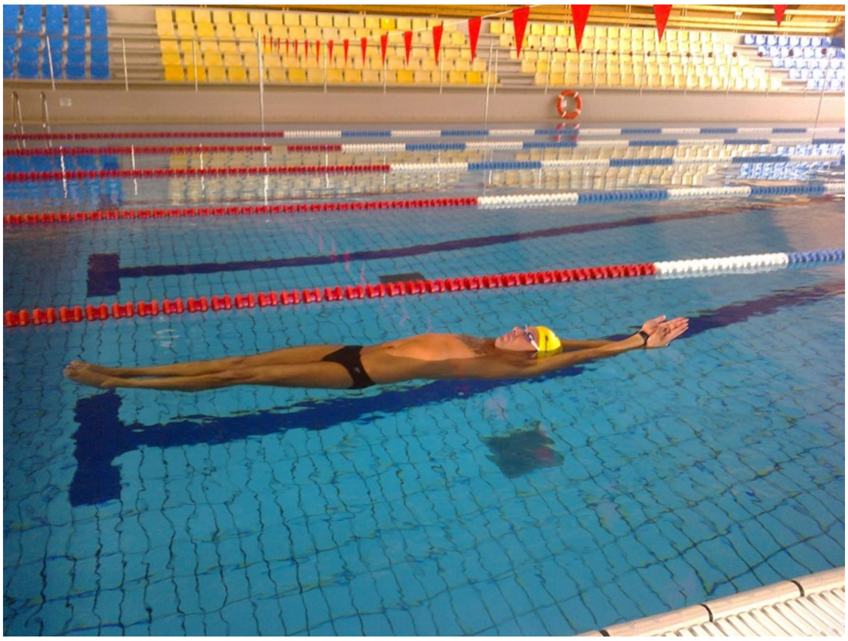

Photo.1: Task 1. Supine floating position, on the same spot with stretched arms/legs, no limb movements- Elite performance by an athlete.

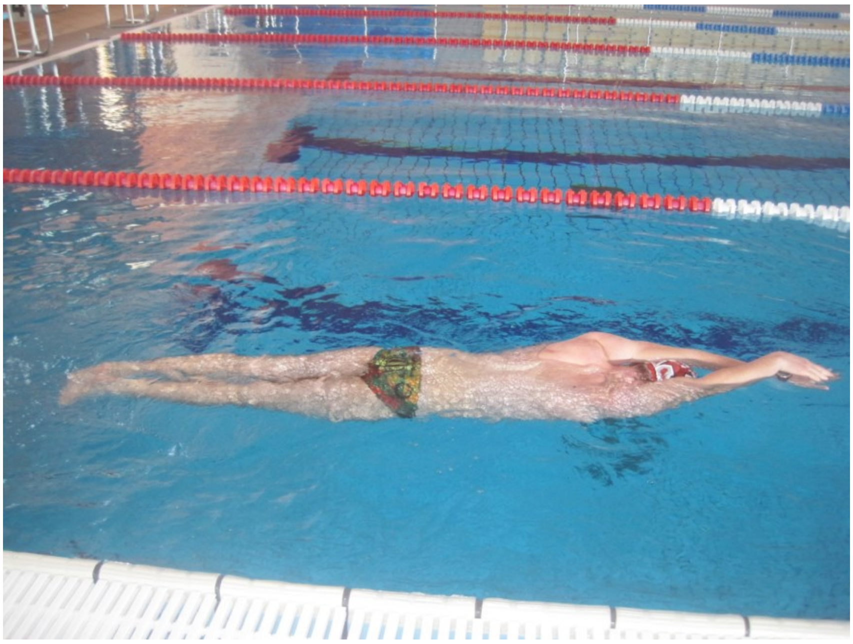

Photo 2: Task 1. Prone floating position, on the same spot with stretched arms/legs, no limb movements- -Elite performance by an athlete.

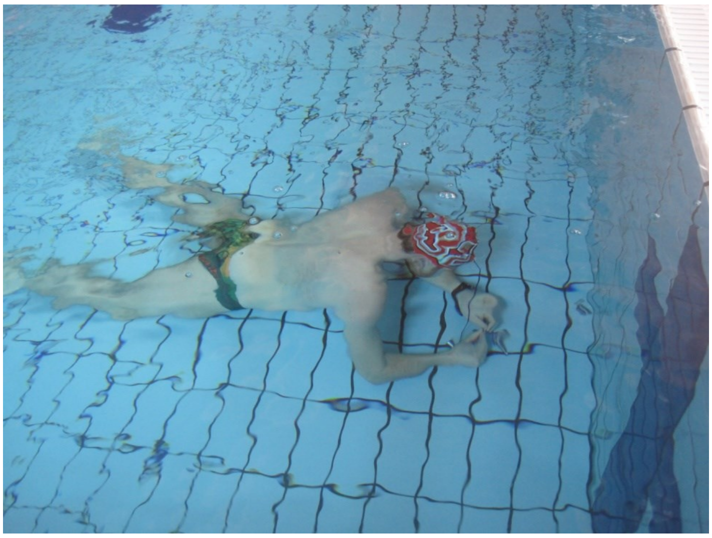

Photo 3: Task 7. Underwater vision: The participants need to put a rope through 7 small weights that are immersed between 1-2m depth - Elite performance by an athlete

Photo 4: Task 7. Underwater vision: The participants need to put a rope through 7 small weights that are immersed between 1-2m depth - Elite performance by an athlete

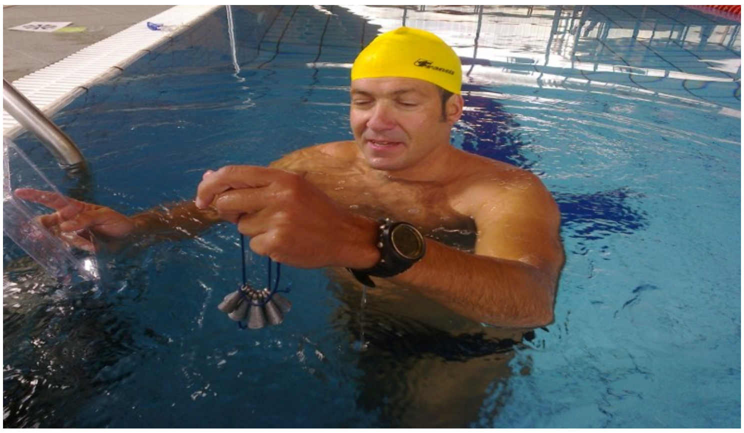

Photo5: Task 7. Underwater vision: Athlete achieving max score

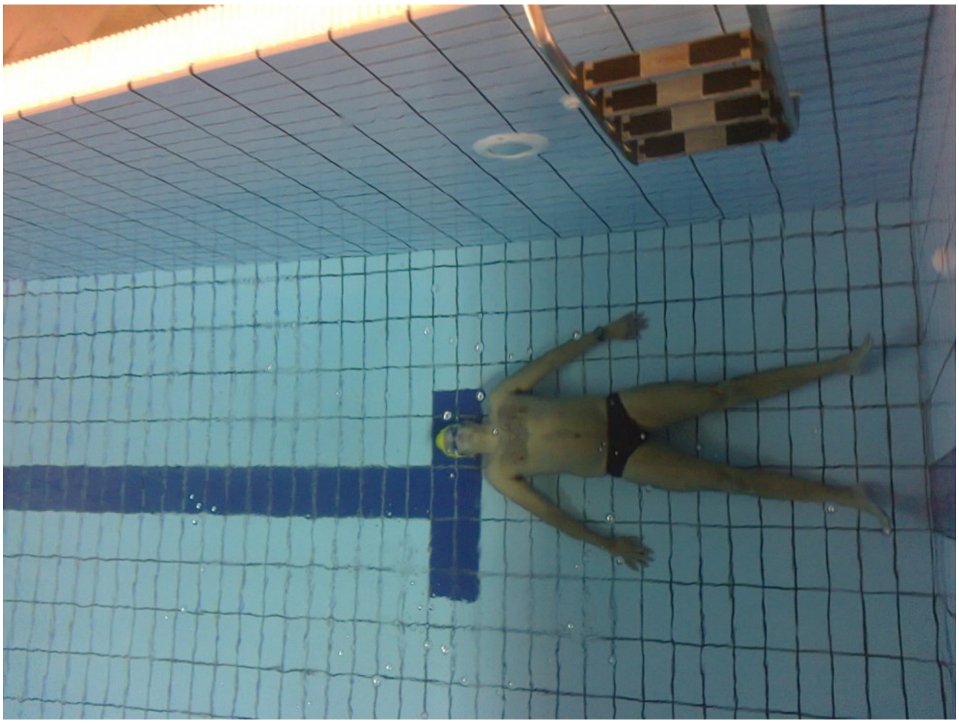

Photo 6: Task 10. Expiratory diving -Elite performance by an athlete, lays on his back on the bottom of the pool.

Appendix 9: Data collection sheets

Data Sheet (Athletes)

ID: Participants Name: Date:

AGE	
WEIGHT	
HEIGHT	
SPORT	
TRAINING AGE	

MEDICAL CERTIFICATE	YES	NO

Aquaticity Assessment test- AAT

1. Surface buoyancy and balance	
2. Breathing control	
3. Underwater hydrodynamic position	
4. Surface freestyle swimming technique	
5. Physical fitness adequacy in the water	
6. Treading water	
7. Underwater senses - vision	
8. Underwater senses - hearing	
9. Underwater swimming – Dynamic Apnea	
10. Expiratory diving	
TOTAL SCORE:	
Notes:	

Data Sheet (Non-athletes)

ID: Participants Name: Date:

AGE	
WEIGHT	
HEIGHT	

MEDICAL CERTIFICATE	YES	NO
SWIMMING EXPERIENCE	YES	NO
If YES please explain:		

Aquaticity Assessment test- AAT	Ex.A	Ex.B
11. Surface buoyancy and balance		
12. Breathing control		
13. Underwater hydrodynamic position		
14. Surface freestyle swimming technique		
15. Physical fitness adequacy in the water		
16. Treading water		
17. Underwater senses - vision		
18. Underwater senses - hearing		
19. Underwater swimming – Dynamic Apnea		
20. Expiratory diving		
TOTAL SCORE:		
Notes:		

Intervention Study Data Sheet

Group:____________________________

ID:

Participants Name: Date:

AGE	
WEIGHT	
HEIGHT	

MEDICAL CERTIFICATE	YES	NO
PARENTS APPROVAL	YES	NO

Aquaticity Assessment test- AAT	PRE	POST
21. Surface buoyancy and balance		
22. Breathing control		
23. Underwater hydrodynamic position		
24. Surface freestyle swimming technique		
25. Physical fitness adequacy in the water		
26. Treading water		
27. Underwater senses - vision		
28. Underwater senses - hearing		
29. Underwater swimming – Dynamic Apnea		
30. Expiratory diving		
TOTAL SCORE:		
Notes:		

ATTENDANCE SHEET

Group: Week Number:

	DATE:	MONDAY	WEDNESDAY	FRIDAY
	NAME	NOTES	NOTES	NOTES
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

TRAINER'S NOTES: