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ORIGINAL RESEARCH

Developing and testing an instrument to assess aquaticity in humans

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Summary 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 to 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 min 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.

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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 human aquaticity depends on mental and physical characteristics and can be improved by frequent exposure to the water element and instruction*" (Varveri et al., 2016).

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 (Varveri et al., 2016). The ideal state of aquaticity is achieved through the activation of the diving reflex, when the human body is totally immersed in water (Dujic and Breskovic, 2012). Human contact with water seems to promote not only physical wellbeing, but also psychological and emotional health (Capranica and Millard-Stafford, 2011; Peters, 2012; Zhang et al., 2014). 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 (Knight, 2014). 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 (Varveri et al., 2016) 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 (Havriluk, 2014). 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 (Varveri et al., 2016).

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. 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 min from the time of entering the water. Between the tasks there was a minimum of 2 min break.

Equipment

The equipment used to implement the aquaticity testing was: a training swimming pool, depth greater than 2 m; 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 1 m piece of thin white rope (5 mm diameter) with 7 knots and one standard size latex balloon (28 cm/ 11″).

Table 1 Description and components of the Aquaticity Assessment Test.

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

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 $r \geq 0.7$ are considered high, while loadings of $r \leq 0.4$ are considered low (Gorsuch, 1983; Preacher and MacCallum, 2003). 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 (Schnitzler et al., 2015). 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 (DeLong et al., 1988; Flouris et al., 2008). 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 $\leq$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 (Flouris et al., 2004; Flouris et al., 2005; Misailidi et al., 2014), 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. The AAT was easy to perform independently from the fitness level of the participants and it lasted for approximately 25 min 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. 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 $\chi^2 = 713.1$; $p < 0.001$). 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—49.5, with higher numbers reflecting greater physical adequacy in the water.

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. 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 ($z = 5.67$, $p < 0.001$).

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

Table 3 Aquaticity score among groups.

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

AU: Aquaticity Units.

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

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.

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 (Varveri et al., 2016). 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 (Torres-Ronda and Del Alcazar, 2014) 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 (Pendergast et al., 2015). 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 (Zamparo et al., 2012; Cortesi et al., 2014). 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

(Zamparo et al., 2012; Gatta et al., 2015), while the distance covered when continuously swimming for 5 min (task 5) independently from the style of swimming, reflects fitness level (Fernandes and Vilas-Boas, 2012). 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 (Schnitzler et al., 2015) 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 (Gislen et al., 2003; Pau et al., 2011) 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 (Breskovic et al., 2011). 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 (Breskovic et al., 2011).

The AAT differentiated successfully all the aquatic from the terrestrial sports' participants as well as identified participants with high ($\geq$43.3), medium (from 23.8 to 43.2) and low ($\leq$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 (Lindal and Stefansson, 1993).

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.

Conflict of interest

None.

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