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Decoding the aquatic motor behavior: description and reflection on the functional movement

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ABSTRACT. Aquatic environment is widely used for recreational, sporting, and therapeutic activities. However, human motor functional behavior in immersion has not been sufficiently described. Such description is necessary to improve strategies used to perform movements in this environment and to possibly transfer them to land. Our goal is to offer a qualitative description of the aquatic motor behavior. We use action research to observe and describe motor behavior in water, which we systematized using the Aquatic Functional Assessment Scale, effects of water on the immersed body, its relationship with functional movements performed on land, and the International Classification of Functioning, Disability and Health (ICF). The results allowed the systematization of aquatic movements based on unique features of water compared to effects of activities and participation of functional movement, under a biopsychosocial view of ICF. Such systematization of aquatic behaviors enables professionals to increase their strategies and interventions in water, through that understand the complexity of this approach and improve physical and therapeutic interventions that will have an impact on health.

Keywords: exercise; motor activity; hydrotherapy; international classification of functioning, disability and health; physical therapy specialty.

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Introduction

Human movement is the basis for communication and interaction with the environment (Morgan, Novak, & Badawi, 2013). Humans are able to generate behavioral patterns coordinated with the environment and directed to specific goals. This is the basis for the movement to be functional (Bertoldi, Israel, & Ladewig, 2011). Capture information available in the environment is a prerequisite of muscle action (de Wit, de Vries, van der Kamp, & Withagen, 2017), considering the influence played by the environment in which the movement takes place (Santos, Veloso, & Santos, 2017).

Human movement in the land environment (LE) has been numerously studied and described, but few studies have addressed the peculiarities of functional movements in the aquatic environment (AE) (Santos et al.. 2017). This is primarily due to the inherent difficulties posed by the environment for measuring the movement.

The AE is widely used for performing recreational, sporting, and therapeutic activities, and has physical and thermal properties that produce different responses than those observed in the LE (Israel & Pardo, 2000). These properties produce characteristic effects of physiological, cognitive, sensory, and motor nature (Schaefer, Louder, Foster, & Bressel, 2016; Waller et al., 2016). In addition, they allow exploration of three-dimensional effects on the immersed body (Storch et al., 2016), favoring the performance of specific activities.

Despite the wide use of this environment, little description has been made of the motor functional behavior of the immersed individual (Santos et al., 2017). This description is necessary to improve the strategies used to perform or recover body movements and to assist physical interventions and exercises in the AE. These functional aspects of the AE can be better understood when analyzed under the light of the International Classification of Functioning, Disability and Health (ICF) in the domains of activity and participation (Novak et al., 2013), which are directly linked to t body, structure, environmental and personal factors.

The study of movement of the immersed body is necessary since it is not possible to transfer patterns of movement on land to the water and expect the same results. These two environments stimulate different body behaviors, physical actions, temperatures, and intrinsic individual responses. Thus, it is necessary to understand the transfer (Santos et al., 2017) and adjustment of motor skills to functional activities in the LE (McManus & Kotelchuck, 2007), in order to stimulate the individual's participation (Castaneda, Castro, & Bahia, 2014).

The aim of this study was to offer a qualitative description of aquatic motor behaviors for healthy individuals. Secondly, we intended to relate these patterns to those found in the TE, which was carried out taking a biopsychosocial view based on the ICF activities and participation domains.

Material and methods

The present study is an action research (Turato, 2005) (Figure 1) of qualitative, observational, and descriptive nature about the motor behavior observed in the AE. As a means of systematization, we used the hydro-therapeutic treatment phases (Israel & Pardo, 2000), the *Aquatic Functional Assessment Scale* (AFAS) (Israel & Pardo, 2014), effects of immersion on the body, relationship with functional movement on land and with the ICF activity and participation domains CIF (*Organização Mundial da Saúde* [OMS], 2015).

After reviewing current literature on motor functional behavior, the research team performed themselves aquatic exploration in a heated therapy pool. On that occasion, functional aquatic movements both in and out of the water were captured on film.

In a third moment, we categorized our aquatic motor behaviors according to the following phases of Israel (Israel & Pardo, 2000): adaptation, mastering liquid environment, specialized therapeutic exercises, and global organic fitness. This systematization allowed the addition of new motor behaviors not yet described in the AFAS scale (Israel & Pardo, 2014), but relevant enough to expand the possibilities of encouraging motor skills. In parallel, the main effects of the immersed body on the AE were listed for each described behavior. Finally, the aquatic behaviors were discussed in relation to functional movements performed on land, based on the ICF Activity and Participation domains.

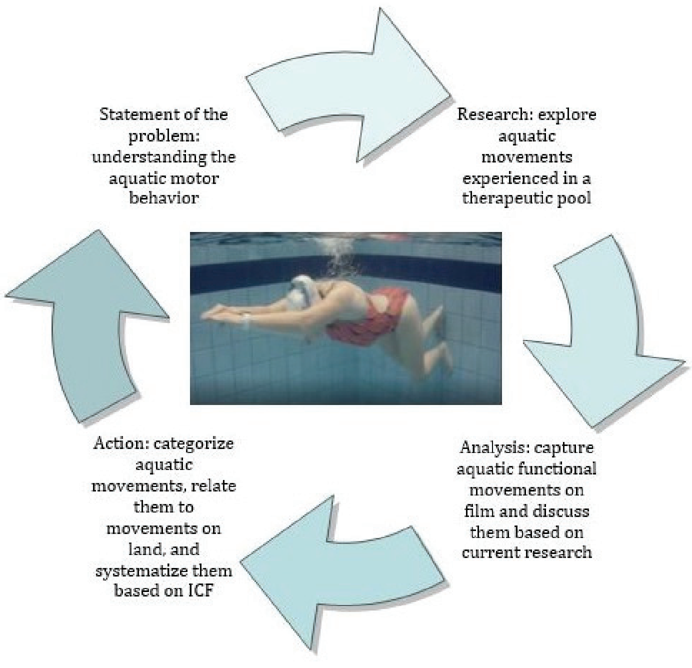

Figure 1. Organization of research-action.
Source: the authors.

Results

New aquatic motor behaviors were identified based on the biopsychosocial view of ICF. Figure 2 shows the result of the adaptation of the ICF structure to the systematization of aquatic human behavior in the AE, which is considered a different environmental domain by ICF, considering the domains for mobility in water and on land.

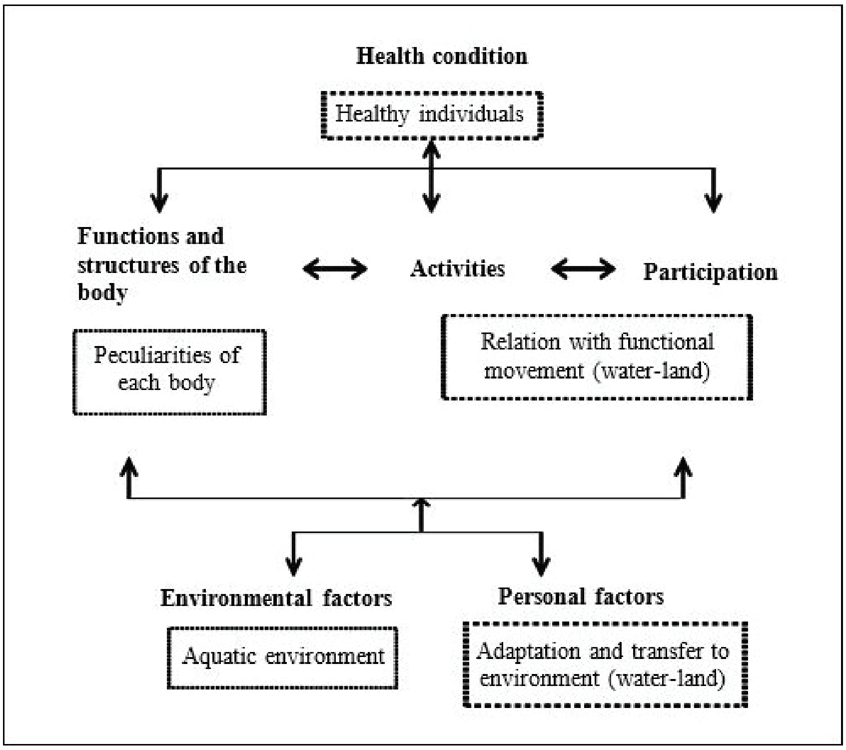

Figure 2. Systematization of aquatic human behavior according to ICF domains.
Source: adapted from World Health Organization (WHO, 2015).

Figures 3 to 6 summarize the results of the present study. They describe motor behavior (AFAS and land), systematized according to the phases of hydrotherapeutic treatment, and the main effects on the immersed body in relation to functional movement on land in order to produce the ICF possibilities of activity and participation as outcomes. Figure 3 shows the motor behavior from A1 to A8 related to Adaptation (A). There is a relation with respiratory control, maintenance of posture, and, to a lesser extent, changes of posture.

Hydro-therapeutic treatment phases	Aquatic motor behaviors (AFAS)	Main effects on immersed body									Motor behaviors (Land)	ICF Activity and participation (Mobility)
		Viscosity	Liquid surface tension	Archimedes principle	Pascal principle	Hydrodinamic drag	Metacentric effect	Turbulent flow	Laminar flow	Relative density		
Adaptation (A)	A1 = enters the pool	X	X	X							Stand up Sit down	d410 Changing basic body position d4101 Squatting d4103 Sitting d4106 Shifting the body's centre of gravity d415 Maintaining a body position d4150 Maintaining a lying position d4151 Maintaining a squatting position d4155 Maintaining head position d420 Transferring oneself d4201 Transferring oneself while lying d445 Hand and arm use d4452 Reaching
	A2 = puts the face in the water	X	X								Neck control	
	A3 = puts the face in the water and exhales	X	X		X						Respiratory control	
	A4 = dips the whole body into the water	X	X	X							Respiratory control Squatting	
	A5 = slides immerse in water	X			X				X		Shift the body's center gravity Crawling	
	A6 = floats supine position			X			X			X	Body balance Respiratory control Voluntary control of muscle tone Proprioception	
	A7 = floats in prone position			X						X		
	A8 = on the platform, passes from prone to sitting position	X		X							Shift to sitting Dissociation of upper and lower limbs	

Figure 3. Adaptation phase.

The Mastering of Liquid Environment (D), shown on Figure 4, is the stimulation of the development of control and postural alignment in the water. It trains dives; slides; transversal, sagittal, longitudinal and combined rotations. These movements allow the exploration of three-dimensional shape in AE, and require greater vestibular, proprioceptive and muscular control, in stabilizations as well as in changes of position. When transferring the gains to the LE, there is a correspondence with the movements of rolling and turning while seating and standing, favoring the mobility, according to the domains of activity and participation of the ICF.

Hydro-therapeutic treatment phases	Aquatic motor behaviors (AFAS)	Main effects on immersed body									Motor behaviors (Land)	ICF Activity and participation (Mobility)
		Viscosity	Liquid surface tension	Archimedes principle	Pascal principle	Hydrodinamic drag	Metacentric effect	Turbulent flow	Laminar flow	Relative density		
Mastering of the liquid environment (D)	D1 = floats upright in water with the aid of upper limbs ("kneeling position")	X		X			X				Body balance Core stability Voluntary control of muscle tone	d410 Changing basic body position d4105 Bending d4106 Shifting the body's centre of gravity d4107 Rolling over d415 Maintaining a body position d4152 Maintaining a kneeling position d4153 Maintaining a seating position d4201 Transferring oneself while lying d445 Hand and arm use d4452 Reaching
	D2 = keeps the balance sitting on the water			X			X	X			Body balance Core stability Voluntary control of muscle tone	
	D3 = changes from supine to prone position (vertical rotation, now called transverse)	X		X			X				Upper body control Shift to sitting	
	D4 = changes from prone to supine position (vertical rotation, now called transverse)	X		X			X				Upper body control Neck control	
	D5 = changes from supine to prone position (horizontal rotation, now called longitudinal) D5A: to RHS D5B: to LHS	X		X			X				Dissociation of upper and lower limbs Rolling from supine to prone position	
	D6 = changes from prone to supine position (horizontal rotation, now called longitudinal) D6A: to RHS D6B: to LHS	X		X							Dissociation of upper and lower limbs Rolling from prone to supine position	
	D7 = performs mixed rotation (vertical and horizontal rotation, now called transversal longitudinal)	X		X							Reach Change body position	
	D8 = rolls freely in the water	X		X							Body control	
	*D9 = Sagittal rotation D9A: to RHS D9B: to LHS	X		X							Reach an object on the ground Upper body control Reach	
	*D10 = front float recovery	X		X							Shift to sitting Shift to upright position Upper body control	
	*D11 = back float recovery	X		X							Lay down Upper body control	

Figure 4. Mastering of Liquid environment.

The Specialized Therapeutic Exercises (E), shown on Figure 5, focus on specific functional objectives. It is important to maintain and/or gain range of motion, strength, resistance and muscle stretching, motor coordination, body balance and task training such as gait and transfer to standing. This phase (transfer to standing position) refers to most of the daily activities of typical psychomotor learning, represented as displacements, maintenance and change of postures. Providing skills training and the many different ways of performing movements.

The Global Organic Fitness (Cd) phase, shown on Figure 6, aims to develop the cardiorespiratory condition, with aerobic activities that will increase circulatory, respiratory and muscle strength. The performance of these activities can relate to diversification of intensity and rhythm; adapted or traditional modalities of swimming; speed exercises; diving with propulsion and locomotion; with the possibility of using propulsion of trunk, upper and lower limbs.

Hydro-therapeutic treatment phases	Aquatic motor behaviors (AFAS)	Main effects on immersed body									Motor behaviors (Land)	ICF Activity and participation (Mobility)
		Viscosity	Liquid surface tension	Archimedes principle	Pascal principle	Hydrodinamic drag	Metacentric effect	Turbulent flow	Laminar flow	Relative density		
Specialized Therapeutic Exercises (E)	E1 = on the platform, goes from sitting to standing			X							Stand up Body control	d410 Changing basic body position d4102 Kneeling d4103 Sitting d4104 Standing d4106 Shifting the body centre of gravity d415 Mantaining a body position d4154 Maintaining a standing position d420 Transferring oneself d4200 Transferring oneself while sitting d445 Hand and arm use d450 Walking d4500 Walking short distances d4508 Walking, other specified d455 Moving around d4550 Crawling d4551 Climbing d4452 Reaching d4554 Swimming
	E2 = Front flot recovery into standing E2A: to RHS E2 B: to LHS			X							Stand up and reach Dissociation of upper and lower limbs Body control	
	E3 = on the handrail, goes to standing			X							Stand up Weight transfer Balance on erect standing position	
	E4 = stands (with or without splint in lower limbs)			X	X						Orthostatism Weight transfer Balance on erect standing position	
	E5 = walks (with or without splint in lower limbs)	X				X					Gait Dynamic balance	
	E6 = Walks sideways	X				X					Lateral gait	
	E7 = walks backwards	X				X					Forward gait	
	E8 = Transfer to a sitting position			X	X						Sitting down	
	*E9 = lateral leg kick E9 A: RHS E9 B: LHS	X				X					Muscle control Dissociated movements of lower limbs Core control	
	*E10 = Alternate leg kicks, supine position, grabbbing handrail	X				X					Dissociated movements of lower limbs Core control	
	*E11 = Alternate leg kicks, prone position, grabbbing handrail	X				X					Dissociated movements of lower limbs Core control Posture	
	*E12 = climb a step E12 A: with RHS leg E12B: with LHS leg			X							Climb a step Weight transfer Single foot balance	
	*E13 = step down E13A: with RHS leg E13B: with LHS leg	X		X							Step down Weight transfer Single foot balance	
	*E14 = Crawling on the platform	X		X	X						Crawling Dissociation of upper and lower limb Weight transfer	
	*E15 = transfer while kneeling on platform	X		X	X						Kneel down Dynamic balance Weight transfer	
	*E16 = transfer while sitting on platform	X		X	X						Transfer while sitting Body pivot	
	*E17 = transfer while seating without platform	X.		X	X						Body pivot Transfer while sitting Body balance Core control	
	*E18 = tandem E18A: RHS E18B: LHS				X						Static balance	
	*E19 = Tandem gait	X									Dynamic balance	
	*E20 = Single foot support E20A: RHS E20B: LHS			X	X						Static balance	

Figure 5. Specialized therapeutic exercises.

As result of the transfer of motor behavior, we can see the improvement of coordination, the use of the upper limbs, associated with the use of the trunk, as well as the conditioning for the execution of functional mobility actions.

These results make it possible to expand the motor skills trained in water, which have repercussions on land environment function and the ICF dimensions.

Hydro-therapeutic treatment phases	Aquatic motor behaviors (AFAS)	Main effects on immersed body									Motor behaviors (Land)	ICF Activity and participation (Mobility)
		Viscosity	Liquid surface tension	Archimedes principle	Pascal principle	Hydrodinamic drag	Metacentric effect	Turbulent flow	Laminar flow	Relative density		
Global Fitness (Cd)	Cd1 = swims utility backstroke	X									Muscle control Core control Voluntary control of muscle tone	d420 Transferring oneself d4201 Transferring while lying d445 Hand and arm use d4450 Pulling d4451 Pushing d455 Moving around d4452 Reaching d4552 Running d4553 Jumping d4554 Swimming
	Cd2 = swims adapted backstroke (with bilateral strokes)	X				X					Muscle control Core control	
	Cd3 = swims adapted backstroke (with alternate strokes)	X				X					Muscle control Core control	
	Cd4 = swims adapted crawl	X				X					Muscle control Core control	
	Cd5 = swims adapted breaststroke	X				X					Crawling Upper body control Posture	
	Cd6 = swims adapted butterfly stroke	X				X					Reach with upper limbs Crawling Upper body control	
	Cd7 = run	X				X					Run	
	Cd8 = hop	X				X					Hop	
	*Cd9 = hop with rotation	X									Hop Jump Dissociation of upper and lower limbs	

Figure 6. Global organic fitness.

Discussion

ICF represents a paradigm shift, focused on health and functional conditions and not just on the disease process. This approach is based on the biopsychosocial model of development, precisely because it allows the assessment of main health conditions, considering its various systems (Duff & DeMatteo, 2015) in the domains of activity and participation, functions and body structures, as well as personal and environmental factors (OMS, 2015).

The biopsychosocial theory suggests that learning occurs when performing motor activities, when exploring the environment in which it lives, and by being active in it (Cano-de-la-Cuerda et al., 2015). Thus, we can say that when exploring the AE there are motor responses used for the LE, because, as Morgan (2013) suggested, the stimulation and the environment interfere directly in motor control and brain plasticity, in order to improve the motor repertoire.

As the individuals in their daily lives perform several functional activities, in order to ensure their participation in the community, it is clear that the roll of stimulations and environment enables new connections. Also, the combination with targeted exercise might even stimulate neuroprotection (Knaepen, Goekint, Heyman, & Meeusen, 2010).

The results obtained in this research show us a diversity of motor behaviors performed in the AE, which undergo the effects of the body in immersion and can have outcomes in the functionality in the LE as well. For example, the act of floating in the prone position, performed in AE, can improve body balance, respiratory control, voluntary muscle tone control and proprioception of the individual in LE. The activities performed in AE interfere with the functionality in the LE. The instability while immersed causes continuous postural adjustments, which also explains the results of body dominance, proprioception and muscle control (Oliveira et al., 2015).

When immersed, the body receives influences of hydrostatic, hydrodynamic and thermodynamic factors, which implies in the knowledge of the physical and thermal principles of water to understand the aquatic human movement and impact on functionality (Becker, 2009; Israel & Pardo, 2014).

The Figure 7 presents the main properties of water. The thrust, defined by Archimedes; hydrostatic pressure, described by Pascal; and water resistances, which together make the environment peculiar and with specific characteristics. These features cause repercussions on body behaviors and differences in movement between environments (Veiga, Israel, & Manffra, 2013).

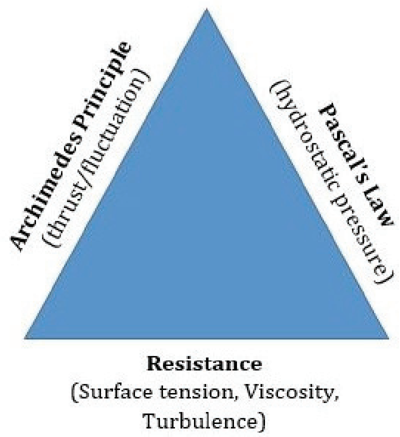

Figure 7. Triangle with the physical properties of water.
Source: the authors.

The figure emphasizes that in the AE, these properties will act together. However, when performing a directed movement with a defined goal, you can make special use of a property, according to the patient´s needs. In this study, we related each behavior to the main aquatic effects (Figure 3).

The Archimedes principle deals with the vertical force exerted in the opposite direction of gravity in AE, with force equal to the volume of mass displaced by the immersed body. When there is balance with body mass, buoyancy center and body density, the individual can float. This force can also generate resistance to movement by holding it toward the bottom of the pool or facilitating the movement toward the surface and supporting or sustaining it when performed horizontally. In addition, it provides apparent weight reduction, with reduced impact and joint stress (Kruel, Peyré-Tartaruga, Coertjens, Dias, da Silva, & Rangel, 2014). We observe that thrust acts with greater emphasis on some specific movements, as for example in the items involving the floating of the immersed body (A6 and A7) described in Figure 3, providing stabilization and support to the body.

Besides thrust, the relative density (mass-volume relationship) will also influence AE behavior, because water is relatively denser than the human body, which physiologically favors buoyancy. Therefore, any submerged object that has a density greater than 1 (one) tends to sink and when smaller than 1 (one) tends to float. Individuals with different body composition, such as the elderly, children, people with changes in muscle tonus, higher lean mass index and other peculiarities may alter the relative density of the body, which leads to different body responses during immersion and floating (Becker, 2009). We need to consider different body densities in the characterization of motor behaviors, since they are specific features of body functions and structures, which ICF approaches in its domain.

In AE, the body mass center undergoes changes in position, and it is necessary to stabilize the forces of gravity, density and thrust, which can lead to rotational movements until the body finds the balance position. We call this center of gravity shift as metacentric effects (Torres-Ronda & Del Alcázar, 2014). The ICF makes a direct connection to "shifting the body's center of gravity" (d4106), showing its relevance. Items D1 and D2 in Figure 4 show these changes: keeping the floating equilibrium due to stabilization between forces results in the development of a good body balance, a better control of trunk and pelvic muscles, and muscle tone voluntary control. The freedom of movements enabled by the AE – either in vertical, horizontal, or tilted body postures – develops and trains motor abilities in a way that would not be possible in another environment. However, water environment also favors unexpected movements such as submersion or rotating movements (Veiga et al., 2013).

The hydrostatic pressure acts especially during rest is a horizontal pressure that takes place equally in all directions of the immersed body and increases with depth (Becker, 2009), therefore, it helps blood flowback, raises intra-thoracic blood volume, increases cardiac output, consequently reducing heart rate, and enhances stability and movement control (Kruel et al., 2014; Torres-Ronda & Del Alcázar, 2014). The motor effect on the behavior E20, displayed in Figure 3, consists of single foot support stability, which, according to the ICF, consists in maintaining a body position (d415).

AE exercises aiming body strengthening are ruled by hydrodynamic physical principles that develop multidimensional resistance to movements. Such resistance increases according to the force applied, which creates minimum overload in body joints (Bento, Pereira, Ugrinowitsch, & Rodacki, 2012).). Therefore, the movement resistance in an aquatic environment is related to the body's direction, size, shape, and speed during movement. These aspects may be used to improve progress parameters for aquatic physical exercise (Israel & Pardo, 2000).

Aquatic resistances, such as viscosity, liquid surface tension and turbulence, most of the times offer body movement resistance (Veiga, et al., 2013); however, they may also be used as a tool to help movement execution (Iucksch, Israel, Ribas & Manffra, 2013).

Viscosity is the friction between water molecules, which is proportional to speed of water movement and the contact area; however, it is inversely proportional to the temperature of water. In addition to promoting three-dimensional resistance to movement, viscosity also favors proprioception and stabilization of posture and body segments (Rebutini, Rodrigues, Maiola, & Israel, 2012; Veiga et al., 2013) and, overall, viscosity also affects aquatic behaviors that involve displacements.

Turbulence is the disordered movement of water molecules, and it creates a turbulent, irregular, and discontinuous flow, which acts as a resistive element to displacement when the opposite movement is generated. When the movement is ordered, a spot with lower pressure is created. This spot, then, acts as a facilitator if the direction of the flow is the same as the direction of the movement (Rebutini et al., 2012).

Hydrodynamic drag is the opposing action of water to the displacement of the submerged body - the higher the displacement velocity, the higher the drag (Rebutini et al., 2012). Turbulent flow and hydrodynamic drag are described on all motor behaviors listed in the global fitness section shown in Figure 6.

In addition to the hydrostatic and hydrodynamic factors, heated water also influences the patient's body. It brings muscle relaxation as well as pain relief, increases the range of joint movements, improves metabolism, and decreases muscle tension (Becker, 2009).

Many responses from the organism can be noticed when the body is submitted to immersion. Among the responses are physiological effects in cardiovascular, respiratory, renal, musculoskeletal and neurologic systems (Mooventhan & Nivethitha, 2014), as well as cognitive, sensory and motor effects (Schaefer et al., 2016).

This study reinforces that the understanding of the aquatic motor behavior is needed due to the several different effects it causes on the body, so that movement possibilities that are consistent to our goals may be explored. Additionally, this understanding contributes to the possibility of using such abilities in LE (Ruiz-Pérez, 2017).

Functional movements correspond to one's ability to perform actions that generate benefits on daily life activities. In this regard, using the ICF enables us to know and understand better the factors that can interfere on one's health (Gannotti, Christy, Heathcock, & Kolobe, 2014). It also helps the proper selection of assessment tools, which are widely used for activities and participation in Brazilian studies conducted with ICF (Brasileiro, Moreira, & Buchalla, 2013).

Concerning aquatic interventions, positive effects related to body systems, activities and participations as well as advances in environmental aspects have been described in disabled people (Güeita-Rodríguez, Garcia-Muro, Cano-Diez et al., 2017; Güeita-Rodríguez, Garcia-Muro, Rodriguez-Fernandez et al., 2017) and have been related to ICF (Güeita-Rodríguez, Garcia-Muro, Cano-Diez et al., 2017).

Some studies describe the motor learning transfer relationship in different environments, which can be related to motor practice and stimulation (McManus & Kotelchuck, 2007; Santos et al., 2017). Therefore, stimulation should be available in different ways as well as in different environments, such as the AE (Garcia et al., 2012). Some studies indicate that motor skills are carried over to the LE when training occurs in the AE. As an example, a study of Parkinson's disease with 25 participants showed that the aquatic exercise program improved functional mobility, balance and walking in LE after 10 weeks, twice a week, for 40 minutes each (Silva & Israel, 2019).

Although several researches have been carried out with aquatic movement in humans, especially focusing in therapeutic benefits for those with special needs (Barker et al., 2014; Bidonde et al., 2014; Mooventhan & Nivethitha, 2014), a deeper understanding of aquatic motor behavior is needed. This need comes from primarily due to the necessity to develop easy-access measurement methods and equipment that would lead to a better understanding of such behaviors in the LE.

Further studies are needed to explain how individuals transfer the benefits obtained in the water and adapts to the water influence on the immersed body. These gaps call for new studies aiming the understanding of aquatic motor behaviors, including health/disease conditions and their impact on functional movement. We, therefore, suggest the use of ICF not only regarding aspects of motor function categorization, but also in a social and cognitive perspective.

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Conclusion

Our study increased the understanding about aquatic movement, in a biopsychosocial view of the ICF, so that we can clearly understand the motor behavior performed in the water, relating them to human functional patterns in the LE. We should consider that such systematization enables professionals who are involved in studying human movements during immersion to have a better comprehension of the complexity of this approach and become able to do practical decisions – for both physical and therapeutic exercises that will have an impact on health, besides increasing their strategies and interventions in water.

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