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Biomechanical responses to water fitness programmes: a narrative review

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REVIEW ARTICLE

ABSTRACT

In the past years, there was an increasing interest in the biomechanical responses in water fitness sessions. The present review consolidates the current "state-of-art" on the biomechanical responses in water fitness programmes. The literature was searched and screened studies on: (i) healthy subjects; and (ii) water fitness sessions and programmes reporting physical condition outcomes. A total of 36 studies met the inclusion criteria and categorized into four categories: (i) kinematics (n = 5); (ii) ground reaction force (n = 10); (iii) neuromuscular (n = 8); and (iv) strength (n = 14). There was a larger amount of evidence on strength, whereas some gaps in the body of knowledge still persist in the remaining categories. The existent studies cover a large range of age brackets (from young adults to the elderly). Women were recruited more often than men to be part of the studies. The effect of music cadence, body segments, exercise type (e.g., alternated or simultaneous), water depth, resistance equipment, and training protocols were the main topics under research.

Keywords: water fitness, kinematics, kinetics, neuromuscular, strength

INTRODUCTION

Over the past decades, many studies have noted the benefits of engaging in water programmes, aiming to improve fitness level and carry out therapy and rehabilitation. Notwithstanding, there is an increasing interest in water fitness exercises (Barbosa et al., 2009) to improve performance (e.g., Martel et al., 2005) and to prevent related-training injuries (Becker & Havriluk, 2006; Grantham, 2002). There is evidence that such programmes can enhance the cardiovascular system output, increase muscular strength, decrease body fat, and enhance body balance. These benefits seem to be related to specific water physical properties that can improve physical exercise adherence or health-oriented recreation practice in the water context (Pinto et al., 2015; Rafaelli et al., 2016).

To date, a few numbers of reviews were published on this topic. Those review papers consolidated articles about: (i) the physiological responses in water (Barbosa et al., 2009); (ii) the strength development in a broad spectrum of subjects (Prado et al., 2016); (iii) the effect of high-intensity exercise (Depiazi et al., 2019); and (iv) changes in body composition and health variables (Marinho et al., 2019). Despite that, the nature of the biomechanical effects while exercising in water is not so clear. So, there is a chance to consolidated in a single review the existent papers about biomechanical responses to these programmes.

Understanding biomechanical behaviours in water fitness sessions and programmes should be a must for physical fitness and a healthy lifestyle. Through the years, most biomechanics interventions relied on kinematic and kinetic characteristics, as ground reaction forces and muscular strength analysis (e.g., Cavanagh & Lafortune, 1980; Tsourlou et al., 2016). Many attempts aimed at dissecting the biomechanical strategies adopted by different types of participants (e.g., Barela & Duarte, 2008), in a broad range of water exercises (e.g., Santos et al., 2019a), considering the music cadence as

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crucial for the exercise stimulus (e.g., Costa et al., 2011). Plus, few authors tried to add findings of the effects of exercising at different water depths (e.g., de Brito Fontana et al., 2012) and using resistance equipment (e.g., Colado et al, 2009b). Thus, at this point, enough experimental or quasi-experimental studies are available in the literature to consolidate the state-of-the-art, even though such a narrative review is yet to be carried out. Such a review can provide practitioners with a more in-depth insight into how to carry out their daily sessions by designing and implementing the most appropriate exercise methods. It may also help researchers go deeply within the topic and fulfill the research gap where needed.

The present narrative review consolidates the current "state-of-art" on the biomechanical responses in water fitness programmes.

Literature search and screening

A search was conducted from January 1st of 1990 until December 31th of 2019 in several databases (e.g., PubMed, Web of Science, Scopus, ScienceDirect) and in conference proceedings (e.g., Symposium for Biomechanics and Medicine in Swimming, International Aquatic Fitness Conference, International Society of Biomechanics in Sports, International Society of Biomechanics). The following keywords and terms were used individually or combined: "water activities", "aquatic activities", "head-out water exercise", "water aerobics", "water fitness", "water-based", "water-resistance equipment/devices", "biomechanics", "kinetic", "kinematic", "neuromuscular", "training", "adaptations" "music cadence" and/or "acute and chronic responses". The analysis of eligibility was made by two independent reviewers that consolidated the search into a single list of studies. The inclusion criteria were defined as studies: (i) with healthy subjects as participants and not patients in treatment; and (ii) relying on water fitness sessions and programmes reporting physical condition outcomes. Here we found a total of 36 studies.

The studies where then categorized into four categories according with their main outputs reported: (i) kinematics (*n* = 5, table 1); (ii) ground reaction force (*n* = 10, table 2); iii) neuromuscular (*n* = 8, table 3): and (iv) strength (*n* = 14, table 4). Some studies were assigned to data in more than one category. As such, those were cited as much as necessary throughout the text.

Kinematics

Literature reports six main groups for the water fitness exercises (Sanders, 2000): (i) walking; (ii) running; (iii) rocking; (iv) kicking; (v) jumping; and (vi) scissors. To increase the session´s diversity, water fitness instructors use several exercises' variants and extensions with different features, such as the number of limbs in action. It is recognized that instructors should also take into account the music cadence to motivate the participants' (Costa et al., 2011), keep the synchronization (Barbosa et al., 2009), and lead up to a desirable level of exertion (Barbosa et al., 2010a). However, participants must be familiarized with the concept of "music rhythm" (Oliveira et al., 2011). Also known as "music cadence" or "water tempo", that is characterized by the countdown of only one beat in every two beats (Kinder & See, 1992) and that is synchronized with a specific limb movement. Some studies point out the 4mmol·L^{-1} of blood lactate to achieve the desirable music cadence (e.g., Costa et al., 2011). However, water fitness practitioners usually adopt dry-land fitness guidelines (Barbosa et al., 2009). Most studies aimed to analyse acute kinematic responses with different music cadences.

It has been reported that the cycle of the period decreased significantly as the execution of music cadence increased for the following exercises: (a) rocking horse (Barbosa et al., 2010a); (b) jumping jacks (Costa et al., 2011); (c) sidekick (Oliveira et al., 2011); and (d) sailor jigs (Teixeira et al., 2011; 2015). Participants under an incremental protocol decreased the range of motion when the absolute duration of full exercise also decreased (Teixeira et al., 2011). The music cadence explains ≈83% of the decrease in the cycle of period behaviour (Oliveira et al., 2011). On the other hand, water fitness instructors are able to keep the range of motion while the music cadence increases (Teixeira et al., 2015). The increase in music cadence induces an increase in segmental velocity (Costa et al., 2011) and, consequently, in drag force (Barbosa et al., 2009). Thus, expert and fit participants seem to increase the segmental velocity of upper- and lower-limbs to maintain the optimal range of motion (Barbosa et al., 2010a; Costa et al., 2011).

Exercises that involve performing multiple hops (e.g., jumping jacks, sidekick, rocking horse) lead to a controlled upward and downward movement. Oliveira et al. (2011) found a bi-modal profile for the vertical displacement and velocity of the centre of mass at a cadence of 135 b•min^{-1}. Since the "sidekick" is characterized by hopping from one leg to the other, the lateral velocity presents a multi-peak profile, as reported regularly in several swim strokes (Barbosa et al., 2010b). Therefore, the increase in music cadence leads to a: (i) decrease in the cycle of the period; (ii) increase or maintain the range of motion; (iii) increase in the segmental velocity (lateral and vertical); (iv) increase in the centre of mass velocity; and (iii) decrease in the upper-limbs displacement. However, it seems yet unclear if participants with different fitness or proficiency levels will vary the kinematic behaviour. So, water fitness instructors must be mindful of how kinematic variables can vary depending on the music cadences selected.

Table 1
Summary of water fitness kinematic studies

Authors (year)	Aim	Participants	Exercises & Variables	Main Findings
Barbosa et al. (2010a)	Analyse the relationships between MC and kinematic characteristics of a basic head-out aquatic exercise	6 water fitness instructors: women, 23.67 ± 0.52 y old	"Rocking horse" CP, 2D linear position ranges, and 2D linear velocity ranges	CP decreased, and segmental velocity increased throughout the experimental protocol
Costa et al. (2011)	Analyse the relationships between the head-out aquatic exercise "Jumping jacks" kinematics and the MC	5 water fitness instructors: women, 23.7 ± 0.5 y old	"Jumping jacks" CP, 2D linear position ranges, and 2D linear velocity ranges	CP and the displacement of upper limbs decreased following the increase of the MC. Lower limbs velocity increased to maintain the ROM
Oliveira et al. (2011)	Analyse the relationship between the head-out aquatic exercise "sidekick" kinematics and the MC	6 water fitness instructors: women, 23.67 ± 0.52 y old	"Sidekick" CP, 2D linear position variation and velocity (vertical and lateral components)	CP decreased, and segmental velocities on the lateral and vertical components increased throughout the incremental protocol, to maintaining the segmental displacements
Teixeira et al. (2011)	Analyse the relationship between "Sailor's jigs" kinematics and increasing MC	6 water fitness instructors: women, 23.50 ± 3.51 y old	"Sailor's jigs" CP, ROM, and angular velocity	Increasing MCs lead to a decrease in the absolute duration of the full exercise. Decreasing the CP is achieved through a combination of decreasing the ROM and increasing the angular velocity
Teixeira et al. (2015)	Analyse the relationship between the angular kinematic pattern of "sailor's jigs" at increasing musical rhythm	6 water fitness instructors: women, 23.50 ± 3.51 y old	"Sailor's jigs" CP, angular displacement, and angular velocity	Increasing rhythm decreased the angular displacement, and the angular velocity stayed unchanged in some anatomical landmarks.

Note: CP, cycle period; MC, music cadence; ROM, range of motion; y old, years-old.

The scarce number of studies about the different variants and extensions of water fitness exercises leads to an imbalance between the number of exercises used during a session and those studied. To the best of our knowledge, just one study reported the kinematics during a simultaneous water fitness exercise (i.e., jumping jacks). Thus, new research should evaluate the upper- and lower-limbs behaviours separately, according to the static and imbalance positions. Moreover, this should be done by comparing subjects by physical activity level, age-group, gender, or equipment. To increase the accuracy of external validity, the researchers should also consider an increase in the number of subjects that compose their sample.

Ground Reaction Force

Most studies on the kinetics field are related to the differences between the in-water and dry-land environment. The ground reaction force (GRF) is one common parameter to assess the external biomechanical load. Nevertheless, the vertical component of the GRF presents the largest magnitude is directly influenced by buoyancy (Myoshi et al., 2004). So, the attention to the GRF has been increasing in the past few years (Alberton et al., 2013).

Walking and running have become popular exercises in water fitness programmes (Barela & Duarte, 2008; de Brito Fontana et al., 2012). For that, there is a consensus that water promotes a different motion pattern when compared with dry-land. Smaller values of the vertical GRF and impulse were observed during water walking (Barela & Duarte, 2008; Barela et al., 2006; Myoshi et al., 2004; Nakazawa et al., 1994). As expected, the in-water stationary running (Alberton et al., 2013) and the in-water running (Haupenthal et al., 2010) point out the same pattern. However, the exercise type may influence the magnitude of reduction in vertical GRF (Alberton et al., 2013; Miyoshi et al., 2004).

The physiological response decreases when the exertion is immersed by the breast (Barbosa, Garrido, & Bragada, 2007), and it seems that the kinetics have a similar trend. De Brito Fontana et al. (2012) observed that at an immersion by the hip and chest level, during stationary running, the forces acting on the body decrease near to 40% and 50%, respectively. On the other hand, Haupenthal et al. (2010) reported that both immersion levels do not present significant differences. The same authors noted that the uncontrolled running speed might explain those findings. However, the GRF components can be changed through the limb position and the speed while keeping it at the same immersion level (Roesler et al., 2006). In order to obtain the hydrostatic pressure effect's maximal benefits, the water surface is recommended to be at the xiphoid process (Kruel et al., 2001). Thus, it is clear that a higher amount of propulsive force will be necessary for a water-efficient walk or run when compared to performing the same exercises on dry-land. Exercises with similar characteristics to frontal kick and stationary running should be considered to maximize the vertical GRF, whereas the adductor hop and jumping jacks minimize (Alberton et al., 2014).

A few studies focused on the anterior-posterior and medio-lateral GRF of water fitness exercises. De Brito Fontana et al. (2012) described smaller values during the stationary running, though it increased with the musical cadence. Increasing velocity leads to an increase in the anterior-posterior GRF (Roesler et al., 2006), whereas a higher immersion level decreases that component (Haupenthal et al., 2013) without differences between genders. However, the medio-lateral GRF has a similar pattern compared to dry-land walking (Myoshi et al., 2004). Therefore, GRF values in water can be explained by: (i) the role of drag force; (ii) the reduced effect of body weight; (iii) the smaller impact on the body due to buoyancy; and (iv) the slower speed of displacement. The most significant advantage seems to be the reductions in joints forces, inducing a lower-risk of musculoskeletal injuries.

Water fitness professionals must pay attention to the depth of immersion to obtain the benefits of water properties and control loads acting on body, considering the participants' and exercises' characteristics (e.g., gender, age, exercising speed).

Neuromuscular

Scarce research has attempted to understand the neuromuscular response in water fitness exercises. This means assessing muscle activation to promote a dynamic motion from a single joint or reach postural control. The existent studies were mainly focused on the walking and neuromuscular response of in-water running. Some reported that the neuromuscular response in water is lower when running at submaximal efforts such as 60, 80, or 100b·min^{-1} (Kelly et al., 2000; Masumoto et al., 2004; Müller et al., 2005; Shono et al., 2007). For instance, this type of effort does not raise enough the EMG amplitude during water fitness exercises.

Table 2.
Summary of water fitness ground reaction force studies

Authors (year)	Aim	Participants	Exercises & Variables	Main Findings
Alberton et al. (2013)	Compare the $V\text{-}GRF_{peak}$ and IMP in water aerobic exercises at different intensities and environments	15 young women, 23.2 ± 2.0 y old	"Stationary running", "frontal kick" and "cross country skiing" $V\text{-}GRF_{peak}$ and IMP	Lower responses of $V\text{-}GRF_{peak}$ and IMP were found in water environment for all exercises. The cross-country skiing presented lower $V\text{-}GRF_{peak}$.
Alberton et al. (2014)	Compare the V-GRF in water aerobic exercises at different intensities	12 young women, 23.8 ± 2.2 y old	"Stationary running", "frontal kick" and "cross country skiing" V-GRF	V-GRF increases at greater intensities (VT_2 and MAX) compared to the lower intensities (VT_1). The cross-country skiing presented lower $V\text{-}GRF_{peak}$.
Barela et al. (2006)	Characterize a complete gait cycle of adults walking in shallow water and compare with walking on land	10 healthy women and men adults, 29.0 ± 6.0 y old	"Walking" V-GRF and AP-GRF	In-water V-GRF was lower than on dry-land by the reduction in walking speed. The AP-GRF showed a different pattern during walking in water
Barela and Duarte (2008)	Analyse the relationship between "Sailor's jigs" kinematics and increasing music cadence	6 elderly healthy women and men, 70.0 ± 6.0 y old	"Walking" V-GRF and AP-GRF	Elderly people were more slowly in water, reduced GRF and increase horizontal impulse, compared to dry-land
de Brito Fontana et al. (2012)	Analyse the GRF during stationary running performed in water and on dry-land, according to the gender, level of immersion, and cadence	22 young healthy women, 23.00 ± 2.5 y old; men, 24.0 ± 3.0 y old	"Stationary running" V-GRF and AP-GRF	V-GRF was lower at water. Increasing running cadence increases vertical GRF in water and on dry-land. The gender had no effect on V-GRF and AP-GRF
Haupenthal et al. (2013)	Analyse the effects of immersion level, running speed, and gender on the V-GRF and AP-GRF during water running	20 healthy adult women, 23.0 ± 2.0 y old; men, 23.0 ± 3.0 y old	"Water running" V-GRF and AP-GRF	Increasing running speed increases V-GRF and AP-GRF, while increasing the level of immersion increases AP-GRF and decreases V-GRF. Women reached greater V-GRF when ran fast by the water at the hip level.
Haupenthal et al. (2010)	Analyse the GRF during shallow water running at 2 levels of immersion	22 young healthy women, 23.00 ± 2.5 y old; men, 24.00 ± 3.0 y old	"Water running" V-GRF and AP-GRF	Levels of immersion had no effect on V-GRF and AP-GRF. Running in deeper water results in lower GRF
Myoshi et al. (2004)	Compare the changes in GRF during walking in water and on land	15 healthy men, 22.8 ± 4.5 y old	"Walking" V-GRF, AP-GRF, and ML-GRF	AP-GRF differed between walking in water and walking on dry-land, whereas the ML-GRF was similar.
Nakazawa et al. (1994)	Compare the GRF between walking in water, considering different depths, and land.	6 young healthy women and men, 25.5 ± 2.3 y old	"Walking" GRF and IMP	Higher immersion showed a decrease in GRF and IMP
Roesler et al. (2006)	Analyse the V-GRF and AP-GRF during the aquatic gait	60 young healthy women and men, 23.0 ± 5.0 y old	"Walking" V-GRF and AP-GRF	GRF components can be altered through the upper limb position and gait speed. Increase the gait speed results in an increase in the AP-GRF

Note: AP-GRF, antero-posterior ground reaction force; IMP, impulse; MAX, maximal effort; ML-GRF, medio-lateral ground reaction force; V-GRF, vertical ground reaction force; $V\text{-}GRF_{peak}$, peak vertical ground reaction force; VT_1, first ventilatory threshold (~50% of VO_{2max}); VT_2, second ventilatory threshold (~70% of VO_{2max}); y old, years-old.

Table 3.
Summary of water fitness neuromuscular studies

Authors (year)	Aim	Participants	Exercises & Variables	Main Findings
Alberton et al. (2011)	Analyse neuromuscular responses obtained during the stationary running in aquatic and dry-land environments.	12 healthy women, 22.3 ± 0.5 y old	"Stationary running" RF, VL, ST and short head of the biceps femoris	In-water submaximal cadences present a lower neuromuscular response, whereas at maximal velocity lead to an optimized. Responses were similar between environments at maximal effort
Colado et al. (2013)	Compare muscular activation performed at maximum velocity with different devices and different depths	24 young fit men, 23.2 ± 1.18 y old	"Shoulder extensions" LD, RA and PA	The xiphoid depth was a better choice for maximum muscle activation than clavicle depth.
Kaneda et al. (2009)	Investigate the activity of hip and trunk muscles during 3 conditions	9 healthy men, 25.1 ± 2.3 y old	"Deep-water running", "water walking" and "land walking" AL, GM, GMa, RA, OE, and PA	A higher percentage of maximal voluntary contraction was showed during deep-water running when compared to the water and land walking
Kelly et al. (2000)	Compare the muscle activation of the rotator cuff and shoulder synergists in water or on dry-land.	6 men, 24.0 ± 2.75 y old	Elevation in the scapular plane with neutral humeral rotation	Shoulder elevation in the water at slower speeds resulted in lower activation of the rotator cuff and synergistic muscle
Masumoto et al. (2004)	Describe muscle activities while walking in water with and without water current and on dry-land	6 healthy men, 23.3 ± 1.4 y old	"Walking" GM, RF, VM, BF, TA, GA, RC, and PA	Muscle activities decrease while walking in water with and without a water current, compared to dry-land
Müller et al. (2005)	Compare the muscle activities in water and dry-land	20 young healthy women	"Sit-up" RF and OE	The activity of the RF at maximum speed in water was lower than on dry-land
Myoshi et al. (2004)	Compare the changes in neuromuscular response during walking in water and on land	15 healthy men, 22.8 ± 4.5 y old	"Walking" MG, TA, BF and RF	Neuromuscular activities of MG and BF increased as in-water walking speed increase.
Shono et al. (2007)	Determine the characteristics of muscle activity during water and land walking treadmill	8 elderly women, 61.4 ± 3.9 y old	"Treadmill walking" TA, MG, VM, RF, and BF	Muscle activity of TA, VM, and BF was higher when compared to land walking.

Note: AL, adductor longus; BF, biceps femoris; GA, gastrocnemius; GM, gluteus medius, GMa, gluteus maxima; LD, latissimus dorsi; MG, medial gastrocnemius; OE, obliqus externus abdominis; RA, rectus abdominis; RF, rectus femoris; TA, tibialis anterior; VL, vastus lateralis; VM, vastus medialis; ST, semitendinosus; PA, paraspinal muscles; y old, years-old.

Interestingly, a lower muscle activation at submaximal cadences is equal to a lower VO_2 (Alberton et al., 2011).

By using maximal velocity, i.e., maximal efforts (Alberton et al., 2011), the neuromuscular response in water is optimized. Moreover, at least five studies suggested that increasing the pace, likewise will increase the EMG amplitude during in-water walking and water-resistance exercises (Alberton et al., 2011; Kaneda, Sato, Wakabayashi, & Nomura, 2009; Kelly et al., 2000; Masumoto et al., 2004; Myoshi et al., 2004).

From another perspective, some research groups aimed to analyse the acute neuromuscular response with equipment and compare it in different environments. Water-resistance exercises for upper-limbs lead to increased drag force (Barbosa et al., 2009). Colado et al. (2013) noted that the small devices (i.e., higher velocity and lower drag force) and large devices (i.e., lower velocity and higher drag force) present a similar muscle activation. Alberton et al. (2011) and Kelly et al. (2000) showed similar EMG amplitudes when comparing the muscle activation between environments (i.e., in-water and on dry-land).

The neuromuscular response to water fitness exercises remains elusive. Understanding how different exercises and extensions and the different types of equipment, according to the main focus of the session (e.g., development of strength, cardiovascular system, etc.) should be addressed in future interventions.

Table 4.

Summary of water fitness strength studies

Authors (year)	Aim	Subjects	Duration & Variables	Main Findings
Butelli et al. (2015)	Compare the effects of single vs. multiple sets WRT on maximal dynamic strength	21 healthy young men	10 weeks E_{FLE}, E_{EXT}, K_{FLE}, K_{EXT}, PD, and IPD (1-RM)	Upper- and lower-limbs maximal dynamic strength increased after 10 weeks. Improvement in strength was independent of the sets number (i.e., single vs. multiple)
Colado et al. (2009a)	Analyse the effects of a short-term periodized WRT on upper-limb maximum strength,	20 young men, 21.2 ± 1.7 y old	8 weeks vertical and horizontal RW, BP, arm lateral raise and squat-jump	Fit young men increased strength after 8 weeks of WRT.
Colado et al. (2009b)	Analyse the effects of 24 weeks of WRT with water resistance devices or elastic bands on physical capacity	46 healthy women	24 weeks Knee push-up test, 60-sec squat test, and abdominal crunch test (reps)	Aquatic exercise group increased muscle endurance after 24 weeks
Costa et al. (2018)	Compare the effects of water based aerobic training and WRT on muscular strength	69 elderly women	10 weeks K_{FLEX}, $E_{EXT,}$ and HSF (1-RM)	Elderly women increased maximal dynamic strength for lower-limbs after 10 weeks
Graef et al. (2010)	Compare the effects between WRT and without resistance control in water exercises	27 elderly women	12 weeks HSF (1-RM)	The WRT group increased the 1-RM for HSF (10.89%) after 12 weeks.
Katsura et al. (2009)	Evaluate the efficacy of aquatic exercise training using the new equipment for the elderly	20 elderly women, 69.1 ± 4.5 y old	8 weeks K_{EXT} (1-RM). P_{FLEX} and TA (1-RM, isometric strength)	Improvements were observed in muscle strength for P_{FLEX} after 8 weeks
Kieffer et al. (2012)	Determine the effects of a short-term novel multidimensional aquatic exercise program	26 elderly women and men	8 weeks Arm curl test and chair stand test (reps)	Water training group increased values on the arm curl test (24.5%) and chair stand test (28.8%) after 8 weeks
Neiva et al. (2018)	Analyse the effects of water aerobics programme in a real-life context on physical fitness	15 men and women, 69.1 ± 4.5 y old	12 weeks Chair stand test and push-ups test (reps)	Muscular endurance strength for the lower limbs increased after 12 weeks
Rafaelli et al. (2016)	Determine the effectiveness of a 9 weeks aquatic training programme on muscle strength	34 healthy young adult women, 26.4 ± 3.8 y old	9 weeks Sit-up test and push-up test (reps). K_{FLEX}, $K_{EXT,}$ and AA (1-RM)	Muscular endurance and maximal strength increased after 9 weeks
Santos et al. (2019a)	Analyse the PF, $RF_{D,}$ and SI during two incremental protocols of two water fitness exercises	22 healthy young women and men, 21.23 ± 1.5 y old	"Horizontal adduction" and "Rocking horse" PF, $RF_{D,}$ and SI	The music cadence of 135 $b \cdot min^{-1}$ showed an optimal RF_D without compromising the motion pattern. Horizontal adduction demonstrated a symmetric motion
Santos et al. (2019b)	Analyse and compare the PF between two basic head-out water exercises	29 young healthy women and men, 21.7 ± 1.9 y old	"Horizontal adduction" and "Rocking horse" PF	PF was higher for horizontal adduction. PF in the dominant upper limb was higher than on non-dominant upper-limb for both exercises
Souza et al. (2010)	Analyse the effects of a WRT upon muscle strength	20 adult women	11 weeks K_{FLEX}, K_{EXT}, H_{AD}, H_{ABD}, RW, and BP (1-RM)	Maximal dynamic strength increased between 12.53 ± 9.28% to 25.90 ± 17.84% for all exercises.
Takeshima et al. (2012)	Determine the physiological responses to a well-rounded exercise programme performed in water	30 elderly women and men	12 weeks K_{FLEX}, K_{EXT}, chest press/pull, and lumbar flexion/extension (1-RM)	Maximal dynamic strength increased between 6 to 18% for all exercises.
Tsoulou et al. 2006	Determine the effectiveness of a water training programme on isometric and dynamic muscle strength	22 elderly women	24 weeks K_{FLEX}, K_{EXT}, GS (isometric strength). Chest press/pull, K_{EXT} and leg press (3-RM)	Improvements were found in K_{EXT} (10.5%), K_{FLEX} (13.4%) GS (13%) and 3-RM (25.7–29.4%) after 24 weeks.

Note: $b \cdot min^{-1}$, beats per minute; RM, repetition maximum; AA, abduction of arms; BP, bench press; E_{FLE}, elbow flexion, E_{EXT}, elbow extension; GS, grip strength; H_{AD}, hip adduction; H_{ABD}, hip abduction; HSF, horizontal shoulder flexion; K_{FLE}, knee flexion; K_{EXT}, knee extension; PD, peck deck; PF, propulsive forces; P_{FLEX}, plantar flexion; RF_D, rate of force production for dominant upper limb; reps, repetitions; RW, row; SI, symmetry index; TA, tibial anterior; WRT, water resistance training; y old, years-old.

Strength

The water-resistive properties can lead to the enhancement of muscular strength. With this in mind, one has to consider two crucial aspects: (i) the force applied in the water during exertion; and (ii) the possible gains obtained in dry-land strength by the implementation of water fitness sessions. Few interventions attempted to find the optimal relationship between the force applied in water and the music cadence to promote a segmental action without compromising the pattern of motion. The horizontal adduction and the rocking horse elicited propulsive force values near 50 N at 150 b•min-1 cadence (Santos et al., 2019b). The propulsive force production increases to follow the music cadence increments while young-healthy subjects reached ≈68% of the maximum force acquire in dry-land (Santos et al., 2019a). The same authors considered that the musical cadence of 135 b•min^{-1} promoted a desirable relative force production to build-up strength without leading to an asymmetric motion.

Positive effects due to water training have been reported as well. Programmes were designed with 8 (e.g., Kieffer et al., 2012) and 12 weeks of duration (e.g., Neiva et al., 2018). At least one study reported a programme with 24 weeks showing improvements in isometric and dynamic strength of upper- and lower limbs (Tsourlou et al., 2006).

Here, most of the studies selected dry-land tests to evaluate muscle endurance (e.g., sit-up test, push up test) and muscular strength (e.g., 1RM, isometric strength). In addition, some studies reported the use of elastic bands and water specific devices (Colado et al., 2009b; Graef et al., 2010) to increase the effort intensity (i.e., by increasing the drag force). Similarly, there is evidence that the increase of limb velocity (i.e. frequency of movement) will increase water resistance (Barbosa et al., 2009). Thus, water fitness practitioners are prone to use the music cadence to elicit the highest exertion. For instance, Souza et al. (2010) reported an increase in isometric strength for upper- and lower-limbs after a programme of 11 weeks and based on water resistance training at a maximum speed of effort.

Improvements in muscle strength were reported for different cohorts, such as: (i) active young men (Butelli et al., 2015; Colado et al., 2009a; Souza et al., 2010); (ii) active young women (Rafaelli et al., 2016); (iii) elderly women (Costa et al., 2018; Graef et al., 2010; Takeshima et al., 2002; Tsourlou et al., 2006); and (iv) elderly women and men (Katsura et al., 2010; Kieffer et al., 2012). It should be expected an improvement near 6-11% in elderly strength after approximately 10-12 weeks of water programs (Costa et al., 2018; Graef et al., 2010).

Despite the well-documented positive benefits of strength parameters on youth and the elderly (Prado et al., 2016), the majority of the studies assessed changes in strength using a dry-land set up. At this point, and considering the tech improvement, we are ready to see if those improvements in strength are reached both in dry-land and in-water actions. Future research needs to go deeper and compare the evolution of propulsive forces with dry-land strength. This can be done while considering the gender effect. Plus, this will allow monitoring the consistency of different exercise methods (i.e. different volumes, repetitions, basic exercises and extended programme durations).

CONCLUSION

There was a larger amount of evidence on strength, whereas some gaps in the body of knowledge still persist in the remaining topics (kinematics, ground reaction force, and neuromuscular responses). The existent studies cover a large range of age brackets (from young adults to elderly). Women were recruited more often than men to be part of the studies. The effect of music cadence, body segments, exercise type (e.g., alternated or simultaneous), water depth, resistance equipment and training protocols were the main parameters under research.

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