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Physiological Responses and Perceived Effort of Older Women When Using Different Buoyant Dumbbells in a Water Fitness Exercise: A Pilot Study

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Abstract

Background/Objectives: The use of buoyant equipment in water fitness sessions appears to elicit a more intense physiological response in water exercises. However, it remains unknown whether the shape of the equipment influences these responses. The present study aimed to analyze and compare the physiological responses and perceived effort while older women using different buoyant dumbbells during horizontal adduction/abduction of the upper limbs (HA exercise). Methods: Ten older women (76.1 ± 5.3 years of age) attended two assessment sessions to perform HA exercise at a music cadence of 120 bpm with different buoyant dumbbells (one pair for each session): round hydro and hydro crystal. Mean heart rate (HR), systolic and diastolic blood pressures (SBP and DBP, respectively), double product (DPr), blood lactate concentration ([La$^-$]), and rate of perceived effort (RPE) were assessed according to pre-exercise (rest), warm-up and the HA exercise (five min effort). Results: The mean HR was also analyzed according to the percentage (%) of the predicted maximal theoretical HR (HRmax). Older women reached ~56 and 61% of HRmax using crystal and round dumbbells, respectively. Differences were found in mean HR, [La$^-$], and RPE with the round dumbbell showing greater values than the crystal dumbbell. Although no differences were found in SBP and DBP, DPr was higher when women used the round dumbbells. Conclusions: The shape of buoyant dumbbells seems to define acute responses of older women as the round dumbbell promotes a more intense physiological response and perceived effort when compared to the crystal dumbbell.

Keywords: aquatic exercise; equipment; upper limbs; heart rate; cardiovascular response; perceived exertion

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1. Introduction

Water fitness is recognized as an effective exercise mode due to improvements in the health and physical fitness of adults without chronic diseases [1]. This type of water program is designed according to the annual periodization, including sessions that typically comprise warm-up, conditioning, and cool-down phases [2]. Although the conditioning phase may include strength or muscular endurance, flexibility, neuromotor, or skill-related training components, this part of a typical session relies mostly on the cardiorespiratory component [3].

To achieve a desirable intensity/effort in water fitness sessions, instructors normally manage the type and duration of exercise, music cadence, number of body segments in action, and the additional equipment used [4]. Considering the principles of hydrodynamics (e.g., density, hydrostatic pressure, buoyancy), any movement in water results in high and low pressures in front and behind (respectively) of the body/object, which leads to increased resistance due to the change in flow, from laminar to turbulent [5]. The velocity and the surface area are the key factors that will define the necessary force exerted to overcome the water resistance due to the multidirectional load [6]. Within this, a feasible way to increase the cardiorespiratory component (physiological responses) is by manipulating the number of body segments or using floating and drag equipment at several music cadences [4,7].

Although acute physiological responses derived from water fitness exercise have been widely reported considering the effects of music cadence on a broad range of ages [8], little is known about when additional equipment is used. Available studies focus mainly on understanding acute responses while practitioners use dumbbells [7,9,10] or ankle shins [7,10–12] during water fitness exercises. At least for young women, the use of Aquafins® on both upper and lower limbs has been shown to trigger higher oxygen uptake, heart rate, and perceived exertion, compared to when used alone on the upper or lower limbs [12]. On the other hand, exercising two limbs with dumbbells (upper limbs) or leggings (lower limbs) appears to be more intense for young women than using all four limbs simultaneously without any equipment [7]. However, using dumbbells in the upper limbs with simultaneous action of the four limbs leads to a higher physiological response [9]. Nevertheless, it is still unclear whether these responses may rely on the shape of the equipment as the surface area impacts the resistance and, consequently, the physiological response.

Despite most water fitness sessions comprising heterogeneous groups, older people are the common target group of this type of program [13]. So, it remains unanswered whether different shapes of buoyant dumbbells affect physiological and perceived effort responses, especially at older ages. Thus, this study aimed to analyze and compare the physiological responses and perceived effort while older women use different buoyant dumbbells during horizontal adduction/abduction of the upper limbs. It was hypothesized that, based on the surface area, different types of dumbbells would promote different physiological responses and perceived effort.

2. Results

The HRmax of older women was 154.7 ± 3.7 bpm. The pre-exercise physiological characteristics between the two sessions are shown in Table 1. Despite large differences being found in [La^-], the mean HR and the blood pressures were similar between both sessions.

Table 1. Descriptive statistics and comparison of physiological variables between the two sessions at the pre-exercise moment.

Variables	Session		Mean Difference (95% CI)	*t* Test (*p*)	ES
	1	2			
Mean HR (bpm)	71.8 ± 12.2	68.8 ± 6.7	3.0 (−3.5 to 9.6)	1.06 (0.318)	0.29
Mean HR (%)	46.3 ± 7.1	44.4 ± 3.7	1.9 (−2.2 to 6.0)	1.05 (0.322)	0.32
[La⁻] (mmol/L)	2.0 ± 0.5	2.3 ± 0.4	−0.3 (−0.4 to −0.1)	−3.77 (0.004)	0.63
SBP (mmHg)	127.2 ± 9.4	123.1 ± 12.4	4.1 (−6.4 to 14.6)	0.88 (0.402)	0.36
DBP (mmHg)	74.1 ± 8.7	72.5 ± 8.8	1.6 (−4.8 to 8.0)	0.57 (0.586)	0.18

ES, effect size; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure; [La⁻], blood lactate concentration.

Table 2 depicts the comparison of physiological and perceived effort responses when using the two types of dumbbells. Large differences were found in mean HR during HA exercise as well as immediately after in [La⁻] and RPE. While warm-up showed a similar response, allowing to reach ~60 of HRmax, the five min effort allowed a response around 61% and 56% of HRmax while older women performed the HA with the round and the crystal dumbbells (respectively). A greater perceived effort accompanied by a higher [La⁻] value was also found for round dumbbells. Although no differences were found in SBP and DBP, DPr was higher when older women used the round dumbbells (round: 13,315.0 ± 1786.5 vs. crystal: 11,615.8 ± 1585.4; mean difference [95% CI]: 1699.2 (116.2 to 3282.2; *t* test [*p*]: 2.42 (0.038); ES: 0.96)).

Table 2. Descriptive statistics and comparison of physiological and perceived effort responses when using the two types of dumbbells in different moments.

Variables	Moment	Dumbbells Type		Mean Difference (95% CI)	*t* Test (*p*)	ES
		Round	Crystal			
Mean HR (bpm)	Warm-up	91.7 ± 14.5	92.9 ± 15.4	−1.25 (−7.4 to 4.9)	−0.46 (0.656)	0.08
	HA exercise	94.6 ± 9.9	87.2 ± 9.3	7.4 (3.1 to 11.6)	3.94 (0.003)	0.74
Mean HR (%)	Warm-up	59.1 ± 8.2	59.9 ± 8.7	−0.8 (−4.8 to 3.2)	−0.4 (0.665)	0.09
	HA exercise	61.1 ± 5.4	56.3 ± 4.9	4.8 (1.9 to 7.5)	3.89 (0.004)	0.89
SBP (mmHg)	HA exercise	139.9 ± 12.8	133.4 ± 14.4	6.5 (−6.5 to 19.5)	1.13 (0.288)	0.46
DBP (mmHg)	HA exercise	77.6 ± 9.2	75.6 ± 9.5	2.0 (−4.9 to 8.9)	0.66 (0.527)	0.20
[La⁻] (mmol/L)	Warm-up	3.0 ± 0.8	3.2 ± 0.6	−0.22 (−0.6 to 0.2)	−1.29 (0.231)	0.27
	HA exercise	4.0 ± 0.5	3.2 ± 0.7	0.78 (0.5 to 1.0)	7.34 (<0.001)	1.26
RPE	HA exercise	12.5 ± 0.8	11.4 ± 0.9	1.10 (0.4 to 1.8)	3.50 (0.007)	1.24

ES, effect size; DBP, diastolic blood pressure; HA, horizontal adductions/abductions of upper limbs; HR, heart rate; RPE, rate of perceived effort; SBP, systolic blood pressure; [La⁻], blood lactate concentration.

3. Discussion

This study aimed to analyze and compare older women's physiological responses and perceived effort when using different buoyant dumbbells during horizontal adduction/abduction of the upper limbs in the water. The shape of buoyant dumbbells seems to define the physiological responses and perceived effort, with the round dumbbell showing a higher response than the crystal dumbbell. Although older women achieve around 61% and 56% of their HR max with round and crystal dumbbells, the cardiovascular response (SBP and DPB) remains similar.

Acute physiological responses in water fitness exercises are dependent on the unique characteristics of the aquatic environment [4,5]. Although the type and duration of exercise, music cadence, number of body segments in action, and the additional equipment used can define the physiological demands [8], other variables can also contribute to a more demanding effort. For instance, the effect of body immersion, water or air temperature, and humidity influence body temperature, oxygen consumption, blood pressure, heart rate, blood lactate, and RPE [4,14,15]. This may explain the fact that [La^-] was different between the two experimental sessions in pre-exercise condition. Although body immersion and water temperature were strictly controlled during warm-up and HA exercise, the air temperature was not measured and could have changed from one session to another. However, it can be argued that the same condition was guaranteed as before the HA exercise (i.e., at the warm-up), and [La^-] response was similar between both sessions.

The use of equipment is widely included in water fitness sessions, mainly to provide diversity in the planned exercises. Floating or drag equipment used during jumping jacks [11], aquatic skiing [11,12], rocking horse [9], frontal kick, or horizontal adduction/abduction [7] seems to promote higher physiological responses. Although previous studies compared the effort characteristics of the subjects using or not using equipment or even while using different types of equipment, an in-depth analysis of how the shape of the same equipment influences physiological responses is still unknown. At least for competitive swimming, studies have been conducted to understand how body/hand shapes, caps or goggles influence performance (e.g., [16]). For instance, higher resistance is obtained when the hand adopts an angle attack of approximately 90° (i.e., nearly perpendicular to the flow) [17], whereas adopting a position of the hand with fingers slightly spread allows to apply higher propulsive forces during swimming [18]. Thus, increasing the surface area given by a body limb or equipment will allow for greater water resistance, promoting higher hydrodynamic forces [19]. This happens in the round compared to the crystal dumbbell, as the area opposed to the fluid direction differs between both equipment.

The American College of Sports Medicine guidelines recommend that the development of the cardiorespiratory component should be within 60% and 90% (moderate to vigorous intensity) of HRmax by targeting large groups of muscles [20]. During HA exercise, older women reached ~56% and 61% HRmax, translating into light and moderate intensity using crystal and round dumbbells, respectively. However, light (~57% of HRmax) [7] and vigorous (~91%) [9] intensity have been reported when young women performed the HA exercise with round dumbbells in a static or dynamic position, respectively. These mixed findings can be underpinned by the age of practitioners (older vs. young), the music cadence (136 bpm and 132 bpm vs. 120 bpm), and the type of exercise (static or dynamic). Notwithstanding, the results of the present study should be analyzed with caution since HRmax was estimated using the formula of Tanaka et al. [21], which does not consider immersion bradycardia [22].

Results showed that round dumbbells promote higher physiological demand during the HA when compared to the crystal dumbbells dictated by mean HR (bpm and % of HRmax) and DPr values. Although crystal dumbbells present a higher diameter based on their extremities, the total surface area is smaller than round dumbbells. These results are in line with a previous study that aimed to compare floating and drag equipment for lower limbs [11]. The authors found that drag ankle shins promote higher HR when compared to floating ankle shins during jumping jacks or water ski exercises at the same cadence. However, Pinto et al. [10] demonstrated that the use of floating equipment (round dumbbells with ankle shins) promotes similar HR activity when compared to drag equipment positioned in all body limbs. Although some equipment presents a small surface area related to the area of the body limb [12], one can argue that the drag coefficient associated with the increase in surface area was sufficient to influence the magnitude of the resistance given by the water, leading to a higher physiological response when using the round dumbbells. Notwithstanding, it should be noted that differences between dumbbells were only ~8 bpm, but it was demonstrated that a 10 bpm change in mean HR for a given workload may indicate a more demanding effort. Also, despite an unchanged SBP, the higher HR contributed to a higher DPr when using the round dumbbell, denoting a higher cardiovascular demand. Still, this was within the acceptable limit for cardiac muscle activity and under this population's dangerous zone of cardiac stress [23].

Although it has been suggested that the music cadence between 130 and 150 bpm can be the most suitable to elicit the aerobic energetic pathway [8], some intra- and inter-individual responses should be considered by water fitness practitioners and researchers. For instance, during the HA exercise with round dumbbells, young women achieved $[La^-]$ of ~4 and 6 mmol/L [7,9]. In fact, the results obtained by Costa et al. [7] seem to be similar to those found in the present study for round (~4 mmol/L) and crystal (~3.2 mmol/L) dumbbells. However, the intensity provided by the music cadence was higher (i.e., 132 bpm) in such studies, which can explain the similar response found between the studies with different age cohorts. Despite this, the results of the present study point out that the shape of dumbbells influences the $[La^-]$ and should be considered by the water fitness instructors while planning the intensity progression within or between their sessions.

The RPE provides an individual's exercise intensity based on their perception of exertion, fatigue, and physical stress in response to aerobic and resistance exercise [24]. Aquatic fitness literature has widely reported that it tends to be greater when the body is immersed in water, mainly when additional equipment is used [25]. Regarding the results of the present study, it seems that round dumbbells elicit a higher perception of effort (12.5) than the crystal dumbbell type (11.4), which corroborates the results of internal load (i.e., as shown by physiological measures). The older women had a greater sense of fatigue, meaning that the brain regulates the RPE well based on awareness of higher metabolic demands when using the round dumbbell.

Despite the novel findings, some limitations can be addressed in this study as follows: (i) the small sample size may not allow generalization for the conclusion; (ii) the uncontrolled effect of air temperature that may had little effect on the physiological measures at rest; (iii) the range of motion was controlled based on visual inspection using verbal cues and not assessing kinematics; (iv) the HRmax was estimated, instead of directly assessed, without considering immersion bradycardia; and (v) use of only one exercise and one musical cadence. Future studies should try to compare the physiological responses from different age cohorts working with the same floating or drag equipment in a broad range of exercises and music cadences, understand responses with different dumbbell shapes (e.g., square, triangular, block, hexagonal, axis) or even try to understand the long-term physiological adaptations using these kinds of devices.

4. Materials and Methods

4.1. Participants

Ten older women (76.1 $\pm$ 5.3 years of age, 62.8 $\pm$ 4.8 of body mass, 154.3 $\pm$ 3.9 cm of height, and 26.3 $\pm$ 1.8 of body mass index) were recruited from a local swimming center who were enrolled in the same regular water fitness program. The inclusion criteria were defined as follows: (i) women aged $\geq$ 65 years; (ii) physically active, with at least two years of experience in water fitness programs; (iii) be able to complete the protocol without failure; and (iv) have not been diagnosed with an injury, condition, or syndrome of a specific nature in the last six months. All women were informed of the benefits and experimental risks prior to signing the informed consent. All procedures were in accordance with the Declaration of Helsinki with respect to human research.

4.2. Design and Experimental Protocol

Women attended two experimental sessions (sessions 1 and 2) on different days (48 h apart, corresponding to their weekly water fitness lessons) and data collection was held at a 12.5 m indoor pool with a water temperature of 30 °C. All women were instructed to abstain from intense exercise the day prior, and tests were performed at the same time of the day to avoid systematic bias due to fatigue and circadian variation.

Participants were instructed to perform one water fitness exercise with different buoyant dumbbells (one pair for each session; Figure 1): (i) round hydro (15 cm × 6 cm, 440 cm^2, Golfinho Sports, Coimbra, Portugal); and (ii) hydro crystal (21.5 cm × 6 cm, 365 cm^2, Golfinho Sports, Coimbra, Portugal). After a 3 min warm-up in each session (prescribed by a certified water fitness professional), the women were instructed to perform horizontal adductions/abductions of upper limbs (HA) for 5 minutes (min) to reach the cardiovascular steady state [7]. The HA exercise is characterized as maintaining a static trunk with lower limbs fixed to the ground (one in front of the other) when performing the adductions/abductions [19]. The upper limbs were extended during motion and the hands positioned at the middle of dumbbells grip at a 90° angle of attack. However, a slight elbow flexion during the motion was allowed to avoid injuries.

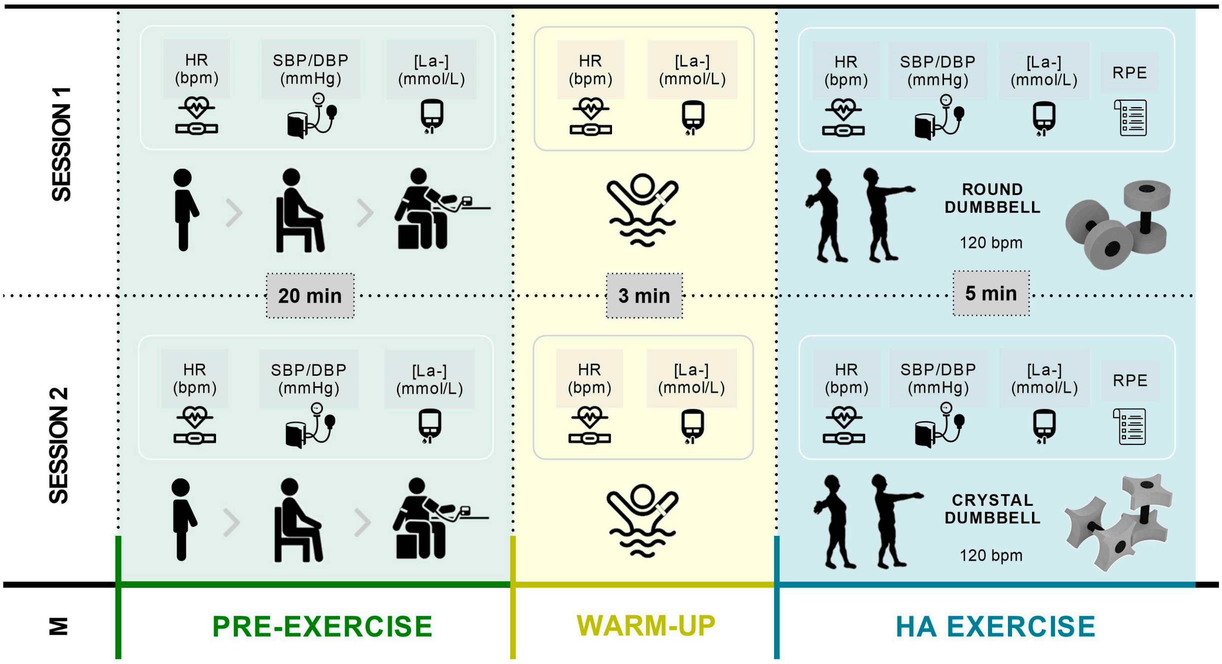

Figure 1. Overview of the experimental setup in sessions 1 (round dumbbell) and 2 (crystal dumbbell). DBP, diastolic blood pressure; HA, horizontal adductions/abductions of upper limbs; HR, heart rate; M, moments; RPE, rate of perceived effort; SBP, systolic blood pressure; [La$^-$], blood lactate concentration.

The protocol (warm-up and HA exercise) was performed with bodies immersed in the water up to the xiphoid process (i.e., near breast level). The HA exercise was controlled by a metronome (Korg, MA-30, Tokyo, Japan) plugged into a sound system and the cadence was set at 120 bpm. A pilot study comprising three music cadences (105 bpm, 120 bpm and 130 bpm) was applied two weeks before the data collection. All women were familiar with the concept of "water tempo" and the two type of dumbbells, but verbal and visual feedback was also given during all protocol.

4.3. Data Collection

Cardiovascular responses were assessed by using the heart rate (HR, in bpm), and systolic and diastolic blood pressures (SBP and DBP, respectively; in mmHg) and double product (DPr) [26]. All variables were considered according to three moments (Figure 1): (1) pre-exercise (rest; dryland); (2) warm-up (in-water); and (3) HA exercise (five min effort; in-water). The pre-exercise moment was considered to understand if cardiovascular responses were similar between the two experimental sessions. The mean HR at pre-exercise, as well as during the warm-up and HA exercise, was assessed with a Polar OH1+ optical HR sensor (sampling frequency: 135 Hz; Polar Electro, Kempele, Finland) placed on the upper arm. At rest, women were instructed to remain relaxed and breathe normally without speaking for 20 min. HR data were stored in the internal memory of the Polar OH1+ optical HR sensor and uploaded to Polar Flow (Polar Electro Oy, Kempele, Finland). After a visual data inspection, data were exported to a Microsoft Excel spreadsheet (Microsoft 365, Microsoft Corporation, Redmond, WA, USA). The mean HR was also analyzed according to the percentage (%) of the predicted maximal theoretical HR (HRmax = 208 − 0.7 × age) [21].

The SBP and DBP were assessed at pre-exercise and immediately after the HA exercise by using a sphygmomanometer (Erka, model D-83646, Bad Tölz, Germany) and a Littmann® stethoscope (Classic III, 3M™ Littmann®, St. Paul, MN, USA). Women remained relaxed and seated on a chair with one arm on a table in both sessions, and the assessments were conducted by a certified technician. Afterwards, the analysis comprised the estimation of DPr (DPr = HR × SBP) [26] being used as a measure for myocardial oxygen consumption [7,23].

Blood lactate concentration ($[La^-]$, in mmol/L) was collected from capillary blood samples (25 µL) in the same fingertip at the pre-exercise, as well as immediately after the warm-up and the HA exercise. Samples were collected using an auto-analyzer (Lactate Pro 2, Arkay Inc., Kyoto, Japan). After the HA exercise, samples were collected at minute 1, and every 2 min until the peak was reached. The rate of perceived effort (RPE) was also assessed immediately after the HA exercise by using the Borg 6-20 scale (auto-reported) [27].

4.4. Statistical Analysis

The Shapiro–Wilk test was used to assess the normality of data. The mean, one standard deviation (M ± 1SD), and 95% confidence intervals (95% CI) were computed as descriptive statistics. A dependent *t*-test was used to compare the two experimental conditions (i.e., round vs. crystal dumbbell) in all variables. Cohen's d was selected as an effect size (ES) and interpreted as trivial if $|d| < 0.2$, medium if $0.2 > |d| < 0.5$, and large if $|d| \geq 0.5$ [28]. All statistical analyses were performed using the SPSS software (version 27) and the statistical significance was set at $p \leq 0.05$.

5. Conclusions

It can be concluded that the shape of buoyant dumbbells seems to define the physiological responses and perceived effort in older women during a water fitness exercise. The round dumbbell triggers a more intense physiological response and perceived effort when compared to the crystal dumbbell, with the mean heart rate reaching about 60% of the predicted maximum value. So, water fitness instructors should plan their sessions by progressing in the way they choose the different dumbbells over time or even how they deliver different dumbbell types according to the participants' conditioning within a heterogeneous group working at the same intensity.

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Abbreviations

The following abbreviations are used in this manuscript:

HA	Horizontal adduction/abduction of the upper limbs
HR	Mean heart rate
HRmax	Predicted maximal theoretical HR
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
DPr	Double product
RPE	Rate of perceived effort
$[La^-]$	Blood lactate concentration

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