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Fuerza de reacción vertical del suelo del ejercicio acuático de patada frontal realizado por mujeres: efectos de la edad

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Resumen

Antecedentes: Aumentar el conocimiento sobre las fuerzas que actúan en diferentes ejercicios acuáticos en mujeres de diferentes edades es importante para una prescripción más eficaz e individualizada. **Objetivos:** comparar la fuerza de reacción del suelo durante el ejercicio aeróbic acuático de patada frontal realizado a diferentes cadencias entre mujeres jóvenes y posmenopáusicas. **Método:** la muestra estuvo compuesta por 24 mujeres, 12 mujeres jóvenes (23,7 ± 3,6 años) y 12 mujeres posmenopáusicas (57,3 ± 2,6 años). Para determinar la fuerza de reacción vertical del suelo de pico y el impulso, las voluntarias realizaron el ejercicio de patada frontal a diferentes cadencias (80, 100 y 120 b.min^{-1}). Para el análisis de datos, se utilizó una ANOVA de dos vías (α = 0,05). **Resultados:** se observó un aumento en la fuerza de reacción del suelo de pico de la cadencia de 80 b.min-1 para las cadencias más altas (p < 0,001). Las mujeres jóvenes tenían valores de fuerza de reacción del suelo de pico más altos en comparación con las mujeres posmenopáusicas (p = 0,012), lo que demuestro que las mujeres posmenopáusicas tenían valores de fuerza de reacción del suelo de pico de 78-82% en comparación con las mujeres jóvenes. Además, se observó una reducción del impulso a cadencias más altas (p < 0,001), con valores similares entre grupos (p = 0,835). **Conclusiones:** las mujeres posmenopáusicas presentaron valores más bajos de fuerza de reacción del suelo de pico (0,65-0,75 PC) e impulso similar (94-133 N·s) en comparación con las mujeres jóvenes, por lo tanto, el ejercicio evaluado puede considerarse de baja probabilidad de lesiones musculoesqueléticas, independientemente de la cadencia de ejecución.
Palabras clave: ambiente acuático; hidroterapia; envejecimiento; cinética.

Abstract: Vertical ground reaction force of the water-based exercise frontal kick performed by women: age effects

Background: Increasing knowledge about the forces that act in different aquatic exercises in women of different ages is important for a more effective and individualized prescription. **Goals:** To compare the vertical ground reaction force during the water-based frontal kick exercise performed at different cadences between young and postmenopausal women. **Method:** Twenty-four participants, twelve young (23.7 ± 3.6 years) and 12 postmenopausal women (57.3 ± 2.6 years), voluntarily completed a session with frontal kick performance in the aquatic environment (cadences 80, 100, and 120 b.min^{-1}) to determine peak and impulse of vertical ground reaction force. Repeated measures two-way ANOVA was used (α = 0.05). **Results:** The peak vertical ground reaction force increased from 80 b.min-1 to the higher cadences (p < 0.001). In addition, young showed greater peak vertical ground reaction values than the postmenopausal women (p = 0.012), revealing that postmenopausal women presented 78-82% of peak vertical ground reaction values observed for young women during water-based frontal kick exercise. Moreover, it was observed a reduction in impulse with the increasing cadence (p < 0.001), with similar values between young and postmenopausal women (p = 0.835). **Conclusions:** These findings highlight the safety of the water-based exercise for postmenopausal women since lower peak vertical ground reaction (0.65-0.75 BW) and similar impulse (94-133 N·s) values were observed in comparison to the young ones, considered as low odds for musculoskeletal injuries, regardless the cadence of performance.
Keywords: aquatic environment; hydrotherapy; aging; kinetics.

Resumo: Força de reação do solo vertical do exercício de hidroginástica chute frontal realizado por mulheres: efeitos da idade

Introdução: Aumentar o conhecimento sobre as forças que atuam em diferentes exercícios aquáticos em mulheres de diferentes idades é importante para uma prescrição mais eficaz e individualizada. **Objetivos:** comparar a força de reação do solo durante o exercício de hidroginástica chute frontal realizado em diferentes cadências entre mulheres jovens e na pós-menopausa. **Método:** a amostra foi composta por 24 mulheres, 12 mulheres jovens (23,7 ± 3,6 anos) e 12 mulheres na pós-menopausa (57,3 ± 2,6 anos). Para determinar a força de reação do solo vertical de pico e o impulso, as voluntárias realizaram o exercício de hidroginástica chute frontal em diferentes cadências (80, 100 e 120 b.min^{-1}). Para análise dos dados foi utilizada uma ANOVA de dois caminhos (α = 0,05). **Resultados:** Foi observado um aumento da força de reação do solo de pico da cadência de 80 b.min-1 para as maiores cadências (p < 0.001). As mulheres jovens apresentaram maiores valores de força de reação do solo de pico em comparação as pós-menopáusicas (p = 0,012), com valores para as pós-menopáusicas correspondentes a 78-82% dos observados para as jovens durante o exercício chute frontal. Além disso, foi observada uma redução do impulso nas maiores cadências (p < 0,001), com valores semelhantes entre os grupos (p = 0,835). **Conclusões:** as mulheres na pós-menopausa apresentaram menores valores de força de reação do solo de pico (0,65-0,75 PC) e impulso semelhante (94-133 N·s) em comparação às jovens, logo, pode-se considerar o exercício avaliado como sendo de baixa chance de lesões musculoesqueléticas, independentemente da cadência de execução.
Palavras chaves: meio aquático; hidroterapia; envelhecimento; cinética.

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Introduction

The aquatic environment is conducive to physical exercise since water resistance is multidirectional, promoting an overload against movements performed in all directions (Torres-Ronda & del Alcázar, 2014). This high muscle overload is elicited with a low osteoarticular load due to buoyancy, which promotes a reduction in the apparent weight of the immersed individuals corresponding to ~70% at xiphoid process depth (Harrison, Hillman, & Bulstrode, 1992; Alberton, et al., 2013). This fact influences the exercise performance, as lower vertical ground reaction force (Fz) values have been observed in different exercises performed in the aquatic environment in comparison to dry land, such as water-walking and running (Barela, Stolf, & Duarte, 2006; Harrison, et al., 1992; Miyoshi, Shirota, Yamamoto, Nakazawa, & Akai, 2004; Orselli & Duarte, 2011), water-based vertical jumps (Colado, et al., 2010; Dell'Antonio, et al., 2016; Louder, Bressel, Nardoni, & Dolny, 2017) and water-based exercises (Alberton, et al., 2015; Alberton, et al., 2013; de Brito Fontana, et al., 2012; Fontana, Ruschel, Haupenthal, Hubert, & Roesler, 2015; Alberton, et al., 2015; de Brito Fontana, et al., 2018).

Middle-aged and older women are the main practitioners of water fitness programs. Nevertheless, the literature regarding Fz responses during aquatic exercises in this population is scarce. The advancing age greatly impacts muscle size and strength (Mitchell, et al., 2012). These declines are associated with an impairment in functional capacity, affecting the performance of daily living activities (Aagaard, Suetta, Caserotti, Magnusson, & Kjaer, 2010; Christensen, Doblhammer, Rau, & Vaupel, 2009). In addition, aging is associated with increased adipose tissue (Snijders, Verdijk, & van Loon, 2009). Such effects are more pronounced in women during and after menopause due to a reduction in the estrogen hormone, associated with increased abdominal and visceral fat, resulting in a total body weight change (Franklin, Ploutz-Snyder, & Kanaley, 2009). These changes affect the practitioners' body fat percentage and, consequently, the apparent weight during immersion and the Fz during aquatic exercise performance.

However, to the best of the authors' knowledge, few studies were found in the literature with Fz analysis during aquatic exercises in middle-aged and older individuals (Barela & Duarte, 2008; Louder, Dolny, & Bressel, 2018; Alberton, et al., 2019). Barela and Duarte (2008) investigated the Fz during the water walking performed by older and young adults (mean age: 70 and 29 years, respectively) and revealed significantly lower Fz responses for the first peak along the Fz curve in older individuals, with values corresponding to ~0.35 body weight. Louder et al. (2018) evaluated the Fz during the water-based countermovement jump in middle-aged and young adult individuals (mean age: 57 and 22 years, respectively) and reported significantly lower Fz peak values during the propulsion phase in the oldest, with values corresponding to 3.8 body weight.

Regarding water-based exercises usually employed in water fitness programs, studies have observed Fz peak magnitudes ranging from 0.5 to 2.0 body weight in young men and women at submaximal and maximal intensities (Alberton, et al., 2015; Alberton, et al., 2013; de Brito Fontana, et al., 2018; de Brito Fontana, et al., 2012; Fontana, et al., 2015). The only study found in the literature investigating these types of aquatic exercise which investigated older women (~69 years) observed a Fz peak between 0.45 to 0.60 body weight in the stationary running exercise performed at submaximal and maximal intensity (Alberton, et al., 2019). Fz magnitude verified in these studies indicates that water-based exercises may be considered low odds for musculoskeletal injuries (Hayes & Myers, 1997).

Different aquatic exercises, such as water walking, jumping, or water-based exercises used in water fitness programs (e.g., stationary running, kicks, jumping jacks, cross country skiing), result in different Fz peak values due to their specific characteristics. The studies above-mentioned observed variation in the Fz outcome from 0.35 to 3.8 body weight for different types of aquatic exercise performed by middle-aged and older individuals (Barela and Duarte, 2008; Louder, et al., 2018). Thus, water-based exercise programs may provide a low-impact alternative to dry land for individuals who need practice exercises with low Fz loads, as it maintains a high neuromuscular stimulus for lower limb muscles (Alberton, et al., 2014).

The efficacy of water fitness programs in several health-related outcomes has been shown in postmenopausal and older population (Costa, et al., 2018; Pinto, et al., 2015; Silva, et al., 2018; Reichert, et al., 2018; Reichert, et al., 2019; Andrade, et al., 2020a; Andrade, et al. 2020b; Reichert, et al. 2020a; Reichert, et al. 2020b). Thus, improving the knowledge regarding Fz magnitude during different water-based exercises in middle-aged women is important due to their performance specificity. Therefore, the purpose of the present study was to compare the Fz during the water-based frontal kick exercise performed at different cadences between young and postmenopausal women.

Methods

The present study is a cross-sectional design, with data comparison of Fz peak and impulse in the water-based frontal kick exercise performed at different cadences (80, 100, and 120 $b.min^{-1}$) between women from different age groups, young and postmenopausal. The data presented are part of a larger research project que was conducted according to the ethical standards of the Declaration of Helsinki and was approved by the Local Research Ethics Committee (18817).

Participants

The sample comprised twenty-four participants, 12 young (20-30 years) and 12 postmenopausal women (52-62 years), who voluntarily took part in the study. As inclusion criteria, participants should be engaged in water-based programs during the preceding three months and be familiarized with the exercise employed in the study. In addition, the young group should have a regular menstrual cycle, and the postmenopausal group should not have had any menstrual cycle in the previous year. Exclusion criteria included any history of osteoarticular, musculoskeletal, and cardiovascular disorders, diagnosed by an anamnesis. All volunteers read and signed a written informed consent, containing all the information concerning the procedures and potential risks involved in the participation.

Procedures

An initial session was held for the anamnesis application and data collection of the sample characterization. Body mass and height measurements were obtained using an analogical medical scale and a stadiometer (FILIZOLA; Sao Paulo, Brazil). Afterward, participants performed a familiarization session with the exercise and cadences, in which all instructions about the care and range of movement that would need to be considered were given.

Frontal kick is a water-based exercise (Figure 1) widely used in water fitness programs, and its Fz responses have been previously investigated in the literature (Alberton, et al., 2015; Alberton, et al., 2014). This exercise is performed with a single support and flight phase. Participants should perform the lower limbs movement in two phases, in which each segmental action (hip flexion or extension) is performed in 1 beat corresponding to a support phase of one limb. The first phase corresponds to the right hip flexion to 45°, knee extension, and ankle plantar flexion starting the flight phase, followed by the right hip extension until the support phase. Lower limb movements are performed alternatingly while the upper limbs perform a light shoulder flexion followed by extension, with the elbow flexed to 90° to maintain corporal balance. The Fz data corresponding to the support phase of the right lower limb in each situation was measured.

The experimental protocol started with the measurement of the apparent weight in the aquatic environment with the participants immersed up to the xiphoid process. Then, individuals perform the water-based frontal kick exercise at three cadences, 80, 100, and 120 b.min^{-1}, each performed during 4 min in a random order, with 5 min intervals between them. Previous studies that evaluated physiological and biomechanical parameters during water-based exercises used these cadence ranges (Alberton, et al., 2011; de Brito Fontana, et al., 2012). Cadences were set using a digital metronome (MA-30, KORG; Tokyo, Japan). Participants performed the protocol barefoot in a swimming pool with the participants immersed up to the xiphoid process depth. Water temperature was maintained between 31 and 32°C.

Figure 1. Frontal kick water-based exercise

Fz was collected with a waterproof force plate (OR6-WP, AMTI; Watertown, USA) previously calibrated according to the manufacturer's specifications. The plate's capacity was 8900 N, the sensitivity was 0.08 μV/[V·N], and the useful working temperature ranged from -17 to +52°C. The sampling rate of the collected values was 500 Hz, and data were acquired using AMTIForce software. Then, files were exported for analysis with SAD32 software (Mechanical Measurements Laboratory, UFRGS; Porto Alegre, Brazil).

The digital signal was filtered using a third-order low-pass Butterworth filter with a cut-off frequency of 30 Hz. Slices corresponding to the first 10 repetitions were performed after the third minute of effort. Fz peak value (Fzpeak) was obtained from the selected repetitions, defined as the maximum value presented by the Fz occurring at any period from the beginning until the end of the cycle. Also, these data were normalized by body weight (BW) measured outside the water and presented as units of BW. Moreover, the impulse was obtained from the integral force-time for the same selected repetitions, and it will be presented as N·s. The five central valid repetitions were averaged to obtain the mean cycle for each participant in each situation. In addition, based on BW and apparent weight, the apparent weight reduction percentage was calculated.

Statistical Analysis

Descriptive statistics were used to report data using mean ± standard deviation (SD). Shapiro-Wilk and Levene tests were used to verify data normality and homogeneity. Paired sample T-tests were applied to compare characterization data between age groups. Two-way ANOVA wit repeated measures was employed to analyze Fzpeak and impulse values with Bonferroni post hoc tests. Effect sizes were calculated using η_p^2 for the main effects in each variable. An alpha level of 0.05 was adopted, and the SPSS program version 20.0 was employed in the análisis.

Results

Significant differences in age, height, body mass, body weight, and apparent weight reduction were observed between the young and postmenopausal women groups. However, similar apparent weight values were verified between groups (Table 1).

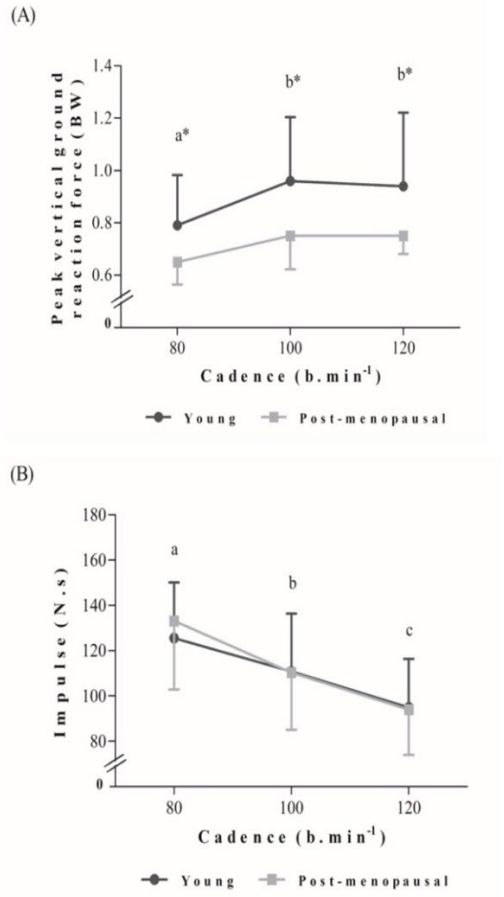
Table 1. Characterization data for young and postmenopausal women.

	Young women (n=12) Mean ± SD	Postmenopausal women (n=12) Mean ± SD
Age (years)	23.7 ± 3.6	57.3 ± 2.6*
Height (cm)	164.1 ± 7.1	158.1 ± 6.9*
Body mass (kg)	60.2 ± 5.1	69.1 ± 10.9*
Total body weight (N)	590.2 ± 50.5	669.2 ± 104.0*
Apparent weight (N)	176.7 ± 41.6	169.9 ± 55.4
AW reduction (%)	70.3 ± 5.5	74.9 ± 5.6*

Note: AW: Apparent Weight; * $p < 0.05$.

Regarding Fzpeak (Figure 2A), a significant increase was found from the cadence of 80 b.min-1 in comparison to the higher ones ($F_{(2;42)} = 9.964$; $p < 0.001$; $\eta_p^2 = 0.322$) for both age groups. In addition, the young presented Fzpeak values significantly greater than the postmenopausal women ($F_{(1;21)} = 7.656$; $p = 0.012$; $\eta_p^2 = 0.267$). Regarding impulse (Figure 2B), it was observed a significant reduction with the increasing cadence ($F_{(2;44)} = 110.500$; $p < 0.001$; $\eta_p^2 = 0.834$) for both age groups, with similar values between the young and the postmenopausal women ($F_{(1;22)} = .045$; $p = 0.835$; $\eta_p^2 = 0.002$). No significant interaction for age group*cadence was observed for Fzpeak and impulse variables.

Figure 2. Peak (A) and impulse (B) of vertical ground reaction force at different cadences between young and postmenopausal women.



Note: Graph A – Vertical axis express the peak vertical ground reaction force (Fzpeak) in units of body weight (BW). Graph B – Vertical axis express the impulse of vertical ground reaction force (Imp) in N·s. Different letters indicate significant differences between cadences (a ≠ b ≠ c). (*) indicates significant differences between groups.

Discussion

The purpose of the present study was to compare Fz values during the water-based frontal kick exercise performed at different cadences between young and postmenopausal women. The main findings were the lower Fzpeak values during the water-based exercise performance for the postmenopausal women group and the lowest evaluated cadence. In addition, impulse values were similar between age groups and reduced with the increasing cadence.

The present findings agree with those reported by Barela and Duarte (2008) and Louder et al. (2018), who investigated Fz values during water-walking and water-based jump, respectively, in older or middle-aged compared to young individuals. Louder et al. (2018) reported significantly lower Fzpeak values during the propulsion phase of the water-based countermovement jump in middle-aged individuals (~57 years) in comparison to young adults (~22 years). Barela and Duarte (2008) also showed lower Fz values in the first peak and impulse during the support phase of the water-walking for older individuals (~70 years) compared to young adults (~29 years), with similar values between groups in the second peak of Fz. Nevertheless, the latter study normalized the Fz values by the apparent weight measured in water. In contrast, in the present study the Fzpeak values were normalized by total body weight (as usually presented in the literature regarding aquatic exercises), a fact that could interfere with the interpretation of the results. In the present study, lower Fzpeak and similar impulse values were observed for the postmenopausal (~57 years) in comparison to the young women group (~24 years) during the support phase of the water-based frontal kick exercise. The differences between age groups reveal that postmenopausal women presented 78-82% of Fzpeak values observed for young women during the water-based frontal kick exercise performed at cadences from 80 to 120 b.min^{-1}. This percentual reduction also agrees with the values observed by Louder et al. (2018), who found values equal to 82% during the water-based countermovement jump performed at maximal effort.

Such difference in the Fz pattern between age groups may be partially explained by the differences in body composition, given that with advancing age, an increase in the practitioners' body fat percentage occurs due to the lean mass reduction and increased adipose tissue (Snijders, et al., 2009). This fact results in a greater apparent weight reduction because adipose tissue floats more than muscle mass (Torres-Ronda & del Alcázar, 2014). In addition, women are more affected by these changes in body composition since there is a reduction in the estrogen hormone during and after menopause (Franklin, et al., 2009). This explanation remains a speculation since the studies mentioned earlier and the present one has not estimated body fat percentages. However, the apparent weight data collected in the present study may help to confirm this explanation. The postmenopausal women group presented a significantly greater apparent weight reduction percentage (75%) in comparison to the young women group (~70%). This apparent weight reduction observed for young women agrees with the literature, which has reported reductions of around 69-71% for this population immersed at the xiphoid process depth (Alberton, et al., 2015; Alberton, et al., 2013; Harrison, et al., 1992). Regarding older individuals, Alberton, et al. (2019) observed a higher percentual reduction, corresponding to 79.5% at the same immersion depth. Thus, our findings are in line with those in the literature and reinforce the role of age on the apparent weight reduction percentage.

Another characteristic which could partially explain the Fzpeak differences between the age groups is the decline in muscle size and strength with aging (Mitchell, et al., 2012). Since these declines are associated with impaired functional capacity (Aagaard, et al., 2010; Christensen, et al., 2009), they may imply a reduction in the projected force during water-based exercises propulsion in postmenopausal compared to the young women. This statement is supported by data from Louder et al. (2018), who also verified a higher unweighting time and a lower peak power during the water-based countermovement jump for the middle-aged compared to young individuals, in addition to the lower Fzpeak values.

In addition, a third aspect to be highlighted is the possible difference in the kinematic parameters during the water-based frontal kick exercise performed by young and postmenopausal women. Barela and Duarte (2008) and Louder et al. (2018) analyzed spatial-temporal parameters during water-walking and water-based jump exercises, respectively, performed by individuals from different age groups. Barela and Duarte (2008) verified differences in length, duration, speed, and angular position for different joints during water-walking strides performed at self-selected intensities between older and adult individuals. Moreover, Louder et al. (2018) also reported differences in lower limb joints' angular position and velocity between middle-aged and young individuals performing water-based countermovement jump at maximal effort. In the present study, kinematical parameters were not measured; however, in contrast to the studies above, in which the intensity was self-selected or maximal and elicited different kinematical parameters between groups, we set the intensity by cadences and the range of motion was visually controlled during the experimental protocol performance, minimizing such differences in the performance technique between age groups.

The present data revealed Fzpeak and impulse values during the water-based frontal kick exercise corresponding to 0.79-0.96 BW and 95-126 N·s for the young women group and 0.65-0.75 BW and 94-133 N·s for the postmenopausal one, respectively. These values agree with those observed in the literature. Regarding young women, values of 0.92 and 1.13 BW for Fzpeak, and 113 and 93 N·s for impulse during the water-based frontal kick exercise performed at individual physiological intensities equivalent to cadences of ~100 and ~120 b.min^{-1}, respectively (Alberton, et al., 2013). Concerning older individuals, values of 0.45–0.60 BW for Fzpeak and 0.07–0.17 N.s/BW for impulse were reported during the performance of the water-based frontal stationary running exercise performed at cadences of 80 b.min^{-1}, 100 b.min^{-1}, and maximal, respectively (Alberton, et al., 2019). In addition, Barela and Duarte (2008) observed Fzpeak values around 0.35 BW for older individuals during water walking, while Louder et al. (2018) reported Fzpeak values corresponding to 3.8 BW for middle-aged individuals (similar age to the present postmenopausal group) during the propulsion phase of the water-based countermovement jump. This great range of Fzpeak values observed for the different types of aquatic exercises reinforces the importance of the present study in verifying age effects on Fz during a water-based exercise widely used in water fitness programs, which have not been investigated in the literature yet.

Regarding cadence, a significant increase in the Fzpeak from 80 to 100 and 120 b.min^{-1} was observed in the present study, whereas a significant reduction in the impulse with the increasing cadence was verified for both age groups. These results corroborate with the literature, since previous studies analyzing water-based exercises (Alberton, et al., 2015; Alberton, et al., 2013; de Brito Fontana, et al., 2018; de Brito Fontana, et al., 2012), water-walking or running (Haupenthal, Fontana, Ruschel, dos Santos, & Roesler, 2013; Haupenthal, Ruschel, Hubert, de Brito Fontana, & Roesler, 2010) and walking or running on land (Cappellini, Ivanenko, Poppele, & Lacquantini, 2006; Nilsson & Thorstensson, 1989) also observed these responses. As the cadence increases, the individuals must perform a

greater propulsive force to overcome water resistance, promoting an increase in acceleration during the support phase and consequently in the Fz (Haupenthal, et al., 2013; Haupenthal, et al., 2010). Due to this, there is an increased angular velocity for the exercise performance while maintaining the range of motion. On the other hand, as intensity increases, the contact time is reduced (Nilsson & Thorstensson, 1989). Consequently, the literature reports that the impulse is decreased regardless of the increase in Fzpeak during water-based exercises (Alberton, et al., 2015; Alberton, et al., 2013).

Conclusion

Based on the present results, the water-based frontal kick exercise presents lower Fzpeak values for postmenopausal compared to young women at the three investigated submaximal cadences, with similar impulse values between age groups. In addition, an increased cadence results in greater Fzpeak and lower impulse responses.

Practical Application

Thus, water fitness sessions may safely employ the frontal kick exercise for young and postmenopausal women since the observed Fzpeak values correspond to a low risk of developing musculoskeletal injuries. However, care should be taken regarding practitioners who should avoid this type of load. For this purpose, water fitness instructors might choose lower intensities to perform the frontal kick at low cadences and to reduce Fz responses in water-based programs for women of different ages. In this scenario, older women may also benefit from lower Fz loads than the youngest.

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