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ANALYSIS OF VERTICAL GROUND REACTION FORCE OF WATER EXERCISES AT DIFFERENT INTENSITIES IN AQUATIC AND DRY LAND ENVIRONMENTS

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SUMMARY

This study aims at evaluating the peak vertical ground reaction forces (V-GRF$_{peak}$) and impulse (IMP) of women performing six water aerobic exercises (stationary running (SR), frontal kick (FK), cross country skiing (CCS), jumping jack (JJ), adductor hop (ADH) and abductor hop (ABH)) at two intensities in aquatic (AE) and dry land (DL) environments. Twelve young women performed 2 sessions in each environment, each one consisting of 3 exercises performed at first (VT1) and second ventilatory threshold (VT2) intensities. Two- and three-way ANOVA were used to analyze the impulse and V-GRF$_{peak}$, respectively, with Bonferroni post-hoc ($\alpha = 0.05$). The results showed that the V-GRF$_{peak}$ and the impulse were significantly lower in AE compared to the DL for all exercises and intensities. In AE, V-GRF$_{peak}$ was lower and impulse was higher at VT1 than VT2 intensity for all exercises. Regarding the exercises comparison, it was observed that, in both environments and intensities, SR and FK elicited significantly higher V-GRF$_{peak}$ compared to the ADH exercise. Therefore, it can be concluded that V-GRF$_{peak}$ and IMP of water aerobics are dependent on the intensity and the exercise performed.

INTRODUCTION

In order to identify aquatic exercises benefits, several studies describing the biomechanical characteristics of water walking can be found in the literature [1-3]. However, the studies that have analyzed water aerobics exercises are scarce regarding the biomechanical pattern [4,5]. Thus, it is necessary to investigate the responses between aquatic (AE) and dry land environments (DL) at different intensities, considering that different water aerobic exercises may show different vertical ground reaction force (V-GRF) patterns. Therefore, the aim of this study is to analyze the peak vertical ground reaction forces (V-GRF$_{peak}$) and impulse (IMP) in women performing six water aerobic exercises at two intensities in AE and DL.

METHODS

Twelve physically active and healthy women volunteered to take part in the present study (mean ± SD – age: 23.4 ± 2.0 years; height: 162.9 ± 7.8 cm; body mass: 58.7 ± 6.0 kg; fat mass: 28.4 ± 4.1 %). The V-GRF of six water aerobics exercises – stationary running (SR), frontal kick (FK), cross country skiing (CCS), jumping jack (JJ), adductor hop ADH) and abductor hop (ABH) – were evaluated. The participants performed the exercises at two intensities, with cadences corresponding to the first (VT1) and second ventilatory thresholds (VT2), both in AE and DL. The cadences were obtained from maximal effort tests performed in AE for each of the six exercises. The subjects participated in 2 sessions in each environment, each one consisting of 10 repetitions of the 3 exercises performed at 2 cadences, in a randomized order. In AE, the subjects were immersed to the xiphoid process depth. The V-GRF corresponding to the right lower limb in each situation was collected with a waterproof force plate (OR6-WP, AMTI; Watertown, USA) in both environments. Both protocols were performed barefoot. The V-GRF$_{peak}$ values were normalized to the body weight measured on DL and they are expressed in units of body weight (BW).

For the data analysis, we have considered the mean values of 5 central repetitions of each test. The IMP has been defined as the area calculated by integral force-time. Descriptive statistics have been used to analyze the collected data, with the data presented as the means ± SD. Two-way and three-way repeated measures ANOVA have been used to analyze the impulse and V-GRF$_{peak}$, respectively, with Bonferroni post-hoc ($\alpha = 0.05$).

RESULTS AND DISCUSSION

The results showed that V-GRF$_{peak}$ and IMP were significantly lower in AE, independent of the exercise and intensity performed (Table 1), corroborating with the specialized literature [1-5].

As for DL, it was observed that the V-GRF$_{peak}$ significantly increased from VT1 to VT2 intensity for the SR, FK and CCS exercises. Those results are in accordance with those we have found in the literature [5,6]. However, no differences have been found between intensities for the JJ, ADH and ABH exercises. For AE, significant differences have been found in the $V\text{-}GRF_{peak}$ between intensities for all exercises, with lower values observed to VT1 compared to VT2 intensity (Table 1). Those results agree with those found in the study of Alberton et al. [5], that evaluated three water aerobic exercises (SR, FK and CCS) performed at three intensities (VT1, VT2 and maximal effort), and they also observed a significant increase in the $V\text{-}GRF_{peak}$ from VT1 to higher intensities. That can be explained based on the hydrodynamic principles that suggest that if the intensity is increased, there is also an increase in the V-GRF, because of the requirement of a higher propulsive force to overcome the drag force, since the velocity is squared and directly proportional to that. Regarding the IMP, VT2 showed significantly lower values than VT1 for all exercises in both environments (Table 1). With the increase of intensity, the support phase tends to diminish, consequently influencing the IMP.

Regarding the comparison of the exercises in AE, it was verified that FK and SR presented significantly higher $V\text{-}GRF_{peak}$ values than JJ and ADH at VT1 intensity. Besides, at VT2 intensity, significant differences were found between FK and other exercises, such as CCS, JJ and ADH, that elicited lower $V\text{-}GRF_{peak}$ responses. Those results may be explained because the SR and FK exercises are characterized as exercises performed with a single support in which all of the body weight is carried by the support leg with a flight phase that produces a higher vertical displacement of the center of mass, increasing the acceleration provided by the body when touching the plate [4,5]. In contrast, JJ and CCS are characterized as exercises performed with a bipedal support without a flight phase, and the change in the foot support phase is performed by sliding; also, there is no great vertical oscillation of the center of mass, reducing the V-GRF [5]. On the other hand, the ADH exercise presented the lowest $V\text{-}GRF_{peak}$ values for both intensities, since it is performed with a great support base that can favor the cushioning during the hop landing phase.

CONCLUSIONS

It can be concluded that $V\text{-}GRF_{peak}$ and IMP have presented lower responses in AE if compared to DL in all situations. The V-GRF magnitude is also dependent on the intensity and the exercise performed. Therefore, if the purpose of the exercise is to reduce the V-GRF, AE is safer than DL. Besides, exercises with characteristics similar to ADH and intensities corresponding to VT1 must be prioritized to minimize the $V\text{-}GRF_{peak}$.

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Table 1: Results of the comparison of impulse and peak vertical ground reaction force ($V\text{-}GRF_{peak}$) between aquatic and dry land environments and cadences corresponding to the first (VT1) and second ventilatory thresholds (VT2).

Exercise	Intensity	Aquatic Environment $V\text{-}GRF_{peak}$ Mean ± SD	Dry Land Environment $V\text{-}GRF_{peak}$ Mean ± SD	Aquatic Environment Impulse Mean ± SD	Dry Land Environment Impulse Mean ± SD
Frontal Kick	**VT1**	0.92±0.20†	1.45 ±0.13*†	112.1±28.95†	343.57 ±52.15*†
	VT2	1.13±0.19	1.83 ±0.23*	97.57±22.51	269.84±33.6*
Stationary Running	**VT1**	0.88 ±0.26†	1.47 ±0.18*†	105.54 ±20.8†	325.15 ±41.42*†
	VT2	1.10 ±0.25	1.97 ±0.37*	79.55 ±16.13	253.57 ±35.73*
Cross Country Skiing	**VT1**	0.72±0.14†	1.32 ±0.10*†	66.42±27.29†	243.76 ±67.69*†
	VT2	0.88±0.14	1.53 ±0.13*	55.45±18.48	184.1±52.44*
Jumping Jack	**VT1**	0.63 ±0.2†	1.12 ±0.21*	64.78 ±16.42†	194.22 ±27.05*†
	VT2	0.75 ±0.18	1.35 ±0.35*	50.72±19.77	152.34 ±27.03*
Adductor Hop	**VT1**	0.51 ±0.12†	1.23 ±0.31*	109.19 ±21.44†	382.98 ±42.1*†
	VT2	0.77 ±0.19	1.15 ±0.26*	93.82 ±20.28	259.23 ±46.91*
Abductor Hop	**VT1**	0.72 ±0.21†	1.33 ±0.30*	134.82±44.76†	385.39 ±61.89*†
	VT2	0.94 ±0.30	1.31 ±0.25*	111.96 ±27.75	282.77 ±49.0*

* indicates significant differences between environments for each exercise and intensity ($p<0.05$). † indicates significant differences between intensities for each exercise and environment ($p<0.05$). The $V\text{-}GRF_{peak}$ is expressed in units of body weight measured out of water (BW) in both environments.