Vertical ground reaction force during land- and water-based exercise performed by patients with type 2 diabetes

Rodrigo Sudatti Delevatti[1], Cristine Lima Alberton[2], Ana Carolina Kanitz[1], Elisa Corrêa Marson[1], Luiz Fernando Martins Kruel[1]
[1] *Federal University of Rio Grande do Sul, Brazil*
[2] *Federal University of Pelotas, Brazil*

Abstract. The aim of this study was to analyze the vertical ground reaction force (V-GRF) during stationary running exercise performed in aquatic and dry land environments by patients with type 2 diabetes mellitus (DM2). *Material and Method*. Nine patients with DM2 performed one session in each environment consisting of the stationary running exercise performed at 2 cadences (80 and 120 b.min^{-1}). In addition, the maximum velocity (MAX) was performed only in aquatic environment. Repeated measures two-way ANOVA and paired t tests were used to analyze the peak V-GRF (α = 5%). *Results*. The results revealed significantly lower peak V-GRF values during the stationary running performed in the aquatic compared with the dry land environment. Furthermore, significantly lower peak V-GRF values were observed at the cadence of 80 than at 120 b.min^{-1} in both environments. The peak V-GRF at MAX intensity revealed significantly greater values than the cadence of 120 b.min^{-1} in the aquatic environment and significantly lower values than the cadence of 120 b.min^{-1} on dry land. *Conclusion*. The aquatic environment is a potential alternative to training patients with DM2 because patients are able to exercise at greater cadences than on dry land with a lower impact and, consequently, a lower risk of injuries.
Key words*: impact, immersion, aquatic exercises.*
.

Introduction

The incidence of diabetes mellitus is increasing worldwide, mainly due to the reduction in physical activity levels and the rise in obesity, which can be considered consequences of current economic development and urbanization (1). This increase in diabetes mellitus has reached epidemic proportions throughout the world, representing a substantial burden on health services (2). The major manifestation of the disease responsible for the epidemic prevalence is type 2 diabetes mellitus (DM2), which has expanded in prevalence due to inadequate diets and reduced levels of physical activity in genetically susceptible participants (3). The disease requires continuous care to prevent acute complications and to reduce the risk of developing chronic diabetes-related complications (4). These complications are associated with chronic hyperglycemia, and the main purpose of DM2 therapy is the maintenance of blood glucose levels within the adequate range. Nevertheless, the disease treatment is complex and extends beyond the glycemic control. Accordingly, a growing body of evidence proposes different interventions with the goal of improving the clinical condition of patients with DM (4).

Therapy for DM2 focuses on physical exercise, diet and medication (5,6). Glycemic control benefits in patients with DM2 have been observed in response to different modalities of physical training (6). Aerobic training is the traditional mode of exercise in disease management and is able to improve insulin sensitivity within one week of its initial application (7). With respect to physical training, studies have demonstrated the importance of the weekly duration of training in the control of the disease (6,8,9). Based on this perspective, recent evidence suggests better glycemic responses in studies with a weekly duration of training greater than 150 minutes (6) and with a higher weekly frequency of sessions (9).

In contrast, a growing body of evidence (10,11) questions the current recommendations regarding the practice of at least 150 minutes of physical exercise per week, suggesting that these guidelines are theoretically simple but rarely feasible.

These authors propose time-efficient modes of training with minimal doses to achieving optimal glycemic control through the use of low-volume, high-intensity interval training (LVHIT) in an attempt to transfer the physiological benefits reported in the literature to practical application. In addition, Adams (12) revised studies that manipulated high intensity training for individuals with and without diabetes and suggested benefits for both groups.

Thus, significant energetic contributions and expressive metabolic effects require that patients be generally exposed to moderate to heavy impact forces on their osteomuscular system due to the exercise duration and/or intensity. These forces are observed in exercises such as running, which is the modality of aerobic training widely reported in studies about DM2, according to the systematic review developed by Oliveira (13). These authors discuss this issue when highlighting the importance of physical training for DM2 patients that minimizes the injuries and ulcerations caused by the impact directly absorbed in the foot in contact with the ground.

An alternative form of exercise for patients with high metabolic risks is water aerobics; this modality of exercise is performed in an aquatic environment using physical properties such as the buoyancy to assists movements and provide low impact forces. Recent studies investigated the ground reaction forces (GRF) during exercises performed in aquatic and dry land environments, including walking, jumping and water aerobics exercises (15-18). These authors observed that when the same exercise is performed in both environments, the vertical GRF is lower in the aquatic environment, with values ranging from 0.2 to 1.2 times the body weight, depending on the exercise and intensity performed. In addition, the use of the principles of hydrostatics and hydrodynamics during aquatic exercises allows patients to perform exercises that they would be unable to perform on dry land (19). This is important to individuals that experience difficulties during the performance of traditional exercises on dry land due to the need to support and carry their own body weight (20). Thus, this type of exercise modality might be indicated for DM2 patients, as the V-GRF is attenuated in this environment, adding a mechanical factor in association with the positive effects of training, such as improved exercise capacity, muscle function and reduction in HbA1c levels observed in the study by Asa et al. (21).

Although the V-GRF had been investigated during aquatic exercises in young and elderly individuals, athletes and non-athletes (14-18, 22, 23), this variable has not been investigated yet in patients with DM2. Based on the optimal possibility that the aquatic environment offers to the treatment of DM2 through the physical training of long duration as well as high intensity as well as the scarcity of knowledge concerning the magnitude of the V-GRF during water aerobics exercises performed at different rhythms of execution and compared with the same exercises performed on dry land in this population, the present study aimed to analyze the peak V-GRF during the stationary running exercise performed in aquatic and dry land environments by patients with DM2. We hypothesized that the V-GRF would be lower during the performance of the stationary running exercise in the aquatic environment at all intensities in comparison with the dry land environment. Additionally, we hypothesized that V-GRF would increase as the intensity increased in both environments.

Material and Method

Five men and four women with DM2 volunteered to take part in the present study. The participants were in medical treatment and had engaged in a water aerobics program for 10 weeks. The exclusion criteria were as follows: non-controlled hypertension, autonomic neuropathy, severe peripheral neuropathy, proliferative diabetic retinopathy, severe non-proliferative diabetic retinopathy, uncompensated heart failure, peripheral amputations, chronic renal failure (TFG by MDRD < 30) and impaired muscle or joint movements that prevented the exercise performance. These criteria were confirmed by medical history, clinical examination and laboratory tests. All patients were required to present an effort electrocardiogram performed within the previous six months. The age, disease duration and medication used by the patients are presented on Table I. To participate in this study, all participants were required to read and sign the written informed consent that contained all of the information about the procedures and the potential risks involved in participation. The study was conducted according to the ethical standards of the Helsinki Declaration and was approved by the Local Research Ethics Committee (108997).

Experimental Procedures. All patients were submitted to anthropometric measurements, fasting blood sampling, familiarization with the stationary running exercise and two sessions corresponding to the experimental protocol, one in each environment.

Anthropometry. An initial session was held to collect sample characterization data. Body mass and height measurements were obtained using an analog medical scale and a stadiometer (FILIZOLA; Sao Paulo, Brazil). Based on these values, the body mass index (BMI) was calculated according to the following equation: BMI = mass (kg) * height $(m)^{-2}$. The waist circumference was measured at the midpoint between the iliac crest and the last rib. The skinfold thickness was obtained with a caliper (CESCORF, Porto Alegre, Brazil) on the right side of the participant's body: triceps, subscapular, suprailiac, abdominal, chest, mid-axillary, thigh and leg. The sum of skinfolds (∑8SF) was calculated, and percent body fat was subsequently calculated using the Siri equation (24).

Blood analysis. Blood samples (4ml) were obtained from an antecubital vein after fasting for 12 to 14 h. The samples were collected in tubes with EDTA and kept frozen at -80ºC as total blood (without centrifugation).

After blood data collection, the levels of HbA1c were determined through high-performance liquid chromatography (HPLC) to characterize the glycemic control of the patients.

Table 1. Participant's characteristics

Age (years)	53.5 ± 10.9
Duration of DM2 (years)	5.4 ± 2.9
HbA1c (% - mmol/mol)	7.3(56.3) ± 2.1
Height (cm)	167.0 ± 1.0
Body mass (kg)	95.6 ± 14.5
Body mass index ($kg.m^{-2}$)	34.1 ± 4.1
Waist (cm)	111.9 ± 11.9
WHR	0.67 ± 0.09
∑8SF (mm)	274.0 ± 65.1
Fat mass (%)	37.64 ± 6.28
Medication	
Metformin	8
Sulphonylurea	5
DPP-4-inhibitors	1
Pioglitazone	1
Diuretics	1
Beta blockers	3
ARAs II	4
Acetyl-salicylicacid	3
Statins	5
Insulin	1

Note. DPP-4: dipeptidyl peptidase-4; ARAs: Angiotensin receptors antagonists; WHR: waist/height ratio;∑8SF: sum of 8 skinfolds. Values of age, duration of DM2 and anthropometric measures are expressed as the mean ± SD; Values of medication are expressed by n.

Familiarization with stationary running and ground reaction force analysis. Two familiarization sessions were performed for each individual, one in the aquatic environment and the other on dry land. Stationary running was performed in both environments at different cadences, and all details of the care and range of movement that would be considered when performing the water aerobic exercise were explained. The stationary running exercise (Figure 1) was chosen because it is widely used in typical water fitness lessons and because its V-GRF has been investigated in the literature in non-diabetic people (14,16).

Figure 1. Stationary running exercise

Stationary running (SR) is characterized as an exercise performed with a single support and flight phase. The exercise is divided into two phases with each segmental action (hip flexion or extension) performed in one beat corresponding to a support phase of one limb. The first phase corresponded to the right hip and knee flexion to 90 degrees starting the flight phase, followed by the right hip and knee extension until the support phase. The cadences selected for the performance of the exercise in both environments were 80 and 120 $b.min^{-1}$ based on previous studies (25,26). The cadences were set by a digital metronome (MA-30, KORG; Tokyo, Japan). In addition, in the aquatic environment, the exercise was performed at the maximum velocity (MAX). The MAX situation was not performed on dry land so as not to expose the patients to high impact forces.

To collect the V-GRF, two sessions were performed, one in the aquatic environment and the other on the dry land environment, with a three-day interval between the sessions. The order of the cadences and environments was randomized. The tests were performed in the different environments at the same time of day to avoid variations related to circadian rhythms (27). The experimental protocol started with the measurement of the body weight (BW) on dry land or apparent weight in the aquatic environment. Subsequently, the exercise was performed in the respective environment at the cadences selected. For each situation, ten repetitions were performed, with 5 min intervals between cadences. In the aquatic environment, the protocol was performed barefoot, whereas on dry land, personal shoes were used. The aquatic protocol was performed in a shallow swimming pool with a depth between 0.95m and 1.30m, allowing the participants to be immersed to a depth between the umbilicus and the xiphoid process. The water temperature was maintained at 32°C, and the room temperature was maintained at 26°C.

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. The force plate was previously calibrated according to the manufacturer's specifications. For V-GRF, the plate's capacity is 8900 N, and sensitivity is 0.08 μV/[V.N];the useful working temperature ranges from -17 to +52°C. The sampling rate of the collected values was 500 Hz, and the data were acquired using AMTI Force software.

The files were later 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 cutoff frequency of 10 Hz. Based on BW and apparent weight, the underwater weight reduction percentage was calculated.

For each cycle, the peak V-GRF ($V\text{-}GRF_{peak}$) during the support phase was identified. The $V\text{-}GRF_{peak}$ was defined as the maximum value exhibited by the V-GRF, occurring at any period of time from the beginning until the end of the cycle. These data were normalized by the BW measured outside the water. Next, the three central valid repetitions were averaged to obtain the mean cycle for each participant in each situation.

Statistical analysis. Descriptive statistics were used to analyze the collected data, with the data presented as the means±SD. Shapiro-Wilk's test was used to verify the normal distribution of the data. Repeated measures two-way ANOVA (factors: cadence and environment) were used to analyze the $V\text{-}GRF_{peak}$ values. When applicable, Bonferroni's post hoc tests were used to localize the significant differences. In addition, paired t tests were used to compare the $V\text{-}GRF_{peak}$ values between the MAX situation and the cadence 120 $b.min^{-1}$ in each environment. An alpha level of 0.05 was adopted. SPSS program version 19.0 was employed in the analysis.

Results

The mean underwater weight reduction was 67.7±12.7% of BW across all participants. The results of the repeated measures two-way ANOVA revealed significantly lower $V\text{-}GRF_{peak}$ values in the exercise performed in the aquatic environment at both cadences compared with the values on dry land. In addition, significant differences between the cadences in both environments were observed (Table II).

The mean values of $V\text{-}GRF_{peak}$ at MAX intensity were determined only in the aquatic environment: 0.93 ± 0.31 BW. This situation resulted in significantly greater $V\text{-}GRF_{peak}$ values compared with the cadence corresponding to 120 $b.min^{-1}$ in the aquatic environment (0.77 ± 0.25 PC; p=0.024).

Table II. Comparison of the peak vertical ground reaction force (V-GRF$_{peak}$) values between the cadences (CAD) 80 and 120 b.min^{-1} and between aquatic and dry land environments (ENV)

	V-GRF$_{peak}$ (BW)						
	Dry land environment		**Aquatic environment**				
Cadence	**Mean**	**± SD**	**Mean**	**± SD**	**CAD**	**ENV**	**CAD*ENV**
80b.min^{-1}	1.22	0.11	0.64	0.19	<0.001*	<0.021	0.191
120b.min^{-1}	1.49	0.32	0.77	0.25			

Note. * indicates significant differences between environments (p<0.05). The V-GRF$_{peak}$ is expressed in units of body weight measured outside the water (BW) in both environments

.

However, significant lower V-GRF$_{peak}$ values were observed when comparing the MAX intensity in the aquatic environment with the cadence corresponding to 120 b.min^{-1} on dry land (1.49 ± 0.32 PC; p<0.001).

Discussion

The main finding of the present study was that significantly lower V-GRF$_{peak}$ values were observed in the aquatic environment compared with those on dry land at all analyzed intensities, consistent with our hypothesis. In addition, significant differences in the V-GRF$_{peak}$ were observed among the cadences in both environments, also corroborating our hypothesis.

Analyzing the difference between the environments, the results of the present study corroborate the literature, in which there is a consensus that the V-GRF responses in immersion are lower than on dry land for different exercises, such as walking (16, 18), jumping (17) and water aerobics exercises exercises (14, 16). However, all of above-mentioned studies were developed with healthy adolescents, young adults and elderly participants. Based on our literature review, this is the first study investigating the V-GRF in DM2 patients. The reduction in the V-GRF$_{peak}$ is due to the physical properties of water; the immersed body is affected by the buoyancy force. This effect can be observed through the mean underwater weight reduction, which in the present research resulted in a value of 67.7 ± 12.7% of BW at the xiphoid process depth, a value similar to those reported by previous studies with young men, women and pregnant women (14, 28, 29). Consequently, stationary running, which is an exercise widely used during water aerobics that is characterized by a vertical displacement of the body, provides reduced acceleration when the foot is touching the plate, resulting in reduced V-GRF$_{peak}$ values.

When relating the results of the present study to the importance and possibilities of physical training in individuals with DM2, it should be highlighted the greater V-GRF$_{peak}$ values at the cadence of 120 b.min^{-1} on dry land compared to the MAX intensity in the aquatic environment. This result implies the possibility of exploring high physiological intensities during exercise in the aquatic environment with a reduced risk of injuries in the lower limbs when compared with the lower cadences on dry land. Therefore, because the impact forces are attenuated in the aquatic environment, especially for the lower limbs, this environment can be considered safer than performing the same exercises and cadence on dry land. In addition, this difference allows the progression in the intensity of training until target zones are predominantly anaerobic in patients with DM2, who are generally overweight or obese, a fact that may be fundamental to the choice of the adequate environment for training. The models of training that involve periodic excursions into ‘‘anaerobic’’ energy pathways facilitate greater improvements in cellular signaling pathways involved in energy metabolism (30). Studies that evaluated interval training with these characteristics have reported optimum responses of important outcomes for the treatment of DM2, such as improvements in sub-maximal and maximal exercise capacity, mitochondrial biogenesis, enzymatic markers associated with glycolysis and decreased glycemic variability (31-33).

However, caution is necessary in the interpretation of the results because the magnitude of the reduction in the V-GRF$_{peak}$ observed in the evaluated exercise performed in the aquatic environment (0.64-0.93 BW) might to be considered not ideal for patients with severe obesity or peripheral neuropathy, in spite of the odds of muscle-skeletal injuries are low when these values were lower than 2 BW. In these types of situations, the concern is not with the environment but with the vertical nature of the chosen exercise. Therefore, other types of aquatic exercises, such as deep-water running or water aerobics exercises based on sliding (i.e., cross country skiing), which were not investigated in the present study, would be feasible alternatives.

Another factor that exerts influence on the V-GRF$_{peak}$ values is the intensity of the exercises performed. In the aquatic environment, the present study demonstrated significant differences between 80 and 120 b.min^{-1} and between 120 b.min^{-1} and MAX intensity with increases in the V-GRF$_{peak}$ shown as increases the intensity. This pattern is consistent with the results of previous studies (14, 16, 23). The study by Brito-Fontana et al. (16) analyzed stationary running, the exercise investigated in the present study, performed by young adults of both genders at cadences of 90, 110 and 130 b.min^{-1}. The authors verified that the V-GRF$_{peak}$ increased as the cadence increased, with significant differences in the lower cadence compared with the two higher cadences. The fixed cadences used in the present study, 80 and 120 b.min^{-1}, are very close to the cadences chosen in the above-mentioned study. Furthermore, Alberton et al. (14) investigated the V-GRF$_{peak}$ during three water aerobics exercises (stationary running, frontal kick and cross country skiing) performed by young women at cadences corresponding to the first ventilatory threshold (≈100 b.min^{-1}), second ventilatory threshold (125-135 b.min^{-1}) and maximal intensity. These authors observed an increase in these values between the lower intensity compared with the two higher intensities, which also supports the present findings. This pattern was also observed in the study by Haupenthal et al. (23), developed with adults of both genders, which analyzed the V-GRF during water walking at two velocities of motion (slow and fast) and at two immersion depths (hip and chest). The authors observed lower values for the V-GRF$_{peak}$ at the low velocity compared with the fast velocity for both immersion depths.

These results concerning the intensities can be explained by the principles of hydrodynamics.

The increase from the cadence of 80 to 120 b.min^{-1}, as well as 120 b.min^{-1} to MAX intensity, promotes an increase in the velocity of motion when the same exercise is performed within a controlled range of motion; consequently, an increase in the acceleration during the contact of the foot with the plate follows, resulting in a greater V-GRF$_{peak}$. In addition, with the increased intensity, an increase in the V-GRF is observed due to the requirement of a higher propulsive force to overcome the drag force, displacing the body (22,23). On the other hand, some studies have reported no significant differences in the V-GRF between intensities during shallow-water walking (18). The different patterns identified between the results of the studies with shallow-water walking and the present results could be due to the different exercises used in each approach. The exercise investigated in the present study was stationary with vertical displacement, in contrast to water walking, which entails horizontal displacement.

With regards to the greater V-GRF$_{peak}$ with increases in the physiological intensity, the study developed by Alberton et al. (14), with young adult women, demonstrated that the cadence corresponding to the first ventilatory threshold during the stationary running exercise is superior to 80 b.min^{-1}, which was one of the cadences used in the present study. In addition, the cadence corresponding to 120 b.min^{-1}, also analyzed in the present study, can be considered as an intensity between the first (103 b.min^{-1}) and the second ventilatory threshold (134 b.min^{-1}) for this same exercise (14). Although the physiological parameters have not been evaluated in the present study, it is possible that the aquatic environment elicits intensities that can optimize the physical training of patients with DM2 through target zones of training next to the second ventilatory threshold or higher, with low risk, even for people with difficulty bearing their own corporal weight.

From a biomechanical point of view, the progression of training using high intensities is safer with respect to the V-GRF in the aquatic environment. Thus, it is more feasible to prescribe the training at intensities corresponding to the second ventilatory threshold, which is an optimal parameter to adjust the intensity training, with a good cost-effectiveness in the treatment of DM2 (34). The present results also suggest that DM2 patients limited by osteoarticular problems but otherwise physically fit could conduct training with anaerobic intensity. According to Earnest (30), this peculiarity in prescribing exercise promotes important metabolic alterations in the treatment of DM2.

Based on our results, we suggest that the aquatic environment is a potential tool for the exercise prescription for DM2 patients, especially for those with difficulties exercising on dry land. This tool can reduce the barrier that exists between the ideal prescription indicated in this population (>150 minutes per week) and the lack of time for training practice reported by the patients (35). In addition, it is believed that this tool could achieve significant energy expenditure with V-GRF$_{peak}$ values inferior to those observed at lower intensities on dry land, where the progression of intensity training for some patients could be restricted, a limitation that is not evident in the aquatic environment.

Acknowledgments.The authors thanks specially to FAPERGS, CAPES and CNPq Brazilian Government Association for its support to this Project. We gratefully acknowledge all the subjects who participated in this research and made this project possible.

References

1. Whiting DR, Guariguata L, Weil C, Shaw J (2011). IDF Diabetes Atlas: Global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Res. Clin. Pract*. 94(3): 311-21.
2. Jayawardena R, Ranasinghe P, Byrne NM, Soares MJ, et al. (2012). Prevalence and trends of the diabetes epidemic in South Asia: a systematic review and meta-analysis. *BMC Public Health*. 12(1): 380.
3. Vadstrup ES, Frolich A, Perrild H, Borg E, et al. (2009). Lifestyle intervention for type 2 diabetes patients – trial protocol of The Copenhagen Type 2 Diabetes Rehabilitation Project. *BMC Public Health*. 9: 166.
4. American Diabetes Association (2012). Standards of medical care in diabetes. *Diabetes Care*. 35 (Suppl 1): S11-53.
5. Bao S, Briscoe VJ, Tate DB, Davis S (2009). Effects of differing antecedent increases of plasma cortisol on counter regulatory responses during subsequent exercise in type 1 diabetes. *Diabetes.* 58(9): 2100-8.
6. Umpierre D, Ribeiro PAB, Kraemer CK, Leitão CB, et al. (2011). Physical Activity Advice Only or Structured Exercise Training and Association With HbA1c Levels in Type 2 Diabetes. *JAMA*. 305(17): 1790-9.
7. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, et al. (2010). American College of Sports Medicine; American Diabetes Association. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. *Diabetes Care*. 33(12): 147-67.
8. Houmard, J. A., Charles, J., Tanner-Slentz, C. A., Duscha, B. D., et al. (2004). Effect of the volume and intensity of exercise training on insulin sensitivity. *J. App. Physiol.* 96(1): 101-6.
9. Umpierre D, Ribeiro PAB, Ribeiro JP, Schaan BD (2013). Volume of supervised exercise training impacts glycaemic control in patients with type 2
10. diabetes: a systematic review with meta-regression analysis. *Diabetologia*. 56(2): 242-51.
11. Bird SR, Hawley JA (2012). Exercise and type 2 diabetes: New prescription for an old problem. *Maturitas*. 72(4): 311-16.
12. Hawley JA, Gibala MJ (2012). What's new since Hippocrates? Preventing type 2 diabetes by physical exercise and diet. *Diabetologia*. 55(3): 535-39.
13. Adams OP (2013). The impact of brief high-intensity exercise on blood glucose levels. *Diabetes Metab. Syndr. Obes.* 6: 113-22.
14. Oliveira CO, Simões M, Carvalho J, Ribeiro J (2012). Combined exercise for people with type 2 diabetes mellitus: A systematic review. *Diabetes Res. Clin. Pract.* 98(2): 187-98.
15. Alberton CL, Tartaruga MP, Pinto SS, Cadore EL et al. (2013). Vertical Ground Reaction Force during Water Exercises Performed at Different Intensities. *Int. J. Sports Med.* 34: 881-87.
16. Barela AMF, Duarte M. (2008). Biomechanical characteristics of elderly individuals walking on land and in water. *J. Electromyogr. Kinesiol.* 18: 446-54.
17. Brito-Fontana H, Haupenthal A, Ruschel C, Hubert M, et al. (2012). Effect of gender, cadence, and water immersion on ground reaction forces during stationary running. *J. Orthop. Sports Phys. Ther.* 42: 437-43.
18. Colado JC, Garcia-Masso X, González LM, Triplett NT, et al. (2010). Two-leg squat jumps in water: an effective alternative to dry land jumps. *Int. J. Sports Med.* 31: 118-22.
19. Roesler H, Haupenthal A, Schütz GR, Souza PV (2006). Dynamometric analysis of the maximum force applied in aquatic human gait at 1.3 m of immersion. *Gait Posture*. 24: 412-17.
20. Batterham SI, Heywood S, Keatinge JL (2011). Systematic review and meta-analysis comparing land and aquatic exercises for people with hip or knee arthritis on function, mobility and other health outcomes. *BMC Musculoskeletal Disorders*. 12: 123.
21. Meredith-Jones K, Waters D, Legge M, Jones L (2011). Upright water-based exercise to improve cardiovascular and metabolic health: A qualitative review. *Complement Ther. Med*. 19(2): 93-103.
22. Asa C, Maria S, Katharina SS, Bert A (2012). Aquatic exercise is effective in improving exercise performance in patients with heart failure and type 2 diabetes mellitus. *Evid Based Complement. Alternat. Med.* 349209
23. Haupenthal, A., Ruschel, C., Hubert, M., de Brito-Fontana, H., et al. (2010). Loading forces in shallow water running in two levels of immersion. *J. Rehabi. Med.* 42(7): 664-9.

24. Haupenthal A, Fontana HB, Ruschel C, Santos DP, et al. (2013). Ground reaction forces in shallow water running are affected by immersion level, running speed and gender. *J. Sci. Med. Sport*, 16: 348-52.
25. Siri, WE (1993) Body composition from fluid spaces and density: Analysis of methods. *Nutrition* 9: 480-91.
26. Alberton CL, Cadore EL, Pinto SS, Tartaruga MP, et al. (2011). Cardiorespiratory, neuromuscular and kinematic responses to stationary running performed in water and on dry land. *Eur. J. Appl. Physiol.* 111: 1157-66.
27. Pinto SS, Cadore, EL, Alberton CL, Silva EM, et al. (2011). Cardiorespiratory and neuromuscular responses during water aerobics exercise performed with and without equipment. *Int. J. Sports Med.* 32: 916-23
28. Winget CH, DeRoshia CW, Holley DC, (1985). Circadian rhythms and athletic performance. *Med Sci Sports Exerc*, 17: 498-516.
29. Harrisson RA, Hillman M, Bulstrode S, (1992). Loading of the lower limb when walking partially immersed: Implications for clinical practice. *Physiotherapy*. 78: 164-66
30. Finkelstein I, Alberton CL, Figueiredo PAP, Garcia DR, et al. (2004). Comportamento da frequência cardíaca e da pressão arterial, ao longo da gestação, com treinamento no meio líquido. [Behavior of heart rate, blood pressure, and hydrostatic weight of pregnant women at different immersion depths]. *Rev. Bras. Ginecol. Obstet.* 26(5): 685-90.
31. Earnest CP, (2008). Exercise interval training: An improved stimulus for improving the physiology of pre-diabetes. *Med. Hypotheses.* 71(5): 752-61.
32. Burgomaster KA, Hughes SC, Heigenhauser GJ, Bradwell SN, et al. (2005). Six sessions of sprint interval training increasesmuscle oxidative potential and cycle endurance capacity in humans. *J. Appl. Physiol.* 98: 1985-90
33. Hood MS, Little JP, Tarnopolsky MA, Myslik F, et al. (2011). Low-volume interval training improves muscle oxidative capacity in sedentary adults. *Med. Sci. Sports Exerc.* 43: 1849-56.
34. Little JP, Gillen JB, Percival ME, Safdar A, et al. (2011). Low-volume high intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. *J. Appl. Physiol.* 111(6): 1554-60.
35. Brun JF, Bordenave S, Mercier J, Jaussent A, et al. (2008). Cost-sparing effect of twice-weekly targeted endurance training in type 2 diabetics: a one-year controlled randomized trial. *Diabetes Metab.* 34(3): 258-65.

Corresponding author
Rodrigo Sudatti Delevatti
750, Felizardo Street. Exercise Research Laboratory
Postal Code: 90690-200
Porto Alegre/Rio Grande do Sul – Brazil.
Phone: +55 (51) 3308-5820.
Email: *rsdrodrigo@hotmail.com*

Received: January 28, 2015
Accepted: March 2, 2015