Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

LOAD DURING THE VERTICAL JUMP IN WATER: VALUES FOR PRESCRIPTION IN HYDROTHERAPY

Alessandro Haupenthal, Caroline Ruschel, Heiliane B Fontana, Daniela P Santos, Paulo R Cerutti and Helio Roesler

Aquatic Biomechanics Research Laboratory, University of the State of Santa Catarina, Florianópolis, Santa Catarina, Brazil

This study aimed to analyse the vertical component of the ground reaction force (GRF) in the vertical jump in water performed by men and women at two levels of immersion. 11 men and 11 women performed three vertical jumps on a water-proof force plate at hip and chest levels of immersion. No effect of gender was observed. No difference between levels of immersion was found for peak of propulsion [1.85 and 1.89 units of body weight (BW) at the hip and chest respectively]. During the landing phase, the force peak was significantly higher at the hip level (2.62 BW) than at the chest level (2.07 BW). The force during the propulsion phase was similar between the immersions; however the vertical load on landing needs to be considered when prescribing this exercise, even in water.

KEYWORDS: biomechanics, aquatic exercises, hydrogymnastics, rehabilitation.

INTRODUCTION: It is common in the rehabilitation process to require partial unloading of the individual's body weight. Since the injured subject normally does not present enough control and proprioception to unload the affected limb during more intense exercise, even with training (Tveit & Karrholm, 2001), physiotherapists currently opt for two alternatives for loading control: body weight support and water exercises in water.
While there is a consensus on the reduction in impact forces when carrying out activities in water, aquatic exercises are generally prescribed without the professional being aware of the exact load acting against body structures (Haupenthal et al., 2010*)*, mainly due to the scarcity of quantitative parameters related to the performance of the different types of exercise in water.
In an effort to improve the evidence base for the prescription of exercises in water, researchers have analysed the ground reaction forces in aquatic activities such as walking and running. However, there is little literature in water vertical jump, even though this activity is a component in exercise programmes designed for the rehabilitation and training (Thein & Brody, 1998; Stemm & Jacobson, 2007).
In this context, this study aimed to analyze the vertical component of the ground reaction force (GRF) in vertical jumps performed in water, comparing the results between men and women and between two levels of immersion.

METHODS: After obtaining approval from the Ethical Committee for Research on Humans of the Institution, 22 subjects (11 men and 11 women) participated in this study. For the male subjects, mean ± SD of age, height, body mass and body fat were 24.0 ± 3.0 years, 1.80 ± 0.05 m, 74.6 ± 6.8 kg and 13.0 ± 2.1 % respectively. For the female subjects, the values were 23.0 ± 2.5 years, 1.67 ± 0.05 m, 56.3 ± 3.8 kg and 21.1 ± 2.9 % respectively.
In order to collect the vertical component of the GRF (Fy), a water-proof force plate (Roesler, 1997), which was covered by a non-slip material, was used (dimensions 500 mm X 500 mm X 200 mm, sensitivity of 2 N and error lower than 1%). In addition to the force plate, the acquisition system contained the signal conditioner and A/D convertor ADS2000-IP as well as the software AqDados 7.02 for signal analysis and editing (Lynx Tecnologia Eletrônica LTDA, São Paulo, SP, Brazil). The sampling rate was set at 1000 samples/second.
The analyzed variables were: (a) Peak of Propulsion: corresponds to the maximum vertical force applied by the subject during the propulsion phase, expressed in units of subject's body weight (BW); (b) Flight Time: time elapsed from the end of the propulsion phase to the beginning of the landing phase, expressed in seconds; (c) Peak of Landing: corresponds to

the maximum force applied by the subject during the landing phase, expressed in BW; d) Loading Rate on Landing: calculated from the linear slope, from initial contact after the flight phase to the onset of maximum force during the landing phase, expressed in BW/s. Figure 1 illustrates the analyzed variables.

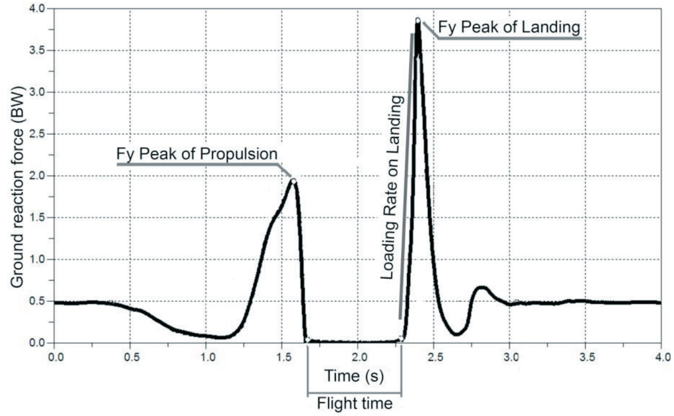

Figure 1: Variables analyzed for the vertical component of the GRF.

After the anthropometrical measurements, the subjects were asked to enter the pool. In order to familiarise themselves with the equipment, subjects were given a five-minute practice. Subjects were then instructed to perform three vertical jumps at each of the chosen levels of immersion: hip and chest. The distance between the water surface and the force plate was adjusted for each subject, based on anatomical points of reference. Hip level corresponded to the subject's iliac crest, and chest level corresponded to the subject's xiphoid process. The choice of levels of immersion was made by the researchers according to anatomical points that could be easily identified and are widely used by professionals who prescribe aquatic exercises in their daily work routines. The order of the immersion levels were randomly allocated by drawing lots and the participants had an interval of 30 seconds between each trial at a same immersion and of 3 minutes between the immersions.

Authors opted for controlling the jump height, which was specific to each subject: at the chest level, the subjects were asked to jump in such a way that their hip reached the water surface; at the hip level, the subjects were requested to jump sufficiently high that the mid-point of the thigh reached the surface of the water. Additionally, we opted for given no instructions were given regarding the upper limbs movements, in order to allow subjects to use their usual jump technique.

All curves were exported and analyzed through a processing routine created with the Scilab 4.1.2 software (Institut Nationale de Recherche en Informatique et en Automatique, École Nationale des Ponts et Chauss, France).

SPSS software version 17.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Mean and standard deviation were calculated for all variables in each analyzed condition. Student's "*t*" test for dependent samples was applied to compare the two levels of immersion and Student's "*t*" test for independent samples was used to compare the data between men and women. An alpha level of $p<0.05$ was used for all statistical tests.

RESULTS: Table 1 presents the values for mean and standard deviation of the variables analysed in the study.

No differences were found between genders for any variable. When comparing the results between the levels of immersion, significant differences were found only for the Flight Time ($p=0.001$) and for the Peak of Landing ($p=0.002$).

Figure 2 shows the average force x time curves of one subject at both levels of immersion.

Table 1
Mean ± SD of variables at the analyzed immersion levels for all subjects and for men and women separately

Immersion	Variable	All (n=22)	Men (n=11)	Women (n=11)
Hip Level	Flight Time (s)	0.55±0.03	0.56±0.03	0.53±0.02
	Peak of Propulsion (BW)	1.85±0.39	1.92±0.36	1.79±0.43
	Peak of Landing (BW)	2.62±1.10	2.44±1.19	2.80±1.02
	Loading Rate on Landing (BW/s)	14.75±7.32	13.63±7.99	15.86±6.78
Chest Level	Flight Time (s)	0.63±0.03	0.65±0.04	0.62±0.03
	Peak of Propulsion (BW)	1.89±0.45	2.02±0.43	1.76±0.44
	Peak of Landing (BW)	2.07±0.77	2.02±0.84	2.13±0.74
	Loading Rate on Landing (BW/s)	12.67±5.45	12.35±6.12	12.99±4.96

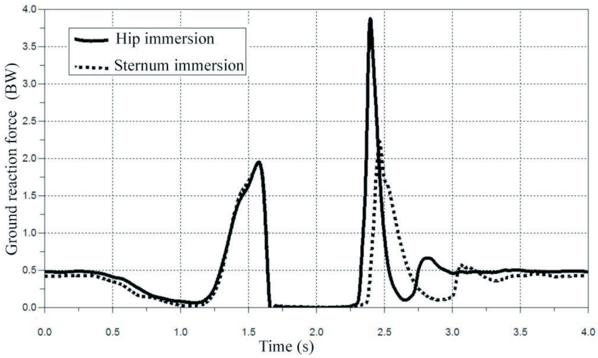

Figure 2: Average force x time curves of one subject at the hip level (solid line) and at the chest level (dashed line).

DISCUSSION: The results of this study showed very similar values for the Peak of Propulsion at both levels of immersion. Thus it seems that the force generated by the subjects to perform the propulsive phase of the jump is the same when immersed to the chest and to the hip. It is important to mention that the control of the jump height might have influenced the values of the Peak of Propulsion. We believe if subjects performed a maximum jump they would have to apply a higher amount of force during the propulsion phase at the chest level, due to need to displace a bigger “column of water”. Further investigations regarding the rate of force production during the propulsion phase could bring additional information on this topic, in order to better support the prescription of strength training in water.

An important benefit of aquatic functional rehabilitation is a reduction of the risk of injury, since the water physical properties attenuate the load when landing at the bottom of the pool. As expected, the lower the level of immersion, the higher the vertical force during the landing phase, due to the action of the buoyant force, which decreases the effective force applied by an individual in proportion to the degree of immersion. When thinking about vertical jumps on dry-land, regardless of the type of jump the landing phase represents the moment in which the mechanical stress applied to the locomotor apparatus is higher. On dry-land, the vertical GRF during the landing phase can vary from 3.0 to 7.9 BW (Gross & Nelson, 1988; Dufek & Bates, 1990; McClay et al., 1994). In water, the values obtained in this study were lower; however, the magnitude of the forces remains considerable – e.g., when compared to those observed for the over ground walking and running (Rose and Gamble, 1994; Keller et al., 1996) –, mainly when this exercise is prescribed to an individual with load restriction.

Due to the resistance presented by the water during the flight phase, the time for preparation of landing is longer. According to McNitt-Gray (2004) the duration of this preparation for

influences the ability of the subject to choose a strategy for contact, which can vary according to the positioning and speed of the segments before contact and/or activation of the muscles responsible for control of the reaction forces. In the water, due to the greater time available for preparation (which is significantly longer at the chest than at the hip), the capacity of the individual to control their actions preceding landing is enhanced. As a result, a good landing technique can be trained during rehabilitation in the pool phase, and adopted later when carrying out jumps on land.
Another factor deserving of attention is that the water offers the possibility of developing the propulsion phase while avoiding landing loads. To achieve that the individual could use strategies, such as arm movements, to decelerate the fall phase and ensure that the movement is completed before touching the bottom of the pool. If during the process of rehabilitation the individual already has the capacity to tolerate the landing phase, work can start from the greater depth of immersion, which could be gradually reduced according to the evolution of treatment. No significant differences were observed between men and women. Consequently, it seems that the vertical jump with a controlled height could be prescribed for healthy individuals without distinction between the genders.

CONCLUSION: The propulsion force applied by subjects to perform a vertical jump in water is similar when they are immersed to the hip and to the chest. However, the vertical load during the landing phase is different between the hip and chest levels: the lower the level, the higher the peak of landing. Regardless the gender comparison, there was no difference between men and women, which may support the adoption of common parameters when prescribing the water jump for these two groups.

REFERENCES:

Dufek, J.S. & Bates, B.T. (1990). The evaluation and prediction of impact forces during landings. *Medicine and Science in Sports and Exercise*, 22, 370-7.

Gross, T.S. & Nelson, R.C. (1988) The shock attenuation role of the ankle during landing from a vertical jump. *Medicine and Science in Sports and Exercise,* 20, 506-14.

Haupenthal, A., Ruschel, C., Hubert, M., Fontana, H.B. & Roesler, H. (2010). Loading forces in shallow water running at two levels of immersion. *Journal of Rehabilitation Medicine*, 42, 664-9.

Keller, T., Weisberger, A., Ray, J., Hasan, S.S., Shiavi, R.G., Spengler, D.M. (1996). Relationship between vertical ground reaction force and speed during walking, slow jogging, and running. *Clinical Biomechanics*, 11(5), 253-9.

McClay, I.S., Robinson, J.R., Andriacchi, T.P., Frederick, E.C., Gross, T., Martin, P., Valiant, G., Williams, K.R. & Cavanagh, P.R. (1994). A profile of ground reaction forces in professional basketball. *Journal of Applied Biomechanics,* 10, 222-36.

McNitt-Gray, J.L. (2004) Carga no sistema musculoesquelético durante a aterrissagem. In: V.M. Zatsiorsky (Ed.). *Biomecânica no esporte: performance do desempenho e prevenção de lesão* (pp. 409-31). São Paulo: Guanabara Koogan.

Roesler, H. (1997). Desenvolvimento de plataforma subaquática para medições de forças e momentos nos três eixos coordenados para utilização em biomecânica. Doctorate Thesis. Porto Alegre: Universidade Federal do Rio Grande do Sul.

Rose, J. & Gamble, J.G. (1994). *Human walking*. 2nd edn. Baltimore: Williams & Wilkins.

Stemm, J.D. & Jacobson, B.H. (2007). Comparison of land- and aquatic-based plyometric training on vertical jump performance. *Journal of Strength and Conditioning Research,* 21, 568-71.

Thein, J.M. & Brody, L.T. (1988). Aquatic-based rehabilitation and training for the elite athlete *Journal of Orthopaedic and Sports Physical Therapy,* 27,32-41.Tveit, M. & Karrholm, J. (2001) Low effectiveness of prescribed partial weight bearing: continuous recording of vertical loads using a new pressure-sensitive insole. *Journal of Rehabilitation Medicine,* 33, 42-6.

Acknowledgement

We gratefully acknowledge the University of the State of Santa Catarina and CAPES scholarship Programme.