JUMPS IN DIFFERENT LEVELS OF WATER: AN OPTIMAL ENVIRONMENT TO JUMP ON LAND

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The purpose of this study was to compare rate of force development (RFD) and rate of impact force (RIF) among on-land and in different levels of water jumps. Fourteen male participants were recruited in this study. Participants carried out the testing on land first and followed by testing in knee-high (LOW), trochanter major high (MID), and nasal-high (HIGH) of water. In each condition, participants performed 3 countermovement jumps (CMJ) separated by 15 sec rest. RFD and RIF were calculated. A repeated measure ANOVA was used for assessing the differences of variables among different conditions. The results showed that RFD for LOW is significantly lower than the others, and loading impact on-land is significantly higher than the others. Jumping in MID and HIGH are optimal levels of water for jumps training.

KEY WORDS: countermovement jump, training, rate of force development, impact force.

INTRODUCTION: Jumping trainings, including vertical jump, depth jump and plyometric jump are commonly used by athletes to improve jump height, jump speed and power (Matavulj, Kukolj, Ugarkovic, Tihanyi and Jaric, 2001), and to improve joint stability and increase bone mineral density (Alev & Merih, 2005). Jumping training often involves repeated drills. However, the repeated impact on knee during landing phase may contribute to injuries (Stemm & Jacobson, 2007).

Instead of jumping on land, jumping in water may provide benefits and may be a training way to practice and maintain muscle strength and jump ability for patients during rehabilitation period (Donoghue, Shimojo & Takagi, 2011). The benefits could be attributed to the characteristics that the buoyancy of water that works on subjects to reduce their apparent body weight (Robinson, Devor, Merrick, & Buckworth, 2004).

A recent study by Stemm & Jacobson (2007) compared land- and water-based plyometric training on jump height. After 6 weeks, both land- and water-based training had benefits on jump height. Researches comparing jump performance on land and in water focused on single level of water. However, the buoyancy, resistance and ground reaction force in water mainly depend on level of water that individual immerses and speed of movement (Harrison, Hillman & Bulstrode, 1992).

Typically, jumping performance are frequently evaluated by data of peak ground reaction force, rate of force development (RFD),rate of impact force (RIF) and landing impulse (Fowler & Lees, 1998; Jensen & Ebben, 2007; Colado, Garcia-Masso, Gonzalez, Triplett, Mayo & Merce, 2010; Donoghue et al., 2011). To date, few studies concerned those responses between in different levels of water and on land. Therefore, to identify the optimal water level to carry out jumping training, the purpose of this study was to compare RFD and RIF among on-land and in different levels of water jumps.

METHODS: Fourteen male division II collegiate volleyball players (age: 19.6 ± 1.0 years; height: 175.1 ± 3.9 cm; mass: 63.6 ± 4.8 kg) were recruited in this study. All participants were free from any musculoskeletal injury.

All participants were requested to perform a standardized warm-up and be familiar with standardized CMJ with hand touching on head before testing. Participants carried out the testing on land first and followed by testing in randomized different levels of water. The different levels of water were knee-high (LOW), trochanter major high (MID), and nasal-high (HIGH). In each condition, participants performed 3 CMJs separated by 15 sec rest.
Force-time signals of CMJ were recorded by a waterproof force plate (AMTI, Newton, MA), operating at 1000 Hz. The RFD were defined as slope of the lowest ground reaction force to highest ground reaction force during jumping phase, and RIF were defined as peak of impact divided by the time from initial landing to peak of impact. All variables were normalized to body weight on land to compare with variables on land (Donoghue et al., 2011).
A repeated measure ANOVA was used for assessing the differences of variables among on-land and in different levels of water. Significance level was set at $p \leqq .05$.

Figure 1: Example of a trial and analysis of aquatic CMJ with the MID level. A = rate of force development (RFD); B = rate of impact force (RIF).

RESULTS: RFD among different conditions showed that LOW is significantly lower than the others ($p < .05$). RIF among different conditions showed that the impact of jumping on-land is significantly higher than the others ($p = .00$), and LOW is also significantly higher than MID and HIGH ($p = .00$).

Table 1
Duration time of each phase rate of force development (RFD) and rate of impact force (RIF) among on-land and in different levels of water jumps:
Mean ± S.D. (second; body weight per second)

Condition	Jumping phase		Landing phase	
	time	RFD	time	RIF
On-land	0.52 ± 0.06	7.00 ± 2.92	0.54 ± 0.13	72.30 ± 22.68 *
LOW	0.49 ± 0.07	4.13 ± 1.39 *	0.64 ± 0.20	23.39 ± 9.38 #
MID	0.40 ± 0.04	6.05 ± 1.82	0.68 ± 0.14	11.90 ± 4.36
HIGH	0.39 ± 0.05	6.00 ± 1.64	0.69 ± 0.15	11.08 ± 6.32

* Significant difference from the others conditions
# Significant different from MID and HIGH

DISCUSSION: The main issue associated with this study deals with the response of jumping on land and in different levels of water, identifying the optimal level of water for training in water. In this study, we found that the jumping in MID and HIGH were similar to jumping on land, and the RIF in MID and HIGH were much smaller than on land.
The characteristics of water assist people to reduce their apparent body weight. At the same time, it may resist people to do movement as well (Harrison, Hillman & Bulstrode, 1992). Therefore, we tried to examine the differences among different level of water and understand the force parameters among those conditions. In our study, participants who jumped in LOW developed lower RFD than the others. It might be due to the buoyancy and resistance of water, which were both little compared with MID and HIGH. Therefore, the effects on jump

performance were not obvious. On the other hand, the RFD of jumping in MID and HIGH were similar to jumping on land. Though buoyancy and resistance work at the same time, the forces of them were unequal and had a great effect on human body. When individual jumps in water, the resistance depended on the speed individual developed and the buoyancy depended on the volume individual immersed (Harrison, Hillman & Bulstrode, 1992). Therefore, characteristics of water affected participant significantly when they were in higher level of water (Martel et al., 2005).

Moreover, RIF showed that there were smaller impact in different levels of water than on land. It could be attributed to buoyancy of water. Jumping in water has a great potential for decreasing the risk of injury because of less landing force (Martel et al., 2005; Colado et al., 2010).

Jumping on land is the most common and convenience training for healthy athletes. However, the great impact may cause injuries. In our study, the results showed that there are similar training effects among land, MID and HIGH. In addition, the impact of MID and HIGH are quite smaller than on land. Therefore, jumping training in water is recommended to prevent from injury.

CONCLUSION: The results of the present study indicate the response to jumping in trochanter major high and nasal-high is similar to jumping on land. Therefore, jumping in trochanter major high and nasal-high are optimal level of water for jumps training. Athletes and patients with lower extremities injuries could carry out jump training in those levels of water to prevent from injury, as well as to improve muscle strength and jump ability.

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