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HEART RATE VARIABILITY OF SQUAT JUMP ACTIVITY ON LAND-, SAND- AND AQUATIC-BASED SURFACES

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The purpose of this study is to examine the variability of heart rate in squat jump activity performed on three different surfaces and environment: land-, sand-, and aquatic-based. Three male subjects aged 20–23 years (mean ± SD, ages: 21.67 ± 1.53 yr, weight: 71.00 ± 11.36 kg, height: 168.33 ± 7.64, BMI: 24.93 ± 2.32) voluntarily participated in the study and completed three days of plyometric squat jump testing. Nonparametric K-related sample (Friedman's test) was used to measure the difference between performances for plyometric exercises on three different surfaces. Statistical analysis proved no significant differences ($p > .01$) for average and maximum heart rate for the three different surfaces ($p = 0.717$ and $p = 0.097$, respectively). The subjects agreed that the aquatic-based plyometric testing had reduced their muscle soreness during the testing.

Keywords: Heart Rate Variability, Land-, Sand-, Aquatic-Based, Squat Jump.

1. INTRODUCTION

Plyometric is described as

> "an exercise that allows muscle to reach maximum strength in as short time as possible" (Chu, 1998).

This terminology was used in the American track and field (Wilt, 1975; Chu, 1998). In the late 1960s, plyometric or the shock method was invented by Yuri Verkhoshanky. Later on, the method became one of the training methods used to improve the performance of athletes.

Wilt (1975) described plyometric training as a quick and powerful movement that involves an eccentric contraction that is followed immediately by an explosive concentric contraction. The plyometric training allows muscles to achieve maximal force in the shortest time possible, hence a useful method for activities that involve explosive and powerful movements in a short period of time (Kobak *et al.*, 2015). In particular, the method combines a stretch-shortening cycle (SCC) with an eccentric-concentric coupling phase. Three distinct phases of SCC are involved in plyometric training: loading (eccentric contraction), amortisation (transition), and unloading (concentric contraction) (Chimielewski *et al.*, 2006).

Researcher have attested the improvements of many variables that are due to land-based training, among which are explosive strength, power, and vertical jump due to land-based training (Hewett *et al.*, 2006; Miller *et al.*, 2006; Ploeg *et al.*, 2010; Tsang *et al.*, 2011). Plyometric trainings have also shown improvement in

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jumping performance, balance, and neuromuscular control during impact on ground (Miller *et al.*, 2006; Myer *et al.*, 2006). In Miller *et al.*'s (2002) study, they demonstrated that plyometric trainings had improved the performance in explosive sports or activities that depend on agility and power, such as hockey, basketball, soccer, volleyball, and track and field. Plyometric training consists of jumping, hopping, bouncing, or shocking training, which involve different intensity (Miller *et al.*, 2002). Most of the plyometric training sessions take place on land, and trainings on land are often associated with injuries and muscle soreness such as patellar tendinopathy due to high ground impact (Miller *et al.*, 2001; Miller *et al.*, 2007; DePalma and Perkins, 2004; Donoghue *et al.*, 2011). A number of studies have examined the efficiency of aquatic-based surface and environment for plyometric training because the environment is deemed advantageous in terms of physiological and psychological aspects (Miller *et al.*, 2001; Wyatt *et al.*, 2001; Jensen, 2008; Colado *et al.*, 2010; Donoghue *et al.*, 2011; Myer *et al.*, 2011). An aquatic-based plyometric training has similar performance effects as land-based training (Markovic, 2007), but the former specifies that the decreased forces of ground impact are related to the buoyancy of water, which in turn, reduces the risk of injuries and imparts less stress to the lower body muscles (Colado *et al.*, 2008; Triplett *et al.*, 2009; Donoghue *et al.*, 2011). The impact of forces and joint loading are also reduced because of the buoyancy forces during the downward movement of the body, which at the same time, assists the upward concentric phase of jump.

Another study has shown that muscle injury can be reduced when the activity is performed on a sand surface rather than on a firm surface such as wood or grass (Miyama and Nosaka, 2004). Sand exercises are related to greater energy cost and low impact to the ground (Impellizzeri *et al.*, 2008; Gaudino *et al.*, 2013). In another study, Binnie *et al.* (2013) attested that the interval trainings on sand produced greater heart rate (HR), blood lactate (BLa) responses, and high relative training intensity. Nevertheless, concentric movements such as jumping and hopping on a sand surface produce lower reuse of elastic energy and energy loss (Miyama and Nosaka, 2004). In order to decrease the impact of the exercise on lower body muscles, it can be induced that training on sand surfaces can be useful for rehabilitation programs.

Hence, this preliminary study was conducted to examine the variability of heart rates in a squat-jump activity on three different surfaces and environments: land-, sand- and aquatic-based.

2. METHODOLOGY

2.1 Participants

In the preliminary study, 3 male university students aged 20–23 years (mean ± SD, ages: 21.67 ± 1.53 yr, weight: 71.00 ± 11.36 kg, height: 168.33 ± 7.64, BMI:

24.93 ± 2.32) voluntarily participated in the study. The participants performed a plyometric squat jump testing on three different surfaces and environments (land-, sand-, and aquatic-based). Polar Heart Rate M400 was used to measure the participants' heart rate during the testing sessions. The descriptive statistics of the samples are presented in Table 1.

TABLE 1: DEMOGRAPHIC DATA OF PARTICIPANT (MEAN ± STANDARD DEVIATION)

Variable	*Total (N = 3)*
Age (years)	21.67 ± 1.53
Weight (kg)	71.00 ± 11.36
Height (cm)	168.33 ± 7.64
BMI	24.93 ± 2.32

BMI = Body Mass Index

2.2 Testing Protocol

The testing protocol lasted for three days, with each session lasting 20–30 minutes per day. The introductory part of the testing consists of a fifteen-minute warm up and stretching. The plyometric testing used in this study was a squat jump (SJ) activity. The participants completed the land-based testing on the first day followed by the sand-based testing and aquatic-based testing on the second and third day, respectively. The total number of jumps in the testing depended on the participant's ability to perform the SJ activity in one minute. They were free to cease performing the SJ activity if they were unable to jump in one minute. A three-minute rest was given to the participants before they performed the second trial of the SJ activity. The depth of water was 50 cm and the temperature was between 23°C and 25°C. All the participants underwent the first testing of squat jump in order to adapt to the plyometric exercise.

2.3 Muscle Soreness

The muscle soreness of the participants were recorded on a seven-point Likert scale at the end of testing session (as adopted by Vicker *et al.*, 2001). The scale consisted of seven points that ranged from 0 to 6, where 0 indicates a complete absence of soreness and 6 reveals a severe pain with limited ability to move (see Table 2).

2.4 Statistical Analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) for Windows (SPSS version 16.0). A nonparametric K-related sample (the Friedman's Test) was used to analyze the variance of heart rate of the participants while they performed the plyometric SJ activity on the three difference surfaces.

TABLE 2: THE SEVEN-POINT LIKERT SCALE OF MUSCLE SORENESS (VICKER *ET AL.*, 2001)

Point	*Descriptions*
0	A complete absence of soreness
1	A light pain felt only when touched/a vague ache
2	A moderate pain felt only when touched/ a slight persistent pain
3	A light pain when walking up or down stairs
4	A light pain when walking on flat surface/painful
5	A moderate pain, stiffness, or weakness when walking/ very painful
6	A severe pain that limits my ability to move

3. RESULT AND FINDINGS

The polar Heart Rate M400 recorded several parameters, but this article will only report three parameters: average heart rate, maximum heart rate, and calories. Table 3 shows the average and maximum heart rate of the participants while performing the plyometric SJ activity on the three difference surfaces. The average and maximum heart rate of the participants for the land-based surface were 138 ± 13.61 and 161 ± 13.32, respectively, which are lower than those performed on the sand-based surface (148 ± 10.5 and 168 ± 13.75, respectively) and the aquatic-based surface (141 ± 4.62 and 170 ± 9.26, respectively).

TABLE 3: AVERAGE AND MAXIMUM HEART RATE ON THREE DIFFERENT SURFACES

	Average Heart Rate (bpm)		*Max Heart Rate (bpm)*	
Surfaces	*Mean*	*SD*	*Mean*	*SD*
Land-Based	138	13.61	161	13.32
Sand-Based	148	10.5	168	13.75
Aquatic-Based	141	4.62	170	9.26

TABLE 4: LEVEL AND CALORIES OF SUBJECTS' MUSCLE SORENESS

	Muscle Soreness Level		*Calories (kcal)*	
Surfaces	*Mean*	*SD*	*Mean*	*SD*
Land-Based	5	0	12	2.08
Sand-Based	5	0	15	2.08
Aquatic-Based	3	0.58	13	0.58

As shown in Table 4, the trainings performed on aquatic-based surface show the least level of muscle soreness and medium calories used on the three different surfaces during the testing session. The muscle soreness level and calories used for the three different surfaces are as follows: for land-based (5 ± 0) and (12 ± 2.08), sand-based (5 ± 0) and (15 ± 2.08), and for the aquatic-based (3 ± 0.58) and (13 ± 0.58), respectively.

TABLE 5: THE FRIEDMAN'S TEST ON THE AVERAGE AND MAXIMUM HEART RATE FOR HE THREE DIFFERENT SURFACES

Test Statistical[a]	*Average Heart Rate*	*Maximum Heart Rate*
N	3	3
Chi-Square	.667	4.667
df	2	2
Asymp. Sig.	.717	.097

a. Friedman Test.

Friedman's test was applied to the average heart rate data to analyze the differences between the performances on the three surfaces. The results indicated no statistically significant changes in terms of average heart rate for the activities performed on the three different surfaces (Chi-square value of $X^2 = .667$, $df = 2$, $p = 0.717$). In addition, no statistically significant changes of maximum heart rate were recorded for the activities performed on the three different surfaces ($X^2 = .4.667$, $df = 2$, $p = 0.097$).

4. DISCUSSION

This preliminary study was performed to examine the variability of heart rates for squat jump testing on three different surfaces: land-, sand- and aquatic-based. The findings noted no significant differences in terms of the participants' heart rate for the squat jump.

The statistical analysis also showed no significant differences in terms of average and maximum heart rate for the trainings performed on the three different surfaces. The mean value of average heart rate for sand-based training was higher than that obtained for aquatic-based training and land-based training. This result indicates that the sand-based squat jump required more energy compared to the land- and aquatic-based squat jump. However, the mean value of maximum heart rate for the sand-based training was slightly lower than that for the aquatic-based training. This is due to the unique characteristics of sand surfaces that require 41.2-1.6 times the total energy cost (Pinnington and Dawson, 2001; Gaudino *et al.*, 2013). Besides, running on a sand surface contributes to greater energy expenditures than running of a firmer surface (Pinnington and Dawson, 2001; Pinnington *et al.* 2005). Thus, there will be significant influences on the subsequent training stimulus due to the different types of sand used, and the environment situations of the sand training locations.

The mean value of maximum heart rate for the aquatic-based training was higher than those obtained from other trainings, probably due to the increasing resistance to the movement and the dynamic properties of water, which includes surface, wave drag, and high viscosity of this medium (Miller *et al.*, 2002; Robinson *et al.*, 2004; Miller *et al.*, 2007). Besides, the buoyancy effect of water makes an aquatic-based training an optimal exercise for athletes. There will be resistance in the water because of the viscosity and drag force of water (Wilder and Brennan, 2004), which require additional muscle activities to overwhelm the resistance and produce similar result as land-based training, particularly in terms of improved performance. It is shown that the presence of resistance in water caused the individual to require more energy compared to those who performed land-based training (low resistant). Although the average heart rate for the aquatic-based training is lower than that in sand-based training, the maximum heart rate for aquatic–based training showed a higher mean value than those obtained for the other two surfaces. This is because in the aquatic-based training, the subjects were able to achieve a maximum heart rate during the squat jump activity.

A plyometric training is usually performed on a firm surface such as wood, grass, hard-court, and track. The impact of forces to the ground and muscle soreness can be reduced by performing the plyometric training on a non-rigid surface like sand or aquatic surface. One study was conducted on non-rigid surfaces to determine if similar improvement in jumping and sprinting performance was noted as those obtained from traditional training, but with less muscle soreness (Markovic and Mikulic, 2005).

The mean values of muscle soreness recorded are as follows: for land- (5), sand-(5) and aquatic-based (3). This finding shows that the aquatic-based plyometric training had demonstrated lower muscle soreness during the squat jump activity. Such a performance can be attributed to the buoyancy effect which reduces the ground impact forces hence giving less stress to the muscles (Colado *et al.*, 2008; Donoghue *et al.*, 2011). In fact, aquatic training has also been proven to reduce the risk of chronic injuries including tendonitis (Myer *et al.*, 2011). In contrast, training on sand surfaces is associated with lower impact force to ground. According to Miyama and Nosaka, (2004), jumping on a sand surface can lower muscles' damage compared to jumping on a rigid surface such as grass or wood. However, the mean value obtained for the sand-based training was similar to that obtained from the land-based training, probably due to the small number of respondents and the duration of the activity.

5. CONCLUSION

The result of this study marks no significant differences of average heart rate variability for the plyometric activity performed on the three different surfaces. Nevertheless, a significant value was marked for the maximum heart rate variability ($p < 0.05$). The aquatic-based training also showed that the training can produce similar performance as those obtained from to land- and sand-based training, hence can be useful in reducing muscle soreness and chronic injury due to lower ground forces impact.Further studies in this area are to compare the usage of energy or calories on three different surfaces with a much larger sample size of participant from different sport background and different level of sport performance.

References

Binnie, M. J., Dawson, B., Pinnington, H., Landers, G., and Peeling, *P*. (2013). Effect of training surface on acute physiological responses after interval training. *The Journal of Strength and Conditioning Research*, 27(4), 1047-1056.

Binnie, M. J., Dawson, B., Pinnington, H., Landers, G., and Peeling, *P*. (2013). Part 2: Effect of training surface on acute physiological responses after sport-specific training. *The Journal of Strength and Conditioning Research*, 27(4), 1057-1066.

Colado, J. C., Tella, V., and Triplett, N. T. (2008). A method for monitoring intensity during aquatic resistance exercises. *The Journal of Strength and Conditioning Research*, 22(6), 2045-2049.

Colado, J. C., Garcia-Masso, X., González, L. M., Triplett, N. T., Mayo, C., and Merce, J. (2010). Two-leg squat jumps in water: an effective alternative to dry land jumps. *International Journal of Sports Medicine*, 31(02), 118-122.

Chu, D.A. (1998). Jumping into Plyometric (2nd ed.). Champaign, Illinois: Human Kinetics.

Chmielewski, T. L., Myer, G. D., Kauffman, D., and Tillman, S. M. (2006). Plyometric exercise in the rehabilitation of athletes: physiological responses and clinical application. *Journal of Orthopedic and Sports Physical Therapy*, 36(5), 308-319.

DePalma, M. J., and Perkins, R. H. (2004). Patellar tendinosis: Acute Patellar tendon rupture and jumper's knee. *The Physician and Sports Medicine*, 32(5), 41-45.

Donoghue, O. A., Shimojo, H., and Takagi, H. (2011). Impact forces of plyometric exercises performed on land and in water. *Sports Health: A Multidisciplinary Approach*, 3(3), 303-309.

Gaudino, *P*., Gaudino, C., Alberti, G., and Minetti, A. E. (2013). Biomechanics and predicted energetics of sprinting on sand: hints for soccer training. *Journal of Science and Medicine in Sport*, 16(3), 271-275.

Hewett, T. E., Ford, K. R., and Myer, G. D. (2006). Anterior cruciate ligament injuries in female athletes Part 2, A meta-analysis of neuromuscular interventions aimed at injury prevention. *The American Journal of Sports Medicine*, 34(3), 490-498.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Martino, F., Fiorini, S., and Wisloff, U. (2008). Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. *British Journal of Sports Medicine*, 42(1), 42-46.

Jensen, R. L. (2008). Kinetic responses during landings of plyometric exercises. *In Proceedings of the XXVI Confernce of the International Society of Biomechanics in Sports,* 393-396.

Kobak, M. S., Rebold, M. J., DeSalvo, R., and Otterstetter, R. (2015). A Comparison of Aquatic- *vs.* Land-Based Plyometrics on Various Performance Variables. *International Journal of Exercise Science*, 8(2), 4.

Marginson, V., Rowlands, A. V., Gleeson, N. *P*., and Eston, R. G. (2005). Comparison of the symptoms of exercise-induced muscle damage after an initial and repeated bout of plyometric exercise in men and boys. *Journal of Applied physiology*, 99(3), 1174-1181.

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine*, 41(6), 349-355.

Markovic, G., and Mikulic, *P*. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports medicine*, 40(10), 859-895.

Miller, M. G., Berry, D. C., Gilders, R., and Bullard, S. (2001). Recommendations for Implementing an Aquatic Plyometric Program. *Strength and Conditioning Journal*, 23(6), 28-35.

Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C., and Michael, T. J. (2006). The effects of a 6-week plyometric training program on agility. *Journal of Sports Science and Medicine*, 5(3), 459-465.

Miller, M. G., Cheatham, C. C., Porter, A. R., Ricard, M. D., Hennigar, D., and Berry, D. C. (2007). Chest-and waist-deep aquatic plyometric training and average force, power, and vertical-jump performance. *International Journal of Aquatic Research and Education*, 1(2), 6.

Miyama, M., and NOSAKA, K. (2004). Influence of surface on muscle damage and soreness induced by consecutive drop jumps. *The Journal of Strength and Conditioning Research*, 18(2), 206-211.

Myer, G. D., Ford, K. R., Brent, J. L., and Hewett, T. E. (2006). The effects of plyometric vs. dynamic stabilization and balance training on power, balance, and landing force in female athletes. *The Journal of Strength and Conditioning Research*, 20(2), 345-353.

Myer, G. D., Faigenbaum, A. D., Ford, K. R., Best, T. M., Bergeron, M. F., and Hewett, T. E. (2011). When to initiate integrative neuromuscular training to reduce sports-related injuries in youth? *Current Sports Medicine Reports*, 10(3), 155.

Pinnington, H. C., and Dawson, B. (2001). The energy cost of running on grass compared to soft dry beach sand. *Journal of Science and Medicine in Sport*, 4(4), 416-430.

Ploeg, A. H., Miller, M. G., Holcomb, W. R., O'Donoghue, J., Berry, D., and Dibbet, T. J. (2010). The effects of high volume aquatic plyometric training on vertical jump, muscle power, and torque. *International Journal of Aquatic Research and Education*, 4(1), 6.

Potach, D. H., and Chu, D. A. (2000). Plyometric training. *Essentials of Strength Training and Conditioning*, 2, 427-471.

Triplett, N. T., Colado, J. C., Benavent, J., Alakhdar, Y., Madera, J., Gonzalez, L. M., and Tella, V. (2009). Concentric and impact forces of single-leg jumps in an aquatic environment versus on land. *Medicine and Science in Sports and Exercise*, 41(9), 1790-6.

Tsang, K. K., and DiPasquale, A. A. (2011). Improving the Q: H strength ratio in women using plyometric exercises. *The Journal of Strength and Conditioning Research*, 25(10), 2740-2745.

Vickers, A. J. (2001). Time course of muscle soreness following different types of exercise. *BMC Musculoskeletal Disorders*, 2(1), 1.

Wilt, F. (1975). Plyometrics: what it is and how it works. *Athletic journal*, 55(5), 76.

Wyatt, F. B., Milam, S., Manske, R. C., and Deere, R. (2001). The effects of aquatic and traditional exercise programs on persons with knee osteoarthritis. *The Journal of Strength and Conditioning Research*, 15(3), 337-340.