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ORIGINAL

EFFECTS OF LAND VS. AQUATIC PLYOMETRIC TRAINING ON VERTICAL JUMP

EFECTOS DEL ENTRENAMIENTO PLIOMÉTRICO ACUÁTICO VS. SECO SOBRE EL SALTO VERTICAL

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ABSTRACT

The aim of this study was to compare the effects of two plyometric training program (aquatic vs. land) on vertical jump. 65 male physical education students took part in this study and were randomly assigned to three groups: aquatic plyometric training group (APT, n = 20), plyometric training group (PT, n = 20) and control group (CG, n = 25). The training program was performed for 10 weeks with a frequency of 2 sessions per week. Volume was increased from 10 sets of 10 repetitions to 10 sets of 55 repetitions. Both APT and PT increased the performance in CMJ and SJ with respect to pretest ($P \leq .001$), whereas CG remained unaltered. No statistically significant difference was observed between APT and PT. In conclusion, APT may be an alternative method to PT, because both training protocols have produced similar gains in the vertical jump, but APT might cause lower mechanical stress.

KEY WORDS: countermovement jump, squat jump, plyometric, dip, strength.

RESUMEN

El objetivo de este estudio fue comparar los efectos de dos programas de entrenamiento pliométrico (inmersión vs. seco) sobre el salto vertical. 65 hombres físicamente activos fueron asignados aleatoriamente a tres grupos: entrenamiento pliométrico acuático (EPA, n 20), entrenamiento pliométrico (EP, n=20) y grupo control (GC, n=25). Los grupos EPA y EP entrenaron 2 sesiones por semana durante 10 semanas, mientras que GC no realizó entrenamiento alguno. El volumen de entrenamiento fue aumentado desde 10 series de 10 repeticiones en la primera semana hasta 10 series de 55 repeticiones en la última. Tanto EPA como EP aumentaron su rendimiento en CMJ y SJ con respecto al pretest (P≤0,001) sin encontrar diferencias significativas entre grupos, mientras que GC no mostró cambios. Como conclusión, el EPA puede ser un método alternativo a EP ya que ambos producen similares mejoras sobre el salto vertical y el estrés mecánico producido por EPA es menor.

PALABRAS CLAVES: Salto con contramovimiento, salto sin contramovimiento, pliometría, inmersión, fuerza.

INTRODUCTION

Plyometric jumps (or plyometric training, PT) is a training method widely spread among athletes of many fields, which has been thoroughly studied throughout the last few decades (Markovic and Mikulic, 2010). Plyometrics involves an eccentric and concentric movement of the muscle, which shows the stretch-shortening cycle (SSC) (Cavagna, 1970; García et al., 2003; Márquez García, 2013). Plyometric exercises are characterized by a high intensity SSC and jumps with drops from heigths between 20 and 80 cm, usually performed on a rigid or flat surface (Milogrom et al., 2000; Nicol et al. 1996).

It has been previously demonstrated that PT produces improvements in physical performance (Saez de Villarreal, Requena, and Cronin, 2012). These improvements of performance after the execution of a PT could be due to a series of functional muscular adaptations caused by the PT itself (Kato et al., 2006; Kubo et al., 2007; Grosset et al., 2009). On the other hand, as it has been demostrated in other studies (Harrison et al., 2001; Hennessy et al., 2001; Myer et al., 2005), the combination of PE with short-length maximum-strength actions can improve muscle strength, vertical jump and speed performances.

As we have mentioned previously, PT consists of an eccentric phase and a concentric phase. The eccentric component is one of the main factors that contribute to muscle damage (Golden et al., 1992; Newhham et al., 1983; Newhham et al., 1983; Cabral de Oliveira, 2001). This is why, although the intensity of the jumps is considered to be beneficial for the improvement of explosive strength, these training methods have been criticized for their potential to increase the appearance of injuries (Blattner et al., 1979; Cometti, 1998; Miller et al., 2002; Chimera et al., 2004). Due to the great impact and stress exerted on musculo-tendinous structures, PT must be applied with caution, adapting the load to the characteristics of the individual in all cases (García et al., 2003).

Thus, in order to reduce the impact upon landing and attenuate muscle damage, powerful muscle contractions are required. Moreover, the landing impact and the risk of injury could be reduced by changing the type of flooring (Komi, 2000; Pettineo et al., 2004; Tillman et al., 2004). A study performed by Miyama and Nosaka (2004), compared the stress produced after performing a jump from a height of 60 cm on a hard wooden surface and on a sandy surface (0.2 m depth). The jump on the rigid surface produced greater decrease of maximum isometric strength and greater muscle pain and creatine kinase (CK) plasma concentration than the jump on the sandy surface.

The present study was designed to increase the knowledge about the effects produced after the performance of an aquatic plyometric training (APT) vs. PT. Thereby, the aim of this study was to compare the effects produced by a plyometric training underwater and a regular plyometric training on vertical jump performance.

MATERIAL AND METHODS

Participants

A total of 65 subjects, physically active and students of physical education at the University of Malaga participated in this study. All of them were healthy males and their characteristics are listed in Table 1.

The participants were distributed in three groups: APT (n=20), PT (n=20) and CG (n= 25). The groups who performed training, i.e. APT and PT, did so for 10 weeks, in 2 sessions per week, with a minimum of 48 hours of recovery between them. The number of sets during the experimental phase was kept at 10 sets, whereas the number of jumps was increased in 5 more jumps per week. CG did not perform any training throughout the duration of the study. Prior to the beginning of the study, the participants were informed of the potential risks and benefits involved, and they signed an informed consent. None of them took any kind of drug that could alter their physical or hormonal balance before or during the investigation. The study was approved by the Scientific Ethics Committee of the University of Malaga.

Table 1. Descriptive statistics of the sample (n = 65).

	AGE (years)	*HEIGHT (cm)*	*WEIGHT (kg)*	*FAT MASS (%)*	*BMI*
APT	21.8 ± 3.4	177.8 ± 5.6	79.0 ± 10.7	12.9 ± 6.3	24.8 ± 2.9
PT	20.8 ± 3.1	176.7 ± 6.0	75.3 ± 10.3	13.2 ± 6.5	24.2 ± 2.7
CG	20.1 ± 2.2	178.0 ± 7.2	73.9 ± 10.3	13.0 ± 4.4	23.3 ± 2.5

The data are expressed as mean ± standard deviation. BMI: body mass index

Facilities

The training exercises of the underwater group were carried out in a 2.2 m deep swimming pool, with a constant water temperature of 27ºC, whereas the training exercises of the regular group were performed on a solid concrete surface in a sports court.

Materials

Following the guidelines of Bosco (1991), jumping capacity was measured by using the “Bosco Ergo-jump plus System” platform (Byomedic, S.C.P., Spain). Weight, fat percentage and body mass index (BMI) were measured by the use of an impedance meter (TANITA BC-418, Japan), following the instructions provided by the manufacturer. Subject height was measured using a wall mounted stadiometer (Seca model 216, Germany) with an accuracy of 1mm.

Procedure

The effects of the different types of training were assessed through the change in vertical jump, before (T1) and after (T3) the 10 weeks of training, with an intermediate measurement (T2) at the end of the fifth week of training. The preparation was the same for all the jump tests. All subjects were given written information about how to perform the tests and prior to their performance they were taught with practical and visual demonstrations how to carry out the correct execution for each exercise, with two familiarization sessions.

The jump tests applied in this study were Squat Jump (SJ) and Countermovement Jump (CMJ). In the first test, a concentric work was performed with a knee angulation of 90º without executing any previous movement. The second test consisted of a concentric work preceded by an eccentric activity in which the body drops rapidly with a knee flexion of approximately 90º in order to reach the maximum possible height.
The jumps were assessed based on the best value of two attempts, which were separated by a 30 min rest. The jumps were considered invalid in the following cases: landing out of the platform; changing the initial stance when gaining momentum; performing a small countermovement before the jump, in the case of SJ; and if there was a rebound action at landing.

The APT program was performed twice a week for 10 weeks in the swimming pool mentioned previously. Each individual was placed next to each other along 25 m in the track of the swimming pool that is close to the edge, in order to let the participants rest on the side step during the resting times between sets. The individuals were separated by 1 m from each other, in order to allow enough space between them to prevent the jumps from being hindered by any kind of contact between the participants.

The regular plyometric training consisted of carrying out exactly the same number of jumps with the same distribution of sets, repetitions, protocol and rests as those performed underwater. The characteristics of the training program conducted are listed in Table 2.

Table 2: Training program

Weekly schedule and jumps performed in each session		
	2 Sessions per week	
1st week	10 x 10 jumps per session = 100 jumps	Total 200 jumps
2nd week	10 x 15 jumps per session = 150 jumps	Total 300 jumps
3rd week	10 x 20 jumps per session = 200 jumps	Total 400 jumps
4th week	10 x 25 jumps per session = 250 jumps	Total 500 jumps
5th week	10 x 30 jumps per session = 300 jumps	Total 600 jumps
6th week	10 x 35 jumps per session = 350 jumps	Total 700 jumps
7th week	10 x 40 jumps per session = 400 jumps	Total 800 jumps
8th week	10 x 45 jumps per session = 450 jumps	Total 900 jumps
9th week	10 x 50 jumps per session = 500 jumps	Total 1000 jumps
10th week	10 x 55 jumps per session = 550 jumps	Total 1100 jumps
		TOTAL 6500 jumps

Statistical analysis

The results were analyzed with SPSS 17.0 software for Windows (SPSS, Chicago). The normal distribution of the initial characteristics of the sample was assessed through the Kolmogorov-Smirnov test and the homoscedasticity was checked using the Levene test.

As a statistical test between groups, a one factor ANOVA was performed in T1. For the analysis of the between-group and intra-group effects, a 3x3 repeated measures factorial analysis with a Bonferroni´s Post-Hoc was conducted, using a between-group factor (APT, PT and Control) and an intra-group factor (T1, T2 and T3). Likewise, for the assessment of effect sizes (ES), Hedges´ g was used to estimate the magnitude of the effect of training on vertical jump. A statistical significance level of $P \leq 0.05$ was set for all tests.

RESULTS

No significant differences were found between groups in any of the variables in T1 ($P \leq 0.05$). Both training groups (APT and PT) obtained significant improvements in T2 and T3 with respect to T1, both in SJ ($P \leq 0.001$) and CMJ ($P \leq 0.05$), with no significant improvements between groups (Table 3).

Table 1. Jump height results in SJ and CMJ for groups APT and PT

	T1	T2	T3	ES_{2-1}	ES_{3-1}
SJ – APT (cm)	31.5 ± 3.6	35.3 ± 5.6 ***	35.1 ± 6.0 ***	**0.81**	**0.73**
SJ – PT (cm)	29.8 ± 5.8	34.9 ± 5 ***	34.1 ± 5.4 ***	**0.88**	**0.77**
SJ - Control (cm)	30.8 ± 4.0	32.0 ± 5.2	32.0 ± 4.5	**0.26**	**0.64**
CMJ - APT (cm)	33.5 ± 4.3	38.4 ± 10.9 *	36.9 ± 9.0 *	**0.59**	**0.48**
CMJ - PT (cm)	31.4 ± 4.9	35.5 ± 5.8 *	35.0 ± 5.0 *	**0.76**	**0.68**
CMJ - Control (cm)	33.7 ± 5.0	34.3 ± 5.0	33.6 ± 4.7	**0.12**	**0.02**

Significant intra-group differences with respect to T1: * $P \le 0.05$, ** $P \le 0.01$, *** $P \le 0.001$

SJ: Jump without countermovement. CMJ: Jump with countermovement.

APT: Aquatic plyometric training. PT: Regular plyometric training.

ES: Effect size.

On the other hand, no significant differences were observed for any of the groups in T3 with respect to T2, neither in SJ nor in CMJ.

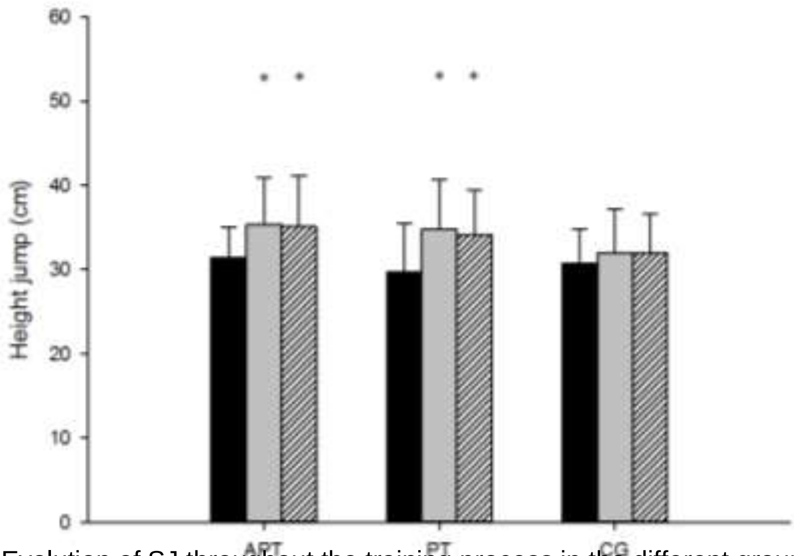

Figure 1. Evolution of SJ throughout the training process in the different groups. Significant intra-group differences with respect to T1: * $P \le 0.05$

The control group remained practically constant and without statistically significant changes in all the tests. No significant differences were observed in such group for any of the exercises (Table 3).

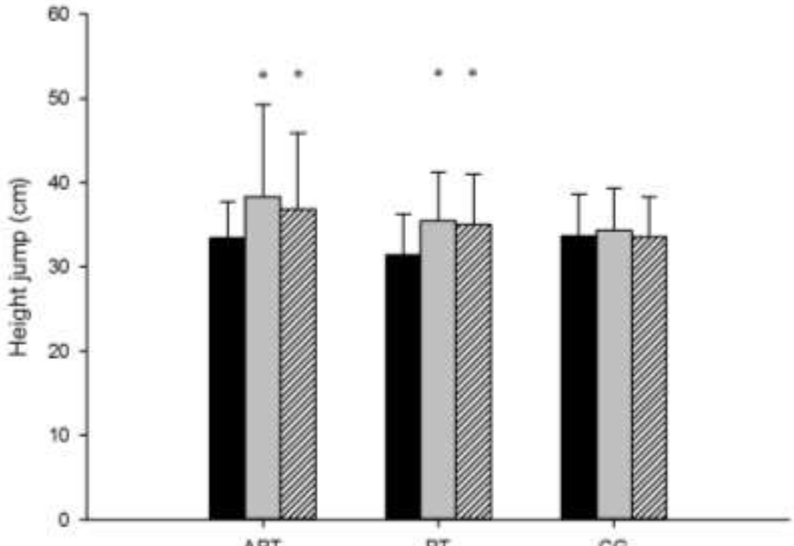

Figure 2. Evolution of CMJ throughout the training process in the different groups. Significant intra-group differences with respect to T1: * $P \leq 0.05$

ES was higher in the two exercises assessed for the two experimental groups with respect to the control group (Table 3).

DISCUSSION

The main finding of the present study was that both APT and PT obtained a similar increase in the performance of vertical jump, both in SJ and CMJ. The buoyancy involved when performing an APT lowers the impact at landing, thus attenuating the mechanical stress (Sanders, 2002), which reduces the risk of injury. These results suggest that aquatic plyometric training could be an alternative method to regular plyometric training.

A previous study (Miller et al., 2002) did not find any improvements in the performance of vertical jump in any of the training groups after an 8 week-long training program. The differences in the methodology used with respect to our study could account for the differences observed between the results of both studies. The number of jumps performed in the mentioned study was considerably lower than the number of jumps performed in our study (80 - 120 vs. 100 - 550 jumps per session), which could be an insufficient number of jumps to cause changes in the performance. Furthermore, the plyometric training was carried out in an aquatic centre, with a water level up to the waist, whereas in our study the depth of the swimming pool was greater; this fact may have affected the adaptations produced by the APT. The groups were formed by both genders, whereas in our study all the individuals were males. All these differences in the methodology hinder the direct comparison between the results of both studies.

On the other hand, in line with the results provided by our research, previous studies (Stemm and Jacobson, 2007; Robinson et al., 2004) have found similar improvements on the performance of vertical jump caused by the realization of an aquatic plyometric training, with respect to a regular plyometric training. Moreover, Martel et al. (2005) conducted a 9 week-long APT vs. PT training program with volleyball female players, in which similar increases were found in the performance of both training groups. This finding has an additional importance, since the usual training of this sport involves a large number of jumps over a solid surface. These jumps may cause an excessive stress, which may be increased with the addition of traditional plyometric training. Therefore, if the aquatic plyometric training has shown to produce similar improvements to those produced by a regular plyometric training, with the advantage of preventing additional stress, then the underwater plyometric training should be considered as a good option for the improvement of vertical jump performance in the case of these athletes. This assertion is supported by previous studies (Hewett, 1996; Chimera et al., 2004; Wilkerson et al., 2004), which state that APT may reduce the risk of injury with respect to the regular plyometric training.

On the other hand, a study by Carrasco and Vaquero (2010), conducted with women at risk of bone fracture, found that a program of aquatic exercises offered significant gains, both in jump capacity and body composition. Thereby, an APT is beneficial for the improvement of functional capacity, health and life quality in individuals of these characteristics. In this line of research, Díaz et al. (2010) obtained a trend toward the improvement of bone stiffness index in women over 50 years of age. Water level seems to be an important factor, since the group that conducted the training in a deep swimming pool seemed to have had greater effect on the bone stiffness index than a second group, who performed the aquatic training with lower water level.

The fact that in the present study both training groups had obtained better performance in the intermediate tests could be related to the training volume. It seems that for both training groups the volume carried out from the sixth week (350 – 500 jumps per session) could involve excessive fatigue, which may decrease vertical jump performance. On the other hand, in a recent study (Jurado-Lavanant et al., 2013), a training program (APT vs. PT) was carried out to improve SJ and CMJ for six weeks, after which no significant differences were found between the two groups. In this study, lower increases were found in vertical jump performance with respect to the present study (5-6 vs. 11-13 %). The difference between the results of both studies could be due to the longer duration of the training program carried out in the present study (10 vs. 6 weeks), in addition to the greater total number of jumps (6500 vs. 2700 jumps). In view of the present results and those in the literature, there seems to exist an optimal training volume, so that if a different volume is performed, either lower or higher, the results produced over physical performance would not be the best possible (Gonzalez-Badillo, Gorostiaga, Arellano, e Izquierdo, 2005).

CONCLUSIONS

To sum up, we can conclude that PT and APT produce similar gains in jump capacity in SJ and CMJ after 10 weeks of training. Both programs were effective in the development of the elements involved in vertical jump performance. However, the lower stress produced by APT due to the impact attenuation caused by buoyancy (Miller et al., 2002; Sanders, 2002) suggests that aquatic plyometric training is a good alternative method to the traditional plyometric training for the improvement of vertical jump performance.

On the other hand, the decrease in the results from the fifth week with a total of 300 jumps per session could be a reference for future research. This evolution suggests that there is an optimal training volume, from which the training not only stops providing any gains, but it could even cause the decrease of performance.

Therefore, we can confirm the hypothesis established: *“Jump performance is improved with underwater training”,* since the results have proven that this training method is at least as efficient as the traditional training.

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