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

EFFECTS OF EXTERNAL LOADING ON POWER OUTPUT DURING VERTICAL JUMPS: A COMPARISON BETWEEN WATER POLO AND VOLLEYBALL PLAYERS

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The purpose of this study was to compare results of the effects of external loading on power output during vertical jumps performed on a force platform by twelve male water polo athletes and ten female volleyball players. Peak power output was calculated from time-force curves during vertical jumps with and without external additional loads corresponding to 0%, 5%, 10% and 15 % of their body weight. The jumps were performed from a squat position, without lower limb counter-movement or arm swings. The results showed no significant differences in peak power output between the different loading conditions for volleyball athletes, but a significant difference between 0% and 10% loading conditions for water polo athletes. This study suggests that for both groups the load that generates maximum power output is body weight.

KEY WORDS: training, biomechanics, force platform.

INTRODUCTION: Many coaches have applied external loading during physical training. Assuming that power is the product of force and velocity, some studies have shown that to increase power output athletes should train with velocity and resistance that maximizes mechanical power output (Kawamori and Haff, 2004; Cormie et al. , 2006). Driss et al. (2001) support the hypothesis that the effect of external loading on power output in a squat vertical jump depends on physical activity. The water polo athletes are supposed to have very similar power characteristics to volleyball players, but their activity happens in a different fluid, water. Platanou (2005) describes that the performance of the water polo athletes in the water vertical jump correlates poorly with the height assessed in the dry-land vertical jump. Thus, based on power output during vertical jumps performed on a force platform, this paper compared results of the effects of external loading on the variables: peak power output, peak velocity, peak force and jump height assessed among twelve water polo players and ten volleyball players.

MATERIALS AND METHODS: Twelve male water polo athletes and ten female volleyball athletes from a national elite team volunteered to take part in this study. Their age and physical characteristics are shown in table 1.

Table 1
Physical characteristics of the players

Athletes	Age (years)	Body Mass (kg)	Height(m)	% Body Fat
Water polo	23.33 ± 6.81	84.95 ± 5.25	1.84 ± 5.14	19.16 ± 3.71
Volleyball	22.20 ± 6.61	75.64 ± 8.77	1.84± 6.90	18.69 ± 3.71

Peak instantaneous output power, peak instantaneous velocity and peak instantaneous force were determined during standardized vertical jumps with both legs, performed on an AMTI force platform. Power calculation used the measurement of the vertical force in addition to the subjects weight (including any objects they were holding) to determine the net force acting on the body. By applying Newton’s second law (F=M.A) the acceleration of the body was calculated using vertical force and body mass. Vertical velocity was subsequently determined by integrating acceleration. Output power was calculated by using vertical velocity and vertical force. Peak instantaneous power output corresponded to the highest instantaneous power output before take-off at each load during three jumps. Peak instantaneous velocity and peak instantaneous force did not correspond with the values used to calculate peak instantaneous output power, but, as stated by Driss et al. (2001) these values presented a very similar pattern. The maximal height was assessed by the double integration of the vertical force. Force data was sampled at 500 Hz for a total of 3s. Jumps were performed from a squat position with heels on the platform and thighs in a horizontal position. Lower limb counter-movement and swinging of the arms were not allowed; the participants grasped the collar of their shirts with their hands. The external loads were put on a special belt and the participants jumped with no load (0%), or with an external load corresponding to 5%, 10% or 15% of their relevant body weight. The loads were distributed on the trunk in accordance with previous standardization (Driss et al., 2001). After a warm-up they performed three vertical jumps at each load with at least 90 s between jumps in random order. Participants were encouraged to reach a maximum height with every trial in an attempt to maximize power output. For each load the best trial was that corresponding to the highest peak instantaneous power. The results were analyzed using two-way analysis of variance (ANOVA) for repeated measures followed by the Tukey test for multiple comparisons. Statistical significance for the analyses was defined by $P \leq 0.05$.

RESULTS: The values of peak instantaneous power in the different loading conditions for both analyzed groups are shown in table 2.

Table 2
Power output in the different loading conditions for the two analyzed groups

Athletes	Additional Load (% BW)*	Peak Power ($W.kg^{-1}$)
Water Polo	0	56.32 ± 3.61
	5	53.35 ± 5.51
	10	49.85 ± 4.88
	15	50.45 ± 8.51
Volleyball	0	51.51 ± 6.64
	5	48.64 ± 6.53
	10	46.89 ± 6.47
	15	44.15 ± 5.53

* Total load (N) = Body weight + additional load

The results showed no significant differences in peak power output between the different loading conditions for volleyball athletes and a significant difference between 0% and 10% loading condition for water polo athletes.
Values of peak force, peak velocity and height assessed in the vertical jump for the different loading conditions for both groups are shown in Figures 1, 2 and 3. The results showed no significant differences in peak force, peak velocity or maximal height attained between the different loading conditions for both groups – water polo and volleyball athletes. However in water polo athletes there was a tendency of an average increase of 3% in peak force with each additional load while in volleyball players this tendency was lower, 1% for the first additional load, 2% for the second and less than 0.5% for the third. In relation to the tendency in peak velocity both groups reached a total of 10% decrease in the third load condition.

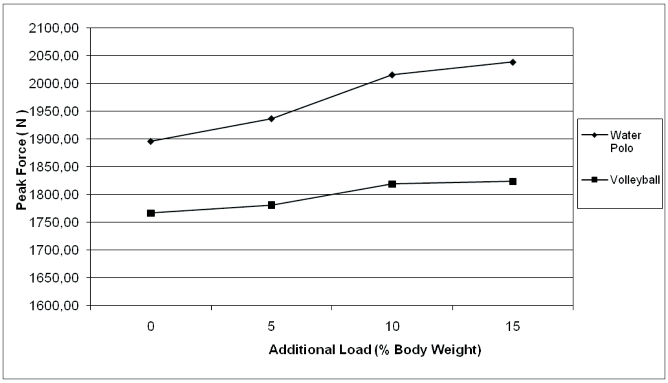

Figure 1: Relationship between peak force (absolute) and load expressed as a percentage of body weight for the water polo and volleyball athletes.

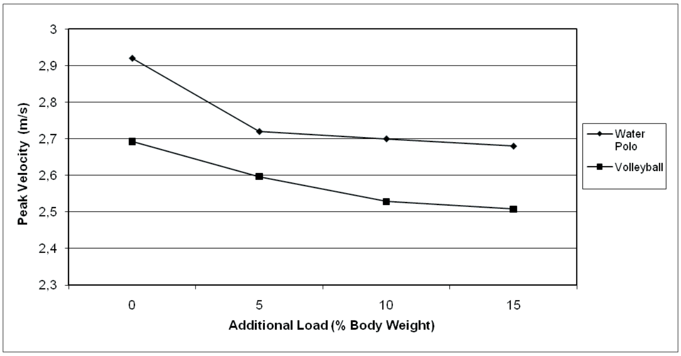

Figure 2: Relationship between peak velocity and load expressed as a percentage of body weight for the water polo and volleyball athletes.

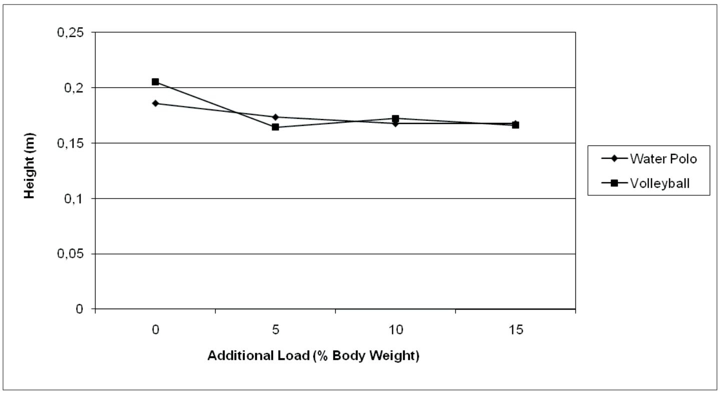

Figure 3: Relationship between height attained in the vertical jump and load expressed as a percentage of body weight for the water polo and volleyball athletes.

DISCUSSION: The values of peak power presented by water polo athletes were similar to those described for male volleyball players and weight lifters; female volleyball athletes' results were lower than these values and higher than those described for sedentary males and females (Driss et al., 2001). Driss et. al. (2001) described that for sedentary males and females peak instantaneous power in a squat jump at 0 kg external load was significantly higher than at 5 and 10 kg, but the differences at 0, 5, and 10 kg were not significant among strength and power athletes. The results for water polo athletes did not agree with this and this difference probably occurred due to velocity changes between the segments combined in a different way to other power athletes, used to performing on land. This is supported by their changes in peak force and peak velocity derived from the additional loads that were very similar to results presented by other power athletes. In accordance with Riggs and Shepard (2009) the relative peak power demonstrated the strongest positive correlation to vertical jump height for male and female beach volleyball players, and males were able to produce significantly higher power output for peak power. The difference was attributed to females having reduced lower extremity muscle mass. So, although many investigators support the idea of using the optimal load to develop maximum mechanical power output, there is inconsistency in what the optimal load to generate the highest power production is (Kawamori and Haff, 2004). The results of the current investigation identified the optimal additional load as 0% of the body weight for both analyzed groups – water polo and volleyball athletes. Cormie et al (2007) identified the optimal load in the jump squat for athletes as 0% of 1 RM. In contrast Stone et al. (2003) reported the optimal load for the jump squat as being 10% of 1RM. So, body weight alone could possibly correspond to a resistance high enough for the production of maximal mechanical power output.

CONCLUSION: The load that generates maximum power output should be taken into account when designing a program to improve maximal muscular power, because training at this load is most effective in improving maximal power output. This study supports the idea that the load that generates maximum power output for power athletes is body weight without any additional load. The program for the volleyball players should be the same proposed for sprinters and jumpers, taking into account gender differences. Results obtained for maximum power output in land jumps executed by water polo athletes were similar to those of other power athletes. Even so, these findings do not contribute greatly to their training program. The way of measuring power output in water needs to be improved, as does the understanding of the relationship between technical skills and maximum power output.

REFERENCES:

Cormie, P.; Mccaulley, G; Triplett, T.; Macbride, J. (2007) Optimal loading for maximal power output during lower-body resistance exercises. Med Sci Sports.Exerc, 39, 340-349.

Driss,T;Vandewalle,H.;Quievre, J.; Miller, C.; Monod, H. (2001) Effects of external loading on power output in a squat jump on a force platform: A comparison between strength and power athletes and sedentary individuals. J Sports Sciences, 19, 99-105.

Kawamori, N.; Haff, G. (2004) The optimal training load for the development of the muscle power. J Strength Cond Res, 18, 675-684.

Platanou, T.(2005) On-water and dry land vertical jump in water polo players. J Sports Med Phys Fitness, 45, 26-31.

Riggs, M.P.;Sheppard, J.M. . (2009) The relative importance of strength and power qualities to vertical jump height of elite beach volleyball players during the counter-movement and squat jump. J.Hum.Sport Exerc, 3, 221-236.

Stone, M. H.; O'bryant, H.S. ; Mccoy, L.; Coglianese, R.; Lehmkuhl, M.; Schilling, B. (2003) Power and maximum strength relationships during performance of dynamic and static weighted jumps J Strength Cond Res, 17, 140-147.

Acknowledgement
The authors would like to thank Mackpesquisa from the Presbyterian University Mackenzie for the financial support for the research.