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# KINETIC PARAMETERS DETERMINANTS OF PERFORMANCE IN COUNTER MOVEMENT JUMP

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The aims of this study were: to identify the force and velocity parameters related with performance in the Counter Movement Jump (CMJ); and to compare these parameters between sprinters and volleyball players. Twelve sprinters and 12 volleyball players took part of this study. The jump height, power output, peak velocity (PV), maximum force (MF), rate of force development and time to reach maximum force were analyzed. A significant correlation of jump height with PV and between power output and all variables were found, except between jump height and MF. Difference between sprinters and volleyball players were found - $p<0.05$. Thus, the velocity was the main factor determinant of jump height and the maximum force and velocity were the main determinants of the power output. Sprinters had better performance in the CMJ than volleyball players.

**KEYWORDS:** force, power, performance.

**INTRODUCTION:** The performance in vertical jumps (VJ) is considered one of the best indicators of level of lower limbs muscle power (Kraska, 2009). Thus, the VJ is an important predictor of performance in various sports that require explosive actions such as in speed races and volleyball (Hennessy & Kilty, 2000; Kraska, 2009). From the biomechanical point of view, power is characterized as the work rate accomplishment per unit time, more specifically the product of force and velocity. Regarding strength, studies have showing that many of its characteristics as the level of maximum force (Fmax), the time to reach maximum force (TFmax) and rate of force development (RFD) are related to performance in VJ (Stone et al. 2003; McLellan, Lovell & Gass, 2010). An important aspect is the fact that the strength and speed parameters as predictor of power may have different characteristics according to the action developed in each sport. For example, sprinters need power to move as quickly as possible and volleyball players use the power to jump. So, it seems there is a gap in the literature regarding the comparison of these factors in sports that use explosive action in different motor gestures. Based on these aspects, the present study aimed to: i) identify the strength and speed parameters related to performance in CMJ and SJ, ii) compare these parameters between sprinters and volleyball players.

**METHOD:** Twenty-four male athletes, 12 sprint runners (21.2 ± 3.3 years; 69.0 ± 5.6 kg of body weight; 175.5 ± 6.5 cm of height; 8.3 ± 1.8% of body fat) at regional and national level events and 12 volleyball players at national level (23.6 ± 4.1 years; 85.5 ± 16.2 kg of body weight; 196.7 ± 12.8 cm of height; 9.9 ± 2.8% of body fat) took part of this study. All procedures received local ethics committee approval. The athletes performed three Counter Movement Jump (CMJ) on the force plate (Kistler®, Quattro Jump, 9290AD, Winterthur, Switzerland). The ground reaction force (GRF) was analyzed in the concentric phase of the jump (from the moment of the transition of the eccentric to concentric phase until the beginning of the flight phase). From the GRF curve the following variables were identified: a) jump height: the displacement of the center of mass was obtained by double integrating of the force, being the higher vertical displacement considered the jump height; b) Power output: product of the FRS by velocity in the concentric phase of the jump, being considered for the analysis the average values of curve; c) Maximum force (MF): identified as the highest value obtained in the concentric phase of the jump, expressed in absolute terms (N) and relativized by body mass (% BM); d) Time to reach maximum force (TMF) in the concentric phase of the jump; e) Rate of force development (RFD): considered as the slope of the force-time curve in the time interval of 0-150 ms relative to the beginning of the concentric phase; f) Peak velocity (PV): the highest value identified in the velocity curve

(obtained by integrating the force) immediately before the release of the foot with the ground. For data analysis, the t-test for independent samples and Pearson correlation were used, with significance set at 5%.

**RESULTS:** Table 1 shows the comparison of parameters of the CMJ between sprinters and volleyball players.

**Table 1**
**Comparison of parameters of the CMJ between sprinters and volleyball players.**

| | SPRINTERS | VOLLEYBALL PLAYERS |
|---|---|---|
| Height (cm) | 54.72 ± 5.46 * | 48.38 ± 3.96 |
| Power ($W \cdot kg^{-1}$) | 33.31 ± 4.99 * | 27.95 ± 2.93 |
| MF (N) | 1842.49 ± 211.24 | 2045.15 ± 320.54 |
| MF (%BM) | 2.59 ± 0.26 * | 2.43 ± 0.36 |
| TMF (s) | 0.38 ± 0.14 | 0.42 ± 0.14 |
| RFD ($N \cdot s^{-1}$) | 3077.5 ± 2067.7 | 3245 ± 2179.46 |
| PV ($m \cdot s^{-1}$) | 3.04 ± 0.15 * | 2.85 ± 0.13 |

MF: maximum force; TMF: time to reach maximum force; RFD: rate of force development; PV: peak of velocity. * Significant differences between the groups

According to the results in Table 1, it was found that the jump performance (height and power) were higher in sprinters compared to volleyball players. Among the parameters of force and velocity, relative MF and PV also were higher in sprinters.

**Table 2**
**Correlation of height and power with force and velocity variables in the CMJ.**

| | Height | Power |
|---|---|---|
| RFD | 0.19 | 0.45 * |
| MF | 0.05 | 0.12 |
| MF | 0.34 | 0.70 ** |
| TMF | -0.15 | -0.56 * |
| PV | 0.97 ** | 0.75 ** |

RFD: rate of force development; MF: maximum force; TMF: time to reach maximum force; PV: peak of velocity. * $p \leq 0.05$; ** $p \leq 0.01$

As shown in Table 2, the jump height was correlated with PV, while the power obtained in CMJ was related with all variables, except with the MF absolute. Table 2 shows the comparison of variables obtained in the CMJ between sprinters and volleyball players.

**DISCUSSION:** The fact that the PV in this study to be the only determinant of the jump height probably due to the existence of a counter-movement (eccentric phase) prior to the propulsion phase (concentric), allowing the detachment of the ground at high speed. The stretch-shortening cycle (SSC) is an important mechanism that occurs in eccentric-concentric movements, in which there is accumulation of elastic energy that can be reused in the concentric phase (Komi, 2000), contributing to performance on the CMJ. In addition, a rapid

transition between the eccentric-concentric phases (Komi & Gollofer, 1997) and tendon stiffness (KUBO et al., 2006) can contribute to generate speed and consequently to performance at CMJ. There was significant correlation of the power obtained at CMJ with the relative force and velocity in the jump. As Hill (1938), the power produced in the movement is determined by the hyperbolic relationship between muscle contraction velocity and muscle tension developed. The power output in CMJ also correlated with indicators of explosive strength, showing that the time to reach maximum force and rate of force development are important aspects for power production (Kraska et al., 2009, Aagaard et al. 2002). Comparing the performance and velocity and strength parameters between sprinters and volleyball players was observed that performance in CMJ was greater in the sprinters. Furthermore, we observed that the sprinters had higher values of maximal force and peak velocity, confirming the findings of Kollias et al. (2001) that compared the VJ of the sprinters with volleyball, soccer and basketball players. Training characteristics of these sports can explain the differences found (Kollias et al., 2001). The mode of exercise used by sprinters for neuromuscular training is performed in the form of short sprints and also multi-jumps (usually plyometric training), both effective for increasing muscle power levels (Markovic et al., 2007). Considering that volleyball players perform basically multi-jumps training to muscle power (Fatouros et al., 2000), thus the sprint training could be the determinants factor to generate greater force, velocity and consequently higher performance in CMJ (Kollias et al., 2001). Based on results, we can suggest to the volleyball coaches include sessions of short sprints in combination with multi-jumps and plyometric training in order to increase performance in VJ.

**CONCLUSION:** We conclude that the peak velocity was the main determinant of the jump height. The maximal force and velocity were the main determinants of the power output in CMJ. However, the results of this study also point out the importance of RFD and TFmax, showing that athletes with greater explosive force are those with higher power levels at CMJ. Finally, sprinters had better performance in the CMJ than volleyball players, possibly due to the influence of genetic loads and training characteristics.

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