KINETIC PARAMETERS DETERMINANTS OF PERFORMANCE IN COUNTER MOVEMENT JUMP

Juliano Dal Pupo, Daniele Detanico and Saray Giovana dos Santos

Biomechanics’ Laboratory, Federal University of Santa Catarina, Brazil

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.

<table>
<thead>
<tr>
<th></th>
<th>SPRINTERS</th>
<th>VOLLEYBALL PLAYERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>54.72 ± 5.46 *</td>
<td>48.38 ± 3.96</td>
</tr>
<tr>
<td>Power (W·kg⁻¹)</td>
<td>33.31 ± 4.99 *</td>
<td>27.95 ± 2.93</td>
</tr>
<tr>
<td>MF (N)</td>
<td>1842.49 ± 211.24</td>
<td>2045.15 ± 320.54</td>
</tr>
<tr>
<td>MF (%BM)</td>
<td>2.59 ± 0.26 *</td>
<td>2.43 ± 0.36</td>
</tr>
<tr>
<td>TMF (s)</td>
<td>0.38 ± 0.14</td>
<td>0.42 ± 0.14</td>
</tr>
<tr>
<td>RFD (N·s⁻¹)</td>
<td>3077.5 ± 2067.7</td>
<td>3245 ± 2179.46</td>
</tr>
<tr>
<td>PV (m·s⁻¹)</td>
<td>3.04 ± 0.15 *</td>
<td>2.85 ± 0.13</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFD</td>
<td>0.19</td>
<td>0.45 *</td>
</tr>
<tr>
<td>MF</td>
<td>0.05</td>
<td>0.12</td>
</tr>
<tr>
<td>MF</td>
<td>0.34</td>
<td>0.70 **</td>
</tr>
<tr>
<td>TMF</td>
<td>-0.15</td>
<td>-0.56 *</td>
</tr>
<tr>
<td>PV</td>
<td>0.97 **</td>
<td>0.75 **</td>
</tr>
</tbody>
</table>

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

REFERENCES:
The purpose of this study was to investigate the muscle-tendon unit stiffness of the ankle between professional soccer players and non-soccer players. Fifteen soccer players and twenty-one non-soccer players participated in this study. The stiffness of the triceps surae muscle-tendon unit was measured in vivo from the damped frequency of oscillation of the shank about the ankle using a free oscillation technique. Using the t-test no significant differences (P > 0.05) were found between the soccer and the control groups for muscle-tendon unit stiffness of the triceps surae. The soccer group showed stiffness values of 22059 (SD 3623) N/m, while the control group showed values of 20427 (SD 4517) N/m. These results suggest that neither the soccer training nor the games itself affected the stiffness of the ankle of the players.

**KEY WORDS:** Biomechanics, Soccer, Ankle stiffness.

**INTRODUCTION:**
Soccer players require physical, technical and tactical skills to succeed. The role of each one of these characteristics in performance is difficult to discriminate, nevertheless all of them are important and contribute to performance differences. According to Jan Hoff (2005) muscular strength, power and endurance are important physical resources enhancing basic physiological capacities for playing soccer. Bangsbo et al. (1991) reported that acceleration and speed skills such as turning, sprinting and changing pace are critical to soccer and may be improved by increasing the available force of muscular contractions in the appropriate muscle groups. During soccer training, changes of the muscle-tendon units should occur with repercussions for force production which might reflect in stiffness. Typical soccer skills like running (Seyfarth et al., 2002), jumping (Arampatzis et al., 2001) and sprinting (Stefanyshyn & Nigg, 1998) have been reported as being related with leg stiffness. Furthermore ankle stiffness play an important role in leg stiffness (H. Hobara et al., 2007).

The focus of the present work is within the physical characteristics of soccer players, specifically in the study of the muscle–tendon unit (MTU) stiffness of the triceps surae. Generally defined, stiffness can be described as the ratio of force change to length change (Butler et al., 2003). The investigation of stiffness is often developed as it relates to performance and the risk of injury. Particularly, lower and higher values of stiffness may lead to soft tissue and bone injuries, respectively (Butler, et al., 2003). Furthermore studies (Nielsen & Yde, 1989; Engström et al., 1991) on soccer injuries have showed that knee and ankle injuries are the most prevalent.

In summary, soccer training may change the muscles and tendons which in turn can affect the MTU stiffness. Both insufficient and excessive MTU stiffness can increase the risk of injuries. MTU stiffness can be related to soccer performance and the risk of injury. To the authors' knowledge MTU stiffness of professional soccer players has never been assessed.

**References:**