KINETIC AND KINEMATIC FEATURES OF COUNTERMOVEMENT AND *SAUTÉ* JUMPS IN CLASSICAL BALLET DANCERS

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The purpose of this study was to investigate how the external rotations of lower limbs influence the performance of ballet dancers in jumps. Four ballet dancers with high technical proficiency were recruited for a test, they performed three attempts the countermovement and *sauté* jump. Two force plates were used to determine ground reaction forces. Six cameras were used to collect the kinematic data. It was analyzed the peak of knee flexion, peak of ground force reaction and jump height. The performance in countermovement and *sauté* jump tests was compared through box plot analysis. In conclusion, even with a lower degree of knee flexion, dancers can produce higher jumps and more ground force reaction on countermovement jump. The results suggest that the attention focus when jumping is an important determinant of jump performance.

KEY WORDS: biomechanics, dance, jump, external rotation.

INTRODUCTION: Performance in classical ballet demands perfect execution of the technique, which is intrinsically linked to body positioning. As it is known, the positioning of the dancer's bodies in classical ballet is characterized by the use of the maximum external rotation of lower limbs. Gupta, Fernihough, Bailey, Bombeck, Clarke & Hopper (2004) show, for instance, that, as a consequence of ballet practice, dancers have a higher degree of external rotation of lower limbs than regular individuals.

Among the various steps performed by the dancer, jumps are arguably between of the most important ones. High level ballet dancers as Mikhail Baryshnikov are known for their abilities to perform high vertical jumps. In particular, the *sauté* jump can be considered the most performed from early learning to experts practicing**.** The *sauté* jump begins from the first feet position in classic ballet: external hip rotation of both lower limbs with touching heels. From this position follows maximum flexion of hips, knee and ankle, in a preparation for the further propulsion phase when an extension of both lower limbs joints occurs. At the landing, the contact to the ground occurs with double support of the limbs, with maximum flexion of hips, knees and ankles (Brown, Wells, Schade, Smith & Fehling, 2007; Picon, Da Costa, Sousa, Sacco, & Amadio, 2002).

Despite its importance, there are no studies discussing how body positioning affects the dancer's performance in jump. This study starts addressing this gap in the literature by investigating how external rotations of the lower limbs influence the jump performance of ballet dancers. For this, the countermovement jump will be used to compare to *sauté* jump in variable like degree of knee flexion, peak of ground reaction force and jump height. The countermovement jump is a movement similar to the *sauté* jump, except for the factor of not having the use of external rotation of lower limbs. Thus, the purpose of this study was to investigate how the external rotations of lower limbs influence the performance of ballet dancers in jumps.

METHODS: Four ballet dancers with high technical proficiency were recruited for a test, all having at least fifteen years of practicing (1.61±0.05 m height, 51.40±5.29 kg mass, and 23.5±4.9 years old). During, all dancers performed three attempts of countermovement and *sauté* jumps, with a 2-minute resting period between each attempt, as suggested by Taube, Leukel, Lauber, Gollhofer (2012). Kinematic data was obtained using videogrametry. Thirty retro-reflective markers were placed on anatomical references on the dancers' bodies. Six digital cameras (Basler®) recorded images of the tests with 100 Hz of acquisition frequency. Cameras' calibration and 3D reconstruction were performed by DLT (Abdel-Aziz & Karara, 1971). The kinetic data was obtained using two force platforms (Kistler®) with 500 Hz of acquisition frequency each. The dancers performed the jumps with one foot on each

platform. The markers position as a function of time was determined by the automatically tracked markers from the images recorded and processed using the software Dvideo® (Figueroa, Leite & Barros, 2003). The software Visual 3D® was used to model the body segments and calculate the maximum knee flexion degree, during the preparatory phase. The peak of GRF was found by the peak of force during the preparatory phase. The jump height was determined by the maximum height of the midpoint of the posterior superior iliac spines, calculated by the software Matlab®. The results considered only the right side, since there were no significant differences between the sides. The performance in countermovement and *sauté* jump tests was compared through box plot analysis, with confidence intervals calculated according to McGill, Tukey & Larsen (1978).

RESULTS: The peaks of knee flexion in the countermovement and *sauté* jumps are presented in figure 1. It can be seen that, there were no significant differences between the peaks of both jumps.

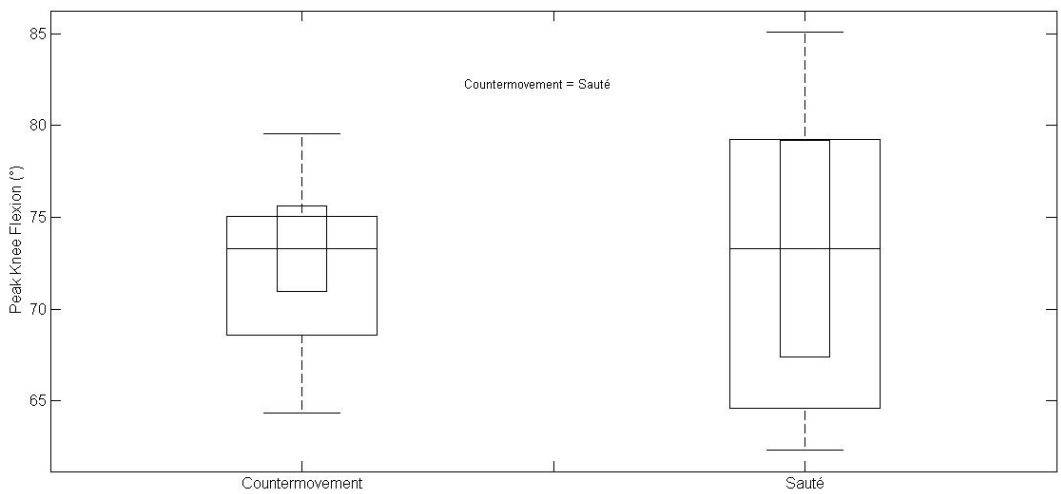

Figure1: Peak of knee flexion in countermovement and *sauté* jumps.

The peak of ground force reaction obtained in the countermovement and *sauté* jump test present in figure 2, and it can be seen that there were no significant differences between both jumps.

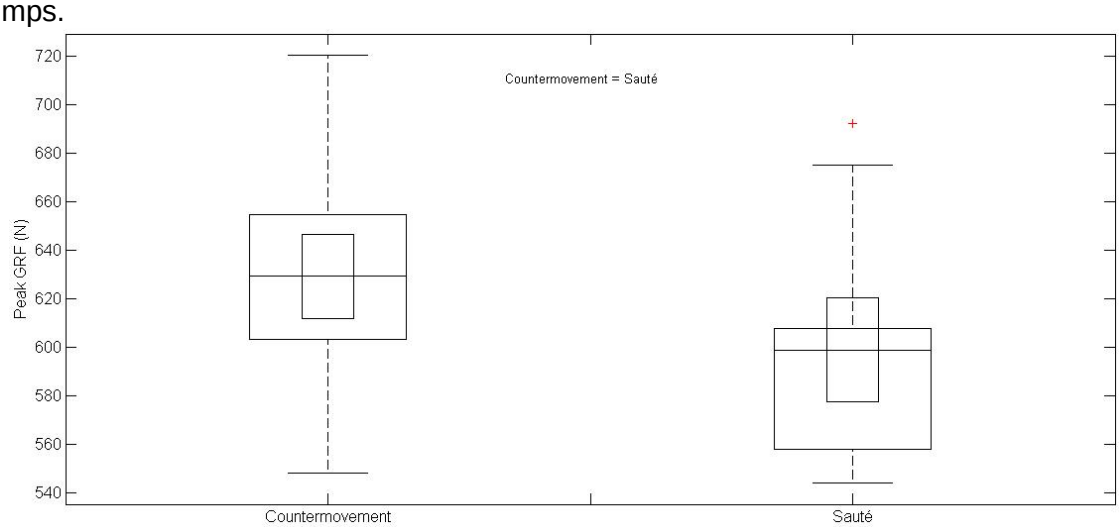

Figure2: Peak of ground for countermovement and *sauté* jumps.

Finally, the jump height obtained in the countermovement and *sauté* jump test present in figure 3. It can be seen, there were significant differences between the jumps.

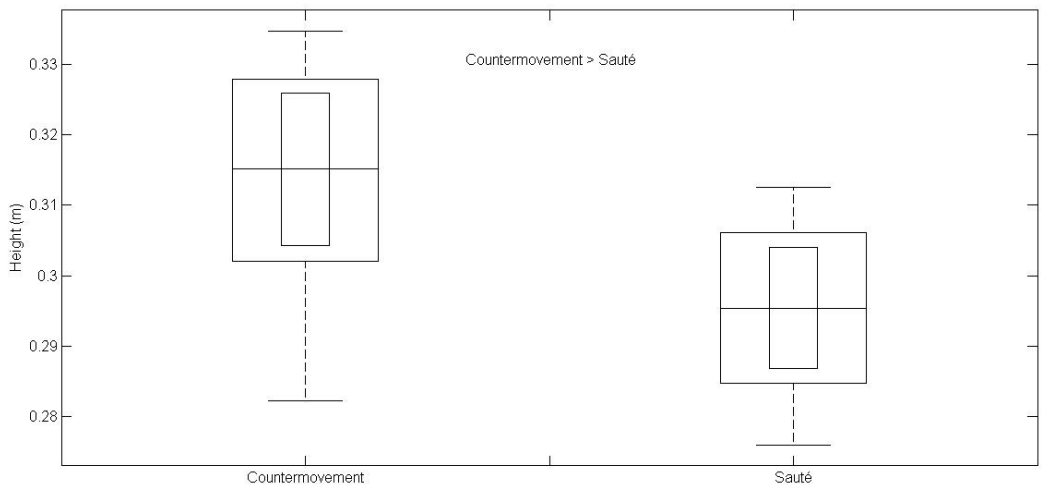

Figure 3: Jump height for countermovement and *sauté* jumps.

DISCUSSION: The purpose of this study was to investigate how the external rotations of lower limbs influence the performance of jump on degree of knee flexion, peak of ground reaction force and jump height. As it was seen, only the height of jumps had significant difference. The knee flexion during the countermovement jump was smaller and had less variation than during *sauté* jump. This can be explained by the fact that ballet dancers have a shortening of the Achilles tendon, due to the overuse of tiptoes (Gans,1985). Thus, the range of heel flexion by the shortening of Achilles tendon will be lower, which will hinder a greater range of knee flexion. When the dancer's bodies is positioned with the external hip rotation, the hip joint will have a greater range of motion, and that will generate a greater range of knee flexion even with the shortening Achilles tendon, which may explain the greater knee flexion during *sauté*.

An interesting finding is the significant differences in the heights of jumps. The heights achieved by de countermovement jump are higher than *sauté* jump. This relates to what is the focus of the dancer when performing each jump. To perform the *sauté* jump the dancer focuses on technique, maintenance of the external rotation, and on the fullest extension of the joints (Picon, Da Costa, Sousa, Sacco, & Amadio, 2002). The height is not principal focus, the aesthetics of the jump can be more important than the height. On the other hand, when performing the countermovement jump, the dancer is not concerned about the aesthetic of the movement, since it is not part of the ballet repertoire, and focus only on its height. This may also explain the higher ground force reaction for the countermovement jump.

As shown, even ballet dancers who are more familiar with the *sauté* jump obtained better results in the countermovement. Possibly, the focus during the jump realization produces different results. So, future studies should attempt to analyze the way torques are generated in these two types of jumps, in order to improve and understanding the performance on classical ballet jumps.

CONCLUSION: In summary, it was shown that were no significant differences for peak of knee flexion and peak of ground force reaction. However, ballet dancers achieved greater heights in the countermovement jump. Even with a lower degree of knee flexion, dancers can produce higher jumps and more ground force reaction on countermovement jump. The results suggest that the attention focus when jumping is an important determinant of jump performance. Future studies should attempt to analyze kinetics and kinematics of jumps performed with different hip joint positions in order to better understand how torques are generated in different conditions in ballet dancers.

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