CENTRE OF PRESSURE DURING COUNTERMOVEMENT JUMP: IS IT RELATED TO EXPERTISE OR PERFORMANCE?

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The purpose of this study was to investigate how specific variables related to the centre of pressure (CoP) trajectory during a countermovement jump (CMJ) carry information related to expertise and performance. The variables investigated were: lengths and average velocities during eccentric (Ecc) and concentric (Con) phases, medio-lateral (ML) and antero-posterior (AP) ranges of movement, and ML bias. In terms of expertise, the curves were tracked and compared over four jump sessions conducted by both experienced and inexperienced jumpers to investigate adaptive changes towards a more efficient way of jumping. Links between performance and those characteristics were also investigated. Our study indicated that no useful information related to either expertise or performance can be extracted from the CoP trajectory during a CMJ.

KEY WORDS: centre of pressure, vertical jump, eccentric, concentric, bias.

INTRODUCTION: CoP measurements collected during postural stability tasks are routinely used in clinical settings to assess balance. It is well known that the CoP during upright stance is affected by fatigue, vision, support surface compliance, age and gender. It is also well known that CMJ is a widely accepted means of assessing explosive leg strength with jump-height measures calculated using the impulse method from force plate (FP) being considered the most accurate and reliable (Street, McMillan, Board, Rasmussen & Heneghan, 2001). However, little is known on how the CoP motion during a CMJ is related to jump expertise and performance and if it has any practical application. CoP characteristics during a CMJ can be easily calculated during the regular assessment of jumping height, force and power.

Traditional CoP time domain measures include “distance”, “area” and “hybrid” variables, while frequency domain measures are related to the frequency spectrum of the CoP path (HongBo, 2006). Time domain “distance” measures aim to measure the length of the stabilogram, and include mean distance, root mean square distance and mean velocity of the CoP. Time domain “area” and frequency domain measures are related to stability, so they were not included under the scope of this study.

The aim of this study was to investigate the relationships between CoP trajectory characteristics during CMJ, as it relates to both expertise and performance. In terms of expertise, we wanted to determine how CoP variables are affected during the learning stages of inexperienced individuals. We also aimed to investigate the relationships between those variables and performance of both experienced and inexperienced jumpers.

METHODS: Eighteen healthy, physically active subjects volunteered for the study. The “experienced” group consisted of subjects with at least 3 years of experience in CMJ, while the “inexperienced” group had no previous CMJ training at all. Group characteristics are shown in Table 1.

Table 1: Subject Characteristics

Gender	Experienced	Inexperienced	Total	Body mass [kg]	Age [y]
Male	7	5	12	79.8 ± 9.9	31.1 ± 4.2
Female	1	5	6	67.9 ± 15.4	26.8 ± 6.9
Total	8	10	18	75.8 ± 13.3	29.7 ± 5.6

All subjects performed a self-selected warm-up before the CMJ trials, including a number of practice CMJs. All subjects were assessed performing 5 CMJs twice a week for 2 weeks (total: 4 sessions, 360 analysed CMJs). During their first 2 test sessions the inexperienced subjects were coached before jumping on how to perform proper CMJs. CMJs started from a stationary position with the subjects' feet symmetrically set about shoulder width apart. All CMJ trials were performed with the subjects' hands remaining on their hips throughout the whole movement. A trial was considered successful when both feet clearly landed wholly on their toes on the surface of the FP. The FP was zeroed before every trial, and data collection started while the subjects were waiting for the testers command whilst maintaining a stationary position on the FP for at least a second before jumping; this was to ensure accurate body weight (BW) data as well as a reliable initial vertical velocity of 0 m/s to start the velocity calculations.

The 3D components of the ground reaction forces were recorded using a 60 x 90 cm multi-component FP (Kistler type 9287BA, Switzerland) sampling at 1000 Hz, which was covered with a competition quality rubber mat (Mondo, Italy) symmetrically marked with lines to assist the jumpers align themselves in an initial position with their feet equally separated from the geometrical centre of the FP.

The raw 3D force data were filtered using a zero-lag, dual pass Butterworth low-pass filter (Winter, 2009): cut-off frequency 23 Hz (pass-band gain: -3 dB), stop-band frequency 18 Hz (stop-band gain: -10 dB) using Bioware V4.0 (Kistler, Switzerland). These filtering parameters were selected based upon numerous trials with various cut-off and stop band frequencies, as well as by visual data inspection. For every jump, the onset of the movement was manually identified, while the reverse point was calculated through the impulse method as the point where the vertical velocity curve changes from negative to positive, using custom-made software (Aspire Force).

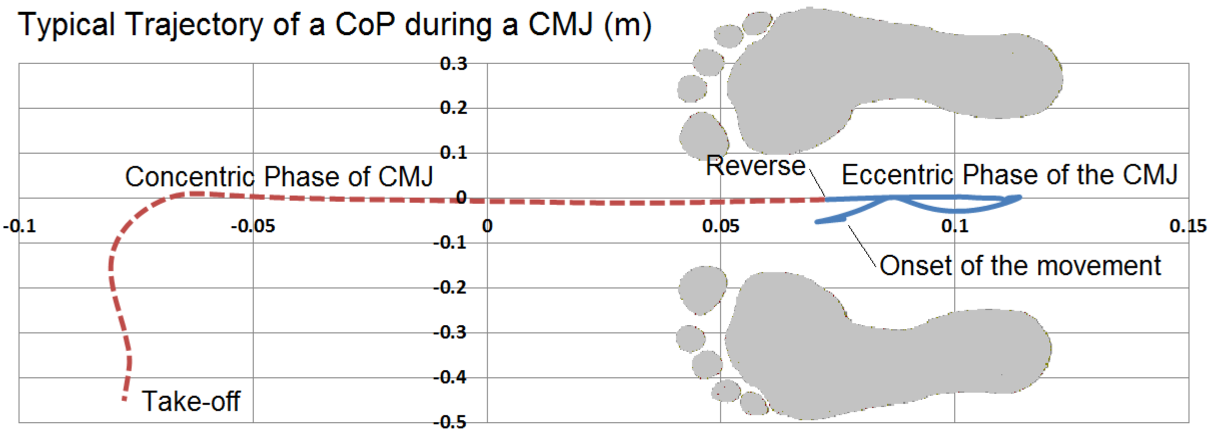

Figure 1: Typical CoP trajectory during a CMJ, showing the initial position of the feet (not to scale) and its two phases. In this case, the subject took off asymmetrically, leaving the ground with his left toe.

The CoP trajectories (Figure 1) were calculated through the FP's eight 3D channels and 3D calculated torques using Bioware V5.0 and corrected using an in-situ protocol provided by the manufacturer (Kistler, Switzerland). The CoP trajectories were then trimmed according to onset and take-off (TO) calculated before, using the TO as a reference with a threshold of 25[N].

The selected variables related to performance of the CMJ were: jump height [m] calculated through impulse method, maximum relative pushing net force [BW], maximum relative power [W/kg] and average relative pushing power [W/kg]. The selected variables related to the CoP were: length of trajectory [m], AP range of movement (RoM) [m], ML RoM [m], ML bias [m], and average speed [m/s]. All of these variables were calculated separately for both Ecc (i.e., from the onset of the movement to the reverse point) and Con (i.e., from the reverse point to the TO) phases of the CMJ.

During the analysis it was common to find higher CoP speeds and longer trajectories prior to TO. This was found within individuals whose TO was not symmetrical, meaning that one of

their feet lost contact with the FP earlier than the other. That led to an instant migration of the CoP from a spot somewhere in between their feet to a spot somewhere on the forefoot still contacting the ground. Also, with some subject's jumping style, their downwards movement was so fast that they lost contact with the ground before the reverse point, and therefore the CoP trajectory became erratic. Such jumps were excluded from analysis as they shouldn't be assessed if CoP measurements are to be monitored.
An Independent Student's T-test was used to analyse the differences in parameters between novices and experienced on the first session. In terms of performance, Pearson product moment correlation coefficient was used to calculate the relationship between CoP parameters and jumping performance within the experienced group. A mixed model Anova (expertise per session) was used to analyse the effects of learning over time in both groups. Alpha was set at $P<0.05$.

RESULTS: Intra-individual bias and other representative variables of these CoP curves were assessed across the 4 test sessions (Figure 2). The T-test showed no significant difference between any of the jump parameters in session one, showing that in our sample population, the experienced jumpers were not better than novice in performing the CMJ.

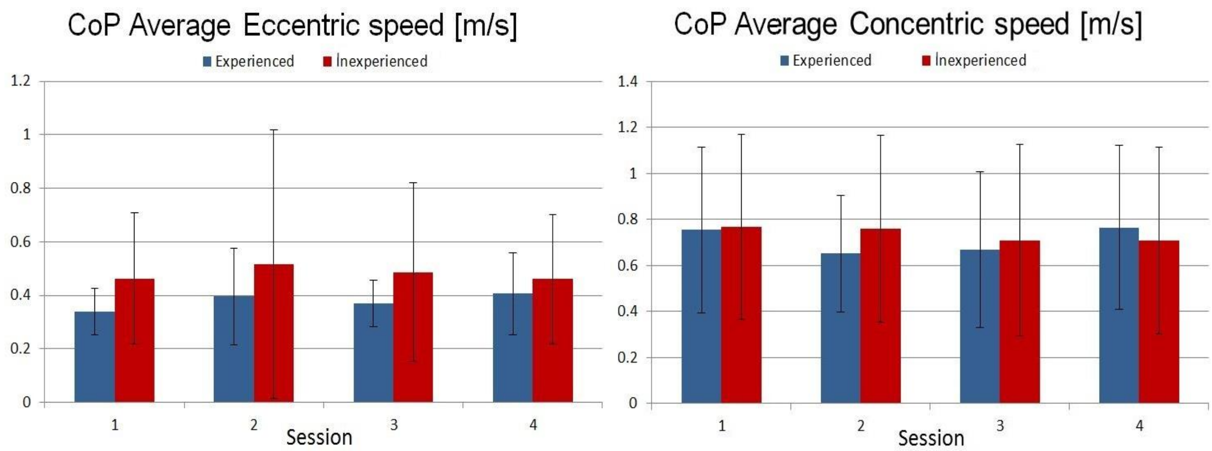

Figure 2: Two selected CoP variables (average speed during the Con and Ecc phases of the CMJ), showing their evolution and their standard deviations across the 4 sessions, for the experienced and inexperienced groups

The mixed model Anova revealed a significant difference for expertise and time. When comparing experienced with inexperienced subjects, a significant difference was in fact identified between eccentric and ML CoP parameters and jumping height and a main effect of time was also identified. No significant difference was identified in concentric CoP parameters. Significant differences in CoP parameters over time were only identified between session 1 and 2 in Ecc CoP length. No statistically significant interaction was identified between expertise and jumping session, suggesting that no changes were evident following 4 sessions in the movement quality.
A moderate relationship was found between CoP average Con speed and maximum relative power (see Table 2). Multiple linear regression analysis showed that all CoP parameters combined presented the best predictor; however this model could only explain 32% of the jumping height performance.

Table 2: Pearson Correlation Coefficient between CoP and Performance paramenters

CoP:	Lenghts		AP	ML		Average Speed	
Performance:	Ecc	Con	RoM	RoM	Bias	Ecc	Con
Pushing duration	0.11	-0.19	-0.13	-0.18	-0.11	-0.07	-0.38
Jumping height	-0.20	0.20	0.19	0.14	0.04	-0.16	0.27
Max. relative Con net force	0.00	0.34	0.26	0.25	0.23	0.11	0.44
Max. relative power	0.02	0.32	0.24	0.30	0.27	0.17	0.46
Average relative Con power	-0.05	0.33	0.27	0.21	0.19	0.09	0.43

DISCUSSION: The results of this study suggest that 4 jumping sessions (totalling 20 jumps) was not enough to show a significant improvement in CoP parameters. Furthermore, they show that CoP time and space domain parameters can only explain part of the CMJ performance, suggesting that movement optimisation in this task is a less relevant parameter than power output. Finally, subjects naïve to jumping movements show a trend for a slightly different motor strategy than experienced jumpers, particularly during the eccentric phase of the jump. However, studies with larger group sizes which include subjects with higher levels of jumping expertise are needed to ascertain if this difference is meaningful and if it has functional implications.

CONCLUSION: This study showed that the trajectory of the CoP during a CMJ and its most directly related kinematic variables cannot be linked to expertise or performance. In other words, neither of its characteristics can be taken as an indicator of expertise nor jumping quality.

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