

IS THE LOCAL MINIMUM IN THE FORCE TIME HISTORY IN COUNTER-MOVEMENT JUMPS RELATED TO JUMP PERFORMANCE?

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The purpose of this study was to investigate the relationship between joint kinematics and joint kinetics of the lower extremity to the decrease in the force time curve in counter movement jumps. Thirty-five sports students performed maximum voluntary counter-movement jumps. Two force plates and a 10 camera optoelectronic system as well as a full-body model were used to measure joint kinematics and kinetics. Twelve subjects showed a characteristic double peak in force-time-history in the concentric phase. This pattern was not directly related to jumping height. However the time for the total movement cycle as well as for the concentric phase of the jump was longer. In some sports it is necessary to produce maximum impulse in the concentric phase in a short period of time. In those cases a different movement strategy might be beneficial.

KEY WORDS: counter-movement jumps, force-time-curve, ground-reaction-force.

INTRODUCTION: Vertical jumps are commonly used in sport practice. Especially counter movement jumps (CMJ) are performed to diagnose muscular strength or 'explosive power'. The time history of the vertical ground reaction force (GRF) of a CMJ decreases below body weight during eccentric phase in the counter movement and rises to a few times body weight in the concentric phase (Vanezis & Lees 2005, Fukashiro & Komi 1987, Hubley & Wells 1983). It has been observed that in some cases the time history of the GRF can be characterized by a clear decrease in the concentric phase close to the actual force peak (figure 1). It has not been understood whether or not this decrease in the force time curve is associated to a performance loss. In order to understand a possible link between the force decrease and jumping performance the source of the force decrease has to be identified. Individual characteristics of coordination patterns could be related to the typical force time history. The purpose of this study was to relate GRF time histories and the force decrease to joint kinetics and kinematics. It was hypothesized that jumpers creating double peaks would have a performance deficit.

METHODS: Thirty-five sports students (5 female, 30 male; age 22 ± 4 yrs, height 1.81 ± 0.07 m, weight 72 ± 9 kg) experienced in vertical jumps participated in this study. All subjects were asked to perform three CMJ and to jump as high as possible. The time histories of the ground reaction force (GRF) were measured with two AMTI force plates (1000Hz). The kinematics of the jumping movements was recorded with 10 Vicon cameras (200Hz). Data were time normalized from beginning of the eccentric phase to the instance of take off. The joint angles and moments in the sagittal plane of the knee, hip and ankle were calculated based on VICON Plug n' Gait Model. Forces and moments were related on body-weight. The double peak in force time curve were defined when the force time curve decrease over 4% of maximum force (F_{max}) and increase immediately over 4% of F_{max} .

The data were analysed via a univariate ANOVA ($\alpha = 0.05$), the independent variable were set on the jumping groups, depending on the pattern of the GRF time-history curves. Normal distribution was ensured via Kolmogorow-Smirnow-tests.

RESULTS: Figure one shows the average of time history of GRF and the knee moment for a jump with ($n=13$) and without force ($n=12$) decrease. The appearance of the force decrease in the concentric phase of the GRF curve was a typical characteristic of certain subjects. Subjects either showed the force decrease in all three jumps or did not show the decrease at all. In thirteen of the tested thirty-five subjects the force decrease was identified. The point in

time of the local GRF minimum was at $78\% \pm 2\%$ of the total movement cycle. At that time the ankle joint was in a dorsal flexed position ($40^\circ \pm 6^\circ$), the knee was flexed at $104^\circ \pm 7^\circ$ and the Hip at $90^\circ \pm 5^\circ$. Subjects showing the force decrease use increased knee and hip flexion for the counter movement, indicating a more pronounced downward movement of the center of mass. Consequently subjects showing the force decrease perform the total movement in a longer time interval ($839 \text{ ms} \pm 108$) than their counterparts without force drop ($672 \text{ ms} \pm 69$) ($p=.001$). They also need a longer time period for the concentric phase ($333 \text{ ms} \pm 41$ vs. $257 \text{ ms} \pm 28$, $p=.001$). Subjects with the force decrease did not show differences in positive impulse ($199 \text{ Ns} \pm 30$ vs. 184 ± 24 , $p=.321$) and therefore jumping height. The data indicates that the force decrease in certain subjects coincides with a not coordinated occurrence of the peaks of ankle, knee and hip joint moments. Usually the contribution of the knee joint was dominant in comparison to ankle and hip. In subjects with force decrease the knee often showed a delayed maximum in the moment time history.

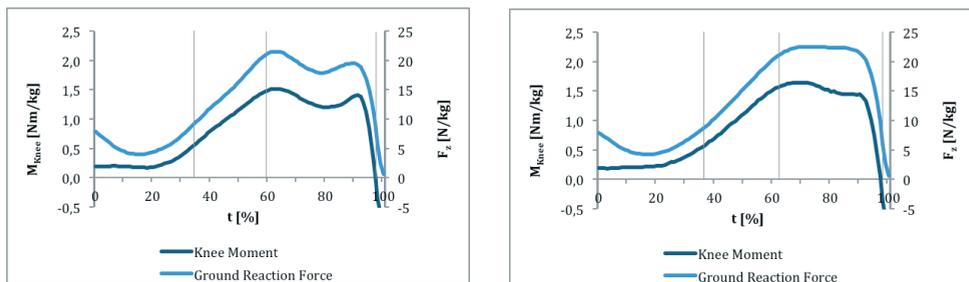


Figure 1: Average force-time-history and moment-time-history for the groups with (left, n=13) and without (right, n=12) force decrease.

DISCUSSION: The local decrease in the time history of GRF in CMJ appears to be an individual characteristic. This characteristic is related to joint kinematics in the sagittal plane; however it is not related to jumping performance in terms of jumping height. Therefore the hypothesis that jumpers creating double peaks in the time history of GRF in CMJ have performance deficit, is rejected. The current stage of the analysis does not allow deducing individual muscular or motor control specifics, which are related to the force drop. It might be beneficial however in some sports to produce the same jumping impulse in a shorter time, in order to jump high or far having a limited time interval. In that context using the jump strategy with force decrease should be disadvantageous. The reason for choosing that particular pattern however is not yet understood.

CONCLUSION: In some sports it is necessary the produce maximum impulse in the concentric phase in a short period of time. Future research should focus on the underlying mechanisms in order to possibly improve power output. A deeper understanding of the source of the force decrease might improve diagnostic tools, possibly including the analysis of individual muscle potentials.

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