STRETCH-SHORTENING CYCLE FUNCTION OF THE KNEE EXTENSOR MUSCLE-TENDON UNIT DURING THE POWER CLEAN

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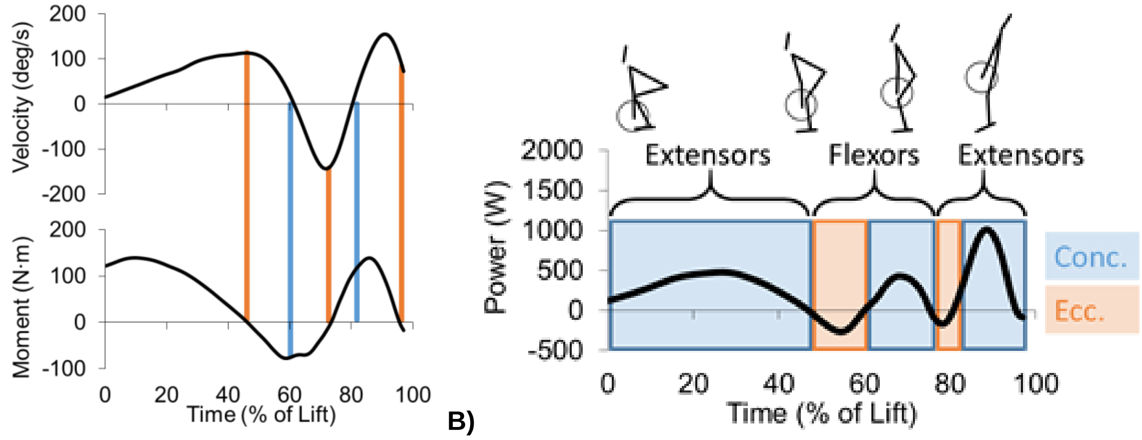
The purpose of this case study was to investigate the stretch-shortening cycle behaviour of the knee extensor muscle-tendon unit during the power clean exercise. Kinematic and kinetic were acquired as a skilled weightlifter performed several repetitions of the power clean at 85% of 1-Repetition Maximum. Knee joint angular velocity, moment, and power time-series during the pull-phase of the power clean were calculated and used to delineate between concentric and eccentric movement phases. The analysis of the kinematic time-series data showed knee extension-flexion-extension movement pattern, whereas the analysis of the kinetic data showed that the movement pattern consisted of dynamic concentric and eccentric sequences, which highlighted stretch-shortening cycle behavior of the knee extensors, and surprisingly also the knee flexor, muscle groups.

KEY WORDS: weightlifting, biomechanics, kinetics.

INTRODUCTION: The power clean is an often used exercise to improve dynamic performance in sports or other dynamic activities, such as vertical jumping (Chiu & Schilling, 2005; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005). The primary rationale for using the power clean in exercise programs are based on its kinematic and kinetic similarities to other athletic tasks, such as the vertical jump (Garhammer & Gregor 1992; Mackenzie, Lavers, & Wallace, 2014). Another purported rationale is that the power clean makes use of the powerful stretch-shortening cycle of the knee extensor muscles during the pull phase (Chiu & Schilling, 2005). Although the presence of the stretch-shortening cycle is often purported based on kinematic data or observation (Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000; Hakkinen, Kauhanen, & Komi, 1984), it has not been rigorously documented in the research literature. An essential step toward this type of analysis would be the investigation of joint kinetics in relation to the concentric and eccentric movement phases, which can only be derived from simultaneous analysis of kinematic and kinetic data (Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988; Enoka, 1988), and is facilitated by examination of the joint energetics. The purpose of this case study was to investigate the stretch-shortening cycle behaviour of the knee extensor muscle-tendon unit during the power clean exercise through full examination of joint level biomechanics.

METHODS: One collegiate-level weightlifter (Body-mass: 110 kg; 1-Repetition maximum power clean: 160 kg) provided written informed consent approved by the local University's IRB. The lifter completed a self-paced warm-up that included lifting light loads up to 50% of his self-reported one 1-RM. After the warm-up, he performed 2-3 repetitions at 65%, 75%, and 85% of 1-RM with approximately 2-3 minutes rest between each set. Kinematic and kinetic data were collected during each set. Kinematic data were acquired from reflective markers attached to the subjects body with a 6-camera Vicon motion capture system that sampled at 250 Hz (Kipp, Harris, & Sabick, 2011). Kinetic data were collected at 1,250 Hz from two Kistler force plates that were built into an 8'x8' weightlifting platform. Kinematic and kinetic data were filtered at 6 Hz and 25 Hz, respectively. Joint-level biomechanics were calculated with a rigid-link model based on foot, shank, thigh, and pelvis segments (Kipp, Harris & Sabick, 2011). Euler angle rotation sequences were used to calculate the sagittal knee joint angle (Grood & Suntay, 1983). Kinematic and kinetic data were combined with anthropometric data and used to solve for net internal knee joint moments with an inverse dynamics approach (Winter, 2005). The central difference method was then used to calculate the knee joint extension/flexion velocity. Knee joint velocity and moment were multiplied to produce knee joint power. Data were calculated for right leg sagittal-plane variables and time-normalized to 100% of the lift phase (i.e. from the time the barbell left the platform to the time the vertical ground reaction force fell below 10 Newtons at the end of the second clean pull-phase).

RESULTS: The kinematic and kinetic time-series data are presented in Figure 1A. The concentric and eccentric movement phases are presented in Figure 1B.



A) B)

Figure 1: A) Knee joint velocity and moment during the pull phase of the power clean (positive y-direction indicates knee extension velocity and moment). B) Knee joint power during the pull phase of the power clean (positive y-direction indicates power generation). NOTE: the extension-flexion-extension pattern present in the joint velocity data is shown by the blue lines and in the joint moment data by the orange lines; the resultant concentric and eccentric movement phases of the knee extensor and flexor muscle groups are shown by the blue and orange boxes on the joint power data.

DISCUSSION: The knee joint kinematic and kinetic data both showed an extension-flexion-extension pattern. The presence of a knee extension-flexion-extension movement pattern agrees well with other reports in the literature, and reflects the commonly used double knee bend technique (Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000; Hakkinen, Kauhanen & Komi, 1984). Although other researchers demonstrated the existence of a kinetic extension-flexion-extension pattern in joint moment data (Baumann, Gross, Quade, Galbierz & Schwirtz, 1988; Enoka, 1988), they did not explicitly investigate or report on the concentric/eccentric movement phases, which precluded any conclusions about the presence of stretch-shortening cycle behaviour.
Investigation of the knee joint power data in the current study showed that the initial knee extension motion was driven by a concentric action of the knee extensor muscles. This initial phase was followed by an eccentric and concentric movement phase of the knee flexor muscles, which signalled the beginning of the transition phase between the first and second pull-phases. Given that eccentric knee extension preceded concentric knee flexion, this patterning indicates the presence of a stretch-shortening cycle of the knee flexors. The presence of stretch-shortening cycle behaviour of the knee flexors is a novel finding and has never been reported in the literature, probably because most other studies focus on the function of the extensor muscle groups (Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988; Kipp, Redden, Sabick, & Harris, 2012). The last phase of the clean is characterized by eccentric and concentric movement phases of the knee extensor muscles. The eccentric pre-stretch of the knee extensor muscles occurs during the latter portion of the transition phase as the knee joint is still flexing, and culminates in powerful knee extension that is the result of a concentric knee extensor moment during the second pull-phase. Based on this pattern it can be surmised that the concentric knee extensor moment, which is crucial for weightlifting performance (Kipp, Redden, Sabick & Harris, 2012), is potentiated by the preceding eccentric pre-stretch. These results therefore support the presence of a stretch-shortening cycle of the knee extensor muscle-tendon unit during the latter portion of the power clean.
Given that explosive muscle action of the knee extensors is considered a pre-requisite for lifting heavier weights and increasing weightlifting performance (Kipp, Redden, Sabick, &

Harris, 2012), the stretch-shortening cycle of the knee extensor muscle-tendon unit does indeed appear to play a significant role in weightlifting technique. The presence of a stretch-shortening cycle may also explain why weightlifting exercises and their derivatives provide a more potent training stimulus than other traditional exercise training programs when it comes to improving dynamic performance, such as vertical jumping (Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005).

Since this report only presents the results of a case study further research is warranted. Collection of data from additional weightlifters would help to more firmly establish the presence of knee extensor stretch-shortening cycle behaviour during the power clean exercise. Moreover, collecting data from weightlifters with different skill levels would provide a better understanding of the relative importance of knee extensor stretch-shortening cycle behaviour. Another limitation is that the biomechanical methods relied on calculation of internal net joint moments, which may over- or under-estimate the actual muscle-tendon force generated by the knee extensor muscle group. In a similar vein, the use of musculoskeletal ultrasound may help further delineate between the individual contributions of either muscular or tendinous structures to the observed stretch-shortening cycle behaviour.

CONCLUSION: This case study highlighted the presence of stretch-shortening cycle behaviour of the knee extensor muscle-tendon unit during the power clean exercise. Based on the presence of the stretch-shortening cycle behaviour, the power clean may be a valid exercise to train this aspect of athletic performance.

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