BIOMECHANICAL ANALYSIS OF THE LUNGE EXERCISE

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Abstract The lunge exercise is being often prescribed by physical therapists and athletic trainers as a rehabilitation regiment for quadriceps strengthening. In this study, a biomechanical analysis was conducted in order to assess and quantify this closed-chain-kinetic exercise. When the distance between the toe of the rear leg and the heel of the front leg (lunging distance) was maximum, a net flexion moment developed at the front knee when it was in an extended position. This moment was reversed to a net extension moment as the front knee became flexed. Meanwhile, significant EMG signals were obtained from the hamstrings of the front leg as it was bent from the extended to the flexed position. These data suggest that during a maximum lunge, quadriceps and hamstring muscles' co-contractions occur in the front leg when it is in the flexed position.

Introduction Open chain exercises have been used in the past as the method of choice for rehabilitating the quadriceps in patients with anterior cruciate ligament deficiency. However, biomechanical analyses of active knee extension exercises pointed out to several problems associated with this rehabilitation regiment. Recent studies have advocated the use of closed chain kinetic exercises [1] as a mechanism to remedy these problems.

Most commonly prescribed closed chain kinetic rehabilitation exercises include squat, lateral step-up, and lunge. The anterior lunge can be described as an exercise in which a person steps forward with one foot, the front knee and hip are bent, and assumes different positions by flexing the front leg, shifting thus the body weight towards the front leg. Squat and lunge are two similar closed kinetic chain exercises. In both exercises, the knees are bent, but the leg positions are quite different. During a squat, the feet are parallel with both lower extremities adjacent to each other. However, during lunge, one foot is in front of the other and the front hip and knee are more flexed than the rear hip and knee.

Several studies have been directed towards understanding the biomechanics of the squat, half-squat and lateral step-up exercises [2-4]. However, a review of the literature reveals that no study has attempted to quantify and assess the biomechanics of the lunge exercise. Since this exercise is commonly prescribed by physical therapists for strengthening the lower extremity, this study is directed towards providing an understanding of the effects of lunging on the moments generated at the knee joint in healthy individuals.

Methods An integrated human motion analysis system that includes an active optoelectronic kinematics data capture system (Optotrak system manufactured by Northern Digital, Waterloo, Ontario, Canada), two AMTI force platforms and an electromyography unit (EMG) was used for data collection. Twenty-four markers were placed at twenty-four locations on the medial and lateral sides of both extremities of each subject to define the different body segments as shown in Figure 1. During testing, subjects were asked to stand straight with both legs on the 1st forceplate, and then to lunge forward as far as possible with the right leg, placing the right foot on the 2nd forceplate while keeping the toes of the left foot fixed on the 1st forceplate. Movement of the left heel from the floor was allowed, as long as the position of the left toes was maintained. The distance between the toes of the left foot and the heel of the right foot was measured and referred to as the distance of maximum lunge. During this first test, the subject was instructed to keep his right leg as extended as possible. This position, position 1, was held for 1 second, the time being monitored by the integrated human motion measurement system. The subject was then asked to repeat the test, but to bend the front knee to different flexion angles until the maximum attainable knee flexion angle, position 2. Figure 1 shows both extended and maximally flexed positions using a stick diagram representation for the different body segments.

A four-segment model (right foot, left foot, right lower leg, left lower leg) was employed in this analysis. At each position, equilibrium equations were written for each segment in order to determine the net joint forces and moments by equating them to the gravitational and ground reaction forces acting on the body segments.

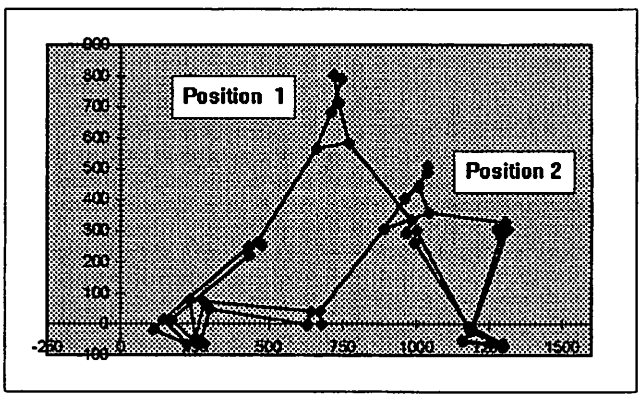

Figure 1. Stick diagram representation of two lunging positions.

Results The kinematics data show that for the conditions tested (maximum lunging distance), and as the front knee was bent from full extension (position 1) to about 60° of flexion, the rear knee remained flexed within a range of 15 to 20 degrees. Past 60° of front knee flexion, the rear knee flexion angle increased and reached about 50 degrees when the front knee was bent to 90°.

The kinetic analysis shows the presence of a net external flexion moment on the front knee when the front leg was in the extended position. This net moment decreased as the front knee was bent, and was reversed to an extension moment at around 60 degrees of front knee flexion, as shown in Figure 2 (moments were calculated as % body weight x height). This extension moment increased as the front knee continued to bend. In addition, significant EMG signals were obtained from the hamstrings of the front leg as it was bent from the extended to the flexed position. Furthermore, the analysis shows that a net extension moment developed at the knee of the rear leg at all lunging positions.

Discussion and Conclusions Our results show that when the front knee was flexed beyond 60 degrees, an external net extension moment was acting on it. Meanwhile, large EMG signals were obtained from the surface electrodes

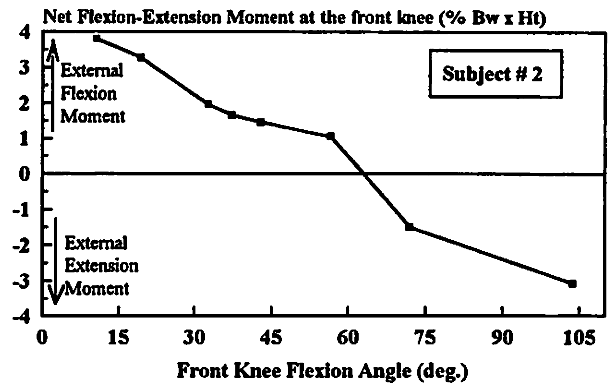

Figure 2. Predicted net flexion-extension moments at the front knee while bent at different flexion angles during a maximum anterior lunge.

placed on the hamstrings of the front leg. These results indicate that while performing a maximum anterior lunge, quadriceps and hamstrings co-contractions occur in the front leg when it is bent beyond 60 degrees of knee flexion. These results are similar to those reported by Lutz, et al. [5] where co-contraction of these two groups of muscles has been observed especially at 60° of knee flexion during a closed-kinetic-chain leg-press exercise. The analysis also shows that during lunging and as the front knee is bent, the quadriceps muscles of the rear leg become contracted. The determination of this functional range provides an initial assessment for this closed-kinetic-chain exercise as a means of strengthening the major knee flexors and extensors.

References

1. Tovin, B.J., et al., "Surgical and Biomechanical Considerations in Rehabilitation of Patients with Intra-Articular ACL Reconstructions", JOSPT, Vol. 15, No. 6, June 1992, pp. 317-322.
2. Castle, Jr., et al., "Posterior Tibial Subluxation of the Posterior Cruciate-Deficient Knee", Clin. Orthop. Rel. Res., No. 284, Nov. 1992, pp. 193-202.
3. Ohkoshi, Y., et al., "Biomechanical Analysis of Rehabilitation in the Standing Position", AJSM, Vol. 19, No. 6, 1991, pp. 605-611.
4. Worrell, T.W., et al., "Effect of a Lateral Step-Up Exercise Protocol on Quadriceps and Lower Extremity Performance", JOSPT, Dec. 1993, pp. 646-653.
5. Lutz, G.E., et al., "Comparison of Tibiofemoral Joint Forces During Open-Kinetic-Chain and Closed-Kinetic-Chain Exercises", JBJS, May 93, pp. 732-739.