BIOMECHANICS DESIGN LABORATORY

Mechanical Testing of Muscle Properties

I. Abstract

The skeletal muscle is critical element and the moment arm of a muscle merely indicates the efficiency of the muscle for rotation of the bony segment about that particular joint axis. In this lab, the main focus is on elbow and collected data with the Biodex which is programmed to prescribe angular position trajectories over time, and measure joint moments. There are two parts of experiments are performed, one is isometric with each 30, 60, 90, and 120 degrees position, another is isokinetic of 30 and 90 degrees with bicep and triceps. From the first experiment, moment-angle data is obtained. From the second experiment, concentric and eccentric data is collected. According to figure 5-8, the optimum length that is defined as the length at which maximum isometric titanic tension may be developed, is between 100 and 120% of the rest length. The active tension developed is a maximum at the optimum length and decreases at greater and lesser length. According to results, the speed of shortening increases, the muscle force decreases. Hill's equation indicates a hyperbolic relation between muscle tensile force and velocity. Figure 17-20 show that relationship that higher the force, the slower is the contraction velocity. The higher the velocity, the lower is force. The force-velocity relationship is determined by the rate of breaking and reforming the cross bridges, with higher rates producing less effective bonds. For example, for biomedical engineers, it is challenge to analyze stroke patients muscle behaviors to understand and improve their mobility with isometric and isokinetic testing.

II. Introduction

Skeletal muscles are biological motors or actuators that enable human movement, have certain intrinsic mechanical properties. Students are going to learn skeletal muscle behavior (flexion and extension) in the horizontal plane with isometric and isokinetic that performed by the Biodex system. The output of the Biodex machine is moment and angular displacement data over time and the input is the force and angle over time. The axis is the joint and the moment is respect to the joint. The sample rate is 100Hz using the LabView program and lab software. Isometric testing is performed under zero velocity and isokinetic testing is performed under constant velocity that both situations have various angular position, such as 30, 60, 90, and 120 degrees. Students are going to focus on muscles behavior of flexion & extension, and concentric & eccentric. To understand skeletal muscle's behavior, angular position and joint moment are important. Patients, who have stroke history or currently have stroke, cannot control their skeletal muscles. Therefore, biomedical engineers analyze stoke patients with isometric and isokinetic testing data to improve their mobility and what skeletal muscles they have difficulties for movement.

III. Methods

**In the laboratory, the Biodex is used to collect human performance data for a joint of interest.

A volunteer is placed appropriately in the laboratory apparatus for elbow flexion-extension testing. The proper position would be the arm is positioned about 20 degrees below from horizontal line of shoulder and about 30 degrees forward from the horizontal line of shoulder. The distance between the seat of volunteer and apparatus should be comfortable for the volunteer and the axis of apparatus and the elbow joint should be aligned. Then padding a forearm of the volunteer with foams and tighten it up with straps. With a goniometer, make the range of motion from 30 degrees to 120 degrees, using the Biodex and a goniometer. Then start the Biodex isometric experiment and the data collection program. The arm is relaxed and position is adjusted at 30 degrees. Then after a second, provide a steady maximal elbow flexion contraction for about 2 seconds then a maximal elbow extension contraction for about 2 seconds, and then relax the muscles. Students performed each at 30, 60, 90, and 120 degrees.

The measurement of contractile muscle velocity property testing, students had a set the Biodex program as isokinetic mode with speed for 30 degree per second. Then provide a much maximal flexion preload. Within a few seconds, the volunteer maintained a steady maximal elbow flexion contraction for about 6 seconds. Students tested same testing with 90 degrees per second. This is the shortening and stretching cycle experiment. Change the speed for the Biodex to 90 degree per second. As for set up mode, start with the arm relaxed at 30 degrees then provide as much maximal flexion preload. Within a few seconds, the volunteer providing a steady maximal elbow flexion contraction for about 4 seconds (90 degrees/s for 90 degree total each way) for two full cycles. Students repeated this experiment with 120 degrees and for maximal elbow extension.

Each testing, students saved data with angle (degree) and moment (Nm). After collect data, students are going to analyze data. Students are going to analyze data with moment-time plot and moment -angle plot for the elbow strength curves for the first experiment. The moment-time and the velocity-time plot are going to be generated for the second plot and the estimated force-velocity relation for an equivalent muscle is going to be compared with Contractile Element Force-length (CE-FL) and Contractile Element Force- velocity (CE-FV).

IV.   Result

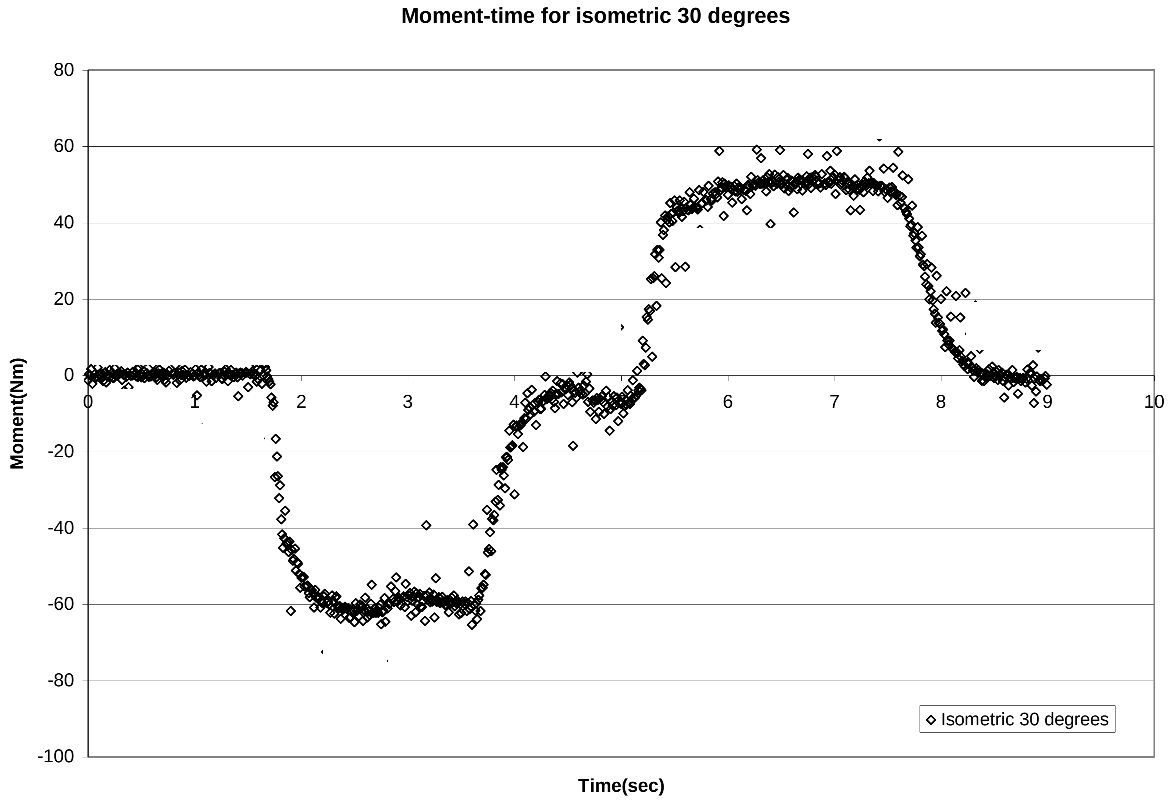

Figure 1. Moment-time for isometric 30 degrees

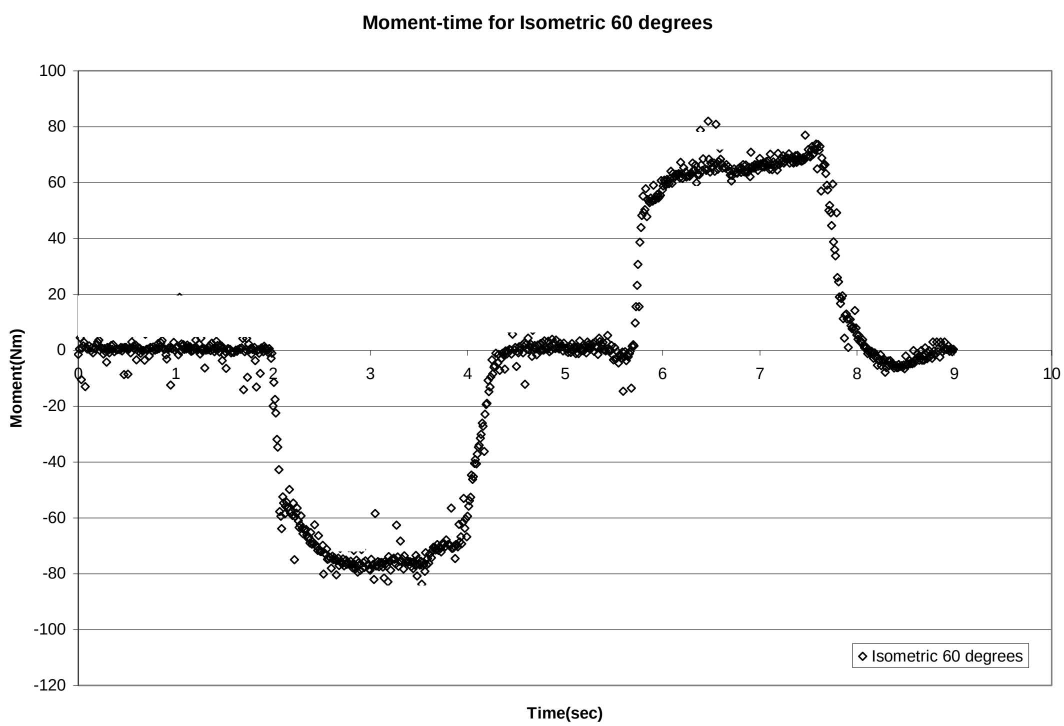

Figure 2. Moment-time for isometric 60 degrees

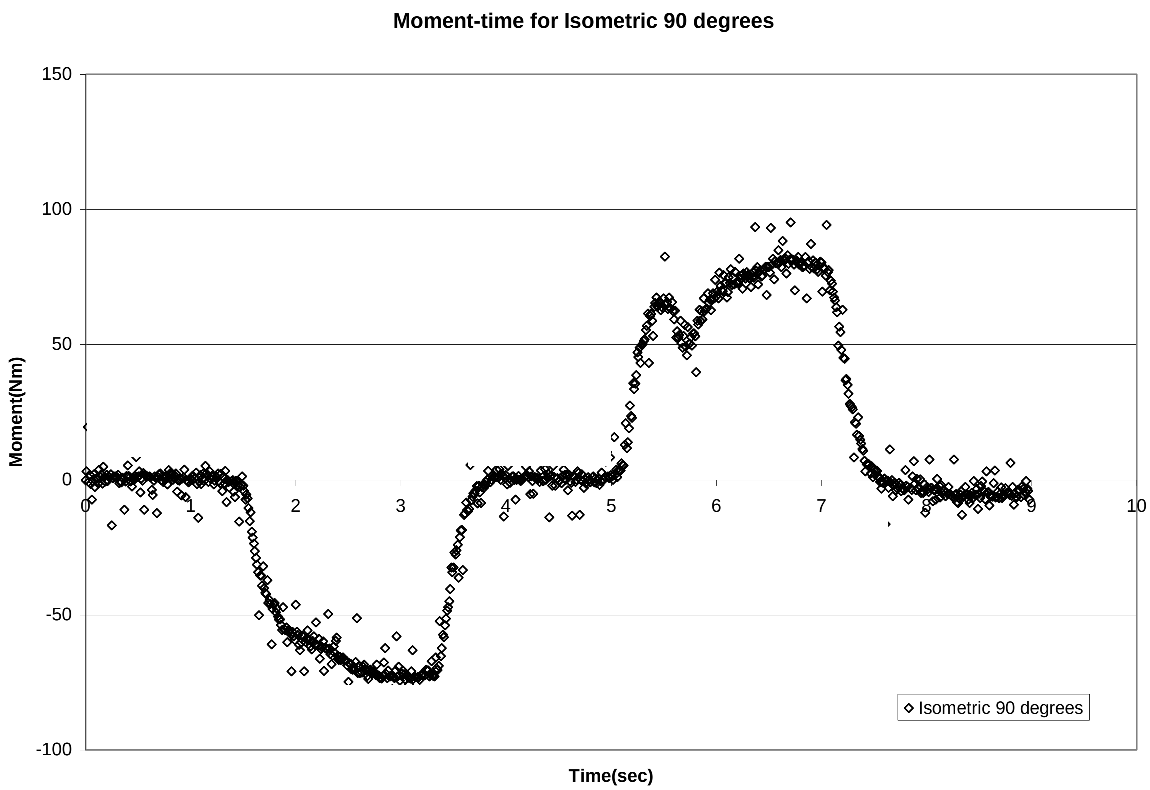

Figure 3. Moment-time for isometric 90 degrees

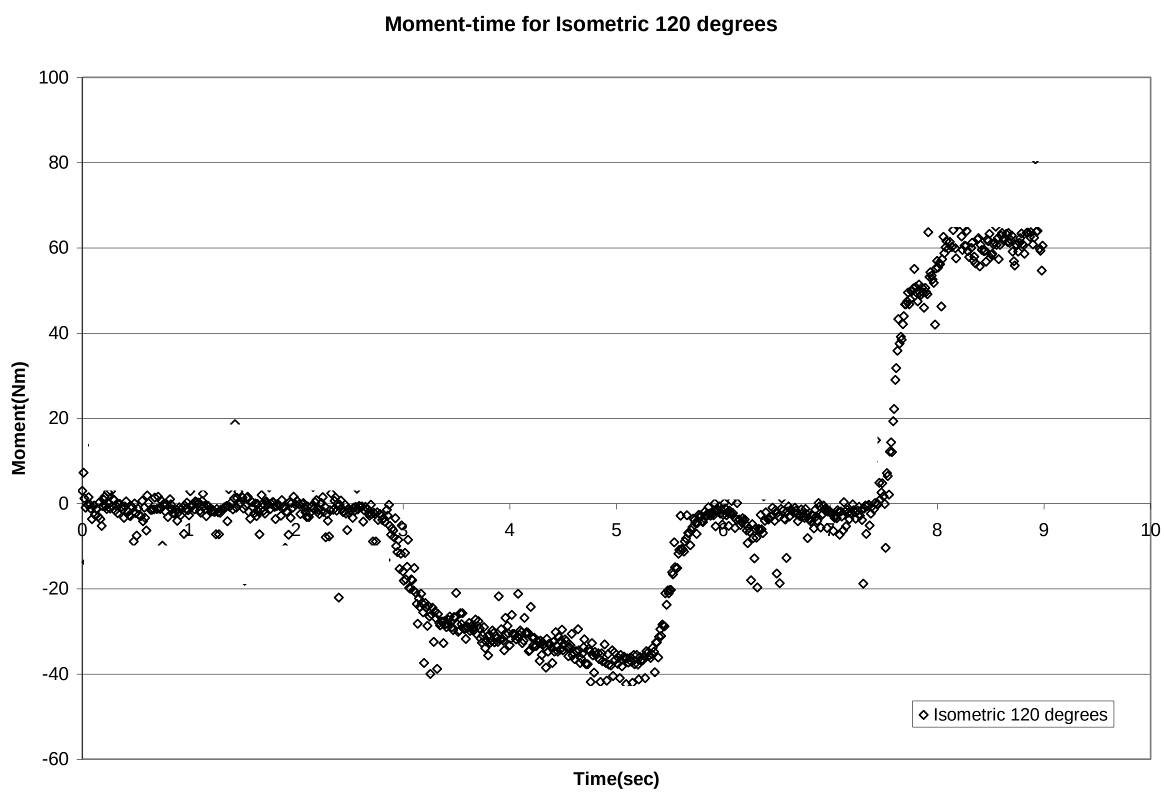

Figure 4. Moment-time for isometric 120 degrees

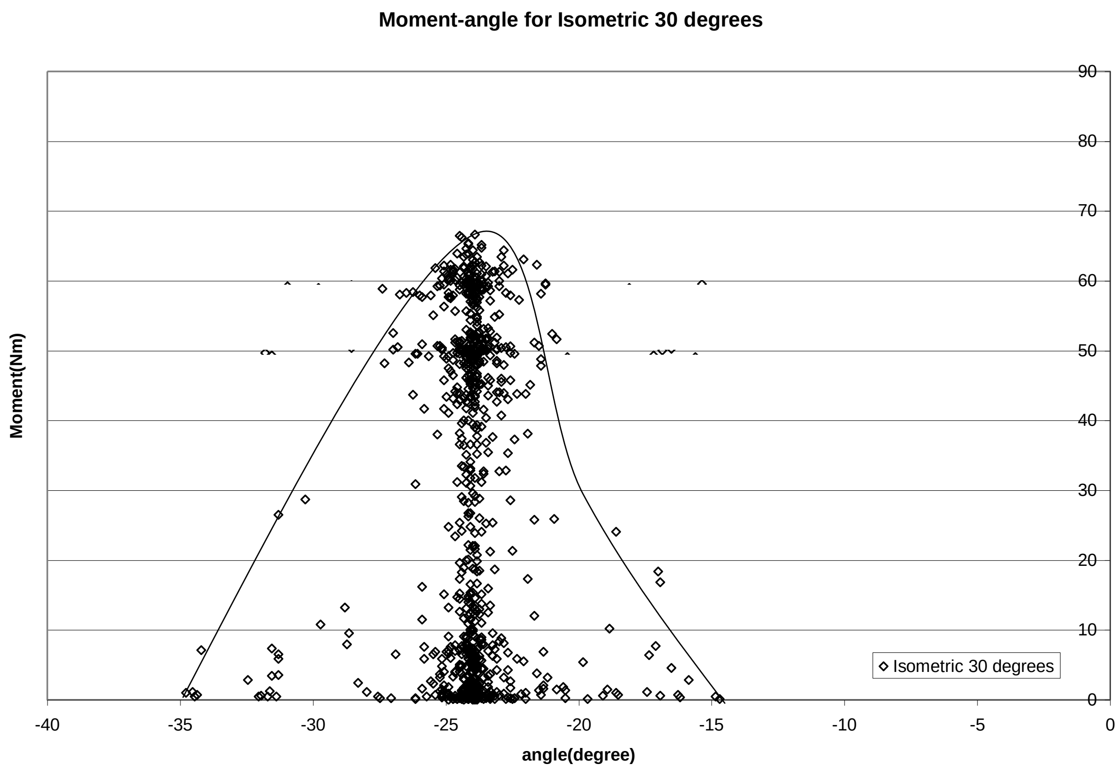

Figure 5. Moment-angle for isometric 30 degrees

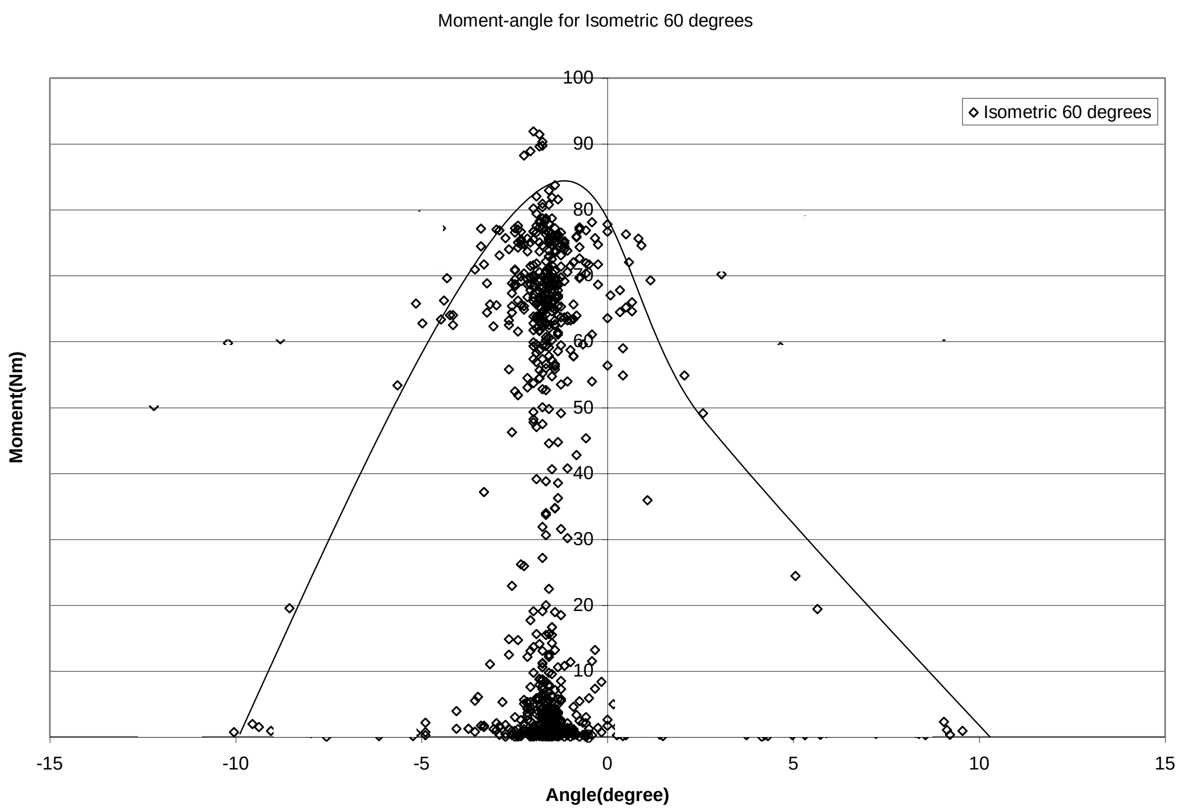

Figure 6. Moment-angle for isometric 60 degrees

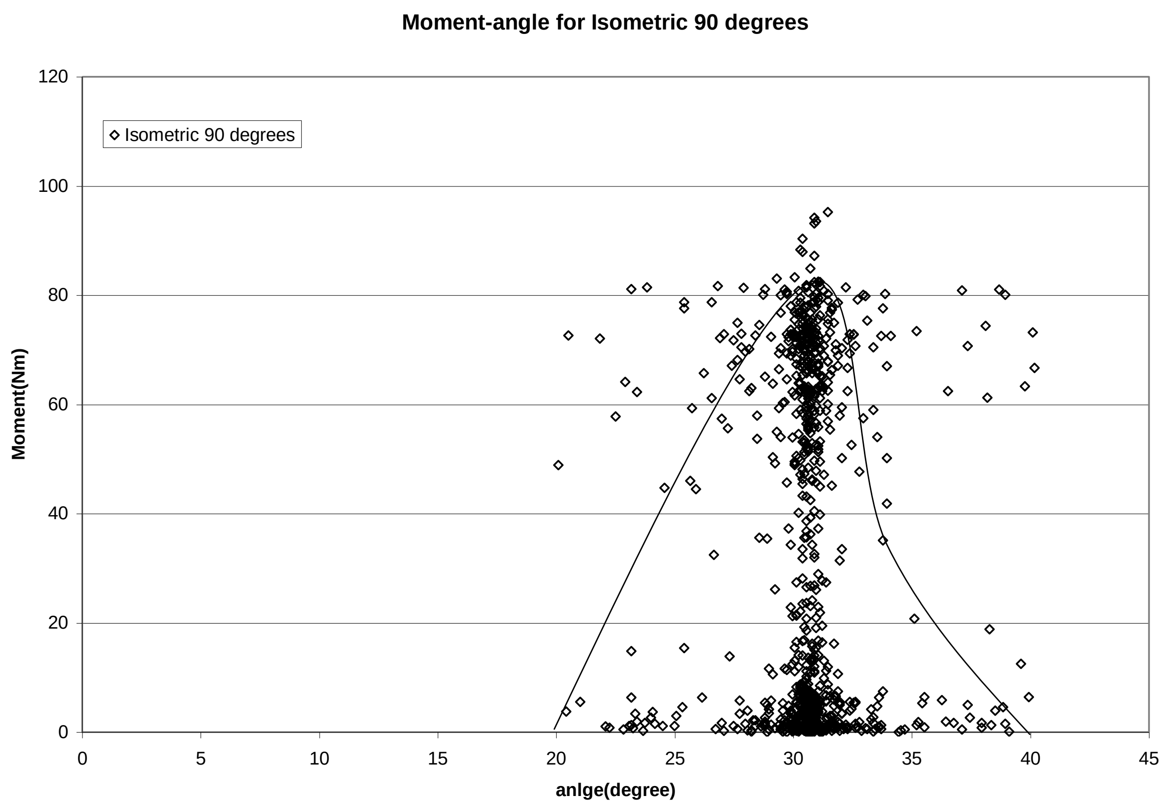

Figure 7. Moment-angle for isometric 90 degrees

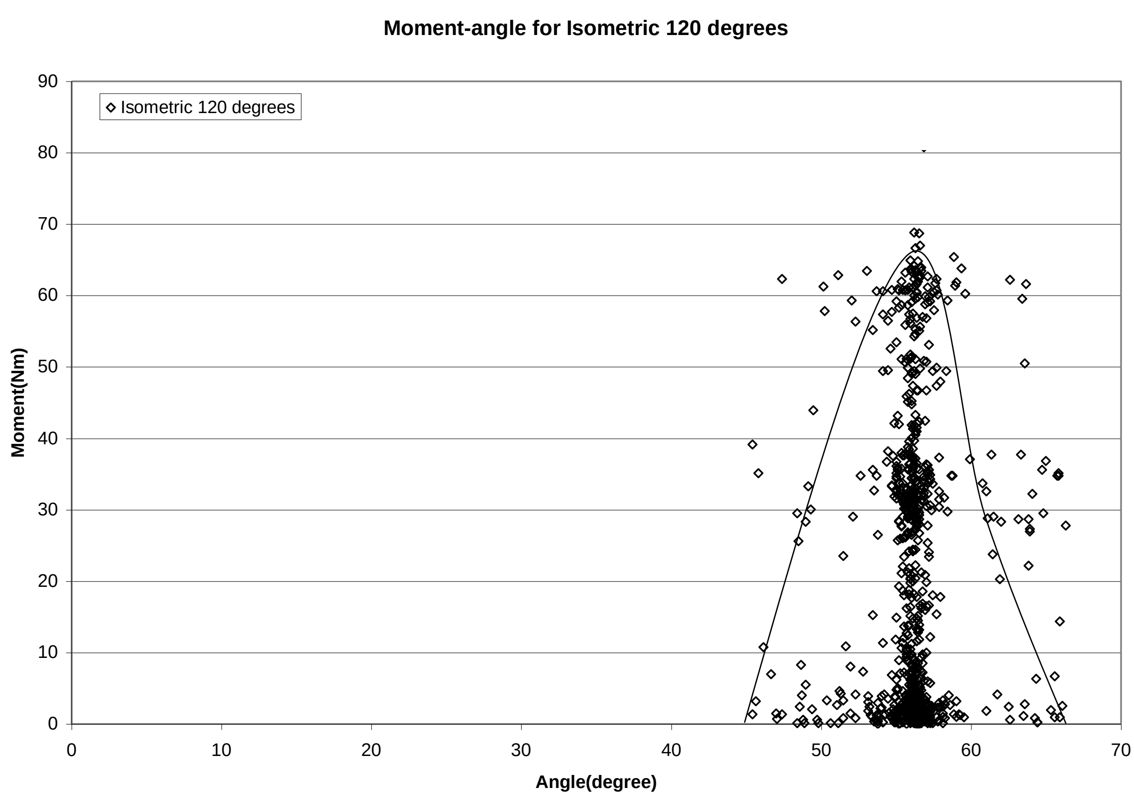

Figure 8. Moment-angle for isometric 120 degrees

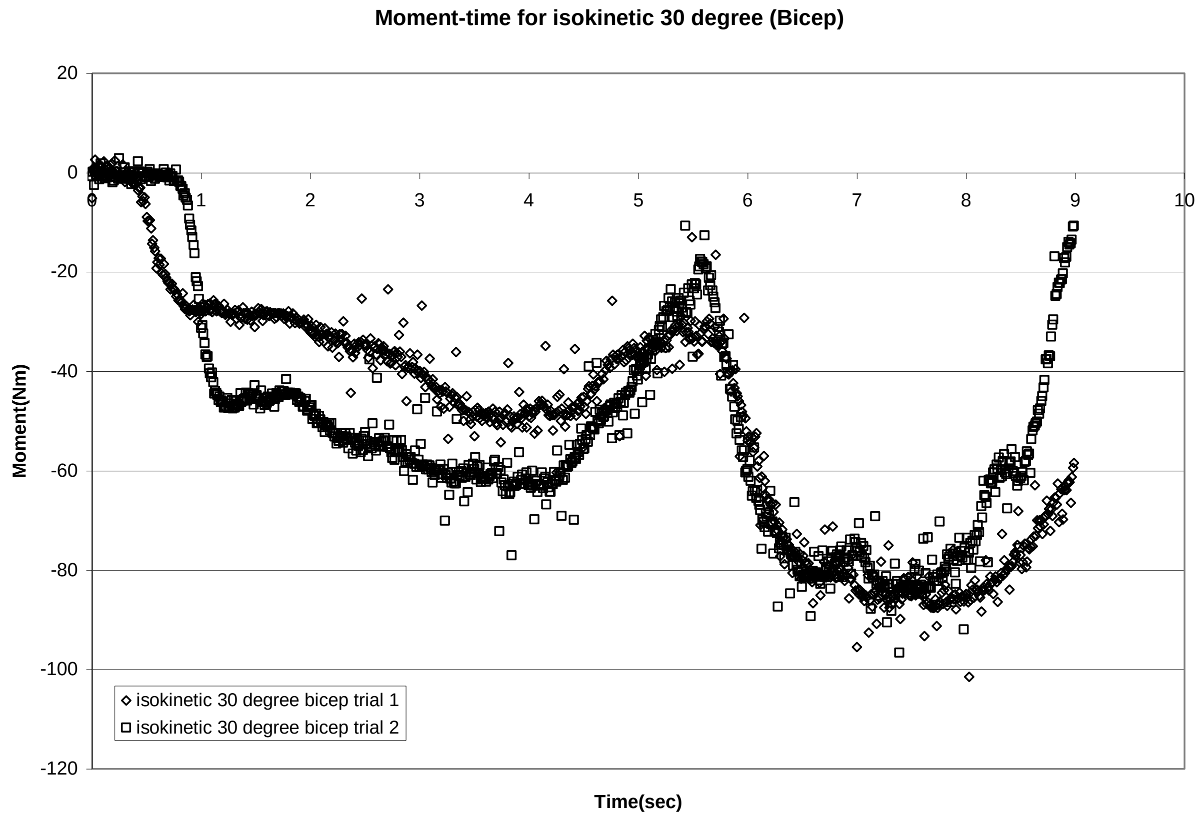

Figure 9. Moment-time for isokinetic 30 degrees bicep

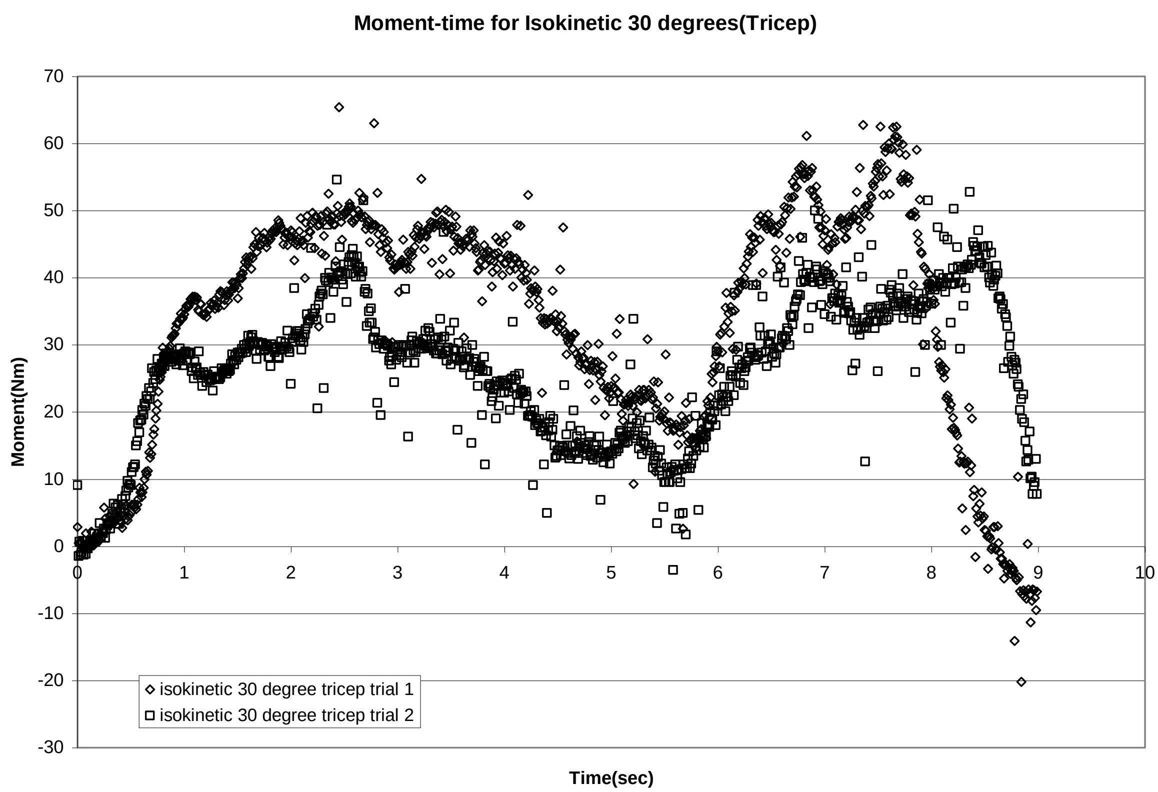

Figure 10. Moment-time for isokinetic 30 degrees triceps

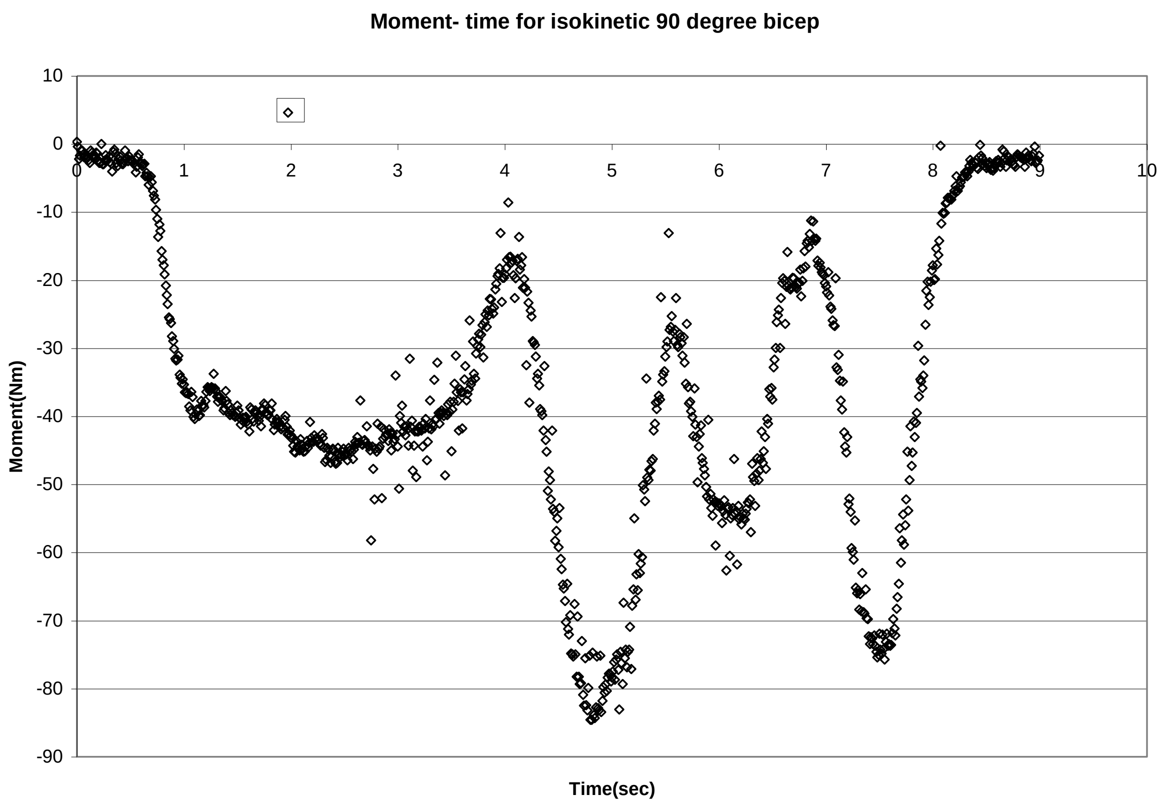

Figure 11. Moment-time for isokinetic 90 degree bicep

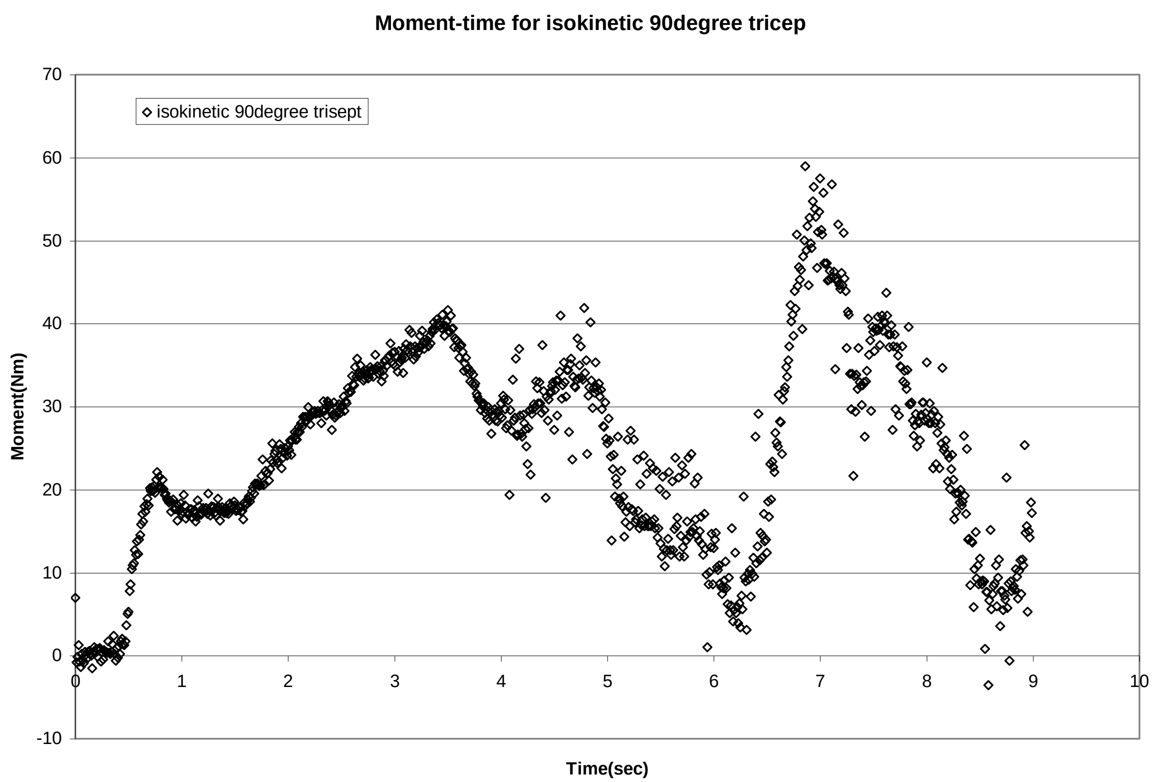

Figure 12. Moment-time for isokinetic 90 degree triceps

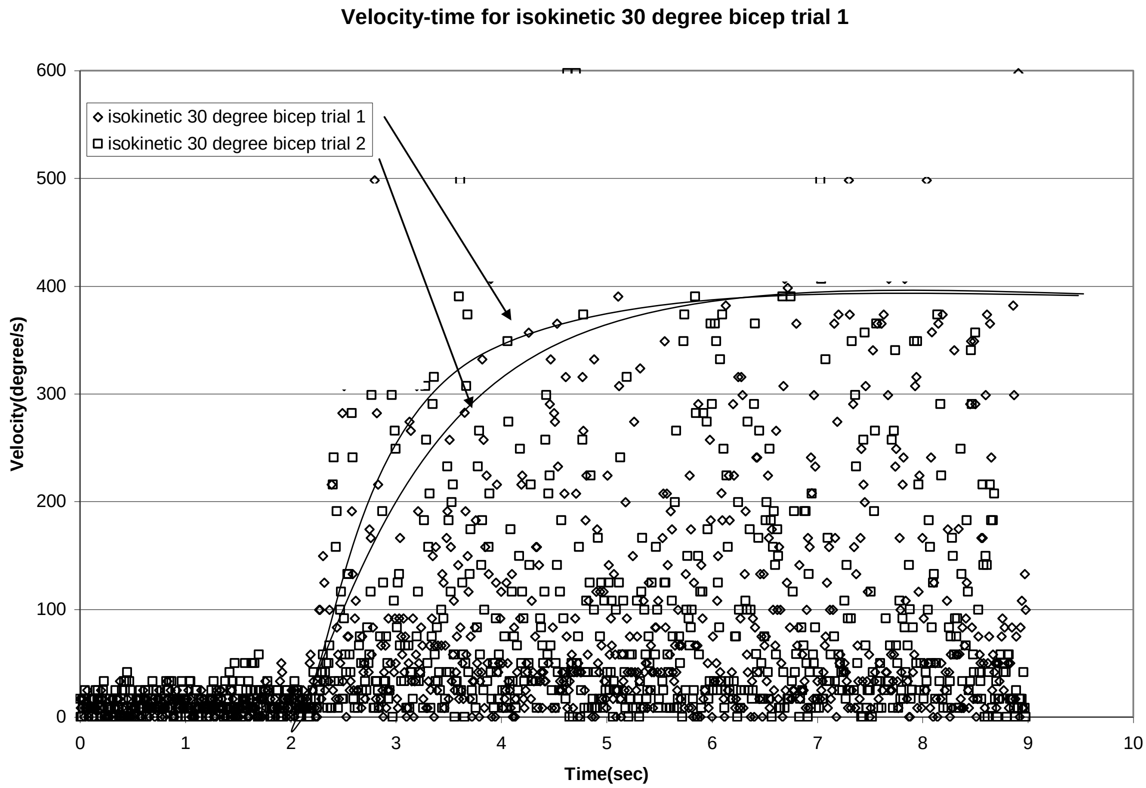

Figure 13. Velocity-time for isokinetic 30 degree bicep trial 1 and 2

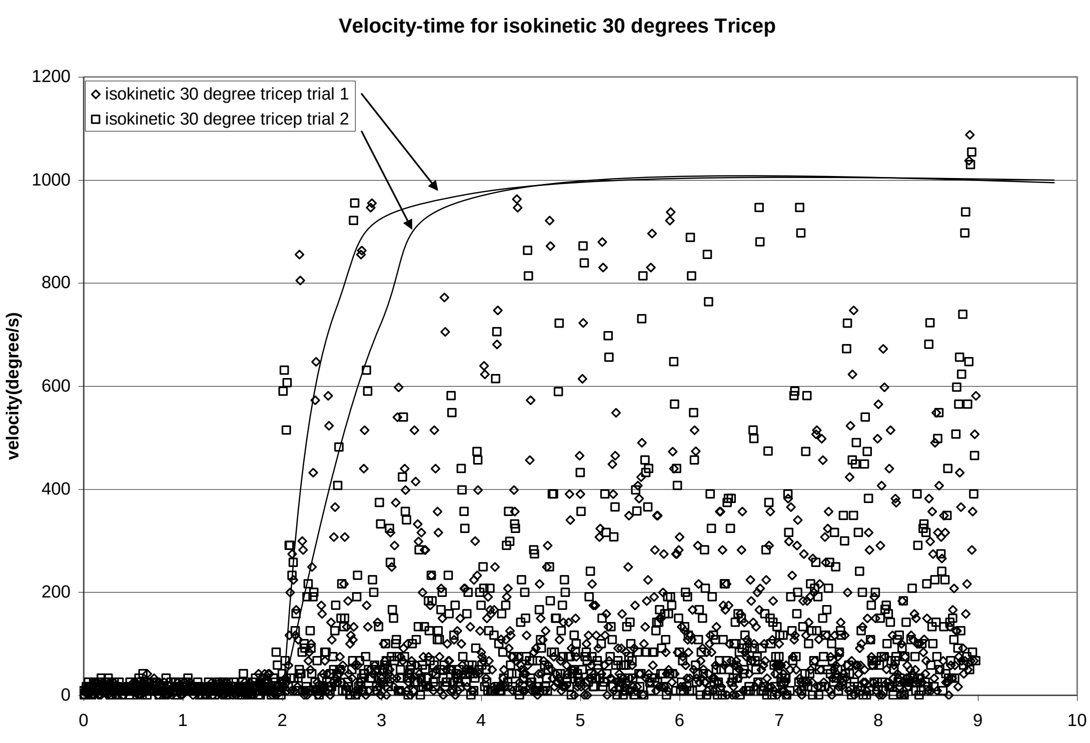

Figure 14. Velocity-time for isokinetic 30 degree triceps trial 1 and 2

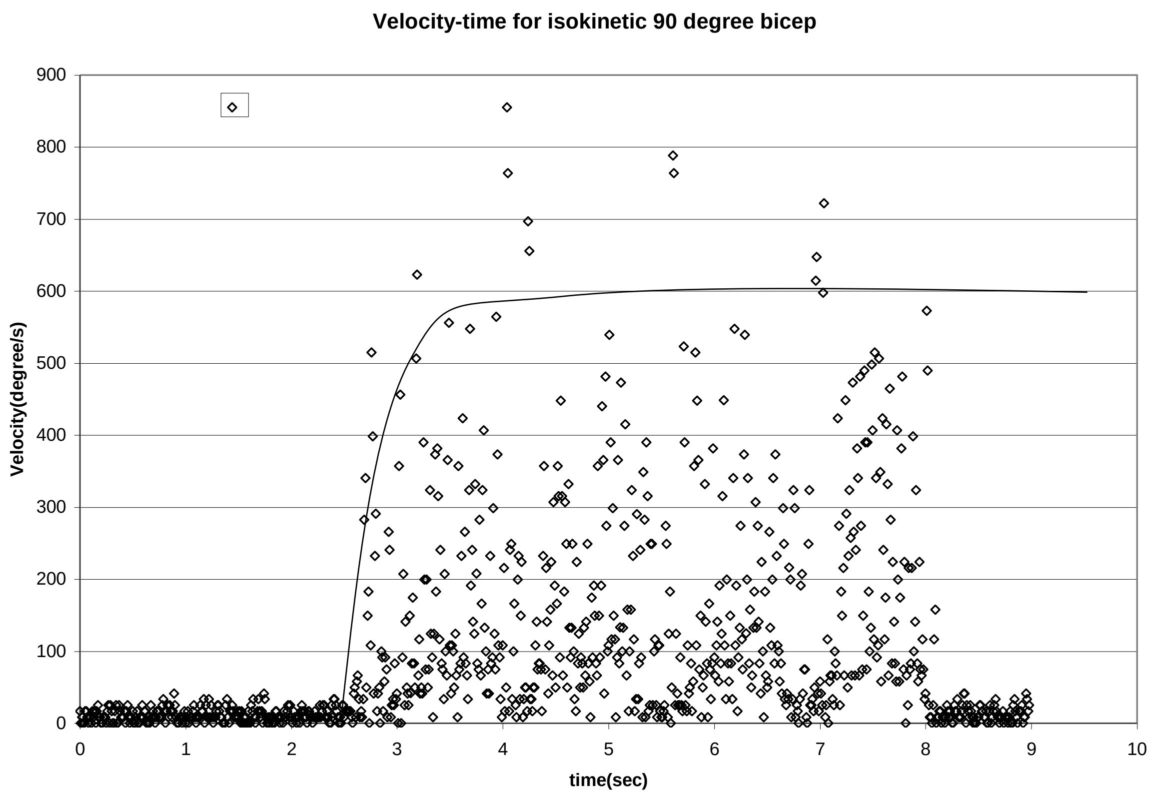

Figure 15. Velocity-time for isokinetic 90 degree bicep

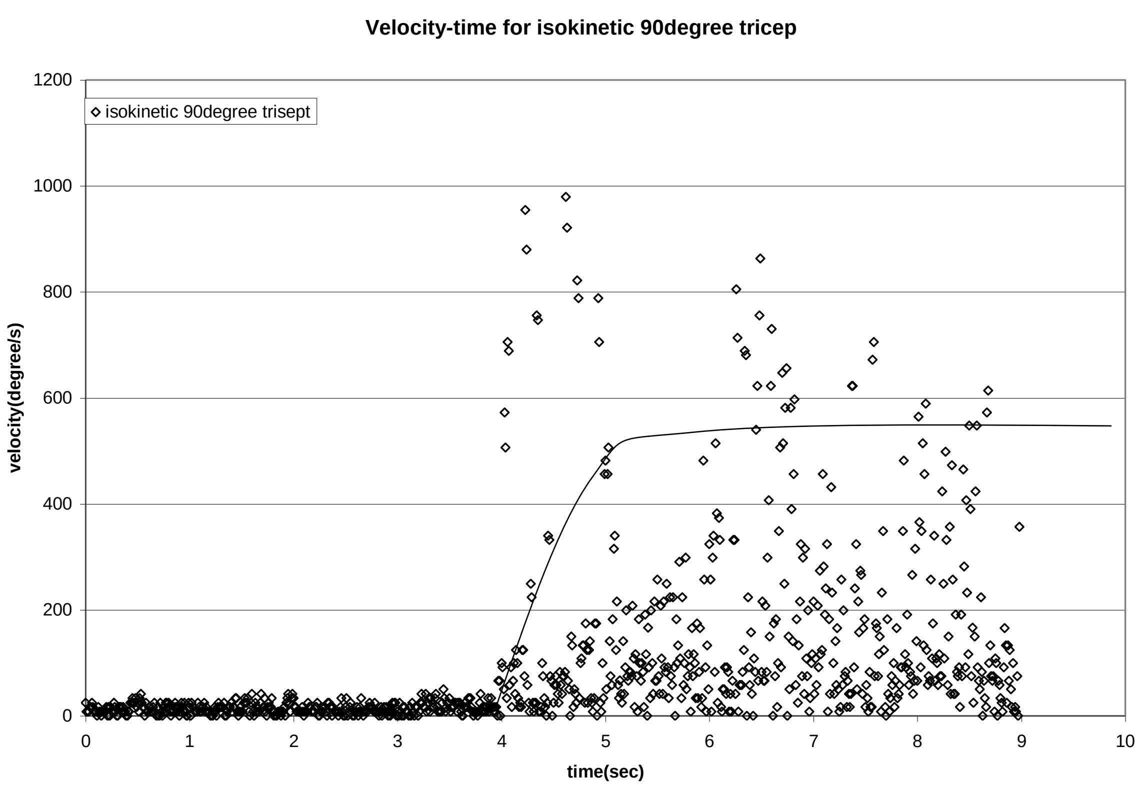

Figure 16. Velocity-time for isokinetic 90 degree triceps

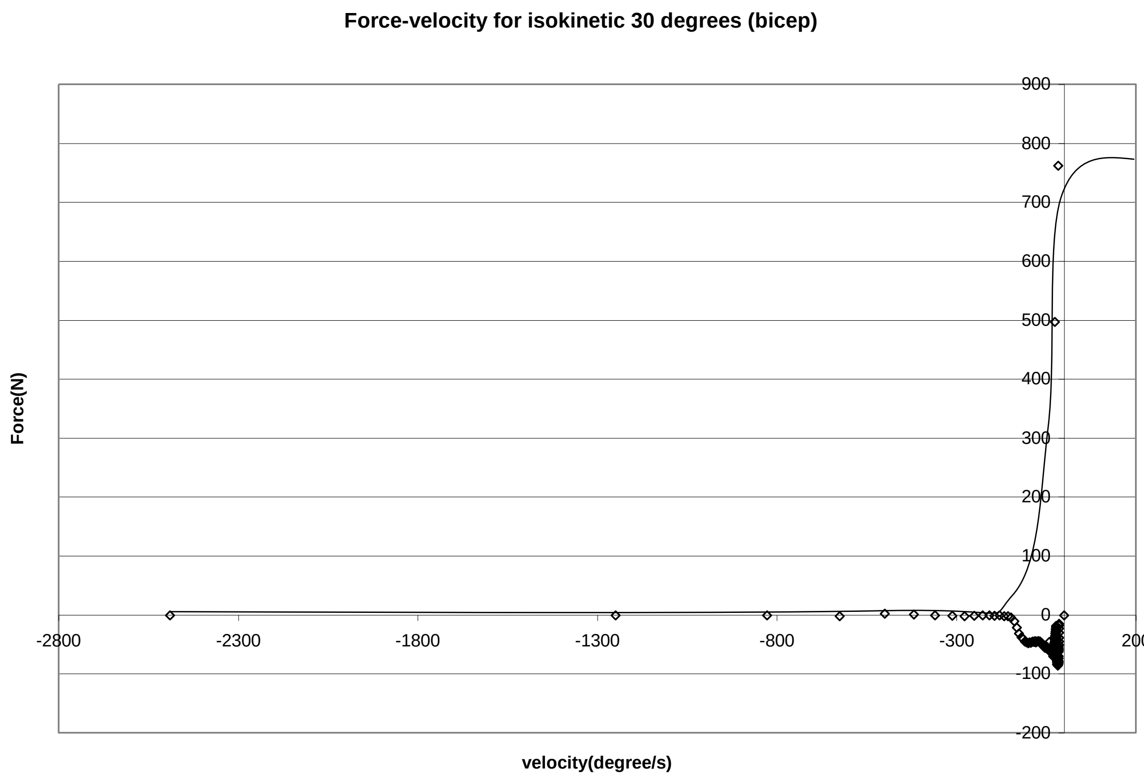

Figure 17. Force-velocity for isometric 30 degrees bicep

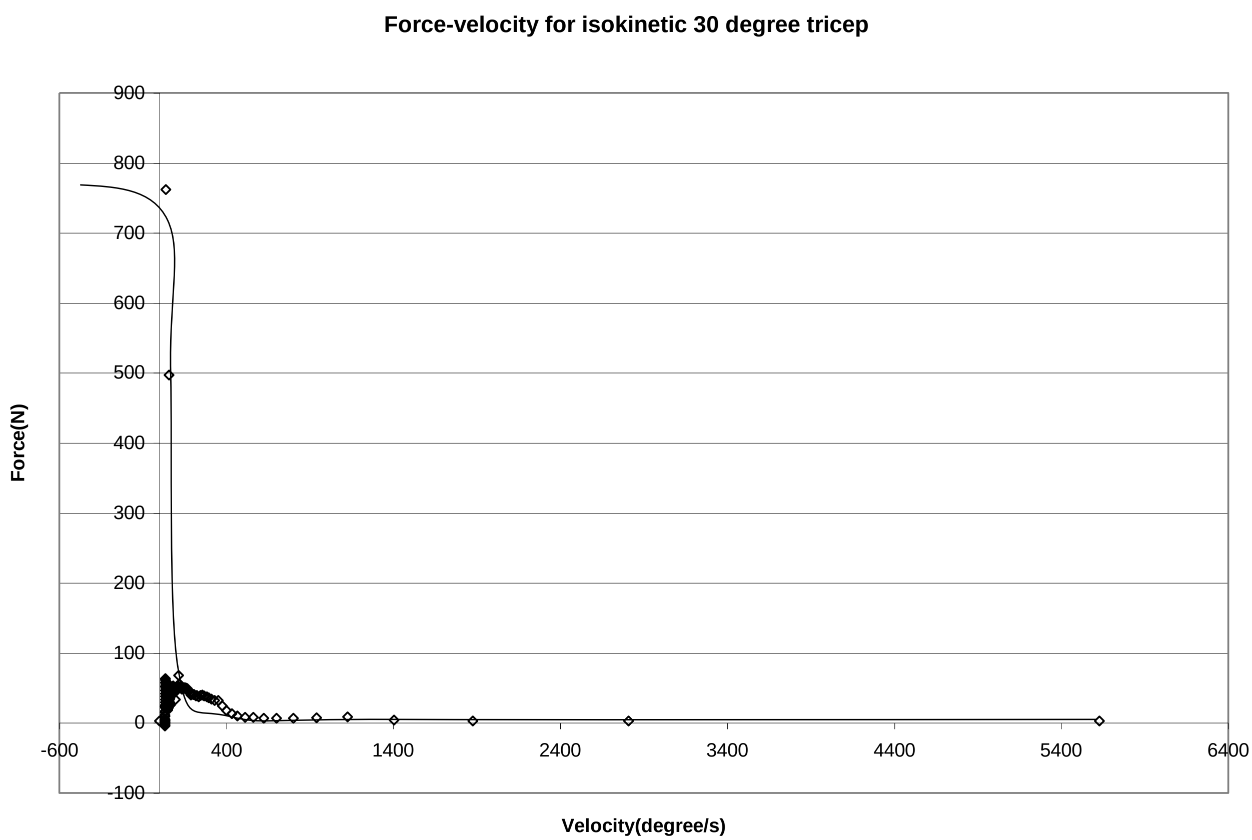

Figure 18. Force-velocity for isometric 30 degree triceps

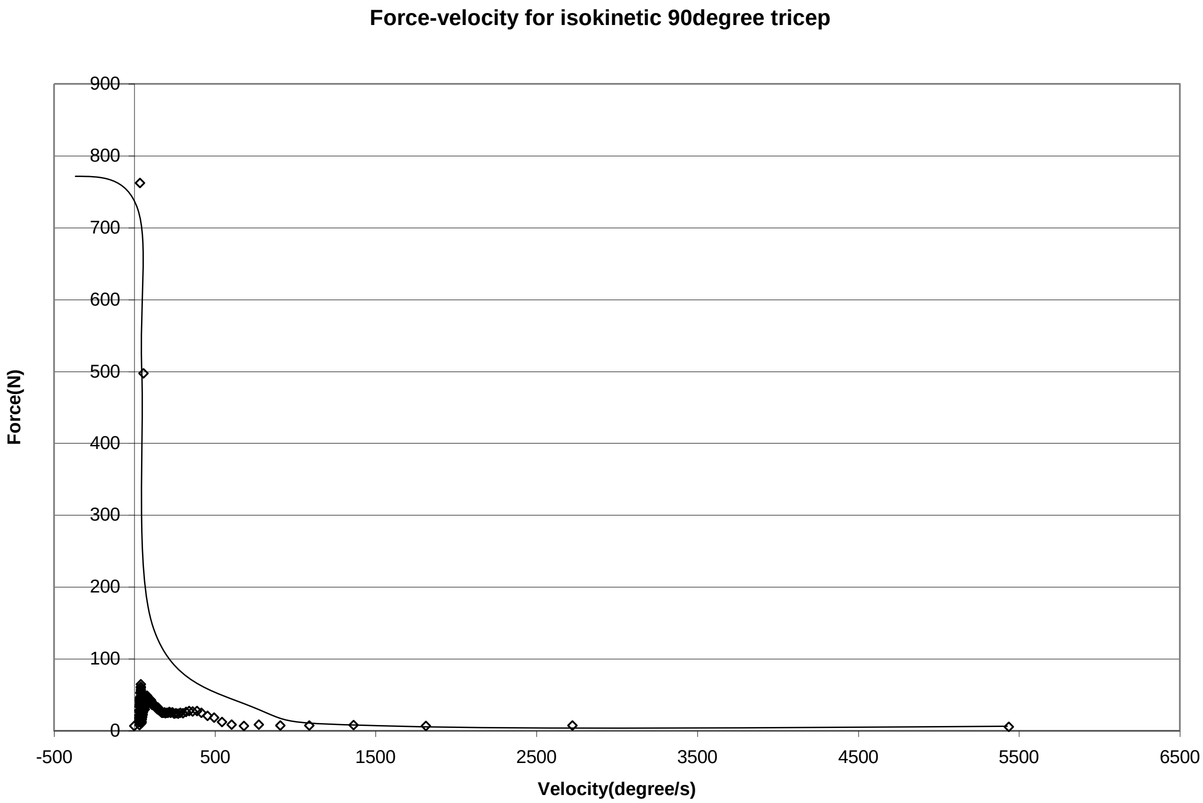

Figure 19. Force-velocity for isometric 90 degrees triceps

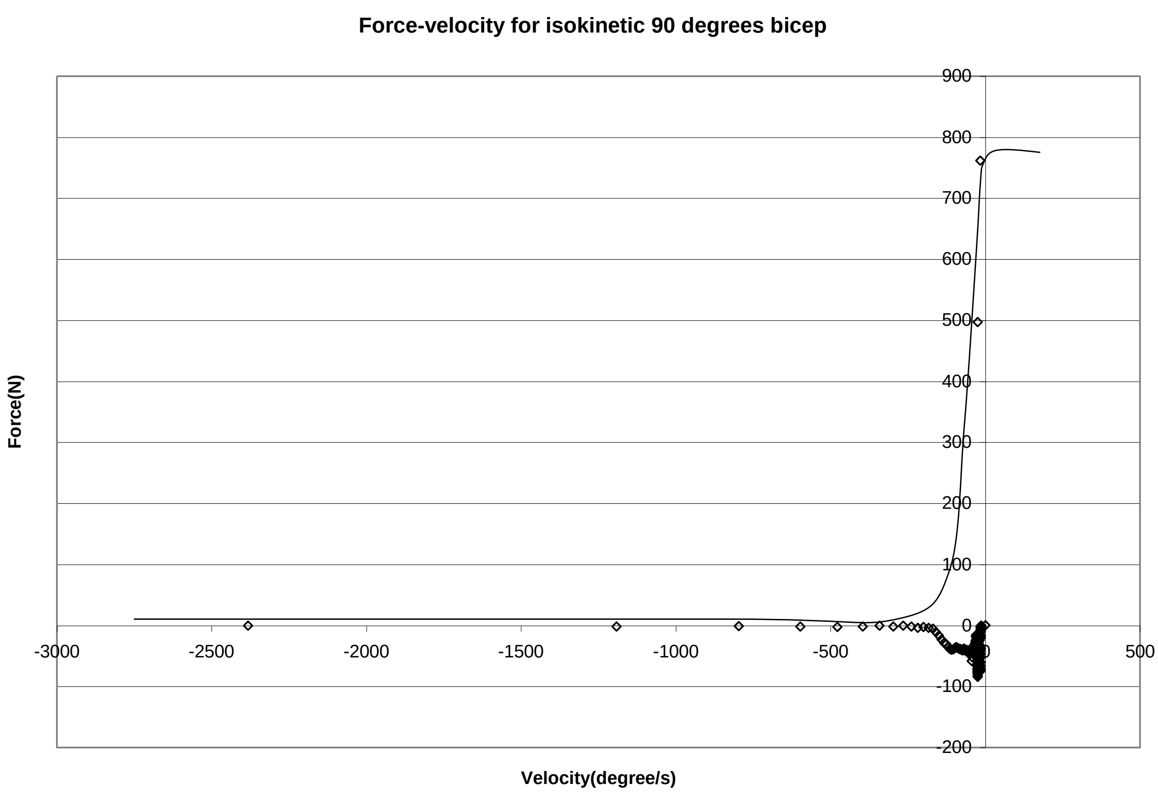

Figure 20. Force-velocity for isometric 90 degrees bicep

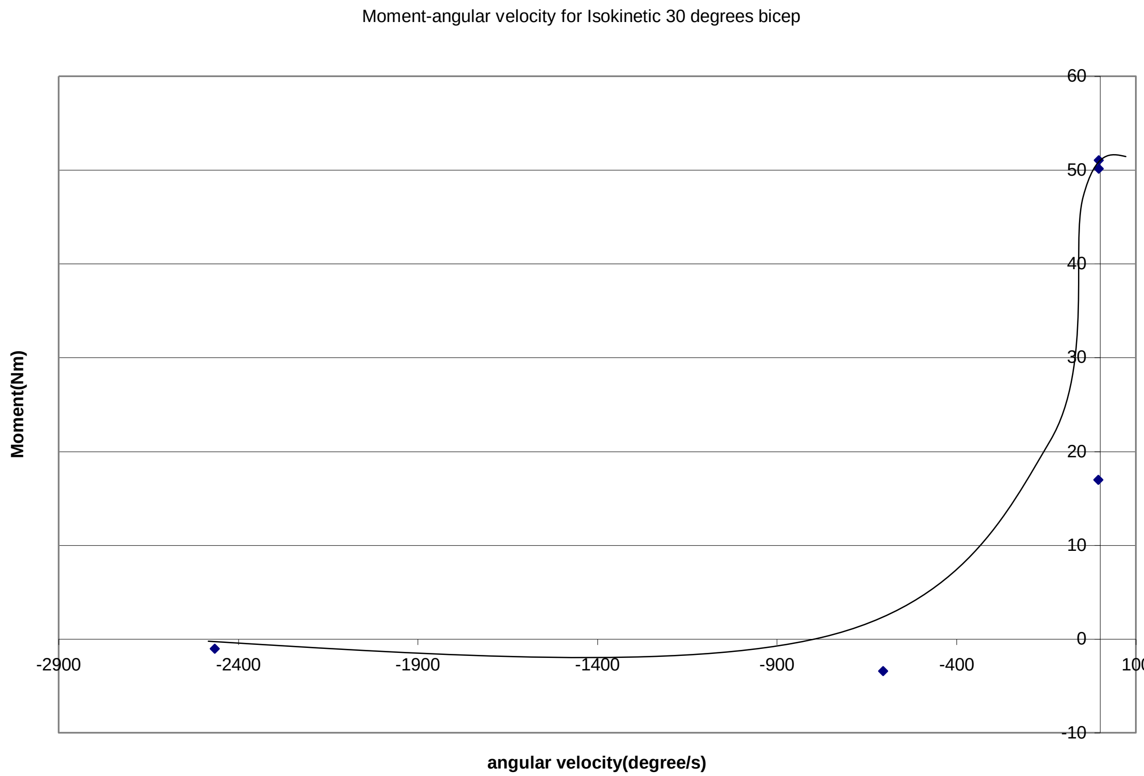

Figure 21. Moment-angular velocity for isokinetic 30 degrees bicep

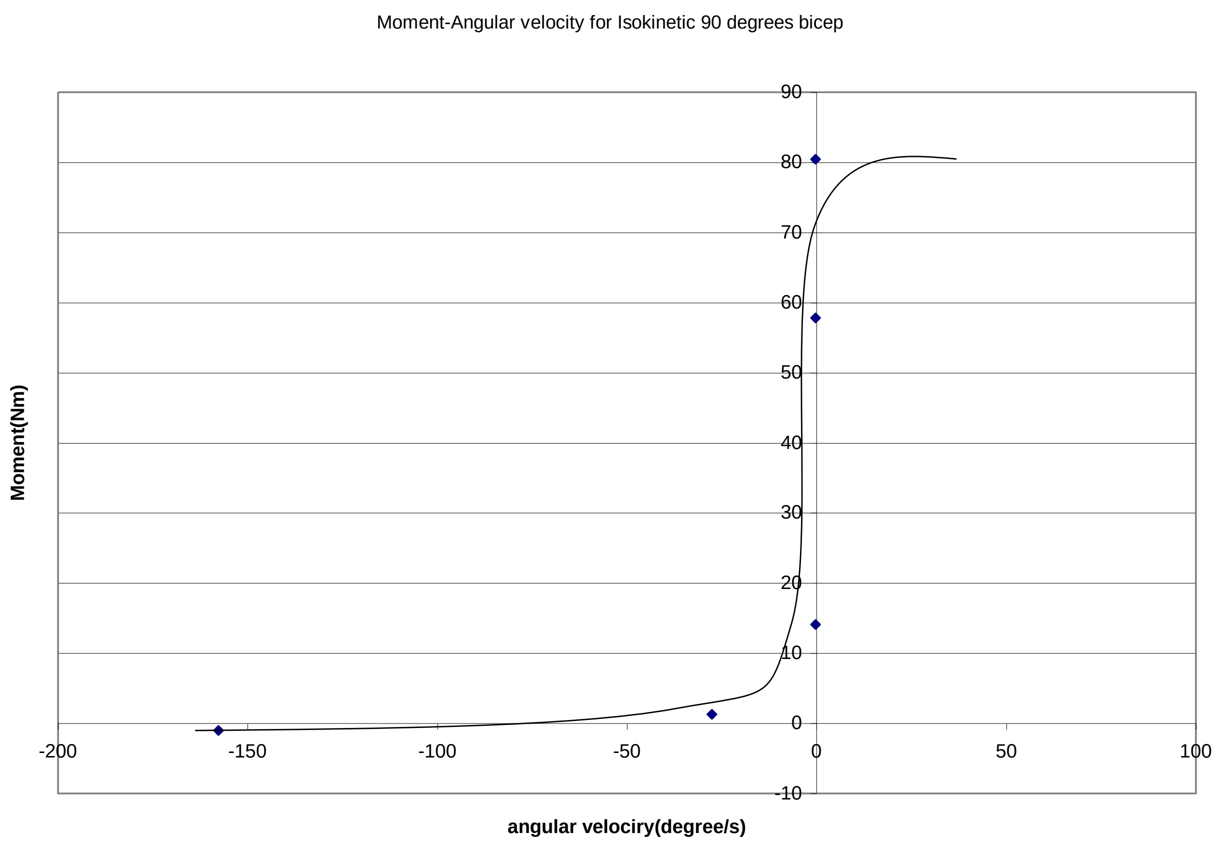

Figure 22. Moment-angular velocity for isokinetic 90 degrees bicep

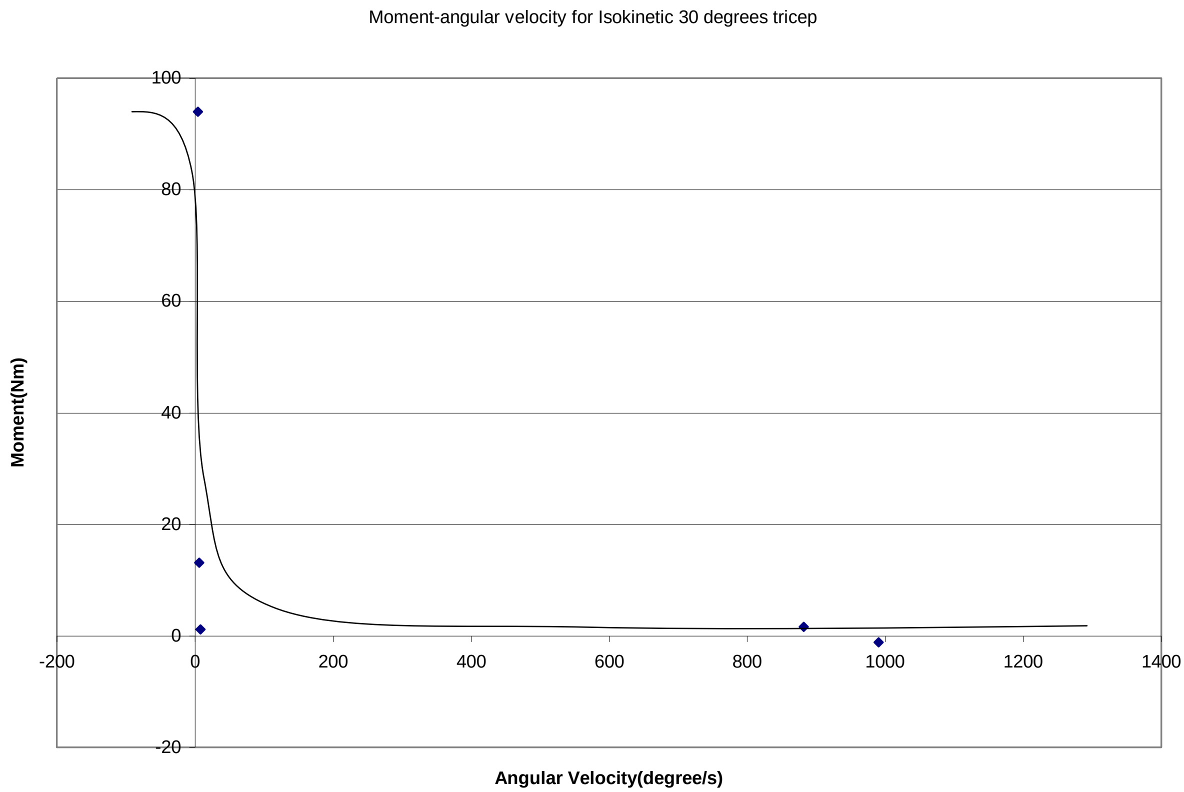

Figure 23. Moment-angular velocity for isokinetic 30 degrees triceps

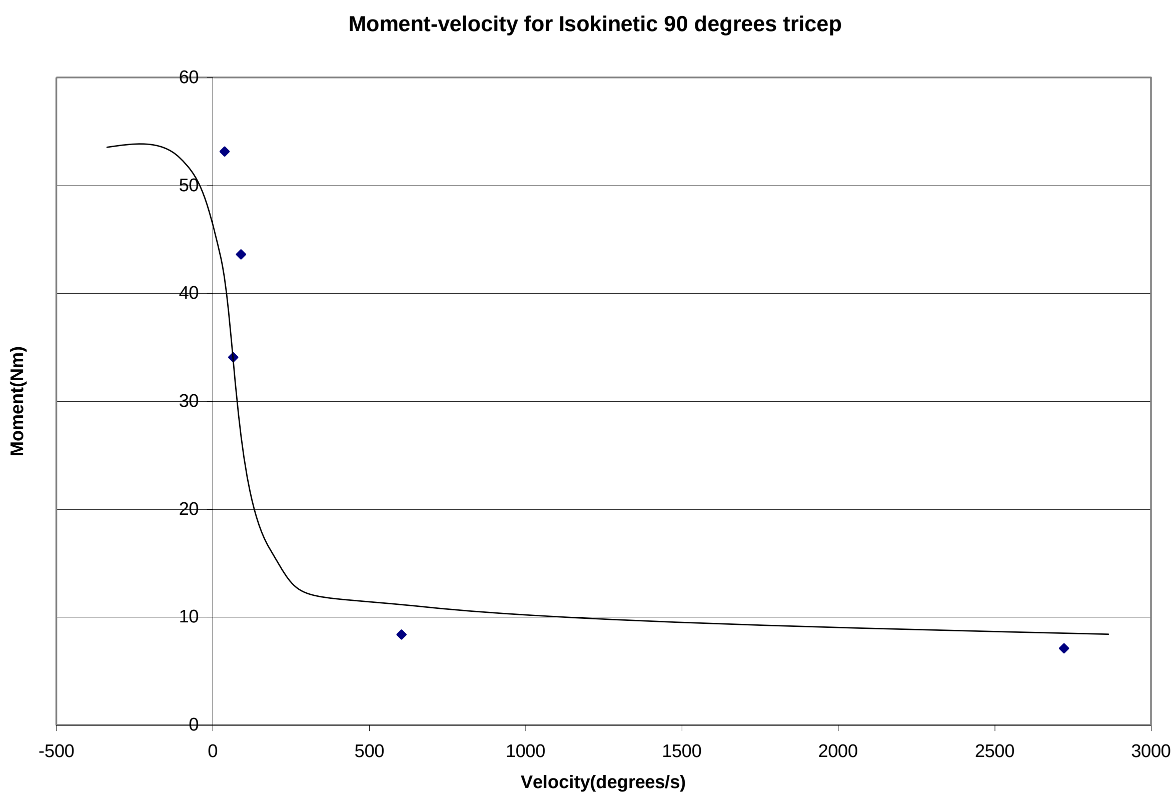

Figure 24. Moment-angular velocity for isokinetic 90 degrees triceps

V. Discussion

1. Moment-time data for the isometric experiment shows that at 60 degrees and 90 degrees have the highest moment. Therefore, moment-angle data for the isometric experiment have the highest moment within the region between 60 and 90 degrees. This region is called the optimum range. Even though the experiment was isometric, the moment-angle shows little of isotonic behavior. However, it still has the isometric characteristics at the beginning of the curve that shortening is occurred. CE-FL represents the same trend of the moment-angle plot. The difference between two is that CE-FL has the CE force which value is the moment divided by moment arm, and the length is the value which angle divided by moment arm. Therefore, CE-FL is dependent on the value of moment arm. When the moment arm is long, the CE force value decreases. When the moment arm is short, the CE force value increases. When the force is high, the velocity is low and vise versa.

2. For moment-angular velocity data for the isokinetic experiment, students assume that the volunteer put 100% maximal effort elbow extension. At 30 degrees, the moment-angular velocity data for the isokinetic experiment shows lower angular velocity than 90 degrees. The moment-angular velocity at 90 degrees shows the faster transition from shortening to lengthening behavior. The negative angular velocity is shortening region and the positive angular velocity is lengthening region. For biceps and triceps are mirrored images. Thus, at 30 degrees position, bicep is shortening and triceps is lengthening. At 90 degrees position, bicep is shortening and triceps is lengthening but it generates more force which is lower velocity but higher angular velocity. CE-FV is dependent on the value of moment arm as CE-FL. When the moment arm is long, the CE force value decreases. When the moment arm is short, the CE force value increases. When moment arm is short, then the skeletal muscle need to generate more force than longer moment arm.

3. The source of error can be the position of length of moment arm and the axis of the Biodex machine. When the volunteer applied force, the elbow position can be not aligned with the axis of the Biodex machine which can create different moment than actual value. Even though the writer performed low pass filter before analyze the data, there are still a lot of noises that might not be filtered and misrepresent the relationships among skeletal muscle behaviors. Also the fatigue of skeletal muscles can be another source of error due to the skeletal muscle, even though skeletal muscles do not have resemblance to the viscoelastic behavior of passive material.

VI. Conclusion

The strength can be generated by each muscle is proportional to the physiological cross sectional area. When skeletal muscle is stimulated, it is rapidly activated and changing from passive tissue into dynamic tissue capable of developing force. During stimulation, the length of the muscle is shortening or lengthening depending on what muscles and forces applied to muscles. The isometric force developed by a stimulated muscle restrained from movement is a function of muscle length. When skeletal muscle is allowed to shorten against a constant load from a fixed initial length, its velocity of shortening is a function of the external constant force and the length of the muscle. Because of the elastic nature of the connective tissues, a muscle isolated from the body will assume a certain length to which it will return if passively stretch and released. According to results, the optimum length that is defined as the length at which maximum isometric titanic tension may be developed is between 100 and 120% of the rest length. The active tension developed is a maximum at the optimum length and decreases at greater and lesser length. According to results, the speed of shortening increases, the muscle force decreases. Hill's equation indicates a hyperbolic relation between muscle tensile force and velocity. Figure 17-20 show that relationship that higher the force, the slower is the contraction velocity. The higher the velocity, the lower is force. This is in direct contrast to the viscoelastic behavior of a passive material for which higher velocity of deformation calls for higher forces. Therefore, the active contraction of a muscle has no resemblance to the viscoelasticity of a passive material. The force-velocity relationship is determined by the rate of breaking and reforming the cross bridges, with higher rates producing less effective bonds.

Reference

[1] Kenton R. Aufman, **Basic Orthopedic Biomechanics**, Raven Press. Ltd., New York 1991.