A COMPARISON OF TORQUE- VELOCITY- POWER CHARACTERISTICS OF MAXIMAL KNEE EXTENSION IN SPRINT AND ENDURANCE TRAINED ATHLETES

A.J. Harrison and J. Coghlan
Department of Physical Education and Sport Sciences, University of Limerick, Limerick, Ireland

This study examined the torque-velocity and power-velocity relationships of quadriceps muscle function in sprint and endurance athletes. Isokinetic maximal knee extension torque was obtained from seven sprinters and seven endurance athletes using a Contrex isokinetic dynamometer. Torque and power measures were corrected for lean thigh cross-sectional area and lean thigh volume respectively. The results indicated that significantly different torque and power velocity relationships existed between the two groups. The implication from this is that the use of isokinetic dynamometry might be a useful non-invasive method for determining qualitatively, the functional capacity of a muscle group.

KEY WORDS: torque, power, velocity, sprinting, endurance.

INTRODUCTION: Performance in athletic activity depends largely on the ability of athletes to exert force effectively and at an appropriate velocity. The force-velocity (F-V) and power-velocity (P-V) relationships of muscle contraction are crucial in describing the muscle's functional capacity. In an isolated muscle contraction the F-V relationship can be described by the formula:

$$(P + a)(V + b) = \text{constant} \qquad \text{(Hill, 1938)}$$

Where: P = force of contraction, V = velocity of shortening; *a* and *b* are constants.
Constant *a*, describes force and depends largely on the cross-sectional area (CSA) of the muscle. Constant *b* relates to velocity and it should be proportional to the length of the muscle (Hill, 1938). The F-V relationship therefore, is determined largely by the size of the muscle. In most cases, direct in-vivo measurement of muscle force is not easy; therefore, measures of joint torques are often used instead assuming the local moment arm variations to negligible, (Andrews, 1982). Since power is the product of force and velocity, it is logical that muscle power should be proportional to the volume of the muscle. In evaluating the effectiveness of muscle contraction, it is important to account for the effects of muscle size on contractile function. A variety of factors, most notably fibre type, will influence the velocity of contraction and therefore, the force-velocity relationship differences between endurance and sprint athletes. The aims of this study were to examine the torque-velocity and power-velocity relationships of the quadriceps muscle group in sprint and endurance athletes and to ascertain whether any qualitative differences exist in the function of this muscle group when the performance outputs are normalised for differences in muscle size.

METHODS: Fourteen competitive adult male athlete subjects participated in this study. Group 1 consisted of seven sprint athletes and Group 2 consisted of seven endurance athletes. The study had obtained ethical approval from the University research ethics committee and written informed consent was obtained from all subjects prior to their participation in the study.

Table 1. Physical characteristics of the subjects.

Group		Age (years)	Height (cm)	Mass (kg)
Sprint	**Mean (±SD)**	22.0 (2.7)	180.3 (±5.9)	79.6 (±6.5)
Endurance	**Mean (±SD)**	21.3 (±2.5)	177.1 (±4.1)	71.0 (±6.8)

All subjects completed three performance tests and the results of these were used to verify the subjects' sprint or endurance capacity. The performance tests were a 30m sprint test from a standing start, a 30m sprint test from a running start (i.e. flying 30m) and 20m progressive shuttle run test (Leger & Lambert, 1982). For both the 30m sprint and flying 30m, performance times were recorded using a Brower photo electronic timing device. Each subject completed 3 trials, with the fastest time being recorded for further analysis. Subjects were given 5 minutes rest between each trial. The 20m progressive shuttle-run was conducted using a pre-recorded cassette tape (NCF, Leeds) and performance score was based on the number of shuttles the subjects completed. Thigh volume was measured on the subjects' dominant leg. Anthropometric measurements comprising of a series of circumference and length measurements were made using a flexible steel tape. Skinfold thicknesses were measured at two sites with a Harpenden fat calliper and the lean circumference measures were calculated using the method of Jones & Pearson (1969). Lean thigh volume was calculated as a series of truncated cones by the method of Katch and Weltman (1975). Isokinetic concentric knee extension torque on the subjects' dominant leg was determined on a Con-Trex isokinetic dynamometer (CVH AG, Dübendorf, Switzerland). Before each test session, the dynamometer was calibrated using the manufacturers instructions. All subjects performed a warm up, which consisted of a 5-minute cycle on a Monarch 814E cycle ergometer (Varberg, Sweden). All subjects also completed a short habituation and practice session using the apparatus. During the tests, subjects were stabilised at the thigh, pelvis, and trunk with velcro straps. The axis of rotation of the dynamometer lever arm was aligned with the posterior aspect of the lateral femoral epicondyle. The distal shin pad of the dynamometer was placed 3 cm proximal to the medial malleolus. Subjects were instructed to place their arms across their chest during the testing procedure. Gravity effect torque was recorded on each subject and this was used to correct torque measurements during tests. Maximum concentric knee extension (Con K.E.) torque was measured at ten different velocities (ranging $30°.s^{-1}$ to $300°.s^{-1}$). Each maximal effort trial was immediately preceded by a sub-maximal extension-flexion movement. This helped to ensure the muscle contracted maximally throughout the measured concentric knee extension exercise. The sequence of the velocities was varied between subjects to negate possible effects of fatigue on the results. Three to five minutes rest was given between each effort. Each subject was given the same level of encouragement during trials. Subjects performed 5 trials at each velocity and Con K.E. torque was recorded continuously throughout the full range of motion. A visual inspection of the angle – time and torque – time graphs of each trial was made to ensure that peak torque occurred at constant velocity. Trials were rejected if the angle – time graph was non-linear at the instant of peak torque. Peak torque values were corrected for thigh CSA by dividing them by the area of the thigh at the one-third sub-ischial level. The corrected torque and velocity values for each subject were fitted to the Hill equation by substituting known values of torque and velocity into a system of three simultaneous equations. This was done using the mid-range velocities of 120, 150 and 180°/sec. The values calculated for the constants *a* and *b* were then substituted back into the equation for the remaining velocities, yielding estimates of torque. The resulting torque predictions were compared with the actual measures obtained on the dynamometer to check the validity of the derived constants. Concentric knee extension power was calculated as the area beneath the torque-velocity curve at each velocity. Power values were then corrected by dividing by lean thigh volume, (Barrett & Harrison, 2001). Student t-tests were performed on the mean Hill equation constants to determine significant differences in the F-V relationship between sprint and endurance groups. Differences in corrected power values between sprint and endurance groups were evaluated using a two-way ANOVA with repeated measures. The general linear model had one within-subjects factor, namely, velocity (with ten levels) and one between subjects factor, namely group (with two levels: sprint and endurance). The dependent variables were torque and power and the model included all interaction terms.

RESULTS AND DISCUSSION: Table 2 presents the results of the sprint and endurance performance tests. The results show very clear differences between the sprint and endurance groups and justify the classification of these groups.

Table 2. Scores in performance tests for sprint and endurance groups.

	30m Standing (s)	Flying 30m (s)	20m Shuttle Run (no. of shuttles)
Group 1 Sprint	3.98 ** (±0.16)	3.18 ** (±0.11)	70.6 ** (±25.7)
Group 2 Endurance	4.60 ** (±0.19)	3.85 ** (±0.23)	134.3 ** (±12.3)

** indicates significant difference between sprint and endurance groups ($p < 0.01$)

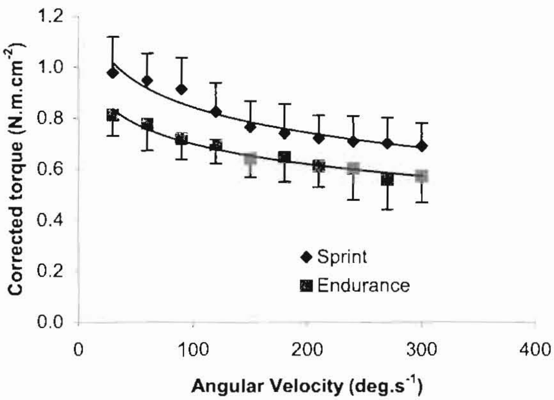

Figure 1. Comparison of the mean cross sectional area corrected force-velocity curves for sprint and endurance groups.

Figure 1 shows the average corrected Con K.E. torque velocity curves for sprint and endurance groups. It is clear from the graphs that Group 1 athletes generated higher Con K.E. torque at all velocities. The Hill equation constants *a* and *b* were derived for the corrected torque values for each subject and the mean Hill equation constants are shown in table 3. A Student t-test on constants *a* and *b* revealed a significant difference between groups for the constant *a* but not *b*. This indicated that across all velocities, sprinters generated higher torque

Table 3. Mean Hill equation constants for sprint and endurance groups.

	Hill Constant *a*	Hill Constant *b*
Sprint	-1.054 * (±0.451)	-0.023 (±0.021)
Endurance	-0.574 * (±0.321)	-0.010 (±0.011)

* significant difference between sprint and endurance groups ($p < 0.05$)

Figure 2 shows the mean P-V graphs for both groups. Due to the velocity limitation of the dynamometer, the peak power values were not achieved. This is a common limitation of isokinetic dynamometers. Despite this, the graphs indicate that the sprint group achieved higher volume corrected power output at all velocities. The results of the GLM ANOVA indicated a significant between-subjects main effect for volume corrected power ($p = 0.006$) and a significant within-subjects interaction effect for group × velocity. This result shows that the corrected P-V relationships were significantly different between the two groups of athletes. These data suggest a qualitative difference in muscle function between the groups, with sprint athletes' able to generate higher power output over the range of 30 -300°.s^{-1}. It is likely that the functional differences observed between the groups were related to factors such as fibre type and muscle contraction velocity. Power generation is vitally important in the performance of athletic activities and it is important that distinctions of muscle performance in athletic activities should take appropriate account for individual variations in muscle size.

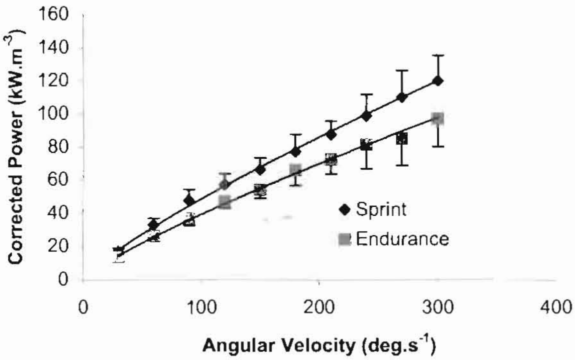

Figure 2. Mean volume corrected power-velocity curves for sprint and endurance groups.

The corrected torque and power-velocity data provides clear indications of the functional differences between sprint and endurance athletes with correction for size variations. More accurate methods of correction for muscle CSA and volume would have been desirable since the methods used in this study did not exclude bone and inactive muscle mass such as the hamstrings. However, accurate measures of the active muscle CSA and volume would require specialised imaging techniques such as MRI scanning which is not easily accessible.

CONCLUSION: This study shows that when F-V and P-V data were corrected for muscle CSA and lean thigh volume respectively, that significant differences were found between sprint and endurance athletes. This suggests that the use of isokinetic dynamometry might be a useful non-invasive method of determining qualitative, functional capacity of a muscle group.

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