Comparison of hamstring/quadriceps isokinetic strength ratios and power in tennis, squash and track athletes

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Isokinetic assessment of elite squash, tennis and track athletes confirms the accepted ratio of 60 to 80 per cent hamstring to quadriceps when testing at 90 deg.sec⁻¹ for peak strength (torque). However, significant variations occur at higher test speeds up to 300 deg.sec⁻¹ with the hamstrings becoming more prominent especially ($p < 0.001$) in the nonpreferred (NP) leg. There was no significant difference between sports, and wide individual differences occurred.

Analysis of (work.sec⁻¹.kg⁻¹ body weight) power showed a significantly higher work output ($p < 0.01$) by track athletes than squash and tennis players but, unlike hamstring/quadriceps ratio, no significant difference between preferred (P) and nonpreferred leg. The maximum power output was achieved around 220 to 250 deg.sec⁻¹.

Power between preferred and nonpreferred legs was the same but the torque ratio differed indicating that the hamstrings provided proportionately more work in the NP leg at higher speeds.

Keywords: Hamstring/quadriceps ratio, isokinetic power, tennis, squash, track athletes, varying speeds, preferred and nonpreferred

Method

Eleven elite track athletes including World and European record holders, eleven squash players all with World or British top 30 rankings, plus eleven top 50 ranked British tennis players were tested in the sitting position on the Lido (Loriden) isokinetic dynamometer. The seat angle was adjusted to 15 deg to the horizontal and the back rest at 15 deg to the vertical. Restraining Velcro strapping was placed around the chest and hips, and a knee brace for maximum stabilization clamped over the distal third of the quadriceps.

The dynamometer was adjusted for leg length, and the subjects allowed to spend a few minutes familiarizing themselves with the machine. Then they performed two easy and one maximal excursion of flexion and extension of the knee prior to each test. Standardized verbal motivation techniques were used to encourage maximal work from the test

subject. Readings were taken for five repetitions at 90, 180, and 240 deg.sec⁻¹ and thirty repetitions at 300 deg.sec⁻¹ was calculated to avoid fatigue effects. A rest period of 90 seconds was allowed between test speeds and three minutes between test limbs. The racket arm and ipsilateral leg were considered preferred.

Results

The torque ratio of hamstrings/quadriceps percentage for squash players, tennis players and track athletes is shown in Table 1.

Anova showed the torque ratio (TR) of hamstring/quadriceps was significantly different ($p < 0.001$) between individuals (Figure 1) especially at higher speeds. No significant difference was noted between the groups. Highly significant differences in mean torque ($p < 0.001$) were recorded between the preferred and nonpreferred legs and test speed (Figure 2); and leg degree test speed interaction throughout the sports (Figures 3, 4 and 5).

Anova for the rates of TR increase with turning speed showed no significant differences between the three groups ($p < 0.2$) but, as expected, a large difference between legs ($p < 0.001$):

	Athletes	Squash	Tennis	All
P	0.118	0.101	0.074	0.098
NP	0.191	0.189	0.150	0.177

Thus TR at 300 deg.sec⁻¹ was lower in the preferred leg than in the other. Although the tennis players increased their TR less than the other two groups, this distinction was not statistically significant at the five percent level.

Results of power analysis showed a significantly higher work output by the track athletes (Table 2).

Work.sec⁻¹.kg⁻¹ (WS) was analysed in two ways:

Full Anova

Since WS rose and then fell with increasing turning speed, an attempt was made to identify the maximum WS and the speed at which it was achieved.

The mean WS differed between the groups. The athletes had a significantly higher mean than both

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Table 1. Torque ratio hamstrings/quadiceps percentage

	90 deg.sec-1		180 deg.sec-1		240 deg.sec-1		300 deg.sec-1	
	p	np	p	np	p	np	p	np
Squash								
average	74	77	84	95	88	104	97	117
mean	77	83	90	97	96	112	103	118
range+-	7	13	20	26	20	33	31	42
Tennis								
average	74	73	80	81	87	94	89	104
mean	79	69	78	76	80	89	82	96
range+-	16	25	18	27	19	32	27	37
Track athletes								
average	77	77	92	90	97	98	108	122
mean	80	83	101	91	103	100	115	145
range+-	13	17	23	19	23	19	26	49

other groups, which did not differ significantly from each other ($p < 0.05$) as shown in Figures 6, 7 and 8.

The recording of only four test speeds per person do not allow for accurate measurement and calculation of the maximum work rate. However, an attempt to do this was done by taking the maximum WS for

each individual and each leg together with the corresponding speed. If WS was the same at different speeds then the mean WS and speed was used. Data was analysed by Anova. Mean maximum work was as follows:

	P	NP	Both
Athletes	2.85	2.80	2.82
Squash	2.29	2.24	2.27
Tennis	2.24	2.37	2.32
All	2.46	2.47	2.46

Figure 1. Torque ratio hamstring: quadiceps – Track athletes

Figure 2. Torque ratio hamstring: quadiceps – All subjects (n = 33)

Figure 3. Torque ratio hamstring: quadriceps – Track athletes

Figure 5. Torque ratio hamstring: quadriceps – Tennis players

Figure 4. Torque ratio hamstring: quadriceps – Squash players

Figure 6. Power (Joules.sec⁻¹.kg⁻¹ body weight) v Speed hamstring: quadriceps – Squash players

Table 2. Analysis of power (joules.sec-1.Kg-1) in squash players, tennis players and track athletes

	90 deg.sec-1		180 deg.sec-1		240 deg.sec-1		300 deg.sec-1	
	p	np	p	np	p	np	p	np
Squash								
average	1.72	1.63	2.19	2.16	2.16	1.97	2.08	2.05
mean	1.71	1.61	2.02	2.21	2.00	1.96	2.06	2.13
range+ -	0.49	0.36	0.50	0.48	0.60	0.44	0.66	0.56
Tennis								
average	1.86	1.75	2.16	2.20	2.15	2.23	1.90	1.99
mean	1.99	1.73	2.22	2.04	2.18	2.37	1.80	2.10
range+ -	0.38	0.27	0.49	0.53	0.60	0.55	0.43	0.61
Track athletes								
average	2.10	2.04	2.57	2.46	2.66	2.53	2.57	2.57
mean	2.11	2.18	2.87	2.67	2.73	2.73	2.53	2.77
range+ -	0.50	0.51	0.72	0.76	1.06	0.86	1.13	1.04

The athletes had a significantly higher work output ($p < 0.01$) than both other groups. Squash and tennis players did not differ. There was no significant difference between preferred and nonpreferred legs.

Analysis of speed (degrees.sec-1) at maximum WS indicated the following means:

	P	NP	Both
Athletes	251	254	252
Squash	240	218	229
Tennis	229	213	221
All	240	228	234

Standard error of difference between means: any two groups 17 legs, 8.3

There was no significant differences between groups or legs. Although the athletes peaked at

higher speeds (252 deg.sec-1) than the other groups (225 deg.sec-1), this distinction was not significant at the five percent level. More speeds would be required to achieve a more sensitive analysis.

Discussion

This paper and most reported data^{7, 10, 12, 15, 19} were obtained on an isokinetic dynamometer uncorrected for gravity, and in these tests both gravity and seat angle² influence absolute readings.

Many trials used test speeds at and below 180 deg.sec-1^{12, 15, 19} where hamstring/quadriceps ratio is similar between preferred and nonpreferred leg and the above results confirm that significant differences between legs at these lower speeds may indicate clinical abnormalities^{1, 5, 6, 8, 17, 18}. Higher test

Figure 7. Power (Joules.sec-1.kg-1. body weight) v Speed hamstrings: quadriceps – Tennis players

Figure 8. Power (Joules.sec-1.kg-1. body weight) v Speed hamstrings: quadriceps – Track athletes

speeds which more approximate to function but perhaps are more influenced by gravity, indicate a significant natural difference between preferred and nonpreferred legs and a wide range of individual values^{8,9,11,13,16}. This suggests great caution should be taken in assuming that equalizing both sides of the body will correct injury.

The fact that the power between the preferred and nonpreferred legs is the same (Figure 9), but the torque ratio differs (Figure 2), indicates that the hamstrings contribute proportionately more power at higher speeds in the NP leg and that high speed rehabilitation² and training regimes are required for the hamstrings.

Variations in individual leg pairs make accurate projection of muscle coordination, hamstring to quadriceps, caused by injury difficult though certainly the general difference in contralateral coordination between P and NP must be considered. Training methods may well influence the hamstring/quadriceps ratio between contralateral legs.

The significantly greater power produced by track athletes may reflect natural selection, movement mechanics, and training. Indications within the results were that sprint, mid distance and long distance athletes may have differences with the sprinters producing more power.

Figure 9. Power (Joules.sec-1.kg-1. body weight) v Speed hamstring: quadriceps – All subjects

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