Evaluation of Muscle Strength Among Different Sports Disciplines : Relevance for Improving Sports Performance

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Abstract

(A pilot cross-sectional study among 262 service sportsmen belonging to different sports disciplines was carried out to evaluate various indicators of muscle strength, such as peak torque, peak torque to weight, time to peak torque, maximum power, explosive work etc., using isokinetic testing during flexion and extension of the knee joint in sitting positions at different angles. It was found that peak torque varied significantly among the various sports disciplines depending on the requirement of each sports discipline ($p < 0.01$). The relevance, advantages and limitations of the tests to enhance sports performance have been discussed. However, discussion has been restricted to review of western literature on the subject as no Indian studies in the field were available for comparison.)

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Key Words : Isokinetic testing; Muscle strength; Peak torque; Sports

Introduction

The superior performance of today's sportsman is the result of a complex blend of many factors [1]. Although the sports scientist can do little to alter what has been determined by heredity, he can suggest optimal training strategies for the sportsmen according to their genetic endowments. The sports scientist can also use tests to monitor the progress that is made. Such testing should be considered primarily a training aid, not a magical tool for predicting future gold medalists. The present study was carried out among sportsmen of various disciplines on indicators of muscle strength (such as peak torque, peak torque to weight, torque production rate, work percentage and explosive power), to determine the different patterns of these indicators across the various sports disciplines.

Material and Methods

A total of 262 services level sportsmen belonging to different sports disciplines (sprinters-12, cross country runners-46, marathon runners-28, throwers-32, jumpers-40, rowing-16, boxers-32, kabaddi-20, cycling-14, and squash-22) were tested using the Kintrex-1000 multi-joint isokinetic system. The athletes were tested for isokinetic parameters of muscle strength during extension and flexion of knee joint in sitting position at 60/60 degrees, 120/120 degrees, and 180/180 degrees. Testing protocol was explained to the athlete. The following indicators of muscle strength were recorded at flexion and extension of knee joint.

Peak torque : Maximum torque developed in both direction of movement during a test or an exercise set. The peak torque represents the maximum muscular force that a muscle or muscle group is able to produce at a constant pre-selected velocity.

Time to peak torque : Time from the beginning of the

Table 1

Comparison of mean muscular strengths of flexion group of 60/60 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt. (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	130.24	394.35	2.00	2.57	127.66	1.90	10.8
Cross-country	46	100.13	485.43	1.66	2.12	93.32	1.74	6.3
Marathon	28	99.64	436.42	1.66	2.00	96.85	1.51	7.35
Throwing	32	138.68	485.31	1.68	2.24	140.21	1.54	8.77
Jumping	40	133.25	405.00	1.97	2.33	142.90	1.89	10.06
Rowing	16	135.56	376.25	1.87	2.19	152.12	1.82	13.15
Boxing	32	109.46	479.49	1.70	2.41	106.83	1.51	7.94
Kabaddi	20	126.75	402.40	1.82	2.12	131.85	1.67	10.36
Cycling	14	115.21	444.35	1.76	2.76	120.85	1.72	9.14
Squash	22	95.95	486.90	1.52	1.84	90.90	1.28	6.71

ANOVA for Peak Torque; F statistic = 19.393, $p < 0.01$, significant

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Table 2

Comparison of mean muscular strengths of extension group at 60/60 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	192.41	537.81	3.02	3.53	171.93	2.61	14.12
Cross-country	46	151.95	505.43	2.5	2.97	117.47	1.90	9.95
Marathon	28	145.67	605.35	2.43	2.80	129.10	2.10	9.16
Throwing	32	220.90	479.68	2.71	2.97	223.65	2.61	18.41
Jumping	40	213.87	525.52	3.17	3.95	209.97	3.10	14.79
Rowing	16	213.68	450.00	2.94	5.70	227.12	2.57	18.16
Boxing	32	177.53	612.35	2.73	3.48	147.17	2.30	9.73
Kabaddi	20	192.15	475.50	2.76	3.33	162.85	2.45	16.06
Cycling	14	176.64	551.42	2.71	3.11	169.50	2.62	13.06
Squash	22	150.90	566.38	2.41	2.69	128.00	1.90	7.75

ANOVA for Peak Torque, F statistic = 7.469, $p < 0.01$, significant

Table 3

Comparison of mean muscular strengths of flexion group at 120/120 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	113.03	193.05	1.75	2.08	196.29	2.84	40.32
Cross-country	46	87.13	277.17	1.45	1.66	145.21	2.23	13.77
Marathon	28	91.00	222.91	1.51	1.72	151.25	2.25	14.64
Throwing	32	120.40	249.58	1.46	1.74	215.12	2.33	19.58
Jumping	40	114.00	238.50	1.73	2.00	208.55	2.78	19.56
Rowing	16	118.12	233.23	1.62	1.86	216.93	2.77	19.91
Boxing	32	90.34	222.50	1.48	1.68	159.06	2.34	15.49
Kabaddi	20	107.65	248.00	1.54	1.85	189.75	2.48	18.25
Cycling	14	102.42	206.44	1.57	1.93	187.14	2.60	18.87
Squash	22	87.54	214.09	1.38	1.57	146.27	2.13	14.54

ANOVA for Peak Torque, F statistic = 66.996, $p < 0.01$, significant

movement until the peak torque is achieved. This value is an indicator of the ability to produce torque quickly.

Maximum work to weight : Ratio of the maximum work to the athlete's body weight.

Maximum power : Maximum work divided by the time it takes to perform this work.

Average power to weight: Total work divided by the time it takes to perform the work.

Explosive work : Amount of work performed in the first 1/8 second of torque production.

The data was collected and analysed in EPI-INFO Version 6, (statistical and epidemiological software). ANOVA test for differences in means of peak torque among the various sports disciplines was done to find out any significant difference across sports disciplines.

Results

It is evident from Table 1 that peak torque is maximum in throwers (138.68 nm) at 60 degrees as they need explosive power and the same goes true for other power events

(nm). Highest average power to weight was noted among jumpers (1.89 W/kg) and sprinters (1.9 W/kg), while explosive work is the requirement of kabaddi (10.36 J) and sprinting (10.80 J).

Table 2 depicts the isokinetic muscle strength indicators at 60/60 degrees in extensor group of muscles at the knee joint. It will be seen that peak torque in the extensor group (quadriceps) is maximum in throwers (220.9 nm) followed by rowers and jumpers (213 nm), as they need explosive power. The peak torque has to be higher for the events like sprinting (192.41 nm) and kabaddi (192.15). Highest average power to weight was noted among jumpers (3.1 W/kg), and sprinters and throwers (2.61 W/kg). Explosive work is the requirement for throwers and rowers (18 J), kabaddi (16.06 J) and sprinters and jumpers (14.12 and 14.79 J).

Table 3 shows the same parameters in flexion group of muscles at the knee joint at 120/120 degrees. It will be seen that peak torque in the flexor group i.e. hamstrings is maximum in throwers (120.4 nm), followed by rowers (118.12 nm) and by jumpers and sprinters (114 and 113 nm) as they need explosive power. The time to peak torque was found

Table 4

Comparison of mean muscular strengths of extension group at 120/120 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt. (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	155.69	327.22	2.45	2.74	254.03	3.76	23.16
Cross-country	46	121.87	307.39	2.03	2.19	189.41	2.95	16.64
Marathon	28	118.37	347.91	1.97	2.23	191.54	3.04	17.16
Throwing	32	182.50	305.52	2.21	2.47	313.06	3.51	28.54
Jumping	40	170.65	297.00	2.51	2.81	299.85	4.20	27.87
Rowing	16	165.50	286.93	2.26	2.50	281.56	3.63	30.62
Boxing	32	138.15	296.87	2.28	2.47	235.40	3.65	23.18
Kabaddi	20	156.20	314.50	2.24	2.50	271.95	3.63	25.95
Cycling	14	140.64	315.00	2.16	2.57	242.78	3.48	21.91
Squash	22	123.50	353.63	1.96	2.16	190.31	2.95	14.17

ANOVA for Peak Torque; F statistic = 29.50, $p < 0.01$, significant

Table 5

Comparison of mean muscular strengths of flexion group at 180/180 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt. (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	100.99	158.39	1.58	1.85	236.10	3.26	25.24
Cross-country	46	76.71	168.69	1.31	1.50	183.69	2.75	18.88
Marathon	28	83.46	151.10	1.60	1.52	182.14	2.63	19.88
Throwing	32	120.53	171.25	1.35	1.53	252.65	2.81	25.60
Jumping	40	105.75	170.62	1.59	1.94	253.40	3.49	26.87
Rowing	16	104.87	128.50	1.44	1.62	262.18	3.45	28.65
Boxing	32	82.63	207.19	1.30	1.64	201.52	2.64	20.52
Kabaddi	20	98.70	108.50	1.41	1.59	237.65	3.00	24.88
Cycling	14	103.21	137.78	1.58	1.74	237.14	3.30	26.89
Squash	22	78.00	134.54	1.23	1.35	175.68	2.43	19.53

ANOVA for Peak Torque; F statistic = 40.87, $p < 0.01$, significant

power to weight was noted among sprinters (2.84 W/kg), jumpers (2.78 W/kg) and rowers (2.77 W/kg). Explosive work is the basic requirement found in sprinters (40.32 J).

The same parameters as above but in the extension group of muscles at the knee joint is shown in Table 4. It is seen that peak torque in the extensor group was found to be maximum in throwers (182.5 nm) followed by jumpers (170.6 nm) and rowers (165.5 nm) at 120 degrees/sec as they need explosive power. The time to peak torque has to be minimal for the events like rowing (286.93 ms), boxing (296.87 ms), kabaddi (314.3 ms) and jumping (297 ms). Highest average power to weight was noted among jumpers (4.2 W/kg), sprinters (3.76 W/kg), boxers (3.65 W/kg), kabaddi and rowers (3.63 W/kg each). Explosive work is the requirement for rowers (30.62 J), jumpers (27.87 J), kabaddi (25.95 J) and sprinters (23.16 J).

Table 5. In flexor group of muscles at knee joint at angle 180/180 degrees, the peak torque was noted to be maximum in throwers (120.53 nm) followed by that in jumpers (105.75 nm). Time to peak torque noted among kabaddi players (108.5 ms) and rowers (128.5 ms) were the lowest.

the basic requirement among rowers (28.65 J), jumpers (26.87 J) and cyclists (26.89 J).

Table 6 shows the isokinetic parameters in the extensor group of muscles at the knee at 180/180 degrees. The peak torque among the extensors was noted maximum in throwers (152.5 nm), and jumpers (143.45 nm). The time to peak torque has to be minimal for events like throwing (215.52 ms). Highest average power to weight was noted among sprinters (4.76 W/kg). Explosive work is the requirement of throwers (38.84 J), and kabaddi players (33.96 J).

Discussion

The relevance and relative importance of strength and power in sport performance vary widely in different sports as has been brought out by the study findings. In most activities (eg. team sports, swimming, rowing, and canoeing), strength and power share importance with endurance. In these activities, the actual relative importance of strength and endurance can be determined only by research. For example, maximum

Table 6

Comparison of mean muscular strengths of extension group at 180/180 degrees according to different sports discipline at knee joint

Discipline	No of athlete	Peak torque (Nm)	Time to peak torque (ms)	Peak torque to Wt (Nm/kg)	Maximum work to Wt (J/kg)	Maximum power (W)	Mean power to Wt (W/kg)	Explosive Work (J)
Sprint	12	129.75	251.86	2.1	2.4	302.51	4.44	29.84
Cross-country	46	97.32	217.82	1.63	1.81	218.80	3.62	23.65
Marathon	28	96.28	272.14	1.61	1.88	215.03	3.45	21.24
Throwing	32	152.50	215.52	1.85	2.10	358.90	4.05	38.84
Jumping	40	143.45	264.62	2.16	2.62	340.92	4.76	32.20
Rowing	16	135.12	246.25	1.86	2.13	317.87	4.15	32.91
Boxing	32	118.32	293.10	1.84	2.39	276.56	3.99	24.41
Kabaddi	20	126.80	237.50	1.82	2.15	291.20	4.02	33.96
Cycling	14	117.21	236.00	1.77	2.08	275.35	4.04	28.26
Squash	22	97.31	255.45	1.54	1.82	213.50	3.11	17.52

ANOVA for Peak Torque, F statistic = 26.14, $p < 0.01$, significant

correlation between power and swimming velocity was 0.90, 0.86, 0.85, and 0.76 for swim distances of 25, 100, 200 and 500 yards, respectively [2]. As might be expected, as the swim distance increased, strength became less and presumably endurance became more important.

A stronger athlete will have greater absolute endurance with heavy loads. Thus, an athlete with a maximum strength of 2,000 N would be able to sustain a load of 800 N, equal to 40% of maximum, for 2 to 3 minutes, whereas an athlete with a maximum strength of 1000 N would be able to sustain a load of 800 N, equal to 80% of maximum, for only 15 to 20 seconds. In contrast, a stronger athlete may have less relative endurance [3].

It follows therefore, that increasing strength by training should increase absolute endurance but perhaps decrease relative endurance. However, strength training can increase short-term [4] and long term endurance [5]. There are four purposes of testing strength and power. The purposes of testing in a particular situation should be established in consultation with the coaches and athletes.

(a) Determining the relevance and relative importance of strength and power to performance. There may be a few sports for which the relevance of strength and power is uncertain. There may be many sports for which the relevance of strength and power is certain but the relative importance uncertain. In sports for which both relevance and relative importance of strength and power is certain, there may be uncertainty about the best training programme design. It may be possible to resolve all these uncertainties by using appropriate tests of strength and power.

(b) Developing an athlete profile : Most sports require several qualities for successful performance : strength and power, aerobic and anaerobic power,

flexibility, skill, and judgement. Within a sport, elite athletes have strengths and weaknesses to these qualities [6]. A battery of appropriate, specific tests of these qualities administered to a group of athletes allows the construction of an athlete profile that can be used by a coach to modify the overall programme for an athlete and concentrate on improving the weak qualities while maintaining and, if possible, improving the strong qualities.

(c) Monitoring training progress : The success of strength and power training programmes can be evaluated by tests administered before and after training periods. Appropriate alterations can be made to the programme on the basis of the test results [7].

(d) Monitoring the rehabilitation of injuries : If pre-injury strength and power data are available for an athlete, the extent of the decrease in strength resulting from the injury can be quantified, as can the course of rehabilitation [8,9].

(e) Implications for talent spotting and allotment of sports disciplines : Some of the above factors also have implications for talent spotting and allotment of sports disciplines in budding athletes. Peak torque may be measured as the greatest torque developed during a contraction, regardless of where in the contraction (and range of movement) it occurs [10-12]. Alternatively, strength may be measured as the greatest torque achieved at a particular point in the range of movement [13-16]. Sometimes both measurements have been made [17-19]. There is inter subject variation in the shape of strength curves [20] because of unknown factors as well as training [11] and muscle fibre composition [18]; thus selecting a measurement at one position only, may bias results in favour of some, and against others.

In the end, the authors would like to bring out certain limitations of the present study. The present study

was a cross-sectional pilot study and hence restricted in its scope. It did not follow up the athletes longitudinally but it has been suggested as a part of monitoring the progress of sportsmen. Another limitation was that comparable data was not available pertaining to Indian athletes. Because of the cost of isokinetic equipment, it is not widely available in our country.

Though the results might be on lines as expected, based on the muscle strength requirements of various sports, the present study provides some baseline quantitative data for future comparisons, which is not available in our country. However, to establish norms for our country, many more such studies with larger sample size across different sports disciplines need to be done. With larger sample sizes, significant differences, if any between power sports, endurance, sports and technical sports could be explored. Scope of future studies should also include correlation with physical motor abilities viz, speed, endurance strength and agility. Lastly, only the muscle groups around the knee joint were selected. This was because, around this joint there are powerful muscle groups both flexors and extensors, which could be easily evaluated.

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