

[Sports Physical Therapy]

Effect of Subject Restraint and Resistance Pad Placement on Isokinetic Knee Flexor and Extensor Strength: Implications for Testing and Rehabilitation

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Background: In clinical practice, several subject restraint and resistance pad placement variations are used when an isokinetic knee flexion/extension test is performed. However, it is unknown if these variations affect the outcome measures. The aims of this study were to determine if these setup variations affect isokinetic outcomes and to establish the smallest detectable difference for these setup variations.

Hypothesis: Variation in isokinetic setup affects outcome measures.

Study Design: Cross-sectional repeated-measures crossover study.

Methods: Ten recreationally active adult men were examined with isokinetic dynamometry on 4 separate days. In the first 3 days, fully strapped and trunk-unstrapped testing was conducted with the resistance pad placed distally on the shin. On days 1 and 3, the unstrapped condition was performed first, followed by the strapped condition. On day 4, the resistance pad was placed proximal on the shin (anterior cruciate ligament testing).

Results: There were no within-condition differences for days 1, 2, or 3 for the strapped and unstrapped conditions ($P > 0.05$). Between-condition comparisons were significant (eg, quadriceps peak torque, $P < 0.001$; hamstring peak torque, $P = 0.043$) for the strapped, unstrapped, and proximal resistance pad placement conditions. The strapped condition generally showed the largest torques, and the unstrapped, the least. The smallest detectable differences were relatively large (eg, quadriceps peak torque strapped = 20.6%). The greatest intraclass correlation values were found when strapped.

Conclusions: Subject setup significantly influences isokinetic outcome measures at the knee. Since the strapped condition demonstrated the greatest repeatability, it is recommended. The smallest detectable differences were relatively high for all variables and should be considered in the interpretation of the effect size of interventions.

Clinical Relevance: Subject setup strapping must be considered when investigating test-retest values or when comparing subjects after isokinetic testing at the knee. The fully strapped condition has the best repeatability and highest torque values.

Keywords: mixed ratio; minimum clinically important change; minimal detectable change; smallest detectable change; hamstrings

Muscle strength is one of the most important components of sport, both for high performance^{3,15,17} and injury prevention.^{1,2,24} Muscle strength can be measured in several ways.¹⁸ The development and improvement of isokinetic technology have made objective quantification of muscle strength a widely accepted practice in performance training and rehabilitation.

Standardized isokinetic testing is reliable for the knee extensors and flexors.^{5,12-14,16} Although the operation manual describes the application of chest, pelvic, and thigh straps (“fully strapped”) as the testing position, clinicians regularly fail to apply the chest and pelvic straps to stabilize the subject. Previous research has examined the effect of deliberate extraneous movement on isokinetic parameters.²² However,

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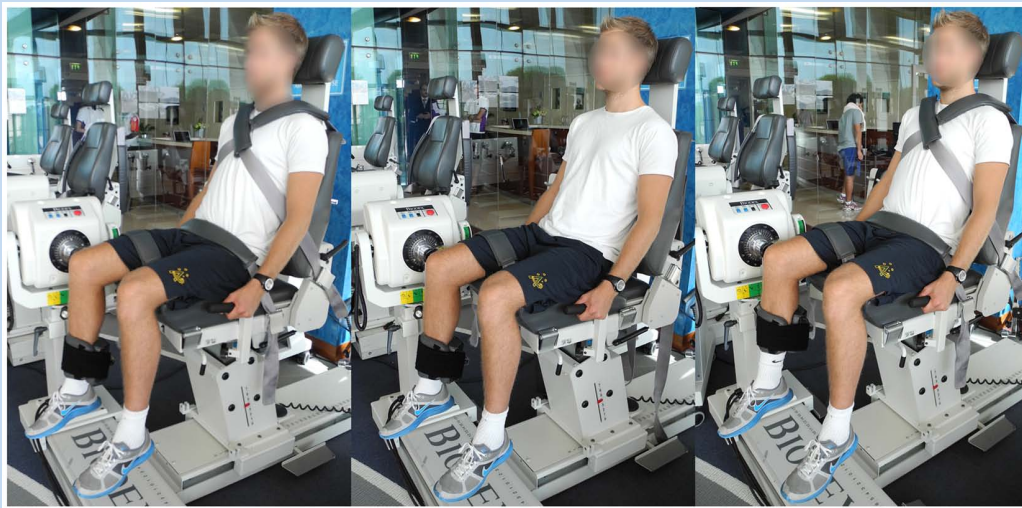


Figure 1. Depiction of each testing situation from left to right: strapped, unstrapped, and proximal pad placement.

the effect of simply varying the strapping condition of the test subject is not known.

The placement of the resistance pad lever arm against the shin varies proximally and distally. Proximal lever arm pad placement is often used after anterior cruciate ligament reconstruction to prevent anterior shearing forces.^{6,23} Li et al¹¹ showed the effect of a modified pad placement during isokinetic evaluation comparing single (distal) pad placement to a dual pad (Johnson antishear pad, Cybex, Division of Lumex, Ronkonkoma, New York, New York). Such variations in setup could lead to variability in isokinetic output values.

The aims of this study were to (1) evaluate the reproducibility and clinical applicability of strapped and unstrapped isokinetic testing; (2) identify differences between the outcome measures of strapped, unstrapped, and proximal lever arm pad placement testing; and (3) establish the smallest detectable differences (SDDs; the smallest clinically important difference) for these measures.⁹

METHODS

Ten healthy male subjects²⁰ (mean age, 37 ± 5 years; median age, 35.3 years), without any recent history (6 months) of knee pain or thigh muscle injury and who participate in recreational sporting activities, were recruited through flyers. Informed consent was obtained prior to participation. The study was approved by the Aspetar Sports Medicine Hospital Review Board, Doha, Qatar.

The subjects performed a 5-minute warm-up on an exercise cycle. Subjects were then placed on an isokinetic dynamometer (System 3, Biodex Medical Systems, Shirley, New York) in an upright sitting position so that the hip and knee were both in 90° of flexion. The lateral femoral epicondyle was aligned with the axis of the lever arm.

The dominant leg was tested for concentric knee flexion and extension (ie, hamstrings and quadriceps, respectively) on 4

days with at least 48 hours of rest between each testing session. Each test took place at the same time of day. Each test was conducted by the same examiner, with the same instructions and encouragement provided on each occasion to attempt maximum effort, after the testing device was calibrated.

Subjects initially performed 5 repetitions at 50%, followed by 3 repetitions at 80% of their maximum as warm-up/familiarization. The test consisted of 5 repetitions at 60° per second and 15 repetitions at 300° per second with 60 seconds of rest in between each set.

For the first 3 test days, the pad of the lever arm was placed distally on the shin, just above the medial malleolus. On each day, the subject performed a “fully strapped” test and an “unstrapped” test (chest and waist straps not attached). On day 1, the unstrapped test was performed first; on day 2, the strapped test was performed first; and then again on day 3, the unstrapped test was performed first. On day 4, the subject was fully strapped, and the center of the lever arm pad was placed 24 cm distal to the lateral epicondyle (proximal pad placement; Figure 1). Between tests, subjects were given 5 minutes of rest (walking slowly).

The SDDs were calculated from the mean square error (analysis of variance table⁹). A 3-way within-subjects analysis of variance for repeated measures was conducted (SPSS 19, IBM, Armonk, New York). The main effects of time, order, and condition were examined. The Mauchly test of sphericity was employed, and where the assumption of sphericity was violated, *F* ratios based on Greenhouse-Geisser correction were utilized. Subsequently, interaction effects (condition and order, time and condition, time and order) were examined. Wherever a significant association was found, Bonferroni post hoc correction was applied. Statistical significance of $P \leq 0.05$ was determined a priori. In addition, intraclass correlation (ICC; 2,1) was calculated for the repeated measures (strapped and unstrapped conditions) along with 95% confidence intervals.

Table 1. Results and means of strapped testing.^a

	Strapped				F(2, 18)	P	Observed Power
	Day 1 (SD)	Day 2 (SD)	Day 3 (SD)	Mean (SD)			
QPT, N-m	224.2 (34.8)	224.3 (39.3)	214.0 (47.3)	220.9 (38.5)	1.3	0.297	0.245
HPT, N-m	119.3 (20.6)	124.6 (21.7)	121.2 (31.2)	121.7 (23.5)	0.673	0.523	0.145
QAPT, °	62.7 (7.0)	66.4 (6.1)	67.6 (7.6)	65.6 (5.2)	2.121	0.149	0.378
HAPT, °	30.7 (4.3)	32.3 (4.1)	32.0 (5.2)	31.7 (3.2)	0.471	0.632	0.115
QT30, N-m	128.6 (31.4)	130.8 (29.3)	117.8 (34.5)	125.7 (28.3)	1.53	0.243	0.282
HT30, N-m	116.9 (20.4)	123.2 (21.4)	119.3 (31.6)	119.8 (23.3)	0.852	0.443	0.173
QTW, J	1017.0 (177.2)	1032.0 (202.5)	966.6 (224.8)	1005.2 (187.2)	1.32	0.292	0.248
HTW, J	625.5 (118.4)	650.8 (130.0)	608.0 (158.7)	628.1 (128.0)	1.338	0.287	0.251
Ratio, %	53.5 (6.5)	55.8 (6.2)	56.7 (8.8)	55.3 (6.4)	1.604	0.228	0.294
QF, %	37.8 (6.3)	39.7 (5.2)	36.0 (7.0)	37.8 (5.4)	2.352	0.124	0.414
HF, %	44.0 (5.7)	43.4 (7.3)	39.9 (9.6)	42.4 (6.1)	1.483	0.253	0.275

^aMeans (standard deviation; SD) for the variables examined each day of testing (strapped condition), along with the significance and the post hoc observed power. QPT, quadriceps peak torque; HPT, hamstring peak torque; QAPT, quadriceps angle of peak torque; HAPT, hamstring angle of peak torque; QT30, quadriceps torque at 30°; HT30, hamstring torque at 30°; QTW, quadriceps total work; HTW, hamstring total work; ratio, quadriceps/hamstring ratio; QF, quadriceps fatigue; HF, hamstring fatigue.

RESULTS

No significant differences in performance were found among days 1, 2, or 3, nor were there any differences regarding the order of testing between days for the strapped and unstrapped conditions (Tables 1-4). There were significant between-condition differences. Broadly, the greatest torque was shown for the strapped condition.

The ICC values for quadriceps peak torque, hamstring peak torque, hamstring torque at 30°, quadriceps total work, and hamstring total work were in excess of 0.75. For the unstrapped condition, the ICC exceeded 0.75 for quadriceps peak torque, quadriceps torque at 30°, quadriceps total work, and hamstring total work.

DISCUSSION

Several studies report the reliability of standardized isokinetic testing.^{5,12-14,16} This study underlines the need for consistent testing methodology. Differences in patient strapping and pad placement influence outcome measures.

Compared with the unstrapped tests, tests that were performed using all the straps showed the highest scores for all outcome measures and greater ICC. Fully strapped testing is the most repeatable method of testing.

It is possible that a high ICC could mask measurement error. Complementary analysis using standard error of measurement and SDD is strongly recommended.¹⁹ This study established the clinically applicable SDD and relative SDD for each utilized outcome measure (Table 4). These SDDs can be used to determine if change in output is due to an intervention. For example, the change between tests should be more than 20.6% for strapped quadriceps peak torque to state (95% certainty) such that there is a meaningful change.²¹

In hamstring injury prevention studies, cutoff of the “mixed ratio” (high-speed concentric quadriceps:low-speed eccentric hamstrings) of 0.89 is recommended for safe participation in professional football.⁴ The inference from this data suggests that the error margin would be in the order of 0.01. The SDD in this study suggests that this level of precision is extravagant.

Isokinetic examination of anterior cruciate ligament–reconstructed knees⁷ recommends that the “greatest acceptable deficiency” is only a maximum of 15%.¹⁰ The appropriate SDD needs to be considered in cut-off values and the margin of error setting.

This is the first study to establish SDDs for healthy male recreational athletes. Kean et al⁸ established the SDD for patients with osteoarthritis (approximately 25%). The values presented here are of a similar magnitude.

Table 2. Results and means of between-condition comparisons: Unstrapped testing.^a

	Unstrapped				F(2, 18)	P	Observed Power
	Day 1 (SD)	Day 2 (SD)	Day 3 (SD)	Mean (SD)			
QPT, N-m	221.8 (42.6)	215.3 (38.1)	215.0 (51.3)	217.4 (42.0)	0.501	0.614	0.12
HPT, N-m	113.4 (19.6)	114.2 (23.8)	116.2 (28.9)	114.6 (21.8)	0.111	0.895	0.065
QAPT, °	66.7 (5.2)	67.0 (7.8)	66.4 (5.9)	66.7 (4.6)	0.03	0.971	0.054
HAPT, °	36.7 (4.1)	33.3 (3.4)	31.9 (4.2)	34.0 (2.1)	3.622	0.048	0.593
QT30, N-m	115.2 (35.8)	115.6 (26.5)	109.6 (31.2)	113.5 (29.6)	0.695	0.512	0.149
HT30, N-m	105.8 (20.1)	110.8 (23.1)	111.8 (26.1)	109.4 (20.9)	0.675	0.521	0.146
QTW, J	977.7 (189.6)	945.5 (186.5)	942.9 (224.5)	955.4 (193.0)	0.796	0.466	0.165
HTW, J	586.6 (105.1)	567.0 (121.6)	584.4 (156.7)	579.3 (119.5)	0.305	0.741	0.091
Ratio, %	51.6 (5.1)	53.3 (7.1)	54.3 (8.6)	53.1 (6.4)	1.358	0.282	0.254
QF, %	37.2 (6.8)	39.1 (8.2)	37.2 (10.7)	37.8 (7.6)	0.421	0.662	0.108
HF, %	35.1 (9.5)	40.1 (9.4)	30.3 (9.4)	35.2 (4.2)	2.2	0.14	0.39

^aMeans (standard deviation; SD) for the variables examined each day of testing (unstrapped condition), along with the significance and the post hoc observed power. QPT, quadriceps peak torque; HPT, hamstring peak torque; QAPT, quadriceps angle of peak torque; HAPT, hamstring angle of peak torque; QT30, quadriceps torque at 30°; HT30, hamstring torque at 30°; QTW, quadriceps total work; HTW, hamstring total work; ratio, quadriceps/hamstring ratio; QF, quadriceps fatigue; HF, hamstring fatigue.
^bObserved power.

Table 3. Results and means of proximal pad placement and between condition comparison.^a

	Mean PPP(SD)	Between Condition Comparison		
		F(2, 18)	P	Observed Power
QPT, N-m	205.6 (39.6)	12.681	< 0.001**	0.990
HPT, N-m	113.7 (26.6)	3.768	0.043*	0.611
QAPT, °	73.1 (4.6)	27.59	< 0.001**	1.00
HAPT, °	40.2 (14.5)	2.458	0.114	0.430
QT30, N-m	94.5 (33.0)	7.573	0.004**	0.902
HT30, N-m	107.6 (27.8)	5.151	0.017*	0.755
QTW, J	872.4 (163.4)	18.396	< 0.001**	0.999
HTW, J	583.5 (146.6)	3.439	0.054	0.569
Ratio, %	55.3 (6.9)	2.315	0.127	0.408
QF, %	38.2 (5.2)	0.035	0.966	0.054
HF, %	37.3 (15.3)	2.002	0.164	0.359

^aMean (SD) for each of the variables in the Proximal Pad Placement condition, as well as significance and observed power for the between conditions comparisons. PPP, proximal pad placement; QAPT, quadriceps angle of peak torque; HAPT, hamstring angle of peak torque; QT30, quadriceps torque at 30°; HT30, hamstring torque at 30°; QTW, quadriceps total work; HTW, hamstring total work; ratio, quadriceps/hamstring ratio; QF, quadriceps fatigue; HF, hamstring fatigue.
 *P < .05. **P < .01.

Table 4. Intraclass correlations, standard errors of measurement, and smallest detectable differences.^a

	Strapped				Unstrapped			
	ICC (95% CI)	SEM	SDD	SDD, %	ICC (95% CI)	SEM	SDD	SDD, %
QPT, N-m	0.834 (0.609, 0.951)	16.44	45.56	20.6	0.855 (0.646, 0.958)	17.28	47.91	22.0
HPT, N-m	0.828 (0.595, 0.949)	10.52	29.15	24.0	0.715 (0.383, 0.911)	13.45	37.29	32.5
QAPT, °	0.332 (-0.020, 0.724)	5.55	15.37		0.279 (-0.125, 0.708)	5.52	15.31	
HAPT, °	0.260 (-0.122, 0.691)	3.92	10.86		-0.065 (-0.250, 0.355)	4.10	11.37	
QT30, N-m	0.675 (0.344, 0.894)	17.83	49.43	39.3	0.837 (0.613, 0.952)	12.82	35.55	31.3
HT30, N-m	0.811 (0.564, 0.943)	10.92	30.28	25.3	0.726 (0.414, 0.914)	12.30	34.08	31.2
QTW, J	0.777 (0.505, 0.932)	94.38	261.62	26.0	0.886 (0.715, 0.967)	68.57	190.08	19.9
HTW, J	0.809 (0.562, 0.943)	58.94	163.36	26.0	0.788 (0.513, 0.936)	61.43	170.26	29.4
Ratio, %	0.663 (0.328, 0.890)	4.14	11.47	20.7	0.704 (0.386, 0.905)	3.80	10.54	19.8
QF, %	0.585 (0.229, 0.857)	3.86	10.69	28.3	0.652 (0.296, 0.887)	5.23	14.50	38.4
HF, %	0.416 (0.043, 0.776)	5.83	16.15	38.1	0.715 (0.383, 0.911)	10.38	28.78	81.8

^aICC, intraclass correlation; CI, confidence interval; SEM, standard error of measurement; SDD, smallest detectable difference; SDD, %, relative smallest detectable difference; QPT, quadriceps peak torque; HPT, hamstring peak torque; QAPT, quadriceps angle of peak torque; HAPT, hamstring angle of peak torque; QT30, quadriceps torque at 30°; HT30, hamstring torque at 30°; QTW, quadriceps total work; HTW, hamstring total work; ratio, quadriceps/hamstring ratio; QF, quadriceps fatigue; HF, hamstring fatigue.

Since there were no preexisting data regarding variance of isokinetic examination for subjects in these different setup configurations, it was impossible to perform an a priori power analysis. The data presented here allow for future research to be planned with adequate power, which could examine whether a net fatigue or learning effect was occurring over the testing period. The results presented (Tables 1-3) provide preliminary information for some variables where adequate power was demonstrated post hoc.

Research in injury prevention commonly employs peak torque and total work as outcome measures.^{5,16} Since the ICC for hamstring peak torque in the strapped condition was 0.83 (95% confidence intervals, 0.60-0.95) in comparison with unstrapped (0.72; 95% confidence intervals, 0.38-0.91), we recommend using the strapped condition.

The limitations of this work include the small sample size. The subjects examined were also familiar with isokinetic testing and therefore may not be truly representative of the broader population of recreationally active men.

CONCLUSIONS

The fully strapped condition demonstrated the greatest torque values, the unstrapped setup the least, and the proximal pad placement was between these 2.

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