Isokinetic Concentric Quadriceps and Hamstring Normative Data for Elite Collegiate American Football Players Participating in the NFL Scouting Combine

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Abstract

Zvijac, JE, Toriscelli, TA, Merrick, WS, Papp, DF, and Kiebzak, GM. Isokinetic concentric quadriceps and hamstring normative data for elite collegiate American football players participating in the NFL scouting combine. *J Strength Cond Res* 28(4): 875–883, 2014—Isokinetic concentric quadriceps and hamstring strength data using a Cybex dynamometer are collected for elite collegiate American football players invited to the annual National Football League Scouting Combine. We constructed a normative (reference) database of the Cybex strength data for the purpose of allowing comparison of an individual's values to his peers. Data reduction was performed to construct frequency distributions of hamstring/quadriceps (H/Q) ratios and side-to-side strength differences. For the cohort ($n = 1{,}252$ players), a statistically significant but very small (1.9%) mean quadriceps strength preference existed for dominant side vs. nondominant side. Peak torque (Newton meters, best repetition) for quadriceps and hamstrings was significantly correlated to player body mass (weight) (the same relationship was found for other variables using peak torque in the calculation). Peak torque varied by player position, being greatest for offensive linemen and lowest for kickers ($p < 0.0001$). Adjusting for body weight overcorrected these differences. The H/Q ratios and frequency distributions were similar across positions, with a mean of 0.6837 ± 0.137 for the cohort dominant side vs. 0.6940 ± 0.145 for the nondominant side ($p = 0.021$, $n = 1{,}252$). Considerable variation was seen for dominant-to-nondominant side difference for peak torque. For quadriceps, 47.2% of players had differences between −10% and +10%, 21.0% had a peak torque dominant-side deficit of 10% or greater compared to nondominant side, and for 31.8% of players, dominant-side peak torque was greater than 10% compared to nondominant side. For hamstrings, 57.0% of players had differences between −10% and +10%, 19.6% had a peak torque dominant-side deficit of 10% or greater compared to nondominant side, and 23.4% of players, dominant-side peak torque was greater than 10% compared to nondominant side. We observed that isokinetic absolute strength variables are dependent on body weight and vary across player position. The H/Q ratios vary only within a relatively narrow range. Side-to-side differences in strength variables >10% are common, not the exception.

Key Words NFL football, H/Q ratio, concentric strength, muscle strain, strain

Introduction

Computer-assisted muscle-testing dynamometers are used for measuring muscle strength and allow for evaluation of muscles and muscle groups in an isokinetic manner. Isokinetic muscle testing is performed with a constant speed of angular motion but variable resistance. Isokinetic dynamometers have been shown to produce relatively reliable strength data when testing simple uniaxial joints, such as the knee, and when testing the spine or knee in flexion and extension. Isokinetic assessment has been criticized because of questions about lack of clinical functionality (8,14). However, one argument in favor is that the open-chain nature of the test allows isolation of the muscle of concern, and enables assessment of strength or deficits in isolated muscles. In contrast, functional weightbearing movements will always involve motion in adjacent joints as well as in the target joint, thus, reflecting multilevel performance.

A potential application is to use isokinetic testing equipment to establish normal ranges for athletes in specific sports or by age and sex. Normative concentric quadriceps and hamstring strength data for college athletes invited to the National Football League (NFL) Scouting Combine have not been

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previously published. Knowledge of expected results at each position may help physicians and athletic trainers identify potential problems or prevent subsequent injury as certain variables such as hamstring/quadriceps ratio (H/Q ratio) may be predictive of hamstring injury based on reports from other sports. For example, some previous studies suggest that strength imbalance between the hamstrings and quadriceps (expressed as side-to-side absolute peak torque difference or as the H/Q ratio) may predict future injury (1–4,7,11,13,19,22,24,25). These studies surmised that an H/Q ratio less than 0.6 suggested a pathological condition that may be significant in predicting lower extremity injury, including hamstring muscle strain or anterior cruciate ligament injury (4,7,11,13,22,25). Although data provided to NFL football teams from the NFL Scouting Combine include concentric strength testing of the quadriceps and hamstrings, no data exist that define what is "normal" for an NFL football player at any given position.

The purpose of this study was to establish a normative (reference) database for isokinetic concentric hamstring and quadriceps strength for elite collegiate American football players participating at the NFL Scouting Combine.

Methods

Experimental Approach To the Problem

This was a retrospective review of previously collected Cybex data from 2008 to 2011.

Subjects

A total of 1,252 players (aged 20–27 years) had complete data sets for analyses (some players had injuries or for other reasons did not have data collected for both right and left sides). Demographic data were also collected for each athlete consisting of playing position, weight, and self-determined dominant lower extremity side. The age range was very narrow as

Table 1. Cybex knee extension/flexion normative data for elite Collegiate American football players participating in the NFL Scouting Combine 2008–2011.*†

	Dominant side		Nondominant side	
Variable	Quadriceps	Hamstrings	Quadriceps	Hamstrings
Peak torque				
Mean ± *SD*	313.6 ± 70.7‡	209.8 ± 44.6	307.8 ± 70.2	208.7 ± 44.1
Range	69.2 to 548	60.0 to 407	67.8 to 521	46.0 to 366
95% CI	309.7 to 317.6	207.3 to 212.2	303.9 to 311.7	206.2 to 211.1
Peak torque/body weight				
Mean ± *SD*	2.90 ± 0.63‡	1.94 ± 0.38	2.85 ± 0.62	1.93 ± 0.37
Range	0.836 to 5.28	0.646 to 3.86	0.820 to 5.23	0.507 to 3.10
95% CI	2.87 to 2.94	1.92 to 1.96	2.82 to 2.89	1.91 to 1.95
Work per repetition				
Mean ± *SD*	286.9 ± 70.9‡	225.1 ± 51.9	283.1 ± 80.0	224.4 ± 51.4
Range	24.4 to 515	24.4 to 400	57.0 to 1,622	29.8 to 407
95% CI	283.0 to 290.9	222.2 to 228.1	278.7 to 287.5	221.5 to 227.3
Range of motion				
Mean ± *SD*	6.67 ± 5.39‡	86.6 ± 7.30‡	7.29 ± 5.95	87.1 ± 7.30
Range	−2.0 to 35.0	50.0 to 112.0	−3.0 to 36.0	60.0 to 115.0
95% CI	6.37 to 6.97	86.2 to 87.4	6.96 to 7.62	86.7 to 87.5
Initial peak torque				
Mean ± *SD*	160.3 ± 33.8‡	132.4 ± 25.9‡	158.0 ± 33.2	131.3 ± 24.5
Range	13.6 to 273	29.8 to 210	25.8 to 278	27.1 to 221
95% CI	158.4 to 162.2	131.0 to 133.8	156.1 to 159.9	130.0 to 132.6
Fatigue index				
Mean ± *SD*	11.2 ± 27.0	11.7 ± 15.9	11.7 ± 26.3	11.8 ± 15.4
Range	−358.0 to 60.0	−181.0 to 67.0	−227.0 to 216.0	−140.0 to 68.0
95% CI	9.72 to 12.7	10.8 to 12.5	10.3 to 13.2	11.0 to 12.7
Total work				
Mean ± *SD*	1,828 ± 483‡	1,585 ± 439	1,798 ± 477	1,606 ± 532
Range	117 to 3,461	90.8 to 2,899	132 to 3,321	123 to 12,048
95% CI	1,842 to 1,855	1,561 to 1,608	1,772 to 1,825	1,576 to 1,635

*Data are for all players, all positions, $n = 1{,}252$, presented in each cell as mean ± *SD*, range, and 95% CI.
†Units for torque and work variables are Newton meters. Peak torque and work per repetition variables measured with isokinetic concentric/concentric testing with 3 repetitions at an angular velocity of 60/60° per second. Initial peak torque, fatigue index, and total work variables collected after 15 repetitions at an angular velocity of 300/300° per second.
‡Significantly different compared with nondominant side, $p < 0.025$ or less (paired *t*-test or Wilcoxon matched-pairs signed-ranks test if data not normally distributed).

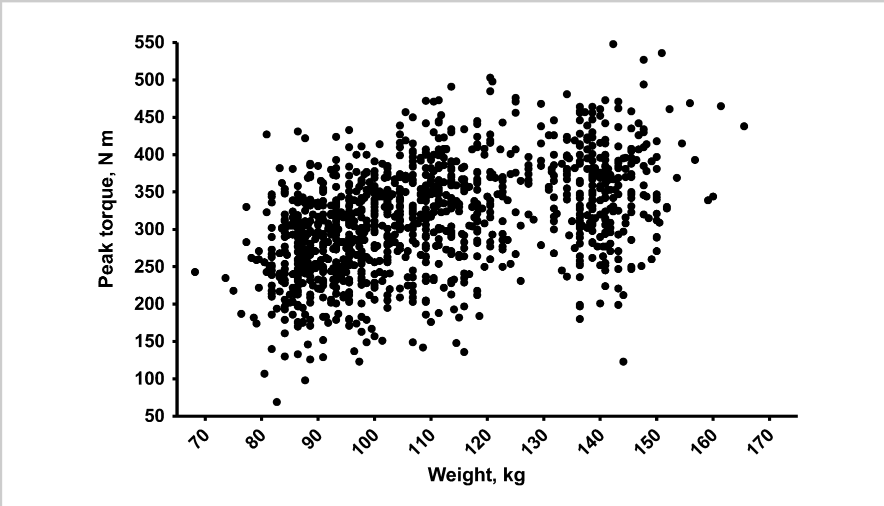

Figure 1. Scatterplot of body weight vs. dominant-side quadriceps peak torque for all players in the cohort ($n =$ 1,252). The regression coefficient ($r = 0.457$) was statistically significant ($p < 0.0001$).

most participants were completing their senior year in college. There were no specific inclusion or exclusion criteria. All players signed a consent form allowing use of their data by teams for the annual draft and also for research purposes. This study was also approved by the Baptist Health South Florida Institutional Review Board.

Procedures (Strength Measurements)

Concentric hamstring and quadriceps measurements were made using a Cybex HUMAC Norm (CSMI Medical Solutions, Stoughton, MA, USA) dynamometer, using software version Humac 2009. The dynamometer was calibrated using four 25-pound certified weights the night before each testing session, and then, a 3-point verification performed. Players had the opportunity to warm-up by riding a stationary bike or by using a stepper device, plus stretching as desired. After a short practice session on the dynamometer consisting of 3 repetitions with increasing level of exertion, staff tested participants at both 60° and 300° per second, with 3 and 15 repetitions recorded at each speed, respectively. Peak torque (best repetition) and work repetition variables were measured with isokinetic concentric/concentric testing with 3 repetitions at an angular velocity of 60/60° per second. Initial peak torque (mean of the first 3 repetitions of the endurance test of 15 total repetitions), fatigue index (the average peak torque of the first 3 repetitions vs. that of the last 3 repetitions stated in percent decline), and total work variables collected after 15 repetitions at an angular velocity of 300/300°·per second. Gravity corrections were not used by the testing personnel. Given the large number of players who are tested in a short period of time, it is acknowledged that the conditions surrounding Cybex testing at the NFL Scouting Combine are not the same as would be required in a controlled laboratory study.

Statistical Analyses

Cybex output is in foot-pounds, and data were converted to Newton meters by multiplying with a conversion factor of 1.356. Descriptive statistics (mean ± *SD*, range, and 95% confidence interval) were calculated for the group and also by playing position. In addition, peak torque values were normalized by body weight and the H/Q ratios calculated. We did not attempt to judge when an extreme value was an outlier or exceptional strength value; thus, all data points were used. Dominant-to-nondominant side comparisons were made using paired *t*-tests, comparisons between playing positions, and other such comparisons were made using unpaired *t*-test or analysis of variance. When data

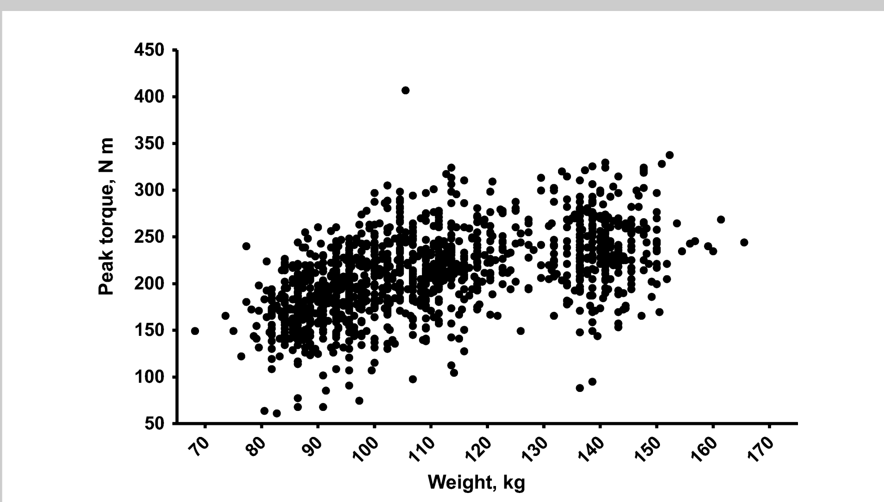

Figure 2. Scatterplot of body weight vs. dominant-side hamstrings peak torque for all players in the cohort ($n =$ 1,252). The regression coefficient ($r = 0.521$) was statistically significant ($p < 0.0001$).

Table 2. Cybex peak torque (absolute and normalized by body weight) by playing position for Elite Collegiate American football players participating in the NFL Scouting Combine 2008–2011.*

Position	Dominant side Quadriceps	Dominant side Hamstrings	Nondominant side Quadriceps	Nondominant side Hamstrings
Defensive backs, $n = 222$				
N·m	285.2 ± 66.0	185.5 ± 37.7	278.5 ± 62.4	182.5 ± 39.2
N·m·kg^{-1}	3.08 ± 0.679†	2.00 ± 0.358	2.98 ± 0.638	1.97 ± 0.379
Defensive line, $n = 218$				
N·m	345.6 ± 69.5	230.5 ± 41.2	339.5 ± 72.7	232.6 ± 38.1
N·m·kg^{-1}	2.74 ± 0.563	1.83 ± 0.325	2.70 ± 0.598	1.85 ± 0.329
Place kickers, punters, $n = 37$				
N·m	276.5 ± 65.1	178.5 ± 34.3	268.5 ± 59.4	178.7 ± 41.1
N·m·kg^{-1}	2.98 ± 0.644	1.93 ± 0.298	2.916± 0.572	1.94 ± 0.390
Linebackers, $n = 123$				
N·m	327.5 ± 72.3	219.0 ± 42.6	316.5 ± 69.7	211.0 ± 35.3
N·m·kg^{-1}	3.01 ± 0.659†	2.02 ± 0.405†	2.91 ± 0.635	1.94 ± 0.331
Offensive line, $n = 204$				
N·m	348.6 ± 66.4	234.3 ± 39.9	342.7± 63.7	235.3 ± 38.8
N·m·kg^{-1}	2.52 ± 0.492	1.69 ± 0.272	2.48 ± 0.474	1.70 ± 0.268
Quarterbacks, $n = 73$				
N·m	304.3 ± 55.7	207.5 ± 41.5	298.6 ± 61.3	206.4 ± 37.2
N·m·kg^{-1}	3.00 ± 0.563	2.04 ± 0.378	2.95 ± 0.632	2.03 ± 0.346
Running backs, $n = 118$				
N·m	303.1 ± 67.7	199.7 ± 40.1	296.6 ± 64.0	197.7 ± 38.9
N·m·kg^{-1}	3.06 ± 0.662	2.02 ± 0.393	2.99 ± 0.626	2.00 ± 0.379
Tight ends, $n = 59$				
N·m	341.6 ± 53.7	231.3 ± 38.7	336.8 ± 58.2	230.2 ± 37.2
N·m·kg^{-1}	2.96± 0.468	2.00 ± 0.328	2.92 ± 0.525	2.00 ± 0.325
Wideouts, $n = 198$				
N·m	278.7 ± 57.6	192.7± 40.5	276.8 ± 57.8	191.3 ± 40.8
N·m·kg^{-1}	3.05 ± 0.557	2.10 ± 0.375	3.04 ± 0.584	2.09 ± 0.396

*Quadriceps peak torque/body weight and hamstring peak torque/body weight for all positions were compared by 1-way analysis of variance with $p < 0.0001$ for each group (meaning at least 1 position was significantly different compared with another).
†Significantly different vs. nondominant side, $p < 0.05$ or less (paired t-test or Wilcoxon matched-pairs signed-ranks test if data not normally distributed).

were not normally distributed, comparisons were made using nonparametric statistics as noted in Results. We chose $p < 0.05$ to represent statistical significance. Only data for peak torque and work per repetition were normally distributed. All other variables had some degree of right-sided skewness.

Results

Players were divided into the following position groups and were characterized by different mean body weights (kilograms): defensive backs, 92.7 ± 8.6 ($n = 222$); defensive linemen, 126.4 ± 12.7 ($n = 218$); linebackers, 108.6 ± 3.8 ($n = 123$); kickers, 92.3 ± 8.6 ($n = 37$); quarterbacks, 101.4 ± 5.5 ($n = 73$); running backs, 98.6 ± 7.3 ($n = 118$); offensive linemen, 139.1 ± 12.3 ($n = 204$); tight ends, 115.5 ± 6.4 ($n = 59$); and wideouts, 91.4 ± 6.8 ($n = 198$). Body weights were significantly different between positions using 1-way analysis of variance ($p < 0.0001$). Subsequent testing using Tukey-Kramer multiple comparison testing showed that all pairwise comparisons were significantly different except: defensive backs vs. kickers and wideouts, kickers vs. wideouts, and quarterbacks vs. running backs.

Data for the cohort are shown in Table 1. Mean body weight was 109.6 ± 20.5 pounds. For strength variables, there was a small but statistically significant effect of dominant side, with dominant-side quadriceps, but not hamstrings, stronger than the nondominant side for peak torque, work per repetition, initial peak torque, and total work. Peak torque (Newton meters, best repetition) for quadriceps and hamstrings was significantly correlated to player body weight ($r = 0.457$, $p < 0.0001$ and $r = 0.521$, $p < 0.0001$ for quadriceps and hamstrings, respectively) (the same relationship was found for other variables using peak torque in the calculation) (Figures 1 and 2). Accordingly, peak torque varied by player position, being greatest for offensive linemen and lowest for kickers ($p < 0.0001$) (Table 2). Linemen and tight ends had mean peak torque values significantly greater than for other positions. Mean peak torque for linebackers and quarterbacks were

Table 3. Hamstring/quadriceps peak torque ratios for elite Collegiate American football players participating in the NFL Scouting Combine 2008–2011.*

	Dominant side				Nondominant side			
Position	Mean ± *SD*	Median	25 Percentile	75 Percentile	Mean ± *SD*	Median	25 Percentile	75 Percentile
All players, $n = 1{,}252$	0.6837 ± 0.137†	0.6651	0.5947	0.7527	0.6940 ± 0.145	0.6699	0.6035	0.7558
Defensive backs, $n = 222$	0.6695 ± 0.144	0.6450	0.5636	0.7489	0.6681 ± 0.126	0.6475	0.5846	0.7337
Defensive line, $n = 218$	0.6832 ± 0.146‡	0.6695	0.5895	0.7571	0.7108 ± 0.198	0.6758	0.6122	0.7723
Linebackers, $n = 123$	0.6850 ± 0.126	0.6778	0.6046	0.7434	0.6893 ± 0.151	0.6568	0.5880	0.7400
Place kickers, punters, $n = 37$	0.6677 ± 0.117	0.6483	0.5883	0.7193	0.6831 ± 0.146	0.6559	0.5892	0.7250
Offensive line, $n = 204$	0.6882 ± 0.145	0.6624	0.6106	0.7517	0.7056 ± 0.165	0.6708	0.6135	0.7648
Quarterbacks, $n = 73$	0.6872 ± 0.099	0.6846	0.6331	0.7418	0.7029 ± 0.109	0.6860	0.6314	0.7565
Running backs, $n = 118$	0.6757 ± 0.143	0.6592	0.5798	0.7320	0.6823 ± 0.128	0.6810	0.5957	0.7404
Tight ends, $n = 59$	0.6875 ± 0.127	0.6709	0.5938	0.7734	0.6959 ± 0.118	0.6801	0.6354	0.7647
Wideouts, $n = 198$	0.7032 ± 0.135	0.6976	0.6020	0.7723	0.7062 ± 0.154	0.6774	0.6020	0.7723

*Dominant-side H/Q ratios were compared between positions using nonparametric Kruskal-Wallis test (data were not normally distributed). Result was $p = 0.057$. Comparing only those positions with a sample size of at least $n = 100$, $p = 0.03$, with the significant difference isolated to defensive backs vs. wideouts. Nondominant-side H/Q ratios were compared between positions using nonparametric Kruskal-Wallis test (data were not normally distributed). Result was $p = 0.116$. Comparing only those positions with a sample size of at least $n = 100$, $p = 0.04$, with the significant difference isolated to defensive backs vs. defensive line. Twenty-five and 75 percentile values represent the cut-point below and above which included 25% of player H/Q ratios.
†$p = 0.021$ compared with nondominant side.
‡$p = 0.024$ compared with nondominant side.

generally between mean values for linemen and tight ends and running backs, defensive backs and wideouts, reflecting the effect of body weight on peak torque. Adjusting for body weight (peak torque/body weight) overcorrected these differences, and peak torque/body weight values tended to be lower with increasing absolute body weight (Table 2).

Mean H/Q ratios and frequency distributions were similar across positions varying only within a narrow range, with a cohort mean of 0.6837 ± 0.137 (range, 0.2642–0.6651 and 95% confidence interval (CI) = 0.6761–0.6913) for the cohort dominant side vs. 0.6940 ± 0.145 (range, 0.3421–0.6701 and 95% CI = 0.6869–0.7041) for the nondominant side ($p = 0.021$, $n = 1{,}252$) (Table 3). The lower H/Q on the dominant side is explained by the slightly but significantly greater dominant-side quadriceps peak torque compared with nondominant side (Table 1). Data are also presented as the median and cut-points for the 25 and 75 percentiles showing the wide range of H/Q values within each position. Because data were not normally distributed, dominant-side H/Q ratios were

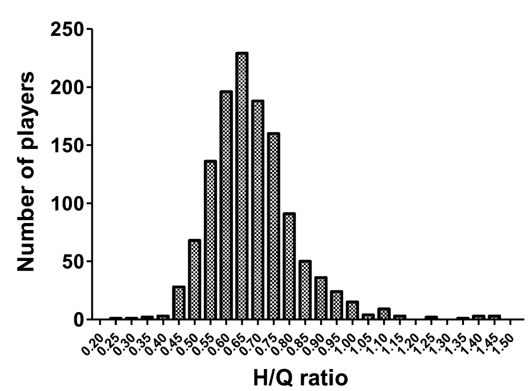

Figure 3. Frequency distribution of dominant-side hamstrings-to-quadriceps peak torque ratio for cohort (all positions combined, $n = 1{,}252$). Distribution is not Guassian by Kolmogorov-Smirnov test, $p < 0.0001$.

Table 4. Cybex dominant-side variables for elite Collegiate American football players participating in the NFL Scouting Combine 2008–2011.*

	Quadriceps				Hamstrings			
Position (*n*)	Mean ± *SD*	Median	Range	95% CI	Mean ± *SD*	Median	Range	95% CI
Defensive backs (222)								
Initial PT	147.1 ± 31.3	150.5	47.5 to 228	143.1 to 151.0	117.7 ± 22.8	118.0	36.6 to 183.1	114.9 to 120.7
Fatigue index	8.42 ± 27.0	15.0	−136.0 to 43.0	4.96 to 11.9	8.9 ± 20.3	12.0	−245 to 61.0	6.3 to 11.5
Total work	1,712 ± 457	1,756	209 to 3,117	1,648 to 1,778	1,452 ± 456	1,436	286.1 to 3,683	1,394 to 1,511
Defensive line (218)								
Initial PT	176.6 ± 34.4	179.7	13.6 to 271.2	171.9 to 181.2	143.3 ± 23.2	142.4	29.8 to 206.1	140.3 to 146.5
Fatigue index	10.4 ± 28.5	17.0	−182.0 to 55.0	6.61 to 14.2	14.0 ± 14.0	16.0	−52.0 to 67.0	12.2 to 15.9
Total work	1,980 ± 475	1,972	381 to 3,461	1,916 to 2,042	1,644 ± 429	1,603	282.0 to 2,736	1,587 to 1,702
Linebackers (123)								
Initial PT	165.3 ± 30.8	168.1	51.5 to 235.9	159.9 to 170.7	136.1 ± 22.8	138.3	40.7 to 183.1	132.1 to 140.2
Fatigue index	−0.67 ± 149	18.0	−1,620 to 40.0	−27.0 to 25.7	8.41 ± 40.9	14.0	−399 to 37.0	1.18 to 15.7
Total work	1,875 ± 484	1,886	652 to 3,117	1,790 to 1,961	1,614 ± 457	1,583	567 to 2,601	1,534 to 1,695
Kickers, punters (37)								
Initial PT	134.0 ± 27.3	135.6	27.1 to 195.3	124.6 to 143.5	112.8 ± 22.2	113.9	35.3 to 155.9	105.4 to 120.3
Fatigue index	25.0 ± 11.9	28.0	−14.0 to 44.0	21.0 to 29.0	13.0 ± 21.2	17.0	−93 to 36.0	5.88 to 20.0
Total work	1,642 ± 454	1,669	194 to 2,722	1,490 to 1,794	1,516 ± 437	1,540	374 to 2,473	1,370 to 1,661
Quarterbacks (73)								
Initial PT	150.1 ± 31.3	147.8	43.4 to 237.3	142.8 to 157.4	129.4 ± 21.8	124.8	62.4 to 210.2	124.1 to 134.4
Fatigue index	16.3 ± 18.58	22.0	−41.0 to 43.0	11.9 to 20.7	12.0 ± 10.8	12.0	−25.0 to 34.0	9.5 to 14.5
Total work	1,636 ± 383	1,687	587 to 2,410	1,547 to 1,725	1,547 ± 376	1,608	662 to 2,217	1,458 to 1,634
Running backs (118)								
Initial PT	159.3 ± 28.7	162.7	67.8 to 225.1	154.0 to 164.8	131.0 ± 21.4	131.5	77.3 to 202.0	126.4 to 134.9
Fatigue index	11.5 ± 30.1	18.0	−193.0 to 60.0	5.99 to 17.0	10.5 ± 11.9	11.0	−24 to 44.0	8.3 to 12.6
Total work	1,797 ± 414	1,817	900 to 3,122	1,721 to 1,873	1,585 ± 408	1,568	629 to 2,738	1,511 to 1,660
Offensive line (204)								
Initial PT	176.6 ± 31.2	178.9	33.9 to 272.6	173.4 to 180.1	147.6 ± 25.1	149.2	58.3 to 206.1	144.1 to 151.1
Fatigue index	11.5 ± 32.9	17.5	−358.0 to 41.0	6.94 to 16.0	14.4 ± 14.6	16.0	−109 to 40.0	12.4 to 16.4
Total work	2,020 ± 498	2,063	542 to 3,127	1,951 to 2,088	1,723 ± 449	1,706	674 to 2,899	1,663 to 1,786
Tight ends (59)								
Initial PT	165.2 ± 32.1	168.1	70.5 to 219.7	156.9 to 173.6	139.8 ± 21.7	141.0	73.2 to 183.1	134.2 to 145.5
Fatigue index	8.88 ± 28.6	17.0	−127.0 to 41.0	1.42 to 16.3	10.5 ± 16.2	15.0	−71.0 to 35.0	6.3 to 14.8
Total work	1,954 ± 438	1,892	808 to 2,952	1,840 to 2,068	1,734 ± 407	1,629	704 to 2,639	1,629 to 1,840
Wideouts (198)								
Initial PT	148.8 ± 29.2	149.8	66.4 to 208.8	144.7 to 152.8	124.8 ± 25.1	124.8	44.7 to 203.4	121.2 to 128.3
Fatigue index	11.3 ± 21.6	16.0	−65.0 to 47.0	8.3 to 14.3	10.6 ± 13.7	11.0	−36.0 to 44.0	8.7 to 12.5
Total work	1,707 ± 426	1,709	116.6 to 2,884	1,648 to 1,766	1,523 ± 412	1,502	90.9 to 2,616	1,466 to 1,580

*Dominant-side initial peak torque, fatigue index, and total work for quadriceps and hamstrings were compared by 1-way analysis of variance followed by Tukey-Kramer multiple comparisons test with all results $p < 0.0001$ except for hamstring fatigue index which was $p = 0.027$.

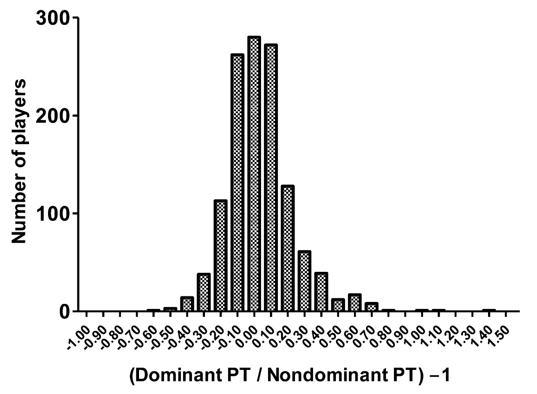

Figure 4. Frequency distribution of absolute peak torque difference between dominant- and nondominant-side quadriceps for cohort (all positions combined, $n = 1{,}252$). Distribution is not Guassian by Kolmogorov-Smirnov test, $p < 0.0001$.

compared between positions using nonparametric Kruskal-Wallis test with $p = 0.057$. Comparing only those positions with a sample size of at least $n = 100$, $p = 0.03$, with the significant difference isolated to defensive backs vs. wideouts. Likewise, non–dominant-side H/Q ratios were compared between positions using nonparametric Kruskal-Wallis test with $p = 0.116$. Comparing only those positions with a sample size of at least $n = 100$, $p = 0.04$, with the significant difference isolated to defensive backs vs. defensive line. Figure 3 shows a frequency distribution of dominant side H/Q ratio with a slight positive skew (skewed to the right, Kolmogorov-Smirnov test, $p < 0.0001$).

Table 4 shows quadriceps and hamstrings initial peak torque, fatigue index, and total work by playing position. Absolute initial peak torque and total work values reflected body size being greatest in linemen and lowest in defensive backs, wideouts, quarterbacks, and kickers. Initial peak torque was highly correlated ($p < 0.0001$) with peak torque (best repetition), and correlations tended to be better for positions requiring explosive power, namely running backs and wideouts. For example, the correlations between initial peak torque and peak torque for quadriceps and hamstrings for offensive linemen were $r = 0.611$ and $r = 0.67$ and for wideouts, $r = 0.713$ and 0.783, respectively. Fatigue index values were characterized by a large variation within each position. Manipulation of the fatigue index values by analyzing differences between quadriceps and hamstring fatigue index, and others revealed no significant differences between playing positions (data not shown).

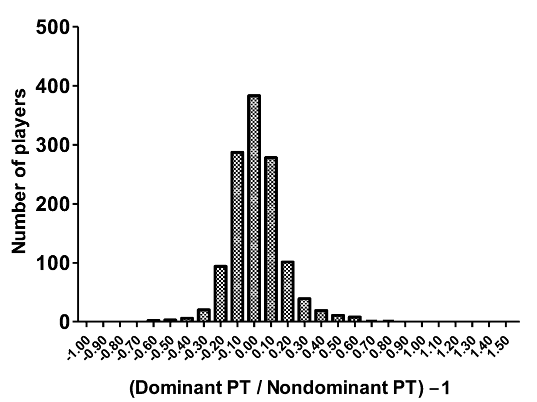

Figure 5. Frequency distribution of absolute peak torque difference between dominant- and nondominant-side hamstrings for cohort (all positions combined, $n = 1{,}252$). Distribution is not Guassian by Kolmogorov-Smirnov test, $p < 0.0001$.

Side-to-side differences (dominant vs. nondominant side) in quadriceps and hamstring peak torque were not normally distributed (Kolmogorov-Smirnov test, $p < 0.0001$) being skewed slightly to the right (Figures 4 and 5). The mean quadriceps dominant-to-nondominant difference was 3.86 ± 21.1% (median, 1.6%; range, −62 to 271%), and the mean hamstrings dominant-to-nondominant difference was 1.66 ± 15.4% (median, 0.6%; range, −64 to 76%). Considerable variation was seen for dominant-to-nondominant side differences for peak torque. For quadriceps, 47.2% of players had differences between −10% and +10%, 21.0% had a peak torque dominant-side deficit of 10% or greater compared to nondominant side, and for 31.8% of players, dominant-side peak torque was greater than 10% compared to nondominant side. For hamstrings, 57.0% of players had differences between −10% and +10%, 19.6% had a peak torque dominant-side deficit of 10% or greater compared to nondominant side, and for 23.4 % of players, dominant-side peak torque was greater than 10% compared to nondominant side. Of values for quadriceps, 95% fell within a range of −41 to +41% and for hamstrings, 95% of values fell within −30 to +30%.

Discussion

Several previous studies have evaluated data from the NFL Combine to assess the relationship between various physical and mental performance characteristics and playing positions, draft order, initial salary, and other such data (9,10,16–18,21). We present normative isokinetic concentric quadriceps and hamstrings strength data for athletes who participated in the NFL Scouting Combine from 2008 to 2011. These data show significant differences between playing positions for some variables, such as peak torque, but also show that the mean of a commonly used calculated variable, concentric H/Q ratio, varies relatively little between positions. This is notable because the mean H/Q ratios for players in positions prone to hamstring injury (wideouts, defensive backs, and running backs) were not uniformly lower than other playing positions. Also, the large variability observed for side-to-side (dominant vs. nondominant) differences calls into question longstanding assumptions about what is considered a "normal range" for side-to-side differences, at least for highly trained elite collegiate American football players. These results may serve a useful purpose because by characterizing expected values after testing, these data could potentially aid evaluation of individual players. For example, if an individual's muscle strength values are at the low end of the normal range, then that should arouse concerns about current or previous injury or perhaps lack of maximal effort during testing. If an individual's muscle strength values are at the high end of the normal range, then that would be noteworthy documentation of superior strength.

Another potential use of a normative database is the ability to predict risk for injury. Hamstring injuries are commonplace and cause considerable morbidity and missed playing time in sports that require bursts of speed and flexibility, such as Australian Rules football, soccer, track and field, and American football (3–5,13). Elliott et al. (6) reported on the prevalence of hamstring injuries in the NFL. More than half of the injuries (51.3%) occurred during training camp and caused an average of 213 man-games lost annually (6). Interestingly, 78.9% of practice injuries occurred during the preseason, with more than 70% happening during July, the first month of the preseason (6). Positions dependent most on speed and acceleration (i.e., wide receiver, cornerback, and special teams) proved most at risk (6). Previous studies have suggested that a strength imbalance between the quadriceps and hamstring (specifically with an H/Q ratio less than 0.6) is predictive of risk for hamstring strain (4,7,11,13,15,22,25). With the intent of being able to predict risk for future injury, we focused considerable attention on analyzing the concentric H/Q ratio for different playing positions. But overall, the mean concentric H/Q ratio did not vary greatly between positions, and variability (range of values) for each position was quite high.

We also carefully scrutinized fatigue index data in an effort to detect patterns that could be characterized by playing position and hence become a potential predictor of injury. However, because of the large variation in fatigue index values with both positive and negative values (negative values indicating increasing torque at the end of the endurance test), the mean values were difficult to interpret and are probably not a useful characteristic of strength by position. We attempted to manipulate the fatigue index values by analyzing the difference between quadriceps and hamstring fatigue index under the assumption that an imbalance with hamstrings being more fatigable than quadriceps could be a risk factor for hamstring injury. However, these analyses revealed no patterns that could be practically used to assist data interpretation. Finally, an additional potentially confounding uncontrolled factor is the adverse influence on data integrity because of lack of maximal effort by players (who may be protecting injuries, and others).

Several investigators in the early days of isokinetic testing suggested that a side-to-side discrepancy of 10% or more between the "normal" balance of the 2 extremities or between the ratio of agonist and antagonist muscle groups represented an abnormal imbalance which theoretically could predispose the athlete to joint or muscle injury (20). Anecdotally, in our experience, this concept has persisted despite several reports suggesting that in fact, side-to-side differences in excess of 10% are not uncommon in both athletes and the normal population (11,12). For the cohort in this study, the mean dominant-nondominant quadriceps difference was only 3.85%, which completely masks the true variability in dominant-nondominant side difference (this is because, when comparing dominant side to nondominant side, there will be both positive and negative numbers and a mean value will not be reflective of the range of side-to-side differences). In reality, more than half of players had dominant-nondominant side quadriceps differences greater than ±10%, and 43% of players had hamstring differences greater than ±10%, with 95% of values within a range of −41% to +41% for quadriceps, and with 95% of values within a range of −30 to +30% for hamstrings. The explanation of such large side-to-side difference may be an opportunity for further study to determine if this reflects true biologic variance between dominant-nondominant or right-left sides, as opposed to measurement error, lack of sincerity in effort by the athlete during testing, or training or conditioning effects idiosyncratic to sport or specific playing positions resulting in 1 leg stronger than the other.

Some, but not all, investigators report greater strength values for the dominant side after strength testing (3,7,8,11,15,19,23). We suggest that some of the discrepancy in the literature can be explained by the fact that typically, with some notable exceptions (4,7), reports are often characterized by relatively small sample size or diverse study populations, with the accompanying risk of making flawed generalizations. We performed post hoc power analysis on the quadriceps peak torque for the cohort. Using the actual *SD* of the differences of 39, the power to detect the difference actually observed of 4.3 was about 95%. Thus, it is notable that if designing a new study with the ability to detect a dominant-to-nondominant difference of 4.3 with 90% power, a sample of 1,000 would be necessary. Thus, we suggest that some previous studies with small sample size reporting no side-to-side difference were confounded by Type II statistical error (that is, failing to detect a true difference due to low power). That said, the differences we observed between dominant-nondominant sides were very small, and although statistically significant, are unlikely to be clinically significant.

This study presents normative isokinetic concentric strength data for athletes participating in the NFL Scouting Combine in the years 2008–2011. Results show relative similarity in H/Q ratios by playing position. Large dominant-to-nondominant side differences are common, calling into question long-standing dogma about what constitutes "normal" side-to-side differences. These data may be useful for evaluating individual player characteristics.

Practical Applications

These data may benefit NFL franchises in their strength assessments of individual players and also may be used to predict risk for future injury. That is, if an individual's muscle strength values are at the low end of the normal range, then that could arouse concerns about current or previous injury or perhaps lack of maximal effort. If an individual's muscle strength values are at the upper end of the normal range, then that would be noteworthy documentation of superior strength.

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