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Isokinetic Peak Torque in Young Wrestlers

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The purpose of the present study was to examine age-related changes in isokinetic leg flexion and extension peak torque (PT), PT/body weight (PT/BW), and PT/fat-free weight (PT/FFW) in young wrestlers. Male wrestlers (*N* = 108; age $M \pm SD = 11.3 \pm 1.5$ years) volunteered to be measured for peak torque at 30, 180, and $300° \cdot s^{-1}$. In addition, underwater weighing was performed to determine body composition characteristics. The sample was divided into six age groups (8.1–8.9, *n* = 10; 9.0–9.9, *n* = 11; 10.0–10.9, *n* = 25; 11.0–11.9, *n* = 22; 12.0–12.9, *n* = 28; 13.0–13.9, *n* = 12), and repeated measures ANOVAs with Tukey post hoc comparisons showed increases across age for PT, PT/BW, and PT/FFW. The results of this study indicated that there were age-related increases in peak torque that could not be accounted for by changes in BW or FFW. It is possible that either an increase in muscle mass per unit of FFW, neural maturation, or both, contributes to the increase in strength across age in young male athletes.

Typically, during childhood and adolescence, strength increases coincide with changes in body weight (BW) and fat-free weight (FFW) (1, 15, 16). Recent studies of high school wrestlers, however, have reported age-related increases in isokinetic peak torque (PT) for leg extension (7), forearm flexion (7), arm flexion and extension (5), and arm horizontal adduction and abduction (29) that could not be accounted for by changes in BW or FFW. The physiological mechanism underlying this age effect for strength increases (independent of FFW) in adolescent athletes is unknown, but may be attributable to an increase across age in muscle mass per unit of FFW, neural maturation, or both (5, 7, 8, 9, 26, 29).

Compared to high school athletes (5, 6, 7, 10, 29), little is known about the factors that contribute to the normal growth and maturation of strength in younger athletes (23, 25, 26). For example, with the exception of a recent investigation of elite runners by Thorland et al. (26), no studies have examined the covariate influ-

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ences of BW and FFW on age-related increases in isokinetic PT in young male athletes. Furthermore, Thorland et al. (26) presented data for leg extension only. Therefore, the purpose of the present investigation was to examine age-related changes in isokinetic leg flexion and extension PT, PT/BW, and PT/FFW in young wrestlers.

Methods

The subjects for this study were 108 Caucasian male wrestlers (age $M \pm SD$ = 11.3 ± 1.5 years; range = 8.1–13.9 years). In addition to wrestling, 96 of the 108 subjects also participated in one or more other organized youth sports program including football, soccer, baseball, basketball, track, softball, swimming, karate, volleyball, tennis, golf, gymnastics, and diving. Forty-one of the subjects had participated in three or more organized sports within the last year. The total sample (N = 108) was divided into six age groups: AG1 = 8.1–8.9 (n = 10), AG2 = 9.0–9.9 (n = 11), AG3 = 10.0–10.9 (n = 25), AG4 = 11.0–11.9 (n = 22), AG5 = 12.0–12.9 (n = 28), and AG6 = 13.0–13.9 (n = 12). The laboratory testing was performed during the first week of training and 1–2 weeks prior to the beginning of the competitive wrestling season. The study was approved by the Institutional Review Board for Human Subjects, and written informed consent was obtained from the subjects and their parents prior to testing.

Underwater Weighing

Body density (BD) was assessed from underwater weighing (UWW), with correction for residual lung volume using the oxygen dilution method of Wilmore (30). Residual volume (RV) was determined on land with the subject seated in a position similar to that assumed during UWW. The average of similar scores (within 100 ml) from two to three trials was used as the representative RV. Underwater weight was measured in a hydrostatic weighing tank in which a metal swing seat was suspended from a Chatillon 9 kg scale. The average of the three highest values from 6 to 10 trials was used as the representative underwater weight (27). Percent body fat (% fat) was estimated from BD using the age-specific conversion constants of Lohman (14), and fat-free weight (FFW) was derived mathematically.

Previous test-retest reliability data for UWW from our laboratory indicated that for young adult male subjects (n = 16) measured 24–72 hours apart, the intraclass correlation (R) was .98, with a standard error of measurement of 0.9% fat. These values are comparable to those reported by Thomas and Cook (24) and Jackson et al. (12). Furthermore, the UWW procedures used in the present investigation were standardized as a part of an interuniversity study (28) and found to be highly consistent with those from three other laboratories. Body weight (BW) and height (HT) were measured using a physician's scale and wall scale with Broca plane, respectively.

Isokinetic Peak Torque

Isokinetic flexion and extension PT for the dominant leg (based on kicking preference) were measured using a calibrated Cybex II dynamometer at 30, 180, and $300° \cdot s^{-1}$. The subjects were positioned and stabilized using the procedures recommended by the manufacturer (11). Three to four submaximal warm-up trials were followed by three consecutive maximal efforts, with the highest PT value selected as the representative score. The PT values were not gravity corrected, and damping on the Cybex II was set at 2. Previous test-retest reliability data from our laboratory for leg flexion and extension PT at velocities of contraction ranging from 30–300° $\cdot$ s^{-1} indicated that for young adult male subjects ($n = 20$) measured 2 to 7 days apart, the intraclass correlations (R) ranged from .85 to .97, with standard error of measurement values that were <5.0% of the means. These reliability coefficients are consistent with those from a number of previous studies reviewed by Perrin (19).

Statistical Analyses

Pearson product-moment correlations were used to determine the relationships among variables. One-way ANOVAs with Tukey post hoc comparisons were used to locate differences between the age groups (AG1–AG6) for leg flexion and extension PT, PT/BW, and PT/FFW for each velocity of contraction. An alpha level of $p < .05$ was utilized for statistical significance for all comparisons.

Results

Table 1 includes the descriptive characteristics of the subjects for each age group. There were significant differences among the age groups for age, HT, BW, and FFW, but not for % fat.

Table 2 provides a zero-order correlation matrix among the variables. Age was significantly correlated ($r = .62–.78$) with HT, BW, FFW, and all of the PT measures. The highest correlation was between BW and FFW ($r = .95$). Furthermore, the PT measures were highly intercorrelated at $r = .82–.94$.

Table 3 includes the PT values for leg flexion and extension, as well as PT/BW and PT/FFW, for each age group. There were significant differences among the age groups for all PT, PT/BW, and PT/FFW comparisons.

Discussion

As shown in Table 4, mean values for the physical characteristics (HT, BW, % fat, and FFW) of the subjects in the present study were between those previously reported for young wrestlers by Sady et al. (20) and Zelesko et al. (32). There were increases across age in HT, BW, and FFW, but no change in % fat (Table 1). BW and FFW were highly correlated ($r = .95$; Table 2), and therefore, much of the age-related change in BW was due to an increase in FFW. The mean HT of the present sample of young wrestlers (Table 4) corresponded closely to the median HT of a national representative sample of 11.5-year-old boys from The National Center for Health Statistics (4). The mean BW of the present sample (Table 4), however, corresponded to approximately the 60–65th percentile of the national sample (4). Therefore, when compared to standard growth curves for children in the United States (4), the athletes in the present study were similar in HT, but heavier than boys of comparable ages.

There are limited isokinetic peak torque data available for children. Table 5 provides leg extension data for normals (13, 21) and track athletes (26) for comparison with the young wrestlers in the present study. The mean values for PT, PT/BW, and PT/FFW from previous studies (13, 21, 26) were within 1 standard deviation of the means for the present sample of young wrestlers. These

Table 1 Descriptive Characteristics

Variable	AG1 ($n = 10$)	AG2 ($n = 11$)	AG3 ($n = 25$)	AG4 ($n = 22$)	AG5 ($n = 28$)	AG6 ($n = 12$)	Total ($n = 108$)	Tukey post hoc comparisons
1. Age (years)*	8.5 ± 0.2	9.4 ± 0.3	10.5 ± 0.5	11.4 ± 0.2	12.5 ± 0.3	13.5 ± 0.3	11.3 ± 1.5	AG6 > 5, 4, 3, 2, 1 AG5 > 4, 3, 2, 1 AG4 > 3, 2, 1 AG3 > 2, 1 AG2 > 1
2. Height (cm)*	129.2 ± 4.5	133.6 ± 4.6	142.7 ± 6.5	146.6 ± 7.8	152.5 ± 8.7	161.4 ± 9.7	145.9 ± 11.7	AG6 > 5, 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 2, 1
3. Body weight (kg)*	28.8 ± 3.0	32.1 ± 4.9	38.9 ± 7.7	39.4 ± 7.4	45.0 ± 10.0	52.6 ± 11.1	40.5 ± 10.4	AG6 > 4, 3, 2, 1 AG5 > 2, 1 AG4 > 1 AG3 > 1
4. Fat-free weight (kg)*	24.4 ± 2.6	27.1 ± 3.3	33.2 ± 5.0	35.3 ± 6.4	39.6 ± 9.6	46.0 ± 10.4	35.3 ± 9.3	AG6 > 4, 3, 2, 1 AG5 > 2, 1 AG4 > 2, 1 AG3 > 1
5. % body fat	15.1 ± 5.5	15.0 ± 7.1	13.8 ± 7.2	10.1 ± 5.2	12.0 ± 7.8	12.7 ± 4.7	12.7 ± 6.7	

Note. AG = age group. Values are $M \pm SD$.
*One-way ANOVA by group sigificant at $p < .05$.

Table 2 Zero-Order Correlation Matrix

Variable	Age	HT	BW	FFW	% fat	FL30	FL180	FL300	EX30	EX180	EX300
Age	1.00										
HT	.78	1.00									
BW	.63	.87	1.00								
FFW	.67	.90	.95	1.00							
% fat	–.18	–.15	.08	–.23	1.00						
FL30	.69	.88	.86	.89	–.14	1.00					
FL180	.69	.88	.88	.90	–.13	.93	1.00				
FL300	.70	.88	.85	.89	–.17	.87	.94	1.00			
EX30	.76	.89	.85	.87	–.14	.89	.89	.86	1.00		
EX180	.74	.90	.89	.92	–.17	.88	.93	.92	.93	1.00	
EX300	.69	.87	.87	.92	–.20	.82	.89	.93	.87	.94	1.00

Note. $N = 108$. $r \geq .19$, $p < .05$. HT = height; BW = body weight; FFW = fat-free weight; % fat = percent body fat; FL30 = leg flexion at 30° · s^{-1}; FL 180 = leg flexion at 180° · s^{-1}; FL 300 = leg flexion at 300° · s^{-1}; EX30 = leg extension at 30° · s^{-1}; EX180 = leg extension at 180° · s^{-1}; EX300 = leg extension at 300° · s^{-1}.

Table 3 Absolute and Relative Peak Torque Values

Variable	AG1 ($n = 10$)	AG2 ($n = 11$)	AG3 ($n = 25$)	AG4 ($n = 22$)	AG5 ($n = 28$)	AG6 ($n = 12$)	Total ($n = 108$)	Tukey post hoc comparisons
				Leg Flexion				
Absolute peak torque (Nm)								
$30° \cdot s^{-1}$*	31 ± 6	37 ± 10	47 ± 14	54 ± 16	66 ± 17	79 ± 23	54 ± 21	AG6 > 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
$180° \cdot s^{-1}$*	22 ± 5	26 ± 6	34 ± 9	38 ± 13	47 ± 13	56 ± 15	39 ± 15	AG6 > 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
$300° \cdot s^{-1}$*	16 ± 4	18 ± 6	24 ± 5	29 ± 9	34 ± 10	42 ± 12	28 ± 11	AG6 > 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1
Peak torque/body weight (Nm/kg)								
$30° \cdot s^{-1}$*	1.05 ± 0.15	1.17 ± 0.31	1.20 ± 0.24	1.36 ± 0.26	1.48 ± 0.24	1.48 ± 0.25	1.32 ± 0.28	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 1
$180° \cdot s^{-1}$*	0.76 ± 0.13	0.80 ± 0.15	0.89 ± 0.17	0.94 ± 0.18	1.04 ± 0.17	1.06 ± 0.10	0.94 ± 0.19	AG6 > 3, 2, 1 AG5 > 2, 1 AG4 > 1
$300° \cdot s^{-1}$*	0.57 ± 0.11	0.57 ± 0.14	0.63 ± 0.10	0.71 ± 0.13	0.76 ± 0.13	0.79 ± 0.10	0.69 ± 0.14	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1

Peak torque/fat-free weight (Nm/kg)								
$30° \cdot s^{-1}$*	1.24 ± 0.19	1.37 ± 0.30	1.39 ± 0.26	1.52 ± 0.27	1.69 ± 0.28	1.70 ± 0.29	1.51 ± 0.31	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 1
$180° \cdot s^{-1}$*	0.90 ± 0.17	0.94 ± 0.15	1.03 ± 0.19	1.05 ± 0.21	1.19 ± 0.19	1.22 ± 0.16	1.07 ± 0.21	AG6 > 3, 2, 1 AG5 > 2, 1
$300° \cdot s^{-1}$*	0.67 ± 0.14	0.67 ± 0.13	0.73 ± 0.10	0.80 ± 0.15	0.86 ± 0.13	0.91 ± 0.12	0.79 ± 0.15	AG6 > 3, 2, 1 AG5 > 3, 2, 1
Leg Extension								
Absolute peak torque (Nm)								
$30° \cdot s^{-1}$*	48 ± 9	59 ± 16	79 ± 17	93 ± 24	116 ± 28	136 ± 35	93 ± 35	AG6 > 4, 3, 2, 1 AG5 > 4, 3, 2, 1 AG4 > 2, 1 AG3 > 1
$180° \cdot s^{-1}$*	28 ± 5	32 ± 10	47 ± 10	55 ± 18	69 ± 19	81 ± 23	55 ± 23	AG6 > 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
$300° \cdot s^{-1}$*	18 ± 5	22 ± 9	31 ± 5	36 ± 13	45 ± 15	53 ± 18	36 ± 16	AG6 > 4, 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
Peak torque/body weight (Nm/kg)								
$30° \cdot s^{-1}$*	1.66 ± 0.26	1.86 ± 0.48	2.05 ± 0.35	2.35 ± 0.40	2.59 ± 0.36	2.59 ± 0.35	2.26 ± 0.48	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1

(continued)

Table 3 *(continued)*

Variable	AG1 ($n = 10$)	AG2 ($n = 11$)	AG3 ($n = 25$)	AG4 ($n = 22$)	AG5 ($n = 28$)	AG6 ($n = 12$)	Total ($n = 108$)	Tukey post hoc comparisons
$180° \cdot s^{-1}$*	0.96 ± 0.13	0.99 ± 0.21	1.23 ± 0.22	1.36 ± 0.26	1.54 ± 0.21	1.53 ± 0.17	1.32 ± 0.30	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 2, 1
$300° \cdot s^{-1}$*	0.62 ± 0.12	0.67 ± 0.19	0.81 ± 0.14	0.89 ± 0.19	0.98 ± 0.19	0.99 ± 0.14	0.86 ± 0.21	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
Peak torque/fat-free weight (Nm/kg)								
$30° \cdot s^{-1}$*	1.96 ± 0.29	2.18 ± 0.54	2.38 ± 0.38	2.62 ± 0.42	2.96 ± 0.43	2.98 ± 0.46	2.59 ± 0.53	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1
$180° \cdot s^{-1}$*	1.13 ± 0.16	1.17 ± 0.25	1.43 ± 0.23	1.52 ± 0.30	1.75 ± 0.24	1.75 ± 0.18	1.51 ± 0.32	AG6 > 4, 3, 2, 1 AG5 > 4, 3, 2, 1 AG4 > 2, 1 AG3 > 2, 1
$300° \cdot s^{-1}$*	0.73 ± 0.16	0.79 ± 0.23	0.93 ± 0.14	0.99 ± 0.21	1.12 ± 0.18	1.13 ± 0.14	0.98 ± 0.22	AG6 > 3, 2, 1 AG5 > 3, 2, 1 AG4 > 2, 1 AG3 > 1

Note. AG = age group, see Table 1 for means and standard deviations. Values are $M \pm SD$.
*One-way ANOVA by group significant at $p < .05$.

Table 4 Physical Characteristics of Selected Reference Groups

Source	Age (years)	*N*	Height (cm)	Body weight (kg)	% fat	Fat-free weight (kg)
Present study	11.3 ± 1.5	108	145.9 ± 11.7	40.5 ± 10.4	17.6 ± 6.7[a]	33.4 ± 9.2[a]
Hamill et al. (4)	11.5		146.4	37.46		
Sady et al. (20)	11.0 ± 1.01	23	140.6 ± 9.7	31.7 ± 5.4	13.3 ± 3.16	27.5 ± 4.8
Zelesko et al. (32)	<14.0	13	146.0	43.2	20.0	34.0

Note. Values are M or $M \pm SD$. Height and body weight from Hamill et al. (4) are median values from normal growth curves for a national representative sample of 11.5-year-old boys from the National Center for Health Statistics. Zelesko et al. (32) did not provide measures of variability.

[a]For comparison with the young wrestler data of Sady et al. (20) and Zelesko et al. (32), the percent fat and fat-free weight values for the subjects in the present study were recalculated using the conversion constants of Siri (22).

Table 5 Isokinetic Peak Torque for Leg Extension in Selected Reference Groups

Source	Age (years)	*N*	Group	Velocity ($^\circ \cdot s^{-1}$)	PT (Nm)	PT/BW (Nm/kg)	PT/FFW[a] (Nm/kg)
Present study	11.3 ± 1.5	108	Wrestlers	30	93 ± 35	2.26 ± 0.48	2.59 ± 0.53
				180	55 ± 23	1.32 ± 0.30	1.51 ± 0.32
				300	36 ± 16	0.86 ± 0.21	0.98 ± 0.22
Larson et al. (13)	12.3 ± 0.3	11	Normal	180	57 ± 12	1.6	
Seger and Thorstensson (21)	11	10	Normal	180	52 ± 13	1.4	
Thorland et al. (26)	11.9 ± 1.1	12	Sprinters	30	95 ± 21	2.2 ± 0.4	2.34
				180	63 ± 22	1.5 ± 0.3	1.55
				300	44 ± 11	1.0 ± 0.1	1.08
Thorland et al. (26)	12.0 ± 0.9	12	Middle	30	80 ± 20	2.2 ± 0.4	2.24
			distance	180	49 ± 12	1.3 ± 0.3	1.37
			runners	300	35 ± 6	1.0 ± 0.2	0.98

Note. Values are *M* or *M* ± *SD*. PT = peak torque, BW = body weight; FFW = fat-free weight.
[a]FFW for the present study and Thorland et al. (26) were calculated using the age-specific conversion constants of Lohman (14).

findings indicated that there is substantial overlap within this general age group for isokinetic PT for normals and athletes in various sports.

The correlational results of the present study supported those from previous investigations (3, 18, 26) that reported moderate to high correlations for PT versus age, HT, BW, and FFW in athletic and nonathletic children. The range of zero-order correlations (r = .69–.92; Table 2) for age, HT, BW, and FFW versus PT in the present study were similar to those (r = .71–.98) for the young (10.00–16.92 years) male track athletes of Thorland et al. (26). Furthermore, Molnar and Alexander (18) reported correlations in 7- to 15-year-old children or r = .8993, .9205, and .7965 for leg extension PT at 30° · s^{-1} versus age, HT, and BW, respectively. The corresponding correlations from the present study were r = .76, .89, and .85, respectively (Table 2). Gilliam et al. (3) found correlations ranging from r = .71 to r = .84 for age, HT, and BW versus PT for leg flexion and extension at 30 and 120° · s^{-1} in a sample of 7- to 13-year-old boys.

The present study indicated that there were increases across age for PT, PT/BW, and PT/FFW for flexion and extension of the leg at 30, 180, and 300° · s^{-1} (Table 3). Thus, the increases in strength for the present sample of young wrestlers were proportionately greater than the increases in BW and FFW (Table 1). These findings were consistent with those from previous investigations of young male (26) and female (25) runners, as well as high school wrestlers (5, 7, 29), that reported age-related increases in strength that could not be accounted for by changes in BW or FFW. It has been hypothesized (5, 7, 26, 29) that the age effect for increases in strength, independent of FFW, may be attributable to (a) an increase in muscle mass per unit of FFW, or (b) neural maturation, which allows for a greater expression of strength.

Lohman (14) has stated that "the increases in muscle mass during growth in males is well documented in terms of absolute size of muscle, but not in terms of the muscle content of FFB [fat-free body]" (p. 342). Recent studies (8, 9) using anthropometric estimations of total body muscle mass (17) in high school wrestlers, however, have reported (a) age-related increases in strength that could not be fully accounted for by changes in estimated muscle mass, and (b) nonsignificant ($p > .05$) first-order partial correlations between age and estimated muscle mass covaried for FFW. Thus, for high school athletes, there is some evidence to suggest that the age effect for isokinetic PT is not due to an increase in muscle mass per unit of FFW (8, 9). To date, however, there have been no studies that have examined age-related changes in the contribution of muscle mass to FFW in younger athletes, such as the wrestlers in the present study. This could be accomplished by combining UWW for the determination of FFW with 24-hour creatinine excretion, total body magnetic resonance imaging, or dual energy x-ray absorptiometry for determining muscle mass.

It is also possible that neural maturation contributed to the age effect for strength increases found in the present study. It has been suggested that the expression of strength during childhood and adolescence is dependent upon neural maturation and the myelination of motor nerves, which is not complete until sexual maturity has been achieved (2, 31). In addition, Blimkie (1) found that 16-year-old boys could voluntarily activate a greater percentage of their available motor units (95.3%) during a maximal isometric contraction of the leg extensors than could 11-year-old boys (77.7%). Based on these observations, Blimkie (1) concluded "it is possible that differences in ability to activate muscle contribute to the age- and sex-associated variation in human voluntary strength during childhood" (p. 143).

In summary, the physical characteristics of the subjects in the present study were similar to those from previous investigations (20, 32) of young wrestlers. Furthermore, there were increases across age in PT for leg flexion and extension at 30, 180, and 300° · s^{-1} that could not be accounted for by changes in BW or FFW. It is possible that this age-effect for strength increase (independent of FFW) was attributable to an increase in muscle mass per unit of FFW or neural maturation. There is a need for longitudinal studies to determine the influence of neuromuscular maturation on strength increases across age, as well as studies designed to quantify the contribution of muscle mass to FFW in children and adolescents.

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