Pediatric Exercise Science, 1990, **2**, 65-72

Age-Related Increases in the Shoulder Strength of High School Wrestlers

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The purpose of this investigation was to examine age-related differences in absolute and relative isokinetic shoulder strength of high school wrestlers. A total of 122 high school wrestlers (*M* age = 16.31 ± 1.18 yrs) volunteered to be measured for arm flexion and extension strength at the shoulder joint using a Cybex II dynamometer at 30, 180, and 300°•s^{-1}. The sample was divided into four age groups: 13.75–15.00 (n=22), 15.08–16.00 (n=27), 16.08–17.00 (n=34), and 17.08–18.83 years (n=39). The results of this study indicated significant increases in absolute and relative arm flexion and extension strength across age when covaried for BW and FFW. In addition, comparisons with previously published data indicated differences between muscle groups in the pattern of strength gains that were dependent upon the speed of muscular contraction and may have been influenced by fiber type distribution characteristics.

Many factors such as strength, body composition, anaerobic capabilities, and strategic knowledge contribute to the improvement in wrestling performance which normally occurs throughout the high school years (4, 9, 10, 13). However, few studies have examined the development of these traits in wrestlers during adolescence. This is especially true with regard to strength for movements other than flexion and extension of the forearm and leg. For example, there have been no studies describing the strength characteristics of high school wrestlers at the shoulder joint, even though the demands of the sport require a substantial amount of strength in these muscle groups and changes in shoulder strength are likely to influence wrestling performance. In addition, information regarding the development of shoulder strength in high school wrestlers can be compared to existing data (10) to examine the differences in the patterns of strength gains between muscle groups of the upper versus lower body as well as between the muscles associated with movements at the elbow versus shoulder joints. Therefore the purpose of this investigation was to examine age related differences in absolute and relative isokinetic shoulder strength of high school wrestlers.

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Materials and Methods

A total of 122 high school wrestlers (*M* age = 16.31 ± 1.18 yrs) volunteered as subjects for this study. They were stratified into four groups corresponding approximately to the ages of wrestlers during their freshman, sophomore, junior, and senior years in high school: Group 1 (G1) = 13.75–15.00 yrs ($n=22$), Group 2 (G2) = 15.08–16.00 yrs ($n=27$), Group 3 (G3) = 16.08–17.00 yrs ($n=34$), and Group 4 (G4) = 17.08–18.83 yrs ($n=39$). All measurements were taken during the preseason (1–2 weeks prior to the competitive season) and informed consent was obtained from each wrestler and his parents prior to inclusion in the study.

Body composition was assessed from underwater weighing using the procedures described by Thorland et al. (21) with corrections for residual lung volumes using oxygen dilution (24). Relative fat (RF) was calculated from body density using both the conversion constants of Brozek et al. (3) and the age-specific conversion constants of Lohman (16) with fat-free weight (FFW) derived mathematically. Body weight (BW) and height (HT) were obtained using a physician's scale and a wall scale with Broca plane, respectively.

Isokinetic flexion and extension strength at the shoulder joint of the dominant arm (based on throwing preference) were measured using a Cybex II dynamometer at 30, 180, and $300° \cdot s^{-1}$. All 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 peak torque value selected as the representative score. Dampening on the Cybex II was set at 2.

One-way ANOVA with Tukey post hoc comparisons were used to locate significant differences ($p<0.05$) between groups for HT, BW, RF, and FFW as well as absolute flexion and extension strength. One-way ANCOVA were used to locate significant differences between groups for flexion and extension strength covaried independently for BW and FFW.

Results

Table 1 presents the descriptive characteristics of the subjects. The age, HT, RF, and BW of the subjects in the present study were similar to samples of adolescent wrestlers previously described (9, 10, 15, 18, 19, 21, 23).

There were significant ($r=0.18$, $p<0.05$) zero-order correlations among all variables except RF, which was not associated with HT, BW, or any of the strength measures. The highest correlation was found between BW and FFW ($r=0.93$) and the measures of muscular strength were significantly intercorrelated ($r=0.75$ to 0.92). All first-order partial correlations among the strength measures (controlling for BW and FFW) were also significant but were generally reduced from the zero-order values and ranged from $r=0.46$ to 0.87. In addition, there were significant ($r=0.37$ to 0.50) first-order partial correlations (controlling for BW and FFW) between age and all of the strength measures.

Table 2 includes the results of the one-way ANOVA and ANCOVA analyses across age for arm flexion and extension strength at 30, 180, and $300° \cdot s^{-1}$. In all cases there were significant ($p<0.05$) increases across age for absolute and relative strength (covaried for BW and FFW), with G4 and G3 always stronger than G1.

Table 1

Descriptive Characteristics of the Subjects ($M \pm$ SEM)

Variables	G1 ($n=22$) ≤15.00 yrs	G2 ($n=27$) 15.08–16.00 yrs	G3 ($n=34$) 16.08–17.00 yrs	G4 ($n=39$) ≥17.08 yrs	Total ($n=122$)
Age (yrs)[a]	14.51 ± 0.32	15.60 ± 0.28	16.58 ± 0.28	17.62 ± 0.40	16.30 ± 1.18
Height (cm)[a]	168.10 ± 1.77	172.40 ± 1.58	173.90 ± 1.03	171.60 ± 1.02	171.80 ± 0.66
Relative fat (%)[a,b]	12.05 ± 1.65	9.19 ± 0.86	6.92 ± 0.80	11.40 ± 0.69	9.71 ± 0.49
Relative fat (%)[a,c]	14.65 ± 1.89	11.76 ± 1.06	9.52 ± 0.99	12.83 ± 0.92	11.93 ± 0.63
Body weight (kg)	61.49 ± 3.11	65.28 ± 2.53	67.77 ± 1.54	68.02 ± 1.48	66.14 ± 1.03
Fat-free weight (kg)[a,b]	54.08 ± 2.60	59.28 ± 2.12	63.08 ± 1.32	60.28 ± 1.27	59.72 ± 0.89
Fat-free weight (kg)[a,c]	52.48 ± 2.13	57.60 ± 1.97	61.32 ± 1.21	59.29 ± 1.14	58.25 ± 0.71

[a]$p<0.05$. [b]Relative fat and fat-free weight were calculated based on the age-specific conversion constants of Lohman (16): G1; RF = ((5.07/body density) − 4.64) × 100; G2 and G3; RF = ((5.03/body density) − 4.59) × 100; G4; RF = ((4.98/body density) − 4.53) × 100. [c]Relative fat and fat-free weight were calculated based on the conversion constants of Brozek et al. (3): RF = ((4.57/body density) − 4.142) × 100.

Table 2

Absolute and Relative Strength Across Age (*M* ± SEM)

Variables	G1 ($n = 22$) ≤15.00 yrs	G2 ($n = 27$) 15.08–16.00 yrs	G3 ($n = 34$) 16.08–17.00 yrs	G4 ($n = 39$) ≥17.08 yrs	Total ($n = 122$)
Arm flexion					
$30° \cdot s^{-1}$(Nm)[a]	50.81 ± 2.54	60.98 ± 2.25	68.55 ± 2.01	70.99 ± 1.88	64.45 ± 1.49
Covaried for BW[a]	54.89 ± 2.13	61.79 ± 2.25	66.97 ± 2.00	69.50 ± 1.89	
Covaried for FFW[a,b]	56.90 ± 2.50	61.45 ± 2.18	64.93 ± 1.98	70.39 ± 1.82	
Covaried for FFW[a,c]	56.87 ± 2.52	61.67 ± 2.20	65.33 ± 1.99	69.90 ± 1.83	
Arm extension					
$30° \cdot s^{-1}$(Nm)[a]	90.43 ± 5.63	105.14 ± 6.06	120.64 ± 3.95	125.34 ± 4.52	113.08 ± 2.71
Covaried for BW[a]	96.97 ± 4.27	106.58 ± 3.80	118.45 ± 3.40	122.38 ± 3.17	
Covaried for FFW[a,b]	101.31 ± 4.01	105.94 ± 3.51	114.15 ± 3.19	124.11 ± 2.92	
Covaried for FFW[a,c]	100.93 ± 4.19	106.34 ± 3.67	115.17 ± 3.32	123.17 ± 3.06	
Arm flexion					
$180° \cdot s^{-1}$(Nm)[a]	42.27 ± 2.78	50.29 ± 3.17	58.02 ± 2.48	65.60 ± 2.63	55.76 ± 1.57
Covaried for BW[a]	44.75 ± 2.73	50.71 ± 2.43	57.10 ± 2.17	64.25 ± 2.02	
Covaried for FFW[a,b]	46.86 ± 2.63	50.43 ± 2.29	55.07 ± 2.09	65.03 ± 1.91	
Covaried for FFW[a,c]	46.65 ± 2.67	50.62 ± 2.33	55.51 ± 2.12	64.59 ± 1.95	

(cont.)

Table 2 (cont.)

Variables	G1 ($n = 22$) ≤15.00 yrs	G2 ($n = 27$) 15.08–16.00 yrs	G3 ($n = 34$) 16.08–17.00 yrs	G4 ($n = 39$) ≥17.08 yrs	Total ($n = 122$)
Arm extension					
$180° \cdot s^{-1}$(Nm)[a]	66.73 ± 3.55	82.72 ± 4.00	93.92 ± 2.70	95.15 ± 2.81	86.78 ± 1.84
Covaried for BW[a]	70.92 ± 2.70	83.53 ± 2.40	92.41 ± 2.14	93.20 ± 2.01	
Covaried for FFW[a,b]	73.44 ± 2.66	83.08 ± 2.32	89.78 ± 2.12	94.38 ± 1.94	
Covaried for FFW[a,c]	73.07 ± 2.82	83.31 ± 2.47	90.49 ± 2.22	93.81 ± 2.05	
Arm flexion					
$300° \cdot s^{-1}$(Nm)[a]	35.32 ± 2.71	46.90 ± 2.58	51.69 ± 1.98	54.38 ± 2.48	48.46 ± 1.36
Covaried for BW[a]	38.06 ± 2.31	47.09 ± 2.06	50.69 ± 1.83	53.02 ± 1.71	
Covaried for FFW[a,b]	39.80 ± 2.29	46.81 ± 2.01	48.90 ± 1.82	53.85 ± 1.67	
Covaried for FFW[a,c]	39.62 ± 2.36	46.97 ± 2.06	49.34 ± 1.86	53.44 ± 1.63	
Arm extension					
$300° \cdot s^{-1}$(Nm)[a]	61.90 ± 3.88	71.31 ± 3.59	81.10 ± 2.90	87.62 ± 2.90	77.41 ± 1.82
Covaried for BW[a]	66.62 ± 2.87	71.95 ± 2.55	79.79 ± 2.28	85.77 ± 2.13	
Covaried for FFW[a,b]	68.17 ± 2.79	71.53 ± 2.44	77.20 ± 2.21	86.88 ± 2.03	
Covaried for FFW[a,c]	67.88 ± 2.92	71.77 ± 2.12	77.85 ± 2.31	86.31 ± 2.12	

Covaried values are adjusted means ± SEM. [a]$p < 0.05$. [b]FFW calculated based on the age-specific conversion constants of Lohman (16). [c]FFW calculated based on the conversion constants of Brozek et al. (3).

Discussion

Few studies have provided normative data with regard to isokinetic flexion and extension strength at the shoulder joint (1, 2, 5, 12). Furthermore, only one of these studies (1) reported absolute peak torque values while the others presented correlations or ratio comparisons for agonist versus antagonist muscle groups (2, 12), dominant versus nondominant arms (5, 12), athletes versus nonathletes (5), or strength values relative to BW or FFW (2, 12). Alderink and Kuck (1) found that the peak torque values for arm flexion and extension at $300° \cdot s^{-1}$ for a sample that included both high school and college-age baseball pitchers were 38.24 and 78.51 Nm, respectively. These values represented 78.9 and 101.4% of the strength for the high school wrestlers in the present study. When strength was expressed relative to BW, however, the high school wrestlers were substantially stronger than the pitchers for both arm flexion (0.73 vs. 0.48 Nm/kg) and extension (1.17 vs. 0.99 Nm/kg). In addition, previous investigations (1, 12) have reported arm flexion/extension strength ratios ranging from 0.48 to 0.80. The corresponding value for the high school wrestlers in the present study was 0.63, which indicated some disagreement among these investigations. Although the reason for the discrepancies is unclear, Alderink and Kuck (1) have suggested that athletes such as pitchers may develop exceptionally strong extensors. This appears not to be the case, however, given the similarity in absolute peak torque values and 18% greater arm extension strength per unit of BW for the wrestlers in the present study compared to the baseball pitchers.

As indicated in Table 2, adjustment of the strength values for FFW calculated using either the conversion constants of Brozek et al. (3) or Lohman (16) had little effect on the group differences found in the present study. Post hoc analyses indicated that the only differences between the two approaches were for arm flexion and extension at $30° \cdot s^{-1}$ and arm flexion at $300° \cdot s^{-1}$, where the use of the conversion constants of Lohman (16) resulted in significant differences between G4 and G3 while the use of the constants of Brozek et al. (3) did not.

Typically, increases in muscular strength across age coincide with changes in BW and FFW. However, recent investigations have described an age effect for flexion and extension strength at the elbow and knee joints that could not be accounted for by changes in BW or FFW (10, 20). The results of the present investigation established that the age effect also occurred for flexion and extension at the shoulder joint. It has been suggested that the mechanism that underlies the age effect involves either neuromuscular factors or an increase in the contribution of muscle mass per unit of FFW (10, 20). The results of the present investigation, however, also suggested differences between muscle groups in the patterns of strength gains that were dependent upon the speed of muscular contraction. For example, the increase in strength covaried for FFW across age for forearm and leg measurements described previously by Housh et al. (10) were found only at 30 (forearm flexion and leg extension) and $180° \cdot s^{-1}$ (forearm flexion).

At the shoulder joint in the present investigation, however, strength relative to FFW increased with age for both flexion and extension at all three speeds of contraction (30, 180, and $300° \cdot s^{-1}$). These data support the hypothesis that fiber type distribution characteristics may influence the expression of strength across age (20). Given that the muscles within an individual can have substantially different percentages of fast and slow twitch fibers (7, 14, 17) and that force capabilities are in part dependent upon the twitch characteristics of the muscle fiber (6, 8, 22), the age effect may be evident at different speeds of contraction depending upon the fiber type distribution characteristics of the muscles involved. Further research is needed to determine whether changes in muscular strength across adolescence are influenced by an interaction between developmental processes and fiber type characteristics.

In summary, this investigation provided unique data regarding the shoulder strength characteristics of high school wrestlers and confirmed the occurrence of an age effect in the muscle groups associated with flexion and extension at the shoulder joint. The results of the present study, when considered in conjunction with previously reported data involving flexion and extension strength at the knee and elbow joints (10), also suggested differences between muscle groups in the patterns of strength gains across adolescence that were dependent upon the speed of muscular contraction and may have been influenced by fiber type distribution characteristics.

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