Residual Effects of Glenohumeral Range of Motion, Strength, and Humeral Retroversion on Prior Overhead Athletes After Cessation of Sport

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Background: Research has shown that repetitive stress from playing an overhead (OH) sport can cause musculoskeletal and osseous adaptations to occur on the dominant side. Additionally, there are limited data about the residual effects of these adaptations after the cessation of sports participation.

Purpose: To investigate the effects of prior participation in an OH sport versus not participating in an OH sport on glenohumeral range of motion (ROM), isometric strength, and humeral retroversion (HR).

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Forty-eight college-aged individuals participated. Participants were split into 2 groups: (1) individuals who previously participated in an OH sport (n = 20; age, 20.3 ± 1.1 years; height, 166.3 ± 15.27 cm; weight, 72.2 ± 13.5 kg) and (2) individuals who previously did not play an OH sport (n = 28; age, 20.6 ± 0.9 years; height, 168.8 ± 6.3 cm; weight, 68.1 ± 15.1 kg). After completing a health history questionnaire, the following were measured: side-to-side shoulder internal rotation (IR) and external rotation (ER) ROM via an inclinometer, isometric shoulder strength via a handheld dynamometer, and HR using an ultrasound imaging machine. A Mann-Whitney *U* test was used to determine group differences, and a Wilcoxon *t* test was used to analyze side-to-side differences within each group.

Results: The Mann-Whitney *U* test revealed a statistically significant group difference for dominant shoulder ER ROM ($U = 162.00$, $P = .014$). Specifically, the prior OH group had significantly more ER than the control group. Within the prior OH group, testing revealed that athletes had significantly more HR ($Z = -2.782$, $P = .005$), ER ROM ($Z = -1.979$, $P = .048$), and ER isometric strength ($Z = -2.763$, $P = .006$) on their dominant than nondominant shoulder and significantly less IR ROM ($Z = -3.099$, $P = .002$) on their dominant than nondominant shoulder.

Conclusion: Prior OH sports participation may have residual osseous and musculoskeletal effects that remain after cessation of the sport.

Keywords: humeral retroversion; isometric strength; range of motion

At birth, every individual has a certain degree of humeral retroversion (HR) that decreases as one ages.[7,10,14] This reduction in HR is typically complete by the age of puberty.[7,10,14] Recent literature has found that overhead (OH) athletes, specifically baseball players, have a slower loss of HR because of the constant external rotation (ER) position endured during the OH throwing motion.[15,34] Additionally, OH athletes typically develop a greater HR degree in their dominant arm than their nondominant arm.[4,11,15,26,30] This side-to-side difference in HR has also been associated with side-to-side differences in glenohumeral range of motion (ROM).[4,26] Other OH athletes, such as tennis, swimming, and handball athletes, have also documented musculoskeletal and osseous adaption owing to their sports participation.[1,8,24,30]

Glenohumeral ROM differences between the dominant and nondominant arm have been documented in OH athletes.[5,9,13] Specifically, OH athletes typically display a gain in ER and a loss of internal rotation (IR) in the dominant arm compared with the nondominant arm. The degree of ER gain in the dominant arm compared with the nondominant arm has been positively correlated with HR.[16,26] It was hypothesized that these musculoskeletal and osseous adaptations in OH athletes are advantageous

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for injury reduction. However, recent insight has speculated that there may be an optimal ROM and HR.[10,25] Increased dominant arm HR has been correlated with a reduced shoulder injury risk, but an increased elbow injury risk in baseball pitchers.[2,19] This increased risk of elbow injury is thought to be a result of the increased ER ROM.

OH athletes need adequate IR and ER strength to maintain proper glenohumeral stability. Altered IR and ER strength ratios have been associated with increased injury risk.[20,28,31-33] Additionally, it has been reported that those athletes with altered ROM, such as glenohumeral IR deficit, have lower strength ratios.[12] Controversially, some studies have found opposing results. Owen et al[22] found that increased strength was associated with decreased glenohumeral stability, and another study[3] found a positive relationship between HR and rotator cuff strength. Thus, it was hypothesized that the increase in rotator cuff strength is a compensatory mechanism to stabilize the humeral head within the glenoid fossa.[3,22] Therefore, further research is needed to explore the relationship between musculoskeletal and osseous adaptions with glenohumeral strength, as this relationship can have implications for rehabilitation protocols.

Current HR research has focused on currently active athletes, with minimal information on previously active or retired athletes. It is assumed that because the decreased HR is complete around puberty, the odds of an athlete's HR angle changing after puberty and/or after they have stopped playing is minimal.[7,23,34] Thus, if the musculoskeletal and osseous adaptations seen in active OH athletes remain constant after sports participation has ceased, then these residual adaptations may explain the causation of shoulder instability and/or other injuries that prior athletes endure in adulthood. Understanding the effects of playing OH sports in both active and retired athletes is valuable information. If research does find lingering musculoskeletal alterations in previously active OH athletes, this will further emphasize the need to decrease youth sport injury rates.

The purpose of this study was to (1) compare HR, glenohumeral ROM, and glenohumeral isometric strength in individuals who were previously an OH athlete and age-matched controls; (2) investigate the relationship between dominant glenohumeral ROM and isometric strength with dominant shoulder HR; and (3) investigate if previous years played is related to the degree of dominant shoulder HR. It was hypothesized that those who played OH sports would experience greater side-to-side differences and have a greater degree of HR than the age-matched controls. It was also hypothesized that HR would be positively correlated with years played, glenohumeral ER ROM, and isometric strength.

TABLE 1
Sports Participation History of the Prior Overhead Athletes (n = 20)

Sport	No. of Athletes
Baseball	4
Softball	2
Volleyball	4
Swimming	5
Tennis	3
Multiple sports[a]	2

[a]More than 1 of the listed overhead sports.

METHODS

The institutional review board of Auburn University reviewed and approved all testing procedures. Before any testing, all testing procedures were thoroughly explained to the participants and informed consent forms were signed. Inclusion criteria consisted of having no upper extremity injury within the past 6 months. A total of 48 college-aged individuals participated in this study. Of these participants, 20 (age, 20.3 ± 1.1 years; height, 166.3 ± 15.27 cm; weight, 72.2 ± 13.5 kg) were categorized as prior OH athletes (Table 1) and 28 (age, 20.6 ± 0.9 years; height, 168.8 ± 6.3 cm; weight, 68.1 ± 15.1 kg) were categorized as the controls.

Side-to-side glenohumeral ROM, isometric strength, and HR were measured for each participant. Upon completion of measurements, a short health history questionnaire was given to obtain prior athletic experience and years of playing experience. The health history was completed last to keep the investigator blind to limb dominance and athletic history until after measurements were taken.

Glenohumeral ROM

Side-to-side glenohumeral ROM measures were assessed using a digital inclinometer (Medline Industries) based on previously established standards.[6,21,27] The participant was supine on an athletic training table with the arm abducted and elbow flexed at 90°. A rolled towel was placed under the humerus for stabilization. For IR, the investigator (J.D.T.) placed one hand under the participant's scapula and passively rotated the arm inward until scapulothoracic movement was felt. The other hand was used to hold the digital inclinometer, which was placed just distal to the

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Ethical approval for this study was obtained from Auburn University (protocol No. 19-418 EP 1911).

TABLE 2
Descriptive Statistics Overall and by Group[a]

Variable	Overall (N = 48)	Prior Overhead Athletes (n = 20)	Controls (n = 28)
Humeral retroversion, deg			
Dominant shoulder	3.55 ± 9.55	1.4 ± 9.57	5.08 ± 9.40
Nondominant shoulder	6.88 ± 9.02	8.22 ± 7.88	5.92 ± 9.79
Internal rotation ROM, deg			
Dominant shoulder	43.69 ± 5.70	43.67 ± 6.88	43.70 ± 4.83
Nondominant shoulder	46.30 ± 5.09	47.52 ± 5.34	45.43 ± 4.80
External rotation ROM, deg			
Dominant shoulder	113.62 ± 13.94	119.20 ± 13.32	109.63 ± 13.19
Nondominant shoulder	109.63 ± 13.84	113.79 ± 12.37	106.66 ± 14.27
Internal rotation isometric strength, N/kg			
Dominant shoulder	10.91 ± 3.37	11.27 ± 3.22	10.65 ± 3.51
Nondominant shoulder	10.63 ± 3.72	11.16 ± 3.40	10.25 ± 3.95
External rotation isometric strength, N/kg			
Dominant shoulder	12.27 ± 3.92	12.87 ± 3.90	11.85 ± 3.94
Nondominant shoulder	11.65 ± 3.76	12.13 ± 3.55	11.31 ± 3.9
Years of playing experience	—	10.9 ± 3.8	—

[a]Data are reported as mean ± SD. deg, degree; N/kg, newtons per kilogram; ROM, range of motion.

radial and ulnar styloid on the posterior side for IR. ER was measured at the capsular firm end-feel with the digital inclinometer on the anterior side just distal to the radial and ulnar styloid. The investigator reported good to excellent intrarater reliability using the technique described above, with an intraclass correlation coefficient ($ICC_{(3,1)}$) of 0.80 to 0.98 for all shoulder ROM measurements.

Isometric Strength

Isometric strength was assessed with the participant in the same position as described above for ROM with a handheld dynamometer (Sakai Med). The dynamometer was placed just distal to the radial and ulnar styloid on the anterior side for IR and on the posterior side for ER. Participants were asked to perform a maximum isometric contraction against the investigator for 3 seconds for IR and ER. All measurements were normalized to body mass. The investigator (J.D.T.) reported good to excellent intrarater reliability using the technique described above, with an $ICC_{(3,1)}$ of 0.86 to 0.97 for all shoulder isometric strength measurements.

Humeral Retroversion

A NextGen LOGIQe Ultrasound (GE Healthcare) was used to assess HR, using previously established methods.[17,18,29,34] The participant was supine on an athletic training table with shoulder abducted and elbow flexed at 90°. One investigator held the ultrasound probe on the anterior side of the humeral head parallel to the plane of the floor, while the other investigator, using the ultrasound screen as a guide, passively rotated the arm until the apexes of the greater and lesser tubercles of the humerus were parallel to the horizontal plane. Once deemed parallel to the horizontal plane, the degree of retroversion was recorded using a digital inclinometer, with 90° being entirely internally rotated and –90° being completely externally rotated. A lesser degree angle is indicative of greater HR. All measurements were repeated for 3 trials, and the average of the 3 trials was used for analysis. The same investigator performed all measurements (J.D.T.).

Statistical Analysis

All data were nonnormally distributed; therefore, nonparametric testing was used. A Mann-Whitney *U* test was conducted to compare HR, ROM, and isometric strength between the prior OH athletes and the controls. Spearman rho correlation testing was used to investigate the relationship between dominant arm HR and ROM, isometric strength, and years of playing experience. Additionally, the Wilcoxon signed-rank test was used to compare the side-to-side differences in HR, ROM, and isometric strength between groups. Statistical significance was set a priori to $P < .05$ for all testing procedures.

RESULTS

Descriptive statistics can be found in Table 2. The Mann-Whitney *U* test revealed a statistically significant difference between the 2 groups for dominant shoulder ER ROM ($U = 162.00$, $P = .014$). Specifically, the prior OH group had significantly more ER than the control group. Furthermore, testing was also done to compare side-to-side differences within each group. The Wilcoxon signed-rank test revealed that the control group was significantly stronger on their dominant shoulder than their nondominant shoulder for both IR ($Z = -2.176$, $P = .030$) and ER ($Z = -2.985$, $P = .003$). For the prior OH group, testing revealed that athletes had significantly more HR ($Z = -2.782$, $P = .005$), ER ROM ($Z = -1.979$, $P = .048$), and ER isometric strength ($Z = -2.763$, $P = .006$) on their dominant than nondominant shoulder. Additionally, the prior OH group had significantly less IR ROM (Z =–3.099, P = .002) on their dominant than the nondominant shoulder.

Spearman rho correlation testing revealed a significant positive correlation for dominant shoulder IR ROM (r = 0.498, P = .026) and a negative correlation for dominant shoulder ER ROM (r =–0.642, P = .002) with dominant shoulder HR in the prior OH group. Specifically, increases in dominant shoulder HR were associated with decreases in dominant shoulder IR ROM and increases in dominant shoulder ER ROM in prior OH athletes. There were no significant correlations with dominant shoulder HR in the control group. There were no significant correlations with dominant shoulder HR and years of playing experience in either group.

DISCUSSION

The purpose of this paper was trifold: (1) compare HR, glenohumeral ROM, and glenohumeral isometric strength between individuals who were previously an OH athlete and age-matched controls; (2) investigate the relationship between dominant shoulder glenohumeral ROM and isometric strength with dominant shoulder HR; and (3) investigate if previous years played is correlated to the degree of dominant shoulder HR. Key findings of the current study include group differences for dominant shoulder ER ROM and side-to-side differences within the prior OH group and not within the control group.

Prior literature has documented numerous occasions of current OH athletes undergoing musculoskeletal and osseous adaptations, changes explicitly in glenohumeral ROM and HR.[4,8,11] However, there is limited research documenting the residual effects of these changes after cessation of sports. The finding of increased dominant shoulder ER ROM in the prior OH group compared with the control group is interesting, as it is one of the first to identify that those musculoskeletal adaptions documented in current OH athletes may remain even after sports participation has stopped. These results cannot be extrapolated to all populations, as the age group used in the current study was a small range and more testing will be required to extrapolate results to other age groups. Furthermore, side-to-side differences within each group were also found. The control group had significantly greater isometric strength in both IR and ER in their dominant than nondominant shoulder. However, this finding was not unexpected, as individuals, irrespective of athletic experience, are typically stronger on their dominant than nondominant side.

Side-to-side differences such as increased ER ROM, decreased IR ROM, and increased degree of HR in the dominant shoulder compared with nondominant shoulder have been documented in current OH athletes.[4,5,13] These adaptations, to a certain degree, have been identified as both advantageous and harmful to the athlete. The results of this study agree with prior literature, documenting similar side-to-side differences in the prior OH group.[4,5,13] These findings may help clinicians better understand glenohumeral injuries endured later in life, after sport activity. Further research needs to be done if the residual adaptions found in the collegiate-aged population continue or if the adaptions return to what would be expected in a non-OH athletic population later in life. One may want to identify prior OH athletic involvement when assessing injuries even if the athlete is no longer actively participating in sports.

The prior OH group demonstrated a significant correlation between the degree of HR and glenohumeral ROM. Specifically, increases in dominant shoulder HR were associated with decreases in dominant shoulder IR ROM and increased dominant shoulder ER ROM in prior OH athletes. These results add to the current body of literature indicating that HR may have a relationship with glenohumeral ROM. The shift in glenohumeral ROM typically presented in OH athletes—decreased IR and increased ER—may partially be explained by HR. However, years of playing experience was not significantly correlated with HR, glenohumeral ROM, or isometric strength. The lack of significance was not anticipated but may result from the population used.

The population used was a limitation, and future studies should include an adult population to see if the present relationships hold in other populations. Additionally, another limitation was only assessing college-aged individuals who stopped playing sports in high school. Although the current population had stopped playing sports within roughly the last 5 years of the study, the results still add important information to the literature. Using a mix of sports is another limitation that needs to be noted. Although all sports are considered OH sports, each makes slightly different demands and could influence the musculature variably. Thus, future research should consider investigating each sport separately. These results lay an important foundation, and the significant differences warrant further research on the topic in older populations. Future investigations should be conducted on prior athletes who have ceased playing for 10 years, 15 years, 20 years, and so on, to give a more accurate view of musculoskeletal adaptations.

CONCLUSION

Musculoskeletal adaptations in current OH athletes may have their benefits, but there is an optimal range, as too much or too little remolding places an athlete at an increased risk for injury. Additionally, the results of the current study found that some musculoskeletal adaptions remain in OH athletes even after they stop playing. Adaptations endured while participating in OH sports may impact one's injury risk later in life because of residual musculoskeletal adaptions, thus providing important information and warranting further research into how musculature adaptions in current athletes manifest postcessation of sporting activity.

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