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Humeral Retroversion and Participation Age in Professional Baseball Pitchers by Geographic Region

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Context: Baseball is played around the world, including in North America and Latin America. The repetitive and stressful act of throwing can lead to adaptations such as increased humeral retroversion (HR) in the throwing arm. This adaptation is often considered beneficial as it allows more glenohumeral external rotation during the cocking phase of pitching without soft tissue stretching. Therefore, it is speculated that throwing should be started at a young age to capitalize on this adaptation. Interestingly, athletes in different geographic regions of the world often begin organized baseball at different ages. However, range of motion (ROM), HR, and the starting age of baseball have never been examined based on geographic region.

Objective: To determine if ROM, HR, and the starting age of baseball players differed between professional baseball pitchers from North America and Latin America.

Design: Cross-sectional study.

Setting: Clinical setting.

Patients or Other Participants: Thirty professional pitchers (North American = 19, Latin American = 11) with no current injury or surgery in the previous 6 months.

Main Outcome Measure(s): Both ROM and HR were measured in the dominant and nondominant shoulder of each participant. The starting age for baseball was self-reported.

Results: The Latin American group had more dominant-arm HR (8.7°; $P = .034$), more nondominant-arm external rotation (5.3°; $P = .049$), and a trend toward more nondominant-arm HR (6.5°; $P = .058$), yet they started playing baseball at a later age (by 3.7 years; $P = .021$) compared with the North American group.

Conclusions: Latin American players had greater HR but started playing baseball at an older age. These findings contradict current thinking that HR would be more pronounced if baseball was started at a younger age. Additional research is required to better understand HR and the genetic, environmental, and nutritional factors that contribute to its development.

Key Words: throwing athletes, North American athletes, Latin American athletes

Key Points

- Latin American players had greater humeral retroversion, despite starting to play baseball at an older age.
- These findings contradict current thinking that humeral retroversion would be more pronounced if baseball was started at a younger age.

Baseball is played in 141 countries around the world, 17 of which are represented in Major League Baseball, according to the World Baseball Softball Confederation (https://www.wbsc.org). For children and adolescents, baseball can serve as a great form of physical activity to maintain long-term physical and mental health. Unfortunately, the repetitive and stressful act of throwing has been shown, in some cases, to lead to significant shoulder and elbow injuries.[1–7] Clinical and tissue-specific adaptations can occur before the actual injury and may be either protective against or predictive of injury.[8–17] The most common clinical adaptation is a decrease in internal rotation (IR) and an increase in external rotation (ER) of the dominant arm compared with the nondominant arm. Although measuring this range of motion (ROM) clinically is important, it has also been demonstrated that bony and soft tissue adaptations cause this altered ROM. The bony adaptation is referred to as *humeral retroversion* (HR), which is commonly increased in the dominant arm versus the nondominant arm.[15,18–23]

The increased HR observed in the dominant arm of baseball players is often considered a healthy adaptation to the stress of throwing and occurs before skeletal maturity.[19,24–26] Increased HR is thought to allow the thrower to gain additional ER during the late cocking phase of throwing without creating additional stress on the soft tissue structures surrounding the shoulder (eg, anterior capsule, labrum) and therefore may protect against injury. However, the implications of HR are still unclear. Previous researchers found that decreased HR was associated with shoulder injury in pitchers[11,21] and that pitchers with increased HR may be at lower risk for shoulder injury but increased risk for elbow injury.[11,19,26] Others[20] noted more elbow injuries in players with a greater HR limb difference.

Interestingly, the natural development of HR in the general population has only been examined in 1 study using dried bone specimens.[25] The investigators determined that a large amount of HR is present at birth and that a normal derotation process occurs through development, thereby reducing the amount of retroversion. This process occurs

Table 1. North American Countries of Origin

Country of Origin	n
Canada	2
United States	17

Table 2. Latin American Countries of Origin

Country of Origin	n
Brazil	1
Dominican Republic	6
Venezuela	4

most rapidly up to the age of 8 years and typically approaches permanent values by age 16. For throwing athletes, the developmental process and mechanisms underlying HR are not known; however, asymmetry has been consistently shown in the amount of retroversion between the dominant and nondominant arms, with the dominant arm demonstrating greater HR. This is postulated to be an adaptive response that results from the stress of throwing at an early age, before growth-plate closure effectively halts the derotation process. Therefore, the general premise is that HR is age dependent and that throwing should be initiated at a young age to capitalize on this adaptation.

Although throwing athletes have consistently displayed increased retroversion in the dominant arm, the magnitude of these differences varies markedly. Previous authors[18] observed bilateral differences in HR ranging from 0° to 40°. This may suggest that other factors are responsible for the development of HR in baseball players. These factors may include the starting age of throwing, sport specialization, throwing history and mechanics, nutrition,[27,28] ethnicity,[24] and inherent genetic variations.[29] Wilhelm et al[30] documented a bimodal distribution of the player's age of specialization in professional baseball players. They postulated that the factors contributing to this distribution might be geographic and cultural. Different geographic regions of the world often institute organized baseball at different ages, which provides an opportunity to examine if the initiation age of baseball contributes to the development of HR.

The objective of our study was to determine if ROM (IR and ER), HR, and the starting age of baseball differed between professional baseball pitchers from North America and those from Latin America. We hypothesized that North American pitchers would have greater HR and ER and less IR than Latin American pitchers as a result of starting to play baseball at a younger age.

METHODS

Participants and Study Design

After receiving an explanation of the study, 30 professional baseball pitchers, 19 from North America (age = 22.7 ± 3.8 years, mass = 95.7 ± 8.4 kg, height = 191.7 ± 5.7 cm) and 11 from Latin America (age = 22.2 ± 3.1 years, height = 189.1 ± 2.9 cm, mass = 96.6 ± 9.8 kg), signed informed consent forms for this institutional review board–approved investigation. Exclusion criteria were a current injury or surgery in the previous 6 months. Recruits were enrolled during spring training for 1 organization. North America consisted of Canada and the United States (including all territories; Table 1). Latin America consisted of all the countries of Central and South America, Mexico, and the Caribbean (Table 2). The baseball starting age was self-reported using a questionnaire provided in both English and Spanish. The specific question asked was, "What age did you start playing baseball?"

Glenohumeral Internal and External Rotation

Glenohumeral IR and ER were measured using a digital inclinometer (Saunders Group, Inc, Chaska, MN) as previously described and having demonstrated excellent reliability by a clinician with more than 15 years of experience.[31] Briefly, the participant was positioned supine, with the arm at 90° of shoulder abduction. The forearm was rotated for IR and ER as the scapula was manually stabilized by the examiner; then a digital inclinometer was placed on the ulnar side of the forearm to measure the angles of IR and ER. Both the dominant and nondominant arms were measured.

Humeral Retroversion

The HR was assessed using diagnostic ultrasound (Titan Diagnostic Ultrasound Scanner; SonoSite, Inc, Bothell, WA). The measurement for HR was made using standard procedures (repeated 3 times and averaged) that have demonstrated validity and reliability.[32,33] A clinician with 1 decade of experience in this technique conducted the HR assessment. Briefly, the participant was positioned supine, with the arm abducted to 90° and elbow flexed to 90°. The examiner positioned a 15-MHz linear ultrasound transducer on the anterior shoulder, perpendicular to the long axis of the humerus in the frontal plane. The humerus was then manually rotated to center the bicipital groove in the ultrasound image so that a line connecting the greater and lesser tubercles was parallel to the horizontal plane. A second examiner placed a digital inclinometer on the ulnar side of the forearm to measure the *forearm inclination angle*, which defines the amount of HR. A position of neutral glenohumeral rotation was reported as a value of zero; a forearm position in the direction of IR was represented by a negative value and a forearm position in the direction of ER was represented by a positive value. Both the dominant and nondominant arms were measured.

Statistical Analysis

Geographic region (North America, Latin America) was defined as the independent variable. We performed separate independent-samples *t* tests to compare IR, ER, and HR in the dominant and nondominant arms and the starting age of playing baseball between North American and Latin American baseball pitchers. Significance was set at $P < .05$.

RESULTS

No differences were observed in IR or ER ROM in the dominant arm of the North American group compared with the Latin American group. In the nondominant arm, ER ROM was larger in the Latin American group (5.3°; $P =$

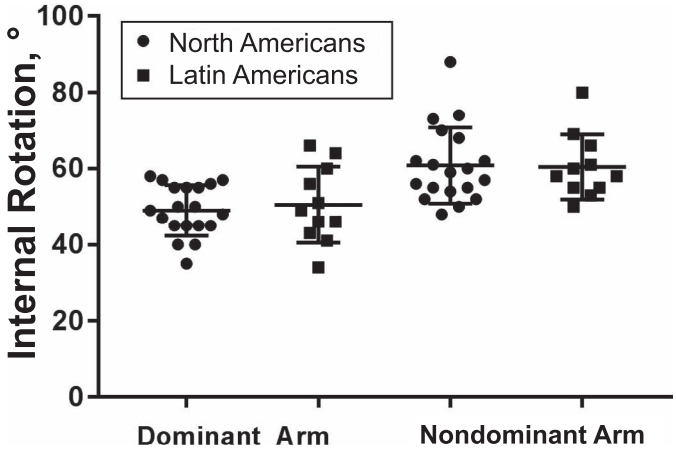

Figure 1. No difference in internal-rotation range of motion was observed between North American and Latin American baseball pitchers.

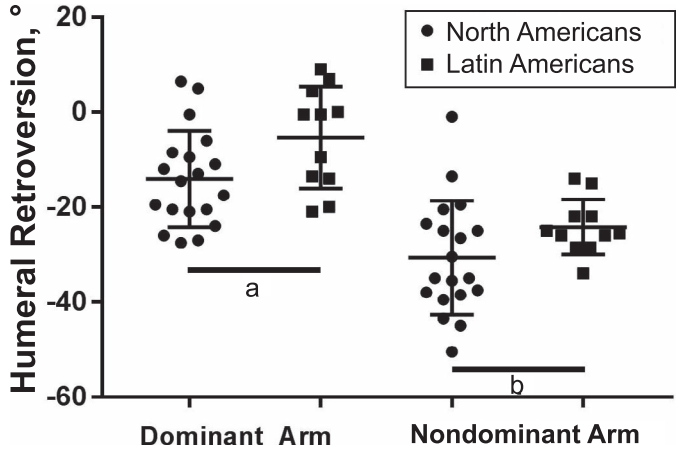

Figure 3. Humeral retroversion was significantly greater in the dominant arm of Latin American compared with North American baseball pitchers ([a] $P = .034$). A trend ([b] $P = .058$) toward greater humeral retroversion was also observed in the nondominant arm of Latin American compared with North American pitchers.

.049; 95% confidence interval [CI] = 0.03, 10.6) than the North American group (Figures 1 and 2). In addition, the Latin American group had more dominant-arm HR (8.7°; 95% CI = –16.8°, –0.7°; $P = .034$) compared with the North American group (Figure 3). No group differences were present for nondominant-arm HR (6.5°; 95% CI = –14.4°, 1.5°; $P = .058$); however, a trend toward increased HR for the Latin American group was observed. Lastly, the Latin American group (mean age = 9.1 ± 4.5 years) started playing baseball at a later age (by 3.7 years; 95% CI = 1.5°, 6.0°; $P = .021$) compared with the North American group (5.4 ± 1.4 years; Figure 4).

DISCUSSION

Baseball pitchers regularly present with increased HR in their dominant arm, which is likely an adaptation resulting from the repetitive stress of throwing.[15,18–23,26,32,33] It has been suggested that HR is age dependent and therefore throwing before skeletal maturity may be beneficial in optimizing this adaptation. Theoretically, it can provide protection from future soft tissue injury by increasing maximal ER through a bony mechanism and minimizing soft tissue strain. However, the mechanisms governing this adaptation in baseball players are currently unknown. Interestingly, different geographic regions of the world often institute organized baseball at different ages, providing an opportunity to examine if the starting age of baseball contributes to the development of HR. To our knowledge, we are the first to examine if ROM (IR and ER), HR, and the starting age of baseball differed between professional baseball pitchers from North America and Latin America.

Dominant-arm ROM (IR and ER) was not different between North American and Latin American players. However, Latin American players had more HR in their dominant arms than North American players. This may suggest that the North American players, despite having less HR, had ROM similar to that of Latin American players (measured clinically), which may result from soft tissue (eg, anterior capsule) stretching and not underlying changes in the bone. Previous researchers[18] demonstrated the importance of differentiating between bony and soft tissue adaptations of the shoulder and observed that when correcting for bony changes (ie, HR), a loss of ER was actually present in baseball pitchers. Alternatively, the

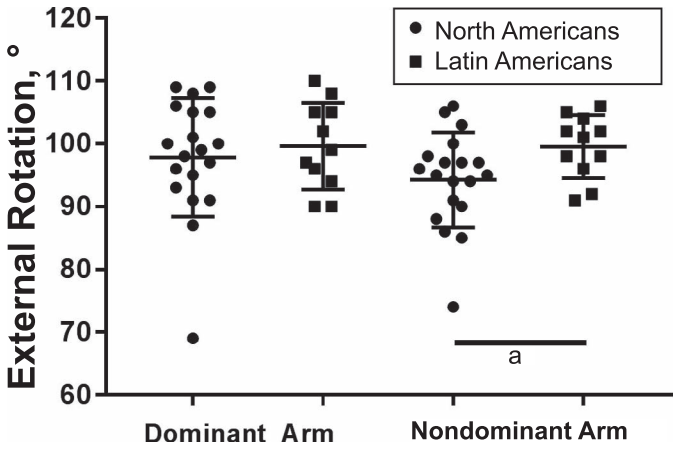

Figure 2. No difference in dominant-arm external-rotation range of motion was shown between North American and Latin American baseball pitchers. Increased external-rotation range of motion was present in the nondominant arm of Latin American pitchers compared with North American pitchers ([a] $P = .049$).

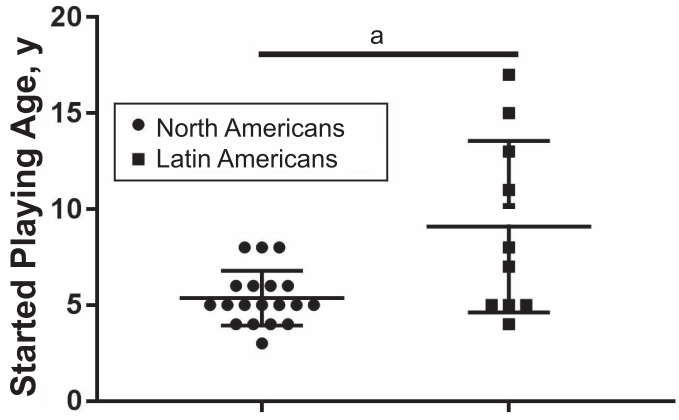

Figure 4. The average starting age of North American pitchers was younger than Latin American pitchers ([a] $P = .021$).

Latin American players may have had greater soft tissue restriction (eg, latissimus dorsi or teres major tightness) than the North American players. With increased HR, the latissimus dorsi and the teres minor, which insert on the anterior portion of the humerus, distal to the humeral head and growth plate, can be prone to injury in baseball pitchers due to increased passive tension or elongation during the late cocking phase of throwing.[7] Unfortunately, the implications of differences in HR are still unclear. Investigators have indicated that decreased HR was associated with shoulder injury in pitchers[11,21] and that pitchers with increased HR may be at less risk for shoulder injury but increased risk for elbow injury.[11,19,26] Others[20] have found more elbow injuries in players with a greater HR limb difference.

Latin American players had increased ER and HR in the nondominant arm compared with North American players. For Latin American players, the findings in the nondominant arm (increased ER and HR) are related and may be considered a genetic (and systemic) control independent of the stress of throwing and based primarily on bony changes. In this case, the amount of HR could be a result of genetic or nutritional differences (or both). The genetic differences include the inherent amount of retroversion at birth and the rate of derotation during development. Edelson[24] found that different ethnic groups did not derotate the same amount through development and into adulthood. It is possible that Latin American players either inherently have a larger amount of HR at birth or derotate at a slower rate than North American players.

Nutrition is also an important factor to consider when evaluating HR, as the growth and development of bone are affected by nutrition, particularly calcium, vitamin D, and protein intake, as well as hormone levels, which also play a role in prenatal development.[28] Differences in prenatal and early childhood nutrition between North American and Latin American players could be factors leading to differences in bone development. However, additional research is needed to identify and distinguish these genetic and nutritional differences.

Based on these findings and the current thinking about HR, we would expect that Latin American players also started playing baseball at a younger age. Yet the Latin American players did not start playing baseball until later in their youth, at an average age of 9 years, whereas the average age for North American players starting baseball was 5 years. This is not completely surprising and is consistent with our original hypothesis, as organized baseball has existed for a longer time in North America, with youth players having access to leagues and baseball academies at very young ages. However, the findings regarding decreased HR in North American players were contrary to our hypothesis and surprising given the current belief that throwing at an earlier age, before skeletal maturity, may lead to more HR. These results suggest that the development of HR is not age dependent, and other mechanisms may be involved in the development process, including the possibility of genetic and nutritional differences, as described earlier, or other environmental factors. The environmental factors contributing to adaptive HR primarily include the varied muscular forces acting on the humerus during growth. One possibility is that the greater HR in the Latin American players may be a result of this secondary adaptive retroversion occurring independent of baseball and instead from cultural and regional differences in activities. It should be noted that our survey did not distinguish between organized baseball and recreational baseball, which may be a limitation.

In conclusion, Latin American players presented with greater HR in the dominant arm compared with North American players. This bony adaptation is considered beneficial as it allows more glenohumeral ER during the cocking phase of the pitching motion without soft tissue stretching. Latin American players also started playing baseball at an older age, which contradicts the current thinking that HR would be more pronounced if baseball was initiated at a younger age. Additional research is required to better understand HR and the genetic, environmental, and nutritional factors that contribute to its development.

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