Asymmetric Hip Rotation in Professional Baseball Pitchers

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Background: There is a renewed interest in examining the association between hip range of motion and injury in athletes, and the data on baseball players are conflicting. Understanding whether asymmetrical hip rotation is a normal adaptation or a risk factor for injury will help therapists, trainers, and physicians develop rehabilitation programs to improve kinetic energy transfer and prevent injury. As our knowledge of hip pathology among baseball pitchers improves, establishing baselines for hip motion is critical in the further assessment of injury.

Hypothesis: Because of the repetitive nature of throwing sports and the adaptive changes documented in the shoulder, elite baseball pitchers would have characteristic patterns of hip internal and external rotations on their dominant throwing side (stance) and their nondominant side (stride) in extension.

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

Methods: Computer software was used to measure passive internal and external rotations on digital photographs of 111 professional baseball pitchers.

Results: In right-handed pitchers, there was significantly more internal rotation in the stance hip than the stride hip ($32.2° \pm 8.2°$ vs $30.8° \pm 8.4°$; $P = .0349$) and significantly more external rotation in the stride hip than the stance hip ($36.3° \pm 7.7°$ vs $30.8° \pm 9.7°$; $P < .0001$). While the mean difference in external rotation was 4.7°, 32% of the subjects had a >10° increase in external rotation on the stride hip relative to the stance hip. This population was statistically different from the remaining group for older age ($P = .0053$), lower body mass index ($P = .0379$), and more years in professional baseball ($P = .0328$). In the smaller number of left-handed pitchers, side-to-side differences in hip rotation were found but were not statistically significant.

Conclusion: Pitchers showed more internal rotation on their stance hip and more external rotation on their stride hip. Although the mean differences are small, there is a subset of pitchers with defined characteristics in whom larger differences exist.

Keywords: hip rotation; baseball pitchers

Baseball pitching is a primarily unidirectional activity, placing high impact and high repetition loads on one extremity in ways very different to its counterpart. Numerous studies have examined the impact of these asymmetric loads on the joints of the upper extremity.[6,9,10,13,17] These studies have shown that the repetitive stress of throwing results in numerous structural changes in the glenohumeral joint, including increased external rotation (ER) of the shoulder, increased retroversion of the glenoid and proximal humerus, and contracture of the posterior soft tissues.[1,2,5,8] Some of these adaptive changes may lead to increased performance in overhead athletes, while others may predispose to injury.[1,5,18] Clearly, different patterns and magnitudes of loading are imposed on the dominant and nondominant upper extremities during pitching.[5,6,8-10] Lower extremities are also subjected to repetitive asymmetric forces; however, joint motion in the lower extremity has not been studied with the same vigor as that of the upper extremity. A previous study by Ellenbecker et al[7] reported on the descriptive profile of active hip rotation in various throwers and concluded that there were no significant changes in rotation between limbs. They also noted that compared with tennis players, baseball players had significantly less motion, suggesting that this may be a study population with altered motion. As our knowledge of problems such as femoroacetabular impingement, sports hernias, and groin injuries improves, establishing "normal" baselines for baseball pitchers' hip motion is important in evaluating hip injuries.

Hip motion is an essential component of pitching as the kinetic energy produced by hip and pelvic motion directly affects ball velocity during the throwing action. Pitchers have been shown to have decreased hip abduction strength and hip internal rotation (IR) in their dominant (stance) leg compared with position players.[11] Abnormal hip motion can lead to alterations in the kinetic chain causing increased force through the shoulder and decreased velocity.[11,16] This could lead to both upper and lower extremity injuries. While the

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TABLE 1
Demographic Data on Pitchers Participating in the Study[a]

	Right-Handed Pitchers (n = 77)	Left-Handed Pitchers (n = 34)	All Pitchers (n = 111)
Age, y	24.2 ± 4.8	23.4 ± 3.9	23.9 ± 4.6
Height, in	74.0 ± 2.1	73.5 ± 2.4	73.8 ± 2.2
Weight, lb	200.0 ± 20.1	191.0 ± 17.5	197.1 ± 19.7

[a]Values are expressed as mean ± standard deviation.

importance of hip motion in pitching has been established, there are few studies reporting the range of axial rotation of the hip in baseball players and the relative magnitudes of IR and ER of the dominant and nondominant extremities.

During our routine preseason screening of major and minor league baseball players, we have noticed an apparent asymmetry of hip rotation between pitchers when tested passively. Therefore, we undertook this study to determine whether there are characteristic differences in hip rotation and total motion in elite baseball pitchers and thus quantify these data in defining normative ranges of motion for potential injury prevention programs.

MATERIALS AND METHODS

Various studies refer to the "dominant" and "nondominant" hips or to "stance" and "stride" hips. A right-handed pitcher (RHP) will start his delivery with his right side back and use this as his "stance" side. He will then vault forward over this with his left "stride" leg, reaching forward toward home plate. Therefore, for an RHP, we defined the left hip as the stride hip and the right hip as the stance hip. For a left-handed pitcher (LHP), the left hip is the stance hip and the right is the stride side.

A total of 112 professional baseball pitchers volunteered to participate in this study. The Institutional Review Board of the Houston Methodist Hospital in Houston, Texas, USA, approved this study. All minor and major league pitchers playing for the Houston Astros Baseball Club from 2008 to 2010 were selected during the start of their spring training program prior to any stretching or warm-up program. The only exclusion criterion was ongoing treatment for hip pain or hip surgery within the past year. One player was excluded because of recent hip arthroscopy, leaving 111 pitchers. Each player had bilateral passive IR and ER measured in the training room. Players' demographic information was also gathered, including age, height, and weight. Additional information regarding the players' side of throwing and batting dominance was also obtained from team records. Pitchers were then grouped according to handedness. There were no significant demographic differences between the groups (Table 1).

Measurement Technique

Subjects were placed in a prone position midline on a treatment table in the training room and positioned with the hip to be examined in 0° of extension, neutral abduction/adduction, and 90° of knee flexion. A single examiner performed all examinations while digital photographs were taken. The examiner placed 1 hand on the pelvis to stabilize and detect pelvic rotation and 1 hand on the distal tibia while standing to the side of the player. The contralateral leg was placed at 0° abduction/adduction and the knee in full extension. Neutral abduction/adduction was defined as the midpoint of the examining table in line with the camera. The examiner then maximally externally rotated and internally rotated the hip (passive range of motion). The examiner determined maximal rotation when there was an anatomic block prior to pelvic rotation or elevation (ie, as far as the hip could be rotated without the pelvis lifting off the examining table). When the hip was at maximal rotation, a standardized digital photograph was taken using a digital single-lens reflex camera at a distance of 6 feet (1.83 m). The camera was mounted on a tripod at the level of the treatment table in line with the center of the table and the center of neutral abduction/adduction of the player. This protocol has been published previously by Ellenbecker et al.[7] This was done for both the right and left hips for all subjects. Five subjects were randomly selected to have hip rotations done at different times to check for intraobserver reliability.

The digital photographs were loaded onto a computer, and rotation was measured using a commercially available screen protractor software program (version 4.0; Iconico Inc, New York, New York, USA) by 1 examiner (Figure 1). The measurements were taken from vertical to lower limb rotation based from tibial tubercle to the center point between the medial and lateral malleolus. The ranges of motion of each player's right and left hips were measured in terms of IR and ER from neutral. The total rotational motion of the hip was also calculated from the sum of the values of IR and ER. Differences between the motion parameters of the stance and stride hips were evaluated statistically using the Student t test, with a threshold for significance set at $P = .05$. These comparisons were made using the data of all pitchers combined together and for RHPs and LHPs evaluated separately.

RESULTS

Combined Pitcher Profile

The mean IR of the stance hip was 32.6° ± 8.7°, and the mean ER was 32.0° ± 8.5°. The mean total arc of motion of the stance hip was 64.7° ± 11.4°. The mean IR of the stride hip was 31.9° ± 7.0°, and the mean ER was 35.5° ± 9.8°. The mean total arc of motion of the stride hip was 67.4° ± 11.7°.

Right-Handed Pitchers

The mean IR of the stance hip was 32.2° ± 8.2°, and the mean ER of the stance hip was 30.8° ± 9.7°. The mean total arc of motion was 62.9° ± 11.9°. The mean IR of the stride hip was 30.8° ± 8.4°. The mean ER of the stride hip was

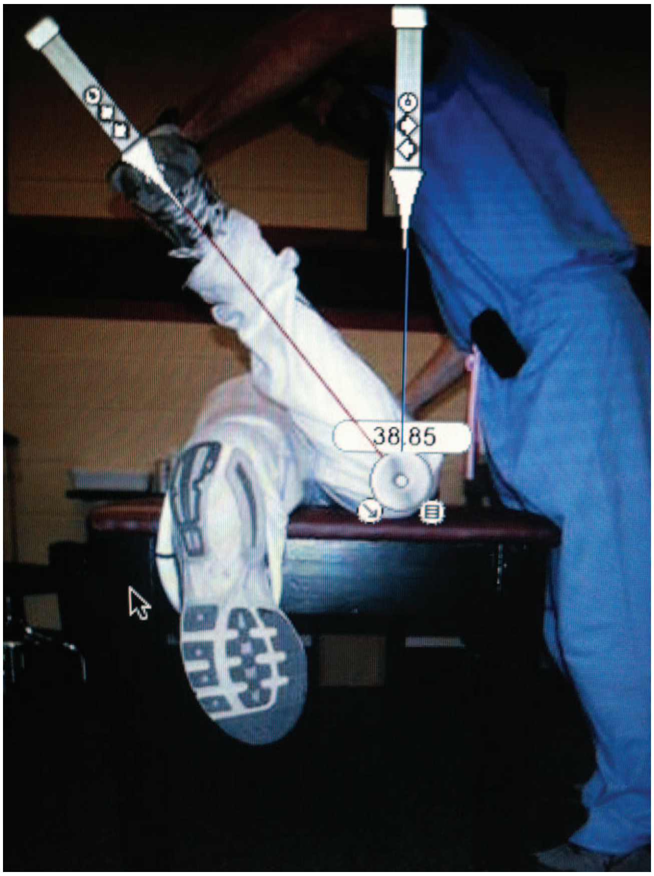

Figure 1. Screen image of the computer software used to measure rotation on the standardized digital photographs.

36.3° ± 7.7°. The mean total arc of motion of the stride hip was 67.1° ± 10.5°.

Left-Handed Pitchers

The mean IR of the stance hip was 34.4° ± 9.0°. The mean ER of the stance hip was 35.9° ± 7.6°. The mean total arc of motion for the stance hip was 70.4° ± 9.6°. The mean IR of the stride hip was 32.8° ± 6.0°. The mean ER of the stride hip was 36.2° ± 11.1°. The mean total arc of motion of the stride hip was 69.0° ± 12.0°.

Comparative Analysis Results

The combined results showed that the difference in rotation between stance and stride hips was not statistically significant (32.6° ± 8.7° vs 31.9° ± 7.0°; $P = .2455$); the stance hip ER, however, was statistically significantly less than the stride hip rotation (32.0° ± 8.5° vs 35.5° ± 9.8°; $P = .0011$) (Figure 2, A and B). The total arc of motion was statistically significantly greater in the stride hip compared with the stance hip (64.1° ± 11.4° vs 66.8° ± 11.7°; $P = .0110$).

In RHPs (n = 77), the stance hip had statistically significantly more IR than the stride hip (32.2° ± 8.2° vs 30.8° ± 8.4°; $P = .0349$). The stride hip had statistically significantly more ER than the stance hip (36.3° ± 7.7° vs 30.8° ± 9.7°; $P < .0001$). While the average difference was 4.7°, 32% (25/77) had a >10° increase in ER on their stride leg compared with their stance leg (Figure 3). On further analysis of this subgroup, these 25 players were unique compared with the remaining 52 in terms of age, body mass index, and professional baseball experience. These players were older (26.7 ± 4.9 vs 23.4 ± 4.75 years), had lower body mass indices (25.2 ± 1.7 vs 26.14 ± 1.9 kg/m^2), and spent more years in professional baseball (2.5 ± 4.2 vs 0.71 ± 2.8) (Table 2). A larger arc of rotation was seen in the stride hip than the stance hip (67.1° ± 10.5° vs 62.9° ± 11.9°; $P < .0002$).

In the small number of LHPs (n = 34), the differences in rotation did not meet statistical significance because of lack of statistical power. The stance hip did not have statistically significantly more IR than the stride hip (34.4° ± 9.0° vs 32.8° ± 6.0°; $P = .1152$), and the stride hip did not have statistically significantly more ER than the stance hip (36.2° ± 11.1° vs 35.9° ± 7.6°; $P = .4549$). There was no statistically significant difference seen in the total rotation arc of the stance and stride hips (70.4° ± 9.6° vs 69.0° ± 12.0°; $P = .2314$).

Test-Retest Reliability Results

Thirty measurements of hip range of motion (ROM) were prepared on 2 occasions on the same 5 subjects. The overall correlation between the 30 repeated measurements (test-retest) was 0.9667 ($P < .0001$). In comparing the test-retest values, the reproducibility of the measured (ROM) values corresponds to 3% to 13% of the mean ROM of the 2 repeated measurements. The mean difference in the repeated measurements was 4.60° ± 3.74°. Statistical power calculations show that the sample size needed to differentiate between 2 groups of players is 54 per group to detect an underlying difference of 2°, 24 per group for 3°, and 14 per group for 4°.

DISCUSSION

The throwing motion is a very complex action that begins with the energy generated through the lower extremity. This pattern of forcible IR during wind-up with concomitant stride limb ER such that the toes point toward the plate during delivery indicates the potential for biomechanical asymmetry. Because of the repetitive nature of throwing sports and the adaptive changes documented in the shoulder, this study was performed to examine the hypothesis that characteristic asymmetrical patterns of ER and IR of the hips would manifest in elite baseball pitchers. For one, this study helps provide normative data for hip range of motion in professional pitchers. Second, this study shows that there appears to be some changes in the hip rotation analogous to those seen in the glenohumeral joint. At least for RHP, the stance hip showed increased IR while the stride hip showed increased ER. It is interesting to note that 32% of these pitchers had more than a 10° side-to-side difference in their ER. Not every pitcher had large

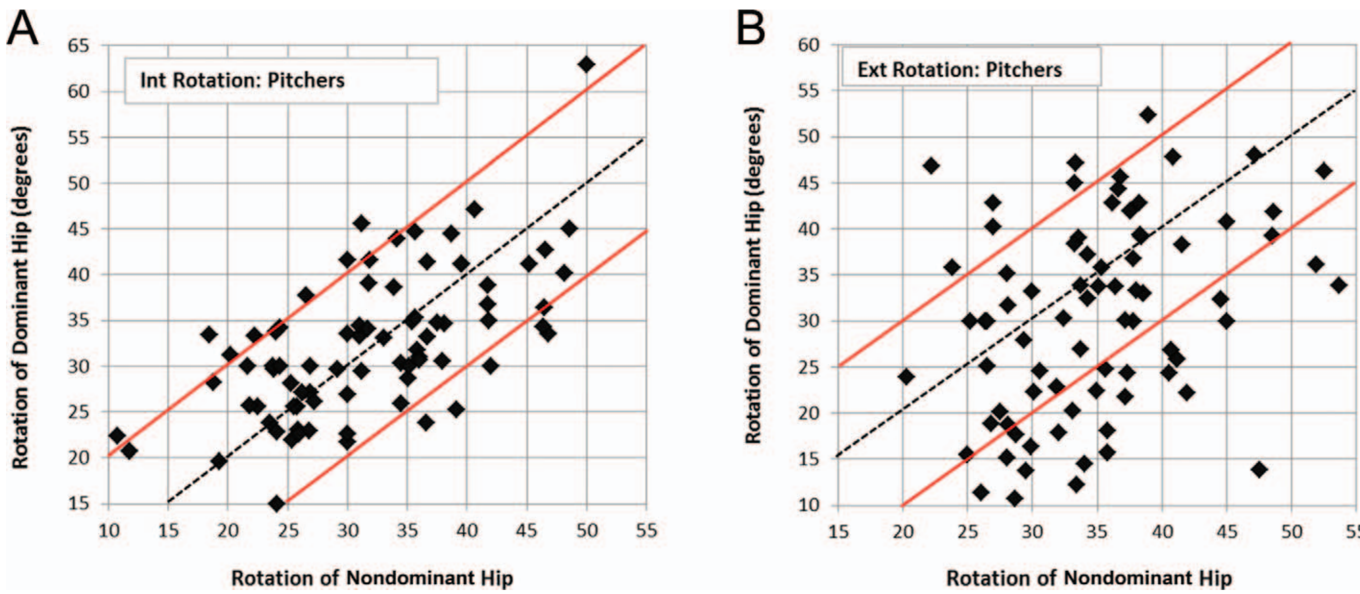

Figure 2. Graphical presentation of the rotation data of the dominant (stance) hip plotted against the nondominant (stride) hip combined for all pitchers: (A) internal rotation and (B) external rotation.

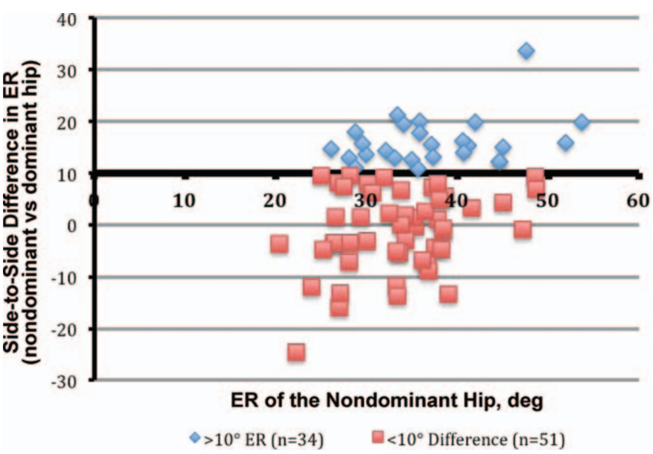

Figure 3. External rotation in the dominant versus nondominant hip for right-handed pitchers. Patients with <10° side-to-side difference for both internal and external rotation (red squares) are plotted against the subset of unique patients for body mass index, age, and professional pitching experience with >10° of external rotation in the nondominant hip (blue diamonds).

TABLE 2
Analysis of Right-Handed Pitchers With Mild and Severe Stride Hip External Rotation[a]

	Stride Hip, Right-Handed Pitchers	
	ER <10° (n = 51)	ER >10° (n = 26)
Age, y	23.4 ± 4.8	26.7 ± 4.9
BMI, kg/m^2	26.1 ± 1.9	25.2 ± 1.7
Professional baseball experience, y	0.71 ± 2.8	2.5 ± 4.2

[a]Values are expressed as mean ± standard deviation. BMI, body mass index; ER, external rotation.

side-to-side differences in their ER. For most, it was fairly symmetrical, which is why the observed mean difference was only about 5°; although statistically significant, this is not the most interesting finding. Rather, the fact that there is a group with larger and potentially clinically significant differences and that this group shares some demographic features is the key point.

These results are not surprising when examining what is known about the role of the hips in pitching. As has been previously shown, the throwing motion depends on sufficient internal hip rotation of the stance leg and ER of the stride leg.[19] Maximal IR of the stance leg occurs during wind-up, as the stride leg internally rotates 90° with respect to the planted limb.[3] IR occurs again as the stance hip extends and internally rotates as the trunk and hip girdle contribute to arm deceleration and follow through. Conversely, ER of the stride hip is critical for positioning of the foot during foot contact and follow through as the trunk and upper extremity rotates.[6,11,19] This is because proper pitching technique calls for the stride foot to land with the toes pointed toward home plate to keep the pitcher's kinetic energy going "downhill" toward the plate rather than "falling off" toward first or third base.[6,11,19] From knowledge of pitching mechanics, the increased IR of the stance hip and ER of the stride hip we observed in the largest cohort (RHP) may be adaptive to the repetitive motions of pitching.

Abnormal hip rotation may lead to a breakdown of the kinetic chain. It has been shown that ball velocity increases with increased pelvic rotation and upper trunk rotation, which are related to hip motion.[14] Improper foot rotation is related to abnormal hip rotation and a decrease in the energy transferred from the hip to the upper trunk for rotation and thus decreased ball velocity.[6] MacWilliams et al[12] showed that increased push-off forces and landing forces at ball release correlated with wrist velocity (and therefore pitch velocity) because of the increased kinetic energy that is generated.[12] Proper lower extremity mechanics are not only important for good pitching, they may also help prevent injury elsewhere in the chain. For example, Burkhart et al[3] stated that weak hip abductors and decreased flexibility of the lower extremities can increase shoulder workload because of a break in the kinetic chain. Scher et al[18] published results on 57 professional baseball players undergoing passive motion and noted that shoulder injury may be associated with specific measures of hip and shoulder ROM. They noticed a relationship between hip extension and shoulder ER in baseball players with a history of previous shoulder injury.[18]

In recent years, there has been growing interest in hip motion in baseball pitchers.[4,7,11,15,16,18-21] Ellenbecker et al[7] were the first to measure hip ROM in professional pitchers but used active ROM rather than maximal passive measurements and did not demonstrate any statistically significant side-to-side differences. However, they made a key observation that a >10° difference in IR was noted for 17% of their pitchers and in ER for 42%.[7] They concluded that baseball pitchers' side-to-side rotations were variable but did not demonstrate a consistent pattern. We found nearly identical numbers for >10° differences (17% for IR and 43% for ER), but did in fact note a clear pattern in that 32% of the pitchers had a >10° increase in ER on the stride hip compared with the stance hip. Since the statistically significant difference in RHPs was small overall, perhaps the focus should be on the more clinically significant difference in the subgroup of older pitchers. The fact that older pitchers possess greater ROM categorically describes this phenomenon as potentially adaptive rather than pathologic. This may be analogous to the fact that some pitchers have a >10° difference in shoulder rotation that on ER we call adaptive and on IR (glenohumeral internal rotation deficit) we are concerned about its relationship to injury. Laudner et al[11] showed that differences did exist between the hip motions of pitchers compared with position players. A recent publication by Robb et al[15] examined passive ROM in a small group of pitchers ($n = 19$) and found clear side-to-side differences. However, they found that nearly all ROMs were less in the stride hip than in the stance hip.[15] Tippett[19] published a small study on hip ROM and strength in 16 collegiate pitchers and found increases in IR of the stance hip. Our study confirms Tippett's findings with a significantly larger (just over 8 times larger) sample size. A significant deficiency of previous studies has been the lack of statistical power. The power of this study in comparing the dominant and nondominant hips was 0.758 for the total arc of motion, 0.934 for ER, and 0.197 for IR.

We chose to measure hip rotation in extension rather than flexion since the majority of the functional motion of the hip in baseball pitching occurs at or near full extension. If one wanted to examine the effect of femoroacetabular impingement on rotation, then using flexion measurements would be preferred. However, we hypothesized that there is a change in hip profile between the right and left hip in terms of ER/IR without an overall change in total arc of motion, similar to that found in the thrower's shoulder. Our expectations were that the stride and stance hips of RHPs and LHPs would demonstrate asymmetries in IR and ER between the stance and stride hips without a change in total arc of motion. For RHPs, the stance hip had significantly more IR than the stride hip, while the stride hip had increased ER. However, they also demonstrated a significantly larger arc of motion for their stride hip compared with the stance hip. Although similar patterns were seen for LHPs, the differences did not meet statistical significance. As is typical in baseball, we had a small number of LHPs compared with RHPs (34 vs 77). Given that sample of LHPs, our statistical power calculations show that the sample size was sufficient only to differentiate between 2 groups with an underlying difference of $\geq 3°$.

There are several limitations to this study. Measurement error may be introduced by the amount of force applied by the examiner and slight difference in limb position at the time the digital images are recorded. Care was taken to minimize these variables by using a single examiner for all examinations and a standardized technique for photography and digital measurements. Also, examining players after proper warm-up and stretching could change the measurements obtained. If all players were given a certain time to stretch and warm up prior to examination, this could be avoided. A larger scale study involving more players would increase the power, especially for LHPs. Future studies could be directed at when such changes are likely to occur, whether they result from bony or soft tissue adaptations, and whether they have any predictive value in terms of injury prevention and need for training modification.

CONCLUSION

Characteristic differences exist in the rotation of the stance and stride hips in professional baseball pitchers. There exists a subset of older, slender, and more experienced pitchers with increased ER on the stride hip that may point toward adaptive changes in response to the repetitive motions involved in throwing, analogous to those rotational differences seen in the shoulders of these same athletes. This study also adds to the normative data for hip rotation in professional baseball pitchers. Such data may help differentiate normal from abnormal motion, which could potentially be a target for interventions to improve pitching or prevent injury.

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