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Factors associated with long head of the biceps tendon tear severity and predictive insights for grade II tears in rotator cuff surgery

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Background: In rotator cuff repair, the long head of the biceps tendon (LHB) is commonly used as graft material. However, factors influencing LHB tear severity are poorly understood, and predicting grade II LHB tears is challenging. This study aimed to identify these factors preoperatively.

Methods: The demographics, medical parameters, and pain severity of 750 patients who underwent arthroscopic surgery from January 2010 to February 2021 were evaluated to determine the factors associated with LHB tear severity and grade II tears. Both overall and large-to-massive rotator cuff tear (RCT) cohorts underwent ordinal and binary logistic regression analyses. Predictive accuracy for grade II LHB tears was determined using the area under the receiver operating characteristic curve (AUC).

Results: In the overall cohort, high-sensitivity C-reactive protein (hs-CRP) >1 mg/L (P<0.001), subscapularis tear (P<0.001), hypothyroidism (P=0.031), and the tangent sign (P=0.003) were significantly associated with LHB tear severity, and hs-CRP>1 mg/L, subscapularis tear, and Patte retraction degree were significantly associated with grade II LHB tears (P<0.001). In the large-to-massive RCT cohort, hs-CRP>1 mg/L, hypertension, and age ≥50 years (P<0.05) were significantly associated with LHB tear severity, and hs-CRP>1 mg/L (P<0.001) and hypertension (P=0.026) were significantly associated with grade II LHB tears. In both cohorts, hs-CRP >1 mg/L demonstrated good predictive accuracy for grade II LHB tears (AUCs: 0.72 and 0.70).

Conclusions: Serum hs-CRP >1 mg/L is associated with LHB tear severity and serves as a reliable predictor of grade II LHB tears, facilitating preoperative assessment of the LHB as potential graft material in arthroscopic rotator cuff repair.

Level of evidence: III.

Keywords: Long head biceps tendon tear; Tear severity; Associated factors; High-sensitivity C-reactive protein

INTRODUCTION

The long head of the biceps tendon (LHB) has been reported as a mechanical stabilizer of the glenohumeral joint, though that is still a debatable issue [1,2]. LHB tears are a common source of shoulder pain [3,4] and have been considered part of a degenerative aging process, similar to a rotator cuff tear (RCT) [5]. On the other hand, the LHB is used in various shoulder repair and reconstruction surgeries. For large to massive RCT management, LHB rerouting [6], anterior cable reconstruction [7], biceps aug-

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mentation using the tenotomized biceps [6,8], and the snake technique (similar to superior capsular reconstruction) [9] have been reported. For recurrent shoulder instability, transfer of the LHB has been reported as a viable option in patients with subcritical glenoid bone loss [10]. Several factors have been proposed as risk factors for LHB tears: age, a posterosuperior rotator cuff tear (PSRCT) and its size [11,12], a superior labrum anterior-posterior lesion [13], a subscapularis tendon (SSC) tear [14,15], glucocorticoid use [16], diabetes [17], and serum high-sensitivity C-reactive protein (hs-CRP) > 1 mg/L [18].

Serum hs-CRP is a marker of inflammation and is widely accepted as a potential risk predictor for several chronic inflammatory diseases, including atherosclerosis and cardiovascular disease [19]. Several studies have reported that an elevated hs-CRP level is associated with chronic orthopedic disorders, including hip and knee osteoarthritis [20], frozen shoulder [21], chronic lower back pain [22], and sciatic pain [22]. A previous study reported that serum hs-CRP > 1 mg/L is independently associated with LHB tears [18]. Lafosse et al. [23] classified LHB tears according to the tear severity in arthroscopic findings: grade 0 (without gross injury), grade I (minor lesion with fraying or erosion involving < 50% of the tendon diameter), and grade II (major lesion with fraying or erosion involving ≥ 50% of the tendon diameter, including complete tears). To use the LHB for augmentation or as a graft material during shoulder surgery, the status of an LHB tear is recommended to be ≤ grade I [24]. However, no readily accessible relevant studies have evaluated factors associated with LHB tear severity or predictive of grade II LHB tears. This study tests the hypothesis that hs-CRP is significantly associated with LHB tear severity and predictive of grade II LHB tears. In addition, this study aimed to determine any factors associated with LHB tear severity and any factors that might predict the presence of a grade II LHB tear before rotator cuff surgery.

METHODS

This study, which was approved by the Institutional Review Board of Gyeongsang National University Changwon Hospital (No. 2022-01-030), retrospectively reviewed the data of 795 patients who underwent arthroscopic shoulder surgery performed by one shoulder and elbow surgeon (HBP) from January 2010 to February 2021. Requirement for informed consent was waived by the Institutional Review Board because of the study retrospective design. Some of those patients were then excluded from the analyses for the following reasons: a history of infection (n = 8), greater tuberosity fractures (n = 7), revision rotator cuff surgery (n = 9), arthroscopy after arthroplasty or fracture fixation (n = 5), or an acute traumatic RCT (n = 16). Therefore, 750 patients were enrolled in this study (Fig. 1). The mean age of the patients at the time of arthroscopic surgery was 60.7 ± 12.3 years; 361 patients (48.1%) were male, and 389 patients (51.9%) were female. All patients underwent arthroscopic surgery in the lateral decubitus position under general anesthesia.

The demographic, physical, social, and serologic parameters; medical comorbidities; intrinsic shoulder lesion; factors related to RCT; and pain severity were evaluated. The demographic variables were age and sex. Patients were grouped by age: < 40 years, 40–49 years, 50–59 years, 60–69 years, and ≥ 70 years. The physical variables were body mass index (BMI) and involvement of the dominant side. BMI was categorized as underweight (< 18.5 kg/m^2), normal weight (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obese (≥ 25.0 kg/m^2). The social variable was smoking. The serologic parameter was the serum hs-CRP level, and it was categorized as ≤ 1 mg/L (low level) and > 1 mg/L (high level). The evaluated medical comorbidities were diabetes, hypertension, hyperthyroidism, hypothyroidism, and dyslipidemia. The studied intrinsic shoulder lesion was RCT, which included both PSRCTs and SSC tears regardless of tear thickness. PSRCTs were further classified as partial- and full-thickness tears. The RCT-related variables were the size, Patte retraction degree [25], and tangent sign [26]. The size was classified as intact and full-thickness tear, with a full-thickness tear further classified as small (< 1 cm), medium (1–3 cm), large (3–5 cm), or massive (> 5 cm) based on arthroscopic findings [27]. The Patte retraction degree of an RCT was categorized as stage 1 (proximal tendon stump near bony insertion), stage 2 (proximal stump at humeral head level), or stage 3 (proximal stump at glenoid level) [25]. The tangent sign was assessed on T1-weighted oblique-sagittal images. It was graded negative if the supraspinatus muscle

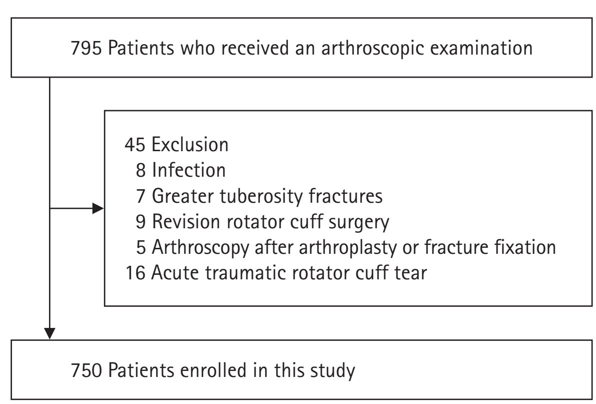

Fig. 1. Flowchart showing the inclusion and exclusion criteria for this study. A total of 750 patients were enrolled in this study in keeping with those criteria.

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crossed a tangent line drawn between the superior margins of the scapular spine and coracoid process and positive if it did not cross the line [26]. Pain severity was evaluated one day before surgery using a visual analog scale (VAS). Pain reported on the VAS was categorized as ≤3, 4 to 7, and ≥8. Table 1 summarizes the prevalence and medians of all studied variables.

Table 1. Studied variables and their medians or prevalences

Studied variable	LHB tear severity			
	Overall (n=750)	Grade 0 (n=406)	Grade I (n=218)	Grade II (n=126)
Age (yr)	61.0 (55.0–69.0)	59.0 (52.0–66.0)	65.0 (59.0–73.0)	64.0 (58.0–73.0)
<40	6.0 (45)	9.6 (39)	1.4 (3)	2.4 (3)
40–49	8.5 (64)	12.6 (51)	4.1 (9)	3.2 (4)
50–59	26.8 (201)	28.6 (116)	23.4 (51)	27.0 (36)
60–69	33.9 (254)	33.3 (135)	35.8 (78)	32.5 (41)
≥70	24.8 (186)	16.0 (77)	35.3 (77)	34.9 (44)
Male sex	48.1 (361)	48.3 (196)	52.8 (115)	39.7 (50)
BMI (kg/m^2)	24.2 (22.4–26.0)	24.3 (22.4–25.9)	24.1 (22.5–26.2)	24.2 (22.2–26.5)
Underweight (<18.5 kg/m^2)	1.2 (9)	1.0 (4)	1.8 (4)	0.8 (1)
Normal weight (18.5–22.9 kg/m^2)	31.9 (239)	32.3 (131)	29.8 (65)	34.1 (43)
Overweight (23.0–24.9 kg/m^2)	27.9 (209)	28.3 (115)	28.4 (62)	25.4 (32)
Obese (≥25.0 kg/m^2)	39.1 (293)	38.4 (156)	39.9 (87)	39.7 (50)
Dominant side-involvement	69.2 (519)	67.5 (274)	72.0 (157)	69.8 (88)
Smoking	33.3 (250)	31.5 (128)	37.2 (81)	32.5 (41)
hs-CRP	0.5 (0.4–1.1)	0.5 (0.3–0.7)	0.7 (0.4–1.5)	1.1 (0.6–1.8)
≤1 mg/L	74.3 (557)	89.7 (364)	61.9 (135)	46.0 (58)
>1 mg/L	25.7 (193)	10.3 (42)	38.1 (83)	54.0 (68)
Diabetes	15.7 (118)	13.5 (55)	18.3 (40)	18.3 (23)
Hypertension	35.6 (267)	34.2 (139)	31.2 (68)	47.6 (60)
Hyperthyroidism	4.5 (34)	4.4 (18)	1.8 (4)	9.5 (12)
Hypothyroidism	2.7 (20)	1.7 (7)	2.3 (5)	6.3 (8)
Dyslipidemia	84.5 (634)	84.5 (343)	88.5 (193)	77.8 (98)
PSRCT	61.5 (461)	54.9 (223)	60.1 (131)	84.9 (107)
SSC tear	31.2 (234)	19.2 (78)	36.7 (80)	60.3 (76)
Size of FTRCT				
Intact	39.3 (295)	46.3 (188)	39.9 (87)	15.9 (20)
Small	9.5 (71)	10.8 (44)	6.0 (13)	11.1 (14)
Medium	16.3 (122)	10.8 (44)	20.6 (45)	26.2 (33)
Large	12.4 (93)	6.9 (28)	16.5 (36)	23.0 (29)
Massive	5.3 (40)	2.5 (10)	6.4 (14)	12.7 (16)
Patte grade				
Intact	55.3 (415)	67.7 (275)	50.9 (111)	23.0 (29)
Stage I	15.3 (115)	15.3 (62)	12.4 (27)	20.6 (26)
Stage II	21.6 (162)	14.8 (60)	27.1 (59)	34.1 (43)
Stage III	7.7 (58)	2.2 (9)	9.6 (21)	22.2 (28)
Tangent sign	28.5 (214)	21.7 (88)	30.7 (67)	46.8 (59)
Pain VAS	6.0 (5.0–7.0)	5.0 (5.0–6.0)	6.0 (5.0–8.0)	6.0 (5.0–8.0)
≤3	3.5 (26)	2.5 (19)	1.4 (3)	3.2 (4)
4–7	75.6 (567)	83.5 (339)	67.4 (147)	64.3 (81)
≥8	20.9 (157)	11.8 (48)	31.2 (68)	32.5 (41)

Values are presented as percent (number) or median (interquartile range).
LHB: long head of the biceps tendon, BMI: body mass index, hs-CRP: high-sensitivity C-reactive protein, PSRCT: posterosuperior rotator cuff tear, SSC: subscapularis tendon, FTRCT: full-thickness rotator cuff tear, Patte grade: retraction degree of Patte, VAS: visual analog scale.

LHB tear severity was determined as grade 0, grade I, and grade II using the Lafosse classification described above (Fig. 2) [23]. The distributions of continuous variables were determined using the Kolmogorov-Smirnov test. When variables were not distributed normally, the median and interquartile range are used to present them.

Ordinal logistic regression analyses, reporting odds ratios (ORs) and 95% confidence intervals (CIs), were performed to determine the strengths of associations between the studied variables and LHB tear severity in both the overall cohort and the large-to-massive RCT cohort. Univariable ordinal logistic regression analyses were performed for all variables, and then multivariable ordinal logistic regression analyses were performed using the variables that were significant in the univariate analyses. The goodness of fit for the multivariable ordinary logistic regression model was assessed using the parallel lines test and McFadden R^2. A significance level of $P > 0.05$ is the standard for the parallel lines test, and McFadden R^2 values from 0.2 to 0.4 indicate that the model has a very good fit [28].

Binary logistic regression analyses were conducted to assess the associations between the variables and grade II LHB tears. ORs with 95% CIs were calculated for both the overall cohort and the large-to-massive RCT cohort. Univariate analyses were initially conducted for all variables, followed by multivariable analyses using variables significant in the univariate analyses while considering multicollinearity. Multicollinearity was assessed using Spearman correlations, the variance inflation factor, and condition index. A Spearman correlation coefficient of ≥0.7 between variables indicates multicollinearity [29]. The multivariable binary logistic analysis was conducted with variables included separately. Multicollinearity was considered absent when the variance inflation factor and condition index were <10 [30]. The Hosmer-Lemeshow test was used to assess the goodness of fit for the multivariable binary logistic regression model, with significance set at a P-value >0.05. ORs were calculated to determine the effect size according to Cohen's d scale: small (0.20–0.49), medium (0.50–0.79), and large (≥0.80) [31]. The number of variables in the final model was limited to 15 events per variable to prevent overfitting of the binary logistic regression analysis [32]. The predictive accuracy of variables significant in the multivariable binary logistic regression analyses for grade II LHB tears was determined using the area under the receiver operating characteristic curve (AUC) for both the overall studied cohort and the large-to-massive RCT cohort. AUC predictive accuracy was assessed as unsatisfactory (0.5≤ AUC <0.6), satisfactory (0.6≤ AUC <0.7), good (0.7≤ AUC <0.8), very good (0.8≤ AUC <0.9), and excellent (0.9≤ AUC <1.0) [33]. The AUCs of the significant variables were compared using the DeLong test [34]. All statistical analyses were performed using SPSS software version 26.0 (IBM Corp.) except the DeLong test, which was performed using MedCalc statistical software (MedCalc Software, version 19.2.6; https://www.medcalc.org; 2020). Statistical significance was set at a P-value of <0.05, with the exception of the parallel line test and Hosmer-Lemeshow test, for which significance was set at a P-value of >0.05.

RESULTS

The 750 patients enrolled had the following LHB tear: grade 0 for 406 patients, grade I for 218 patients, and grade II for 126 patients. Among the 126 grade II patients, 22 had complete tears of the LHB. In the overall cohort, both univariate and multivariable

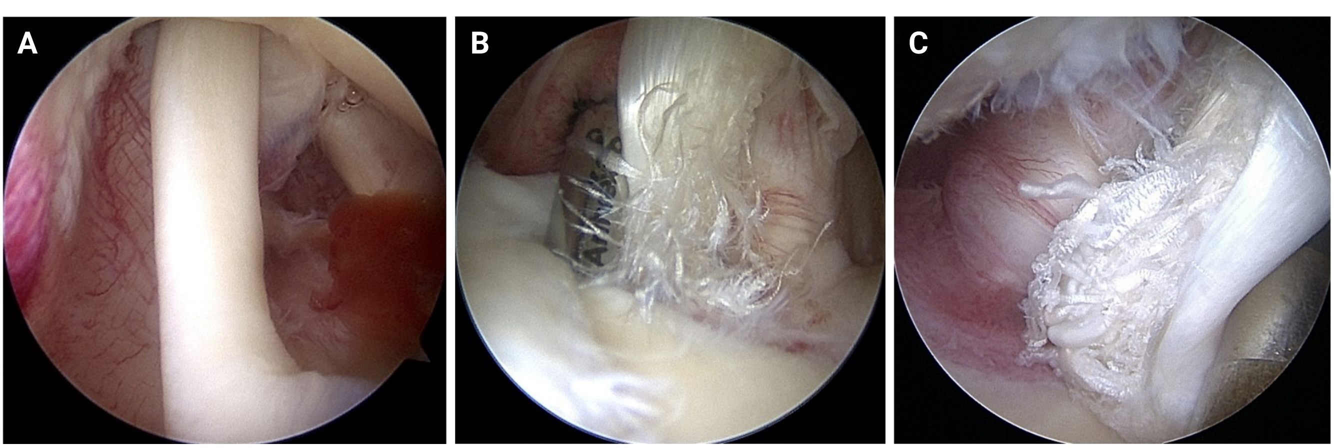

Fig. 2. Arthroscopic findings about the integrity of the long head of the biceps tendon. (A) Grade 0, without gross injury. (B) Grade I, minor lesion with fraying or erosion involving <50% of the tendon diameter. (C) Grade II, major lesion with fraying or erosion involving ≥50% of the tendon diameter, including a complete tear.

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ordinal logistic regression analyses, hs-CRP >1 mg/L, SSC tear, hypothyroidism, and tangent sign were significantly associated with LHB tear severity ($P<0.05$) (Table 2). The univariate binary logistic regression analyses showed that being male, hs-CRP >1 mg/L, a full-thickness RCT, PSRCT, SSC tear, tangent sign, Patte retraction degree ≥stage I, hypertension, hypothyroidism, hyperthyroidism, and age ≥70 years were significantly associated with grade II LHB tears ($P<0.05$) (Table 3). Because multicollinearity existed between a full-thickness RCT (as the tear size) and the Patte retraction degree, those two variables were included in separate multivariable analyses. The first multivariable binary logistic regression analysis showed that hs-CRP>1 mg/L and an SSC tear were significantly associated with grade II LHB tears ($P<0.001$) (Table 4). Both hs-CRP >1 mg/L and SSC tears had satisfactory predictive accuracy for grade II LHB tears, with AUCs of 0.67 and 0.68, respectively. The second multivariable binary logistic regression analysis showed that hs-CRP >1 mg/L and the Patte retraction degree were significantly associated with grade II LHB tears ($P<0.001$), with AUCs of 0.67 and 0.72, respectively (Table 4). The combination of hs-CRP >1 mg/L and SSC tear had a significantly larger AUC than either hs-CRP >1 mg/L or SSC tear alone ($P<0.01$). That combination had good predictive accuracy for grade II LHB tears; its AUC, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were 0.72, 0.82, 0.63, 0.31, and 0.94, respectively. The combination of hs-CRP >1 mg/L and Patte retraction degree did not have a significantly larger AUC than that of hs-CRP >1 mg/L alone ($P=0.069$) or Patte retraction degree alone ($P=0.630$), but it did have good predictive accuracy for grade II LHB tears; its AUC, sensitivity, specificity, PPV, and NPV were 0.72, 0.93, 0.50, 0.27, and 0.97, respectively. The AUCs of the combination of hs-CRP >1 mg/L and SSC tear and the combination of hs-CRP >1 mg/L and Patte retraction degree did not differ significantly from each other ($P=0.783$).

In the large-to-massive RCT cohort, hs-CRP>1 mg/L, hypertension, SSC tear, and age ≥50 years were significantly associated with LHB tear severity in the univariate ordinal logistic regression analyses ($P<0.05$). In the multivariable ordinal logistic regression analysis, hs-CRP >1 mg/L, hypertension, and age ≥50 years were significantly associated with LHB tear severity ($P<0.05$) (Table 5). Both the univariate and multivariable binary logistic regression analyses showed that hs-CRP>1 mg/L and

Table 3. Strengths of the associations between each studied factor and a grade II LHB tear in the overall studied cohort

Studied variable	Univariate binary analysis			
	OR (95% CI)	Cohen's d	Wald	P-value
Male	1.51 (1.02–2.23)	0.23	4.30	0.038
hs-CRP >1 mg/L	4.68 (3.13–6.99)	0.85	56.78	<0.001
Size of FTRCT	1.57 (1.39–1.77)	0.25	56.04	<0.001
Intact	Reference	-	-	-
Small	3.37 (1.61–7.08)	0.67	10.39	0.001
Medium	5.09 (2.78–9.33)	0.90	27.88	<0.001
Large	6.23 (3.31–11.71)	1.01	32.26	<0.001
Massive	9.16 (4.21–19.96)	1.22	31.11	<0.001
PSRCT	4.30 (2.57–7.17)	0.80	31.01	<0.001
SSC tear	4.48 (3.00–6.69)	0.83	54.07	<0.001
Tangent sign	2.67 (1.80–3.95)	0.54	23.74	<0.001
Patte grade	2.20 (1.82–2.65)	0.44	68.57	<0.001
Intact	Reference	-	-	-
Stage I	3.89 (2.18–6.93)	0.75	21.25	<0.001
Stage II	4.81 (2.88–8.04)	0.87	35.89	<0.001
Stage III	12.42 (6.56–23.52)	1.39	59.82	<0.001
Hypertension	1.83 (1.24–2.70)	0.33	9.38	0.002
Hypothyroidism	3.46 (1.38–8.64)	0.68	7.05	0.008
Hyperthyroidism	2.88 (1.39–5.99)	0.58	8.04	0.005
Age ≥70 years	4.34 (1.28–14.68)	0.81	5.57	0.018

Hyphens (-) indicate variables that are not included in the analyses.
LHB: long head of the biceps tendon, OR: odds ratio, CI: confidence interval, hs-CRP: high-sensitivity C-reactive protein, FTRCT: full-thickness rotator cuff tear, PSRCT: posterosuperior rotator cuff tear, SSC: subscapularis tendon, Patte grade: retraction degree of Patte.

Table 2. Strengths of the associations between the studied factors and LHB tear severity

Studied variable	Univariate ordinal analysis				Multivariable ordinal analysis[a]			
	OR (95% CI)	Cohen's d	Wald	P-value	OR (95% CI)	Cohen's d	Wald	P-value
hs-CRP >1 mg/L	5.77 (4.16–8.00)	0.97	110.34	<0.001	5.92 (4.26–8.33)	0.98	109.08	<0.001
SSC tear	3.79 (2.80–5.12)	0.74	75.02	<0.001	3.18 (2.28–4.43)	0.64	46.60	<0.001
Hypothyroidism	2.81 (1.23–6.38)	0.57	6.12	0.013	2.57 (1.09–6.03)	0.52	4.68	0.031
Tangent sign	2.25 (1.66–3.04)	0.45	28.00	<0.001	1.67 (1.19–2.36)	0.28	8.90	0.003

LHB: long head of the biceps tendon, OR: odds ratio, CI: confidence interval, hs-CRP: high-sensitivity C-reactive protein, SSC: subscapularis tendon.
[a]The variance inflation factor and condition index were 1.018 and 6.103, respectively. The P-values of the parallel lines test and McFadden R^2 were 0.140 and 0.137, respectively.

Table 4. Strengths of the associations between each studied factor and a grade II LHB tear in the overall studied cohort

Studied variable	Multivariable binary analysis including size of FTRCT[a]				Multivariable binary analysis including Patte Grade[b]			
	OR (95% CI)	Cohen's d	Wald	P-value	OR (95% CI)	Cohen's d	Wald	P-value
hs-CRP > 1 mg/L	4.66 (2.94–7.40)	0.85	42.70	< 0.001	4.74 (3.07–7.30)	0.86	49.53	< 0.001
SSC tear	5.44 (3.43–8.63)	0.93	51.84	< 0.001	-	-	-	-
Patte grade	-	-	-	-	-	-	-	-
Intact	-	-	-	-	Reference	-	-	-
Stage I	-	-	-	-	4.21 (2.30–7.70)	0.79	21.82	< 0.001
Stage II	-	-	-	-	4.95 (2.89–8.46)	0.88	34.11	< 0.001
Stage III	-	-	-	-	11.96 (6.08–23.52)	1.37	51.68	< 0.001

Because multicollinearity had present between size of full thickness rotator cuff tear and retraction degree of Patte, two studied variables were included separately in multivariate analyses. Hyphens (-) indicate variables that are not included in the analyses.
LHB: long head of the biceps tendon, FTRCT: full-thickness rotator cuff tear, OR: odds ratio, CI: confidence interval, hs-CRP: high-sensitivity C-reactive protein, SSC: subscapularis tendon, Patte grade: retraction degree of Patte.
[a]The variance inflation factor and condition index were 1.792 and 4.872, respectively. The P-value of the Hosmer-Lemeshow test was 0.477. The areas under the receiver operating characteristic curves (AUCs) of hs-CRP > 1 mg/L, and SSC tear were 0.67, and 0.68, respectively. The AUC of the combination of hs-CRP > 1 mg/L and SSC tear was 0.72;
[b]The variance inflation factor and condition index were 1.586 and 4.474, respectively. The P-value of the Hosmer-Lemeshow test was 0.507. The AUCs of hs-CRP > 1 mg/L, and Patte grader were 0.67, and 0.72, respectively. The AUC of the combination of hs-CRP > 1 mg/L and Patte retraction was 0.72.

Table 5. Strengths of the associations between the studied factors and LHB tear severity in the large-to-massive rotator cuff tear cohort

Studied variable	Univariate ordinal analysis				Multivariable ordinal analysis[a]			
	OR (95% CI)	Cohen's d	Wald	P-value	OR (95% CI)	Cohen's d	Wald	P-value
hs-CRP > 1 mg/L	7.09 (3.28–15.32)	1.08	24.87	< 0.001	6.37 (2.88–14.08)	1.02	20.89	< 0.001
Hypertension	2.01 (1.01–4.01)	0.39	3.91	0.048	2.28 (1.06–4.87)	0.45	4.48	0.034
SSC tear	2.29 (1.04–5.07)	0.46	4.19	0.041	2.29 (0.97–5.36)	0.46	3.62	0.057
Age (yr)	-	-	-	-	-	-	-	-
< 40	Reference	-	-	-	-	-	-	-
40–49	4.94 (0.40–52.72)	0.88	1.75	0.186	-	-	-	-
50–59	16.95 (2.03–141.17)	1.56	6.84	0.009	4.51 (1.26–16.18)	0.83	5.35	0.021
60–69	14.89 (1.79–123.59)	1.49	6.26	0.012	4.41 (1.27–15.30)	0.82	5.46	0.019
≥ 70	17.24 (2.13–139.21)	1.57	7.14	0.008	6.75 (2.01–22.71)	1.05	9.51	0.002
Patte grade	NA	NA	NA	NA	NA	NA	NA	NA
Intact	NA	NA	NA	NA	NA	NA	NA	NA
Stage I	NA	NA	NA	NA	NA	NA	NA	NA
Stage II	NA	NA	NA	NA	NA	NA	NA	NA
Stage III	NA	NA	NA	NA	NA	NA	NA	NA

Hyphens (-) indicate variables that are not included in the analyses.
LHB: long head of the biceps tendon, OR: odds ratio, CI: confidence interval, hs-CRP: high-sensitivity C-reactive protein, SSC: subscapularis tendon, NA: non-significant.
[a]The variance inflation factor and condition index were 1.026. and 5.524, respectively. The P-values of the parallel lines test and McFadden R^2 were 0.172 and 0.153, respectively.

hypertension were significantly associated with grade II LHB tears ($P < 0.05$) (Table 6). Serum hs-CRP > 1 mg/L had good predictive accuracy for grade II LHB tears; its AUC, sensitivity, specificity, PPV, and NPV were 0.70, 0.58, 0.81, 0.62, and 0.80, respectively (Fig. 3). Hypertension had satisfactory predictive accuracy for grade II LHB tears; its AUC, sensitivity, specificity, PPV, and NPV were 0.60, 0.44, 0.76, 0.49, and 0.73, respectively (Fig. 3). The combination of hs-CRP > 1 mg/L and hypertension had only satisfactory predictive accuracy for grade II LHB tears with an AUC of 0.69, which was no increase over the AUC of hs-CRP > 1 mg/L alone ($P = 0.710$).

DISCUSSION

The results of this study show that only hs-CRP > 1 mg/L was significantly associated with LHB tear severity and grade II LHB tears

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Table 6. Strengths of the associations between the studied factors and a grade II LHB tear in the large-to-massive rotator cuff tear cohort

Studied variable	Univariate binary analysis				Multivariable binary analysis[a]			
	OR (95% CI)	Cohen's d	Wald	P-value	OR (95% CI)	Cohen's d	Wald	P-value
hs-CRP > 1 mg/L	6.16 (2.76–13.73)	1.00	19.73	< 0.001	6.25 (2.74–14.26)	1.01	19.00	< 0.001
Hypertension	2.55 (1.18–5.49)	0.52	5.76	0.016	2.62 (1.13–6.09)	0.53	5.07	0.026
Patte grade	NA	NA	NA	NA	NA	NA	NA	NA
Intact	NA	NA	NA	NA	NA	NA	NA	NA
Stage I	NA	NA	NA	NA	NA	NA	NA	NA
Stage II	NA	NA	NA	NA	NA	NA	NA	NA
Stage III	NA	NA	NA	NA	NA	NA	NA	NA

LHB: long head of the biceps tendon, OR: odds ratio, CI: confidence interval, hs-CRP: high-sensitivity C-reactive protein, NA: non-significant.
[a]The variance inflation factor and condition index were 1.005 and 2.319, respectively. The P-value of the Hosmer-Lemeshow test was 0.847.

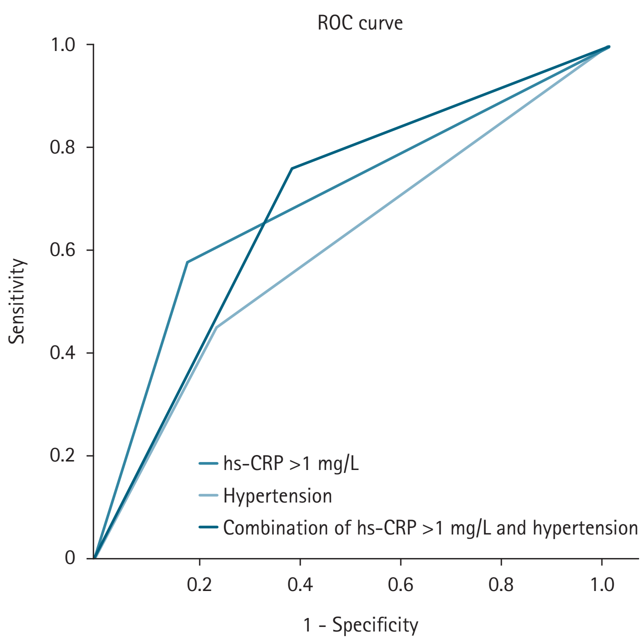

Fig. 3. In the large-to-massive rotator cuff tear cohort, the areas under the receiver operating characteristic (ROC) curves (AUCs) of high-sensitivity C-reactive protein (hs-CRP) >1 mg/L and hypertension were 0.70 and 0.60, respectively. Serum hs-CRP >1 mg/L had good predictive accuracy for a grade II biceps long head tendon tear (P<0.001). The combination of hs-CRP >1 mg/L and hypertension had satisfactory predictive accuracy for a grade II LHB tear. The AUC of the combination of hs-CRP >1 mg/L and hypertension was 0.69, which was not an increase over the AUC of hs-CRP >1 mg/L alone (P=0.710).

in both the overall and large-to-massive RCT cohorts. Therefore, this study has confirmed the hypothesis that hs-CRP > 1 mg/L is a factor significantly associated with LHB tear severity and a good predictor of grade II LHB tears.

Serum hs-CRP is a well-known inflammatory marker. It has been used in the diagnosis of atherosclerosis, cardiovascular disease, and stroke [35]. Several studies have reported that musculoskeletal disorders, including knee osteoarthritis, frozen shoulder, and sciatica, are also associated with subclinical systemic inflammatory responses that can be detected using hs-CRP [21,22,36,37]. Carp et al. [38] reported that elevated CRP can be initiated by a local response and is proportionally amplified in the presence of greater tissue injury and inflammation. Biomolecular studies have reported that in biceps tendinopathy, the gene expressions for proinflammatory or inflammatory cytokines are upregulated, and the gene expression for an anti-inflammatory cytokine is downregulated [3,39]. Histological studies have reported that inflammatory processes are involved in LHB tendinopathy [40,41]. One study reported that serum hs-CRP > 1 mg/L is an independent risk factor for LHB tears without any making distinction in tear severity [18]. The results of this study show that serum hs-CRP > 1.0 mg/L is associated with LHB tear severity, which suggests that inflammatory processes are involved in LHB tears and tear severity. Serum hs-CRP > 1.0 mg/L was also found to be associated with grade II LHB tears and a good predictor of grade II LHB tears in the large-to-massive RCT cohort, which is a clinically helpful finding for determining preoperatively whether the LHB can be used for rotator cuff repair surgery.

The population of this study contained 22 patients with complete LHB tears. Although complete tears of the LHB can be readily diagnosed using magnetic resonance imaging (MRI), these patients were included in this study to determine factors associated with LHB tear severity. An additional study that excluded patients with complete LHB tears from the cohort was conducted to ascertain whether those tears affected the study results. The results of that analysis closely mirror those of the original study, as follows. In the overall cohort, age ≥ 50 years, hs-CRP > 1 mg/L, and an SSC tear were significantly associated with LHB tear severity (P ≤ 0.001). In the large-to-massive RCT cohort, only serum hs-CRP > 1 mg/L was significantly associated with grade II LHB tears (P < 0.001), and it had satisfactory predictive accuracy (AUC, 0.69). Therefore, in a clinical situation, a surgeon planning to repair a large to massive cuff tear, which frequently requires biceps tendon augmentation, could consider hs-CRP test results to predict a biceps tendon injury before surgery.

In this study, in addition to hs-CRP, an SSC tear, hypothyroidism, tangent sign, Patte retraction degree, age ≥50 years, and hypertension were significantly associated with LHB tear severity and/or grade II LHB tears, depending on the studied cohort. SSC tears have been reported to be associated with LHB tears in several studies [18,23]. Medial instability of the LHB has been reported to be associated with SSC tears [23]. Sahu et al. [15] reported that an abrasion or partial tear of the anterior portion of the LHB, the sentinel sign, indicates a coexisting SSC tear. Biomechanical studies have demonstrated that the increase in the load on the LHB is more significant after an SSC tear than after an infraspinatus tendon tear [42,43]. Those previous studies' findings suggest that a meaningful association is present between SSC tears and LHB tears, supporting this study's finding that an SSC tear was significantly associated with LHB tear severity.

Hypothyroidism has been reported to cause deterioration of the extracellular matrix and then induce tendon injury through an accumulation of glycosaminoglycans in the extracellular matrix [44]. Oliva et al. [45,46] demonstrated the presence of thyroid hormone receptors in healthy and pathologic rotator cuff tendons and showed *in vitro* that thyroid hormone enhances tenocyte growth and counteracts apoptosis in healthy tenocytes in a dose- and time-dependent manner. In a clinical observational study, those authors also reported a relationship between thyroid pathology and nontraumatic RCT [45]. Those previous studies' findings that hypothyroidism is associated with tendon injury support this study's finding that hypothyroidism is significantly associated with LHB tear severity.

The chronicity of RCT has been defined as the duration of a tear, which is represented as fatty infiltration and muscle atrophy [47]. The tangent sign is an index of supraspinatus muscle atrophy that was reported to be highly correlated with the retraction grade of the tendon and tear size in RCT [26,48]. Melis et al. [47] reported that a positive tangent sign appeared an average of 4.5 years after the onset of symptoms. Chronic RCT with symptom duration longer than three months or a massive tear has been reported to be associated with LHB lesions [49]. RCT size is known to increase over time [50]. Wu et al. [39] indicated that the size of a coexisting RCT plays a role in the severity of LHB tendinopathy. Those previous findings suggest that the chronicity of RCT, as presented by the tangent sign and Patte retraction degree, is a risk factor for LHB tear severity or grade II LHB tears.

Age has been reported as a risk factor for LHB tears. Takeshima et al. [51] reported that the prevalence of LHB lesions increased with age. LHB tears mostly occur in persons older than 50 years [52]. A histologic study also reported that age is significantly related to LHB degeneration [5]. This study's finding that age ≥50 years was significantly associated with LHB tear severity in the large-to-massive RCT cohort supports the previous studies' findings of a significant association between LHB tears and increasing age.

Hypertension has been reported to be associated with symptomatic RCT [53]. Some studies reported that hypertension is associated with the severity and prevalence of RCT [54,55]. Hypertension has been reported to be prevalent in posterior tibial tendon ruptures and Achilles tendinopathy [56,57]. Previous studies' findings suggest that hypertension deteriorates tendon integrity and increases RCT severity, and then that increased RCT severity affects LHB integrity [58].

This study has some limitations. Although biceps tendon status was evaluated after intra-articular retraction of the biceps tendon, hidden biceps lesions, which would have been far distal to the transverse humeral ligament, were not assessed. Hypertrophied biceps tendons and lipstick sign have been reported as biceps pathologies, but they were not evaluated here [59]. Another limitation is that this study did not include a physical examination to diagnose LHB injury. Several physical tests, including the Speed, Yergason, and uppercut tests, are known to diagnose LHB tears, though without considering severity [60-62]. However, it is difficult to find studies showing whether any physical tests can predict LHB tear severity [63]. Also, physical examinations have issues with intraobserver and interobserver reproducibility [60]. On the other hand, hs-CRP is an objective indicator for diagnosing grade II LHB tears because it has no reliability issues with intraobserver and interobserver reproducibility. However, to increase the predictive accuracy for grade II LHB tears, further research that includes those physical tests should be performed. Nevertheless, given the difficulty of diagnosing LHB tears using conventional 1.5T MRI [64], this study's findings are helpful for predicting biceps tendon status before arthroscopic surgery. Among the studied variables, an SSC tear, hypothyroidism, tangent sign, Patte retraction degree, age ≥50 years, and hypertension were found to be significantly associated with LHB tear severity or grade II LHB tears, depending on the studied cohorts. Conversely, hs-CRP >1 mg/L consistently predicted both LHB tear severity and grade II LHB tears across both studied cohorts. Therefore, hs-CRP >1 mg/L can serve as a reliable predictor of LHB tear severity and grade II LHB tears before surgery.

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CONCLUSIONS

Serum hs-CRP >1 mg/L is associated with LHB tear severity and serves as a reliable predictor of grade II LHB tears, facilitating the preoperative assessment of the LHB as a potential graft material in arthroscopic rotator cuff repair.

NOTES

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Conflict of interest

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Data availability

Contact the corresponding author for data availability.

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REFERENCES

1. Giphart JE, Elser F, Dewing CB, Torry MR, Millett PJ. The long head of the biceps tendon has minimal effect on in vivo glenohumeral kinematics: a biplane fluoroscopy study. Am J Sports Med 2012;40:202–12.
2. Pagnani MJ, Deng XH, Warren RF, Torzilli PA, O'Brien SJ. Role of the long head of the biceps brachii in glenohumeral stability: a biomechanical study in cadavera. J Shoulder Elbow Surg 1996;5:255–62.
3. Schmalzl J, Plumhoff P, Gilbert F, et al. The inflamed biceps tendon as a pain generator in the shoulder: a histological and biomolecular analysis. J Orthop Surg (Hong Kong) 2019;27:2309499018820349.
4. Szabó I, Boileau P, Walch G. The proximal biceps as a pain generator and results of tenotomy. Sports Med Arthrosc Rev 2008;16:180–6.
5. Refior HJ, Sowa D. Long tendon of the biceps brachii: sites of predilection for degenerative lesions. J Shoulder Elbow Surg 1995;4:436–40.
6. Rhee YG, Cho NS, Lim CT, Yi JW, Vishvanathan T. Bridging the gap in immobile massive rotator cuff tears: augmentation using the tenotomized biceps. Am J Sports Med 2008;36:1511–8.
7. Seo JB, Kwak KY, Park B, Yoo JS. Anterior cable reconstruction using the proximal biceps tendon for reinforcement of arthroscopic rotator cuff repair prevent retear and increase acromiohumeral distance. J Orthop 2021;23:246–9.
8. Cho NS, Yi JW, Rhee YG. Arthroscopic biceps augmentation for avoiding undue tension in repair of massive rotator cuff tears. Arthroscopy 2009;25:183–91.
9. Kim D, Jang Y, Park J, On M. Arthroscopic superior capsular reconstruction with biceps autograft: snake technique. Arthrosc Tech 2019;8:e1085–92.
10. DeFroda SF, Gil JA, Owens BD. Recurrent shoulder stabilization with open bankart repair and long head biceps transfer. J Orthop 2018;15:401–3.
11. Desai SS, Mata HK. Long head of biceps tendon pathology and results of tenotomy in full-thickness reparable rotator cuff tear. Arthroscopy 2017;33:1971–6.
12. Kowalczuk M, Kohut K, Sabzevari S, Naendrup JH, Lin A. Proximal long head biceps rupture: a predictor of rotator cuff pathology. Arthroscopy 2018;34:1166–70.
13. Vestermark GL, Van Doren BA, Connor PM, Fleischli JE, Piasecki DP, Hamid N. The prevalence of rotator cuff pathology in the setting of acute proximal biceps tendon rupture. J Shoulder Elbow Surg 2018;27:1258–62.
14. Beall DP, Williamson EE, Ly JQ, et al. Association of biceps tendon tears with rotator cuff abnormalities: degree of correlation with tears of the anterior and superior portions of the rotator cuff. AJR Am J Roentgenol 2003;180:633–9.
15. Sahu D, Fullick R, Giannakos A, Lafosse L. Sentinel sign: a sign of biceps tendon which indicates the presence of subscapularis tendon rupture. Knee Surg Sports Traumatol Arthrosc 2016;24:3745–9.
16. Spoendlin J, Meier C, Jick SS, Meier CR. Oral and inhaled glucocorticoid use and risk of Achilles or biceps tendon rupture: a population-based case-control study. Ann Med 2015;47:492–8.

17. Spoendlin J, Meier C, Jick SS, Meier CR. Achilles or biceps tendon rupture in women and men with type 2 diabetes: a population-based case-control study. J Diabetes Complications 2016;30:903–9.
18. Gwark JY, Park HB. Association of high sensitivity C-reactive protein with tearing of the long head of the biceps tendon. BMC Musculoskelet Disord 2019;20:518.
19. Pietzner M, Kaul A, Henning AK, et al. Comprehensive metabolic profiling of chronic low-grade inflammation among generally healthy individuals. BMC Med 2017;15:210.
20. Pearle AD, Scanzello CR, George S, et al. Elevated high-sensitivity C-reactive protein levels are associated with local inflammatory findings in patients with osteoarthritis. Osteoarthritis Cartilage 2007;15:516–23.
21. Park HB, Gwark JY, Jung J, Jeong ST. Association between high-sensitivity C-reactive protein and idiopathic adhesive capsulitis. J Bone Joint Surg Am 2020;102:761–8.
22. Stürmer T, Raum E, Buchner M, et al. Pain and high sensitivity C reactive protein in patients with chronic low back pain and acute sciatic pain. Ann Rheum Dis 2005;64:921–5.
23. Lafosse L, Reiland Y, Baier GP, Toussaint B, Jost B. Anterior and posterior instability of the long head of the biceps tendon in rotator cuff tears: a new classification based on arthroscopic observations. Arthroscopy 2007;23:73–80.
24. Kim DS, Yeom J, Park J, Cha J. L-shape superior capsular augmentation technique using biceps tendon: the biceps l-shape shifting technique. Arthrosc Tech 2020;9:e703–9.
25. Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res 1990;(254):81–6.
26. Zanetti M, Gerber C, Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Invest Radiol 1998;33:163–70.
27. Cofield RH. Subscapular muscle transposition for repair of chronic rotator cuff tears. Surg Gynecol Obstet 1982;154:667–72.
28. Louviere JJ, Hensher DA, Swait JD. Stated choice methods: analysis and applications. Cambridge University Press; 2000.
29. Jiarpakdee J, Tantithamthavorn C, Treude C. The impact of automated feature selection techniques on the interpretation of defect models. Empir Softw Eng 2020;25:3590–638.
30. Salmerón R, García CB, García J. Variance inflation factor and condition number in multiple linear regression. J Stat Comput Simul 2018;88:2365–84.
31. Cohen J. A power primer. Psychol Bull 1992;112:155–9.
32. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol 1996;49:1373–9.
33. Trifonova OP, Lokhov PG, Archakov AI. Metabolic profiling of human blood. Biomed Khim 2014;60:281–94.
34. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 1988;44:837–45.
35. Bassuk SS, Rifai N, Ridker PM. High-sensitivity C-reactive protein: clinical importance. Curr Probl Cardiol 2004;29:439–93.
36. Hrycaj PZ. Systemic inflammation in osteoarthritis. Ann Rheum Dis 2004;63:750–1.
37. Stürmer T, Brenner H, Koenig W, Günther KP. Severity and extent of osteoarthritis and low grade systemic inflammation as assessed by high sensitivity C reactive protein. Ann Rheum Dis 2004;63:200–5.
38. Carp SJ, Barbe MF, Winter KA, Amin M, Barr AE. Inflammatory biomarkers increase with severity of upper-extremity overuse disorders. Clin Sci (Lond) 2007;112:305–14.
39. Wu PT, Su WR, Li CL, et al. Inhibition of CD44 induces apoptosis, inflammation, and matrix metalloproteinase expression in tendinopathy. J Biol Chem 2019;294:20177–84.
40. Murthi AM, Vosburgh CL, Neviaser TJ. The incidence of pathologic changes of the long head of the biceps tendon. J Shoulder Elbow Surg 2000;9:382–5.
41. Zabrzyński J, Paczesny Ł, Łapaj Ł, Grzanka D, Szukalski J. Is the inflammation process absolutely absent in tendinopathy of the long head of the biceps tendon?: histopathologic study of the long head of the biceps tendon after arthroscopic treatment. Pol J Pathol 2017;68:318–25.
42. Su WR, Budoff JE, Luo ZP. The effect of anterosuperior rotator cuff tears on glenohumeral translation. Arthroscopy 2009;25:282–9.
43. Su WR, Budoff JE, Luo ZP. The effect of posterosuperior rotator cuff tears and biceps loading on glenohumeral translation. Arthroscopy 2010;26:578–86.
44. Berardi AC, Oliva F, Berardocco M, la Rovere M, Accorsi P, Maffulli N. Thyroid hormones increase collagen I and cartilage oligomeric matrix protein (COMP) expression in vitro human tenocytes. Muscles Ligaments Tendons J 2014;4:285–91.
45. Oliva F, Osti L, Padulo J, Maffulli N. Epidemiology of the rotator cuff tears: a new incidence related to thyroid disease. Muscles Ligaments Tendons J 2014;4:309–14.
46. Oliva F, Piccirilli E, Berardi AC, Tarantino U, Maffulli N. Influence of thyroid hormones on tendon homeostasis. Adv Exp Med Biol 2016;920:133–8.
47. Melis B, DeFranco MJ, Chuinard C, Walch G. Natural history of fatty infiltration and atrophy of the supraspinatus muscle in rotator cuff tears. Clin Orthop Relat Res 2010;468:1498–505.
48. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F.

https://doi.org/10.5397/cise.2023.01053

Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res 1997;(344):275–83.
49. Chen CH, Hsu KY, Chen WJ, Shih CH. Incidence and severity of biceps long head tendon lesion in patients with complete rotator cuff tears. J Trauma 2005;58:1189–93.
50. Yamamoto N, Mineta M, Kawakami J, Sano H, Itoi E. Risk factors for tear progression in symptomatic rotator cuff tears: a prospective study of 174 shoulders. Am J Sports Med 2017;45:2524–31.
51. Takeshima M, Morihara T, Kai Y, et al. Prevalence and related factors of lesions of the long head of the biceps tendon in elderly patients. J Shoulder Elbow Surg 2021;30:e184.
52. Moorman CT, Silver SG, Potter HG, Warren RF. Proximal rupture of the biceps brachii with slingshot displacement into the forearm: a case report. J Bone Joint Surg Am 1996;78:1749–52.
53. Zhao J, Luo M, Liang G, et al. What factors are associated with symptomatic rotator cuff tears: a meta-analysis. Clin Orthop Relat Res 2022;480:96–105.
54. Djerbi I, Chammas M, Mirous MP, Lazerges C, Coulet B; French Society For Shoulder and Elbow (SOFEC). Impact of cardiovascular risk factor on the prevalence and severity of symptomatic full-thickness rotator cuff tears. Orthop Traumatol Surg Res 2015;101(6 Suppl):S269–73.
55. Gumina S, Arceri V, Carbone S, et al. The association between arterial hypertension and rotator cuff tear: the influence on rotator cuff tear sizes. J Shoulder Elbow Surg 2013;22:229–32.
56. Holmes GB, Lin J. Etiologic factors associated with symptomatic achilles tendinopathy. Foot Ankle Int 2006;27:952–9.
57. Holmes GB Jr, Mann RA. Possible epidemiological factors associated with rupture of the posterior tibial tendon. Foot Ankle 1992;13:70–9.
58. Wu PT, Jou IM, Yang CC, et al. The severity of the long head biceps tendinopathy in patients with chronic rotator cuff tears: macroscopic versus microscopic results. J Shoulder Elbow Surg 2014;23:1099–106.
59. Grassbaugh JA, Bean BR, Greenhouse AR, et al. Refuting the lipstick sign. J Shoulder Elbow Surg 2017;26:1416–22.
60. Ben Kibler W, Sciascia AD, Hester P, Dome D, Jacobs C. Clinical utility of traditional and new tests in the diagnosis of biceps tendon injuries and superior labrum anterior and posterior lesions in the shoulder. Am J Sports Med 2009;37:1840–7.
61. Neviaser RJ. Lesions of the biceps and tendinitis of the shoulder. Orthop Clin North Am 1980;11:343–8.
62. Yergason RM. Supination sign. J Bone Joint Surg 1931;13:160.
63. Rosas S, Krill MK, Amoo-Achampong K, Kwon K, Nwachukwu BU, McCormick F. A practical, evidence-based, comprehensive (PEC) physical examination for diagnosing pathology of the long head of the biceps. J Shoulder Elbow Surg 2017;26:1484–92.
64. Mohtadi NG, Vellet AD, Clark ML, et al. A prospective, double-blind comparison of magnetic resonance imaging and arthroscopy in the evaluation of patients presenting with shoulder pain. J Shoulder Elbow Surg 2004;13:258–65.