Association Between Cardiovascular Disease Risk Factors and Rotator Cuff Tendinopathy

A Cross-Sectional Study

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Objective: Recent evidence has found potential associations between cardiovascular disease (CVD) risk factors and common musculoskeletal disorders. We evaluated possible associations between risk factors and both glenohumeral joint pain and rotator cuff tendinopathy. **Methods:** Data from WISTAH hand study participants ($n = 1226$) were assessed for associations between Framingham Heart Study CVD risk factors and both health outcomes. **Results:** A strong association was observed between CVD risk scores and both glenohumeral joint pain and rotator cuff tendinopathy. Peak odds ratios (ORs) of the adjusted models were 4.55 [95% confidence interval (95% CI) 1.97 to 10.31] and 5.97 (95% CI 2.12 to 16.83), respectively. The results show a dose–response trend of increasing risk. **Conclusions:** Individual risk factors were associated with both outcomes. Combined, CVD risk factors demonstrated a strong correlation with glenohumeral joint pain and an even stronger correlation with rotator cuff tendinopathy. Results suggest a potentially modifiable disease mechanism.

Learning Objectives

- Discuss recent evidence linking cardiovascular disease (CVD) risk to common musculoskeletal disorders.
- Summarize the new findings on the association between CVD risk and specific shoulder-related musculoskeletal problems.
- Identify possible mechanisms of the observed associations, including potentially modifiable mechanisms.

Musculoskeletal disorders are a common reason patients seek medical treatment, with the third most common complaint being shoulder dysfunction and/or pain.[1–5] Treatment of shoulder disorders is a substantial contributor to health care costs, totaling $7 billion in 2000.[6–10] The 1-month period prevalence of shoulder pain ranges from 19% to 31% and the cumulative lifetime prevalence ranges from 7% to 67%.[11] Musculoskeletal shoulder disorders are known to frequently recur and are often related to a perceived or actual overall decline in health.[12–17]

The pathophysiology of rotator cuff tendinopathy is somewhat unclear. There are two main competing theories. In the 1920s, a biomechanical theory described by Meyer[18,19] and later advanced by Neer,[20,21] stated that tendinopathy was based on the impact of age-related degenerative processes and impingement of the tendon.[20,22–25] The other competing theory is based on reduced vascular supply to the rotator cuff tendons and includes the rubric of vascular compromise by atherosclerotic-related disease processes.[17,26] It is highly possible that a combination of the factors proffered by these two theories is the disease mechanism for tendinopathy. More recently, multiple individual atherosclerosis risk factors have been found to affect tendinopathies, including obesity,[11,27–29] smoking,[16,30–33] hypercholesterolemia,[34] and diabetes mellitus (DM).[17,35–37] Despite these potential pathophysiologic patterns, to our knowledge, a risk-stratified combination of cardiovascular disease (CVD) risk factors has not yet been reported.

In addition to the above biological factors, psychosocial and work-related factors have also been found to be associated with shoulder pain, rotator cuff tendinopathy, and/or related disorders. Some of these risks include job dissatisfaction,[38,39] low social support,[39–41] and symptoms of depression.[42] Job physical strain has also been associated with shoulder disorders and tendinopathy.[43–45]

The purpose of this large study of 1226 workers from diverse work environments was to evaluate the possible relationships between CVD risk factors and (i) glenohumeral joint pain and (ii) rotator cuff tendinopathy. We hypothesize that a risk-stratified combination of CVD risk factors, using a well-validated model for CVD,[46] is associated with rotator cuff tendinopathy.

METHODS

This study was approved by the Institutional Review Boards of the University of Utah and University of Wisconsin-Milwaukee. The baseline data used in this cross-sectional study were from the WISTAH hand study.[47] Detailed publications of the WISTAH study methods were previously published,[47,48] therefore, a summary follows.

In the WISTAH hand study, workers were recruited from 17 diverse production facilities of 15 employers, including food processing, manufacturing, assembly lines, and office jobs from 2001 through 2007. The 17 facilities were located in Wisconsin, Utah, and Illinois. Participants provided informed consent, and no incentives were paid for participation. Participants were enrolled from worksites as convenience samples based on a pre-calculated sample size that targeted workers based on the physical demands of the job: one-third from low, one-third from medium, and one-third from highly physically demanding jobs. The presence or absence of any

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symptoms was not an inclusion or exclusion criterion. A few workers were excluded for severe hand deformities, severe arthritis, or pending retirement.

The Health Outcomes Assessment Team was responsible for collecting baseline health data through questionnaires and structured interviews. The computerized questionnaire consisted of 266 items, including demographics, hobbies, physical activity, job satisfaction, hyperlipidemia, hypertension (HTN), DM, and depression. During the subsequent structured interview, 483 questions were reviewed with a body diagram to help localize symptoms. A standardized musculoskeletal physical examination was performed by a physician, including inspection, palpation, range of motion, and special maneuvers. Body mass indices (BMIs) were calculated from measured heights and weights. Blood pressure (BP) was measured with an automated cuff after participants had been seated for at least 5 minutes. Each participant completed the questionnaire and physical examination regardless of symptoms.

The data were used to define the following health outcomes: (i) glenohumeral joint pain, defined as any pain in the past month (1-month period prevalence) in the right, left, or bilateral glenohumeral areas, and (ii) rotator cuff tendinopathy, defined as glenohumeral joint pain in addition to a positive supraspinatus test against resistance (Empty Can test).

Each worker's job was measured and videotaped by the Job Exposure Assessment Team. Job measurements were used to calculate job physical strain, including from six primary factors that included force, repetition rate, posture, speed of work, duration of exertion, and duration of task per day. After measurement of each worker's job, a composite measure of physical job strain, a Strain Index score, was calculated.[47,49,50]

For this study, each worker's CVD risk score was calculated. CVD variables were scaled in accordance with a modified Framingham Heart Study's risk assessment (Table 1).[46] A CVD risk score was calculated for every participant on the basis of gender, age, history of high cholesterol (>200 mg/dL), BP (previous diagnosis of HTN and current systolic BP reading), a diagnosis of DM, and a history of smoking or tobacco use. Individualized CVD risk scores could theoretically range from 0 to 29. However, in a working-age population, the upper end of the spectrum was anticipated to have little statistical power and an a priori decision was made to collapse high end scores into one group of at least 18 points.

Statistical Analyses

Analyses were run using SAS 9.4 software, Cary NC. Two participants with missing shoulder data were removed from the analyses. Logistic regression was performed to assess the risk between CVD risk factors and (i) glenohumeral joint pain and (ii) rotator cuff tendinopathy. Each level of CVD risk from 0 to 18+ was analyzed, and statistical significance was set at a P value less than 0.05. Univariate analyses were performed with each variable to evaluate its association with each health outcome. Those demonstrating associations were then added to a multivariate logistic regression model to assess independence and influence of confounders. Potential confounding variables with meaningful evidence of association with glenohumeral joint pain ($P < 0.20$) were considered for addition to the multivariate models. The

TABLE 1. Modified Framingham CVD Risk Scores

Score	Age, Years	High Cholesterol Diagnosis	Systolic BP + No High BP Diagnosis	Systolic BP + Yes High BP Diagnosis	Tobacco Use	Diabetes Mellitus
(A) For women						
0	≤34.9	No	<130	<120	No	No
1			130–139			
2	35–39.9		140–149	120–129		
3		Yes		130–139	Yes	
4	40–40.9		150–159			Yes
5	45–49.9		≥160	140–149		
6				150–159		
7	50–54.9			≥160		
8	55–59.9					
9	60–64.9					
10	65–69.9					
11	70–74.9					
12	≥75					
(B) For men						
0	≥34.9	No	<130	<120	No	No
1			130–139			
2	35–39.9	Yes	140–159	120–129		
3			≥160	130–139		Yes
4				140–159	Yes	
5	40–40.9			≥160		
6	45–49.9					
7						
8	50–54.9					
9						
10	55–59.9					
11	60–64.9					
12	65–69.9					
13						
14	70–74.9					
15	≥75					

Points allotted based on the Framingham Heart Study CVD risk tables.[46]
BP, blood pressure; CVD, cardiovascular disease; mm Hg; high cholesterol defined as a laboratory test result >200 mg/dL.

TABLE 2. Population Demographics Stratified Separately for Shoulder Pain and Rotator Cuff Tendinopathy

CVD Risk Factors* Variable (N = 1,226)	Shoulder Pain (n = 386, 31.5%)	No Shoulder Pain (n = 840, 68.5%)	RCT (n = 156, 12.7%)	No RCT (n = 1,070, 87.3%)
Age, years	44.8 (10.6)	40.9 (11.6)	45.6 (10.7)	41.6 (11.4)
Gender				
Female	275 (71.2%)	530 (63.1%)	112 (71.8%)	693 (64.8%)
Male	111 (28.8%)	310 (36.9%)	44 (28.2%)	377 (35.2%)
Diabetes mellitus†				
Yes	29 (7.5%)	37 (4.4%)	13 (8.3%)	53 (4.9%)
No	357 (92.5%)	803 (95.6%)	143 (91.7%)	1,017 (95.1%)
Hypercholesterolemia†,‡				
Yes	84 (21.8%)	135 (16.1%)	34 (21.8%)	185 (17.3%)
No	302 (78.2%)	705 (83.9%)	122 (78.2%)	885 (82.7%)
Hypertension†				
Yes	87 (22.5%)	117 (13.9%)	40 (25.6%)	164 (15.3%)
No	299 (77.5%)	723 (86.1%)	116 (74.4%)	906 (84.7%)
Average systolic BP, mm Hg	129.3 (17.4)	126.9 (16.8)	130.8 (18.3)	127.2 (16.8)
Tobacco use				
Never	184 (47.7%)	404 (48.1%)	78 (50.0%)	510 (47.7%)
Current	109 (28.2%)	230 (27.4%)	44 (28.2%)	295 (27.6%)
Former	93 (24.1%)	206 (24.5%)	34 (21.8%)	265 (24.8%)
CVD risk score	8.4 (4.8)	6.9 (4.7)	8.9 (5.0)	7.2 (4.7)
BMI, kg/m^2	30.2 (6.9)	29.2 (6.6)	29.7 (6.4)	29.5 (6.8)
Physical activity, min/day	25.8 (37.4)	28.1 (39.7)	27.1 (43.8)	27.5 (38.3)
Job satisfaction				
Very satisfied	61 (15.8%)	226 (26.9%)	22 (14.1%)	265 (24.8%)
Satisfied	196 (50.8%)	439 (52.3%)	77 (49.4%)	558 (52.2%)
Neither	90 (23.3%)	130 (15.5%)	41 (26.3%)	179 (16.7%)
Dissatisfied	33 (8.6%)	40 (4.8%)	15 (9.6%)	58 (5.4%)
Very Dissatisfied	6 (1.6%)	5 (0.6%)	1 (0.6%)	10 (0.9%)
Depression				
Never	80 (20.7%)	228 (27.1%)	29 (18.6%)	279 (26.1%)
Seldom	222 (57.5%)	462 (55.0%)	88 (56.4%)	596 (55.7%)
Often	76 (19.7%)	135 (16.1%)	35 (22.4%)	176 (16.5%)
Always	8 (2.1%)	15 (1.8%)	4 (2.6%)	19 (1.8%)
Family problems				
Never	50 (13.0%)	186 (22.1%)	19 (12.2%)	217 (20.3%)
Seldom	232 (60.1%)	474 (56.4%)	88 (56.4%)	618 (57.8%)
Often	80 (20.7%)	133 (16.8%)	40 (25.6%)	173 (16.2%)
Always	24 (6.2%)	47 (5.6%)	9 (5.8%)	62 (5.8%)
Strain Index (per unit)	7.7 (8.3)	7.8 (9.8)	8.2 (9.2)	7.7 (9.4)

Percentages reported as a total of those with or without glenohumeral shoulder pain or rotator cuff tendinopathy. BMI was calculated from measured heights and weights; Diabetes mellitus, hypercholesterolemia, and hypertension were yes/no based on self-reported previous physician diagnosis. BP was measured.

BP, blood pressure; CVD, cardiovascular disease risk index score based on the Framingham Heart Study; RCT, rotator cuff tendinopathy.

*Data reported as averages *n* (%) or mean ± standard deviation.

†Average "Yes" responses to reported physician diagnoses.

‡Hypercholesterolemia defined as a laboratory test result >200 mg/dL.

confounders assessed were gender, BMI, physical activity, job satisfaction, depression, family problems, and job physical strain (Strain Index for the typical job task on the right hand). Logistic regression was performed to assess the adjusted model for associations between CVD risk factors and both glenohumeral joint pain and rotator cuff tendinopathy. See Table 1 for modified Framingham CVD risk score by gender.

RESULTS

There were 1226 workers analyzed in this study (Table 2). The average age was 42.1 (±11.4) years. A majority of the participants were female (*n* = 805, 65.7%). There were 66 (5.4%) participants with previously diagnosed DM, 219 (17.8%) with hypercholesterolemia, and 204 (16.6%) with HTN. Tobacco use either formerly or currently was common, being reported by 638 (52.0%) participants. Of the total population, 386 (31.5%) reported glenohumeral joint pain in the prior month in the right side, left side, or bilaterally. The point prevalence for rotator cuff tendinopathy, a diagnosis of both glenohumeral joint pain in the prior month and a positive supraspinatus test, was 156 (12.7%).

The age of those with rotator cuff tendinopathy was greater at 45.6 (±10.7) than at 41.6 (±11.4) in those without rotator cuff tendinopathy. The average systolic BP among those with rotator cuff tendinopathy was higher, 130.8 (±18.3) mm Hg, than in those without, 127.2 (±16.8) mm Hg. There was a little difference in BMI between the two groups, 29.7 (±6.4) kg/m^2 in those with rotator cuff tendinopathy and 29.5 (±6.8) kg/m^2 in those without. The average CVD risk scores were higher in the group with rotator cuff tendinopathy 8.9 (±5.0) than among those without tendinopathy 7.2 (±4.7).

Each CVD risk factor was analyzed separately to assess associations with (i) glenohumeral joint pain and (ii) rotator cuff tendinopathy (Table 3). Statistically, the older participants were more likely to report glenohumeral joint pain and to be diagnosed with rotator cuff tendinopathy. Females were at an increased risk of glenohumeral joint pain. Gender was not associated with rotator cuff

TABLE 3. Associations Between Individual Variables and Health Outcomes

CVD Risk Factors	Glenohumeral Joint Pain			Rotator Cuff Tendinopathy		
Variable ($N = 1,226$)	**Cases/Total**	**OR**	**95% CI**	**Cases/Total**	**OR**	**95% CI**
Age	**386/1,226**	**1.03**	**1.02–1.04**	**156/1,226**	**1.03**	**1.02–1.05**
Gender: Female versus male	**275/805 F** **111/421 M**	**1.45**	**1.11–1.88**	112/805 F 44/421 M	1.39	0.96–2.01
Diabetes mellitus	**29/66**	**1.76**	**1.07–2.91**	13/66	1.74	0.93–3.28
Hypercholesterolemia	**84/219**	**1.45**	**1.07–1.96**	34/219	1.33	0.88–2.01
Hypertension	**87/204**	**1.81**	**1.33–2.47**	**40/204**	**1.91**	**1.28–2.83**
Systolic blood pressure	**386/1,226**	**1.01**	**1.00–1.02**	**156/1,226**	**1.01**	**1.00–1.02**
Tobacco use						
Never	184/588	(Ref)	—	78/588	(Ref)	—
Current	109/339	1.04	0.78–1.39	44/339	0.98	0.66–1.45
Former	93/299	0.99	0.73–1.34	34/299	0.84	0.55–1.29
BMI, kg/m^2	**386/1,226**	**1.02**	**1.00–1.04**	156/1,226	1.00	0.98–1.03
Physical activity, min/day	386/1,226	1.00	0.99–1.00	156/1,226	1.00	0.99–1.00
Job satisfaction						
Very satisfied	61/287	(Ref)	—	22/287	(Ref)	—
Satisfied	**196/635**	**1.66**	**1.19–2.30**	**77/635**	**1.66**	**1.01–2.73**
Neither	**90/220**	**2.59**	**1.75–3.82**	**41/220**	**2.76**	**1.59–4.79**
Dissatisfied	**33/73**	**3.14**	**1.82–5.40**	**15/73**	**3.11**	**1.52–6.37**
Very dissatisfied	**6/11**	**4.45**	**1.31–15.06**	1/11	1.21	0.15–9.85
Depression						
Never	80/308	(Ref)	—	29/308	(Ref)	—
Seldom	222/684	1.37	1.02–1.85	88/684	1.42	0.91–2.21
Often	76/231	1.62	1.11–2.36	55/231	1.91	1.13–3.24
Always	8/23	1.52	0.62–3.72	4/23	2.03	0.65–6.36
Family problems						
Never	50/236	(Ref)	—	19/236	(Ref)	—
Seldom	232/706	1.82	1.28–2.57	88/706	1.63	0.97–2.73
Often	80/213	2.23	1.47–3.38	40/213	2.64	1.48–4.72
Always	24/71	1.89	1.06–3.84	9/71	1.66	0.71–3.85
Strain Index (per unit)	172/598	1.00	0.98–1.02	71/598	1.01	0.98–1.03

All bold values are $P < 0.05$.
Physical activity defined as the >90 minutes per week between 14 activities with opportunities to add other activities.
Job satisfaction: Responses to the question, (All in all, how satisfied are you with your job?).
Depression: Responses to the question, (How often during the past year have you felt ''down'', blue or depressed?).
Family problems: Responses to the question, (How often do you have family problems that irritate or bother you?).[47]
BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; OR, odds ratio.

tendinopathy. Both DM and hypercholesterolemia were statistically associated with glenohumeral joint pain, but not rotator cuff tendinopathy. However, the point estimates were nearly identical, suggesting underpowering for rotator cuff tendinopathy. A diagnosis of HTN was associated with an increased risk of glenohumeral joint pain and rotator cuff tendinopathy. A current or former history of tobacco use was not significantly associated with either health outcome.

Potential confounders were analyzed separately in order to build two multivariate models (Table 3). Increased BMI was associated with an increased risk of glenohumeral joint pain, but not rotator cuff tendinopathy. Physical activity, defined as minutes per day of physical fitness outside of work, was not significantly associated with either health outcome. Depression was modestly associated with glenohumeral joint pain and rotator cuff tendinopathy. Job satisfaction and family problems were significantly associated with glenohumeral joint pain and modestly associated with rotator cuff tendinopathy. The Strain Index scores were not statistically significant with regard to either glenohumeral joint pain or rotator cuff tendinopathy.

Unadjusted analyses were performed to assess associations between each CVD risk score and the risk of having (i) glenohumeral joint pain and (ii) rotator cuff tendinopathy (reported glenohumeral joint pain and a positive supraspinatus test) (Table 4). Statistical significance was present at multiple CVD risk scores for both health outcomes. The data showed a significant trend between CVD risk scores and glenohumeral joint pain ($P = 0.003$) with a peak OR of 3.75 (95% CI 1.70 to 8.29). The data also showed a significant trend between CVD risk scores and rotator cuff tendinopathy ($P = 0.02$) and a higher peak OR of 4.49 (95% CI 1.66 to 12.2).

Two multivariate models were adjusted for potential confounders from the univariate analyses. These confounders were gender, BMI, job satisfaction, and family problems. The results were largely comparable to the unadjusted rates, although the odds ratios tended to be stronger in the multivariate models (Table 5). There was statistical significance at multiple CVD risk scores for both glenohumeral joint pain and rotator cuff tendinopathy. For glenohumeral joint pain, the trend was stronger ($P < 0.001$) than the unadjusted model and peaked at the highest CVD risk score of 18+ with an OR of 4.55 (95% CI 1.99 to 10.40). For rotator cuff tendinopathy, the trend was also more significant ($P = 0.008$) than the unadjusted model and again peaked at the highest CVD risk score of 18+ with an OR of 5.97 (95% CI 2.12 to 16.83) (Fig. 1).

DISCUSSION

CVD risk factors combined into a modified Framingham CVD risk score demonstrated a strong correlation with both glenohumeral joint pain and rotator cuff tendinopathy. This association remained strong after adjusting for potential confounders of gender, BMI, job satisfaction, and family problems. These results, analyzing baseline data from a large working population in

TABLE 4. Crude OR and 95% CI for Associations Between CVD Risk Scores and Glenohumeral Joint Pain and Rotator Cuff Tendinopathy

CVD Risk Score	Glenohumeral Joint Pain			Rotator Cuff Tendinopathy		
	Cases/Total	OR	95% CI	Cases/Total	OR	95% CI
Ref = 0	24/144	1.0	—	9/114	1.0	—
1	4/21	0.88	0.27–2.87	2/21	1.23	0.25–6.13
2	15/57	1.34	0.64–2.81	6/57	1.37	0.46–4.07
3	19/89	1.02	0.52–2.01	10/89	1.48	0.57–3.81
4	23/106	1.04	0.55–1.98	8/106	0.95	0.35–2.57
5	33/103	1.77	0.96–3.26	11/103	1.40	0.55–3.52
6	17/56	1.64	0.79–3.38	6/56	1.40	0.47–4.15
7	31/108	1.51	0.82–2.79	11/108	1.32	0.53–3.33
8	**42/116**	**2.13**	**1.18–3.83**	13/116	1.47	0.60–3.59
9	13/39	1.88	0.84–4.19	2/39	0.63	0.13–3.05
10	**39/91**	**2.81**	**1.52–5.19**	**19/91**	**3.08**	**1.32–7.19**
11	29/73	2.47	1.29–4.73	16/73	3.28	1.36–7.88
12	**20/55**	**2.14**	**1.05–4.36**	6/55	1.43	0.48–4.24
13	13/49	1.35	0.62–2.95	5/49	1.33	0.42–4.18
14	**17/40**	**2.78**	**1.28–6.00**	6/40	2.06	0.68–6.20
15	11/33	1.88	0.80–4.40	**7/33**	**3.14**	**1.07–9.22**
16	**12/24**	**3.75**	**1.50–9.39**	**6/24**	**3.89**	**1.23–12.3**
17	6/16	2.25	0.74–6.81	3/16	2.69	0.65–11.2
18+	**18/36**	**3.75**	**1.70–8.29**	**10/36**	**4.49**	**1.66–12.2**

All bold values are $P < 0.05$.
Glenohumeral joint pain ($P = 0.003$).
Rotator cuff tendinopathy ($P = 0.021$).
CI, confidence interval; CVD, cardiovascular disease; OR, odds ratio.

multiple industries across three states, suggest that the pathophysiology of rotator cuff tendinopathy is multifactorial and CVD risk factors appear to contribute meaningfully to an underlying disease mechanism. This study adds to a growing body of research that common musculoskeletal disorders are associated with CVD risk factors, including Achilles tendinopathy, carpal tunnel syndrome, and lateral epicondylitis.[17,51–53]

Previous evidence has found individual CVD risk factors to be associated with rotator cuff tendinopathy. Multiple studies have reported DM to be associated with rotator cuff tendinopathy and

TABLE 5. Multivariate Adjusted OR and 95% CI for Associations Between CVD Risk Scores and Glenohumeral Joint Pain and Rotator Cuff Tendinopathy

CVD Risk Score	Glenohumeral Joint Pain*			Rotator Cuff Tendinopathy*		
	Cases/Total	OR	95% CI	Cases/Total	OR	95% CI
Ref = 0	24/144	1.0	—	9/114	1.0	—
1	4/21	1.17	0.35–3.98	2/21	1.73	0.33–8.96
2	15/57	1.60	0.74–3.45	6/57	1.80	0.59–5.46
3	19/89	0.86	0.43–1.74	10/89	1.31	0.50–3.13
4	23/106	1.15	0.59–2.22	8/106	1.06	0.39–2.89
5	**33/103**	**2.06**	**1.09–3.87**	11/103	1.66	0.65–4.25
6	17/56	1.84	0.86–3.95	6/56	1.49	0.49–4.57
7	31/108	1.59	0.84–3.00	11/108	1.44	0.56–3.68
8	**42/116**	**2.34**	**1.27–4.31**	13/116	1.60	0.64–3.96
9	13/39	2.28	0.99–5.25	2/39	1.78	0.16–3.82
10	**39/91**	**3.15**	**1.66–5.95**	**19/91**	**3.39**	**1.42–8.07**
11	**29/73**	**2.83**	**1.44–5.55**	**16/73**	**4.03**	**1.64–9.95**
12	**20/55**	**2.57**	**1.23–5.38**	6/55	1.80	0.59–5.47
13	13/49	1.50	0.67–3.34	5/49	1.54	0.48–4.96
14	**17/40**	**3.01**	**1.34–6.73**	6/40	2.39	0.77–7.41
15	11/33	2.20	0.90–5.37	7/33	3.93	1.29–11.99
16	**12/24**	**3.86**	**1.48–9.86**	**6/24**	**4.44**	**1.37–14.39**
17	6/16	2.77	0.85–8.78	3/16	3.95	0.90–17.37
18+	**18/36**	**4.55**	**1.97–10.31**	**10/36**	**5.97**	**2.12–16.83**

All bold values are $P < 0.05$.
CI, confidence interval; CVD, cardiovascular disease; OR, odds ratio.
Glenohumeral joint pain ($P < 0.001$).
Rotator cuff tendinopathy ($P = 0.008$).
*Adjusted for gender, BMI, job satisfaction, and family problems.

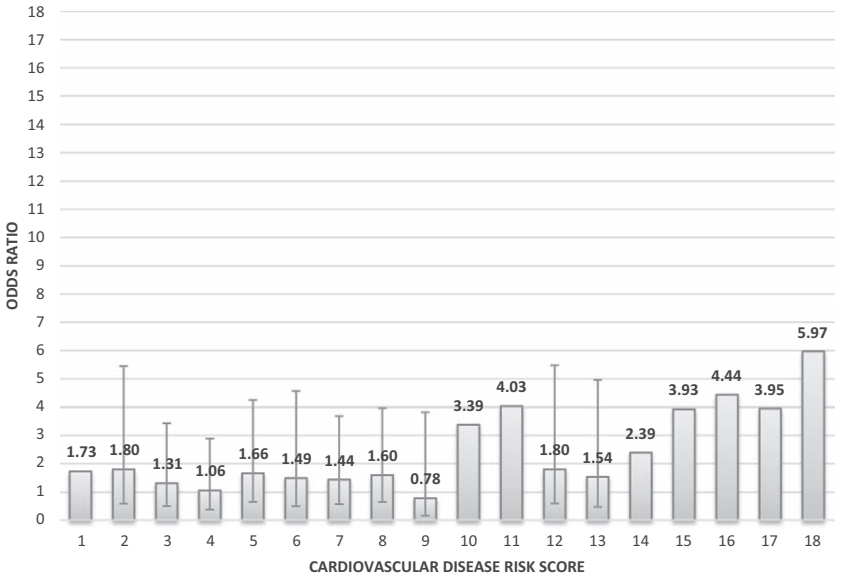

FIGURE 1. Adjusted odds ratios for rotator cuff tendinopathy by CVD risk score ($P \leq 0.001$).

shoulder disorders.[17,35,37,54] Obesity has been identified as a risk factor for rotator cuff tendinopathy.[29,55] Hyperlipidemia (total cholesterol greater than 240 mg/dL) has been shown to be a risk factor for rotator cuff tears.[34] Many other studies have also found associations between tobacco use and rotator cuff disease.[28,30,31,41,56,57]

This study meaningfully contributes to the body of evidence. Univariate analyses of nearly all Framingham CVD risk factors, namely age, gender, BP, cholesterol, and DM, were significantly associated with rotator cuff tendinopathy. Current or former tobacco use was not statistically associated with either health outcome. The association between combined CVD risk factors and rotator cuff tendinopathy using the multivariate model was statistically significant with a stronger correlation than the univariate analyses. This suggests an interaction between the risk factors, which has been well documented in CVD research, and proposes a valid impact on the development of shoulder disorders, including rotator cuff tendinopathy.[58,59]

Strengths and Limitations

Strengths of this study include a large, multistate, multiemployer study population with systematic evaluation of disease status through structured interviews and standardized physical examinations. Data gathering from a variety of occupations, work-sites, and states, likely improves generalizability. Systematic measurement of each worker's BP and measured height and weight to obtain a calculated BMI are added strengths. Although not found to be a significant confounder, the ability to adjust for measured job physical factors is a unique study feature. Although there is no validated ergonomic model for the shoulder, this study used the Strain Index for adjusting ergonomic risks. The Strain Index includes a measurement of force, an important putative ergonomic shoulder risk factor,[28,60,61] along with a potentially unimportant hand/wrist posture component.

Limitations of this study include the cross-sectional design that prevents assessment of temporality. Still, only the unlikely presence of an uncontrolled powerful confounder that has a dose–response impact across the range of CVD risk factors would invalidate this study's findings. Also, the study population is largely in manufacturing, which could theoretically limit generalizability. Nevertheless, the relationships with CVD risk factors seem unlikely to be substantially dissimilar to the general population. The CVD data required modest modifications to fit the Framingham Heart Study risk model, although this would likely have biased toward the null, as exact cholesterol measurements would likely make the association stronger.

CONCLUSIONS

This cross-sectional study's data demonstrate a strong correlation between CVD risk factors and rotator cuff tendinopathy. The results show a dose–response trend of increasing risk is consistent with prior research linking individual risk factors to rotator cuff tendinopathy, and are biologically plausible. Although these results present a potentially modifiable disease mechanism, prospective studies are needed to confirm this mechanism and test whether modification of CVD risk factors changes the clinical course, or prevents rotator cuff tendinopathy.

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