Disability and Rehabilitation

ISSN: 0963-8288 (Print) 1464-5165 (Online) Journal homepage: https://www.tandfonline.com/loi/idre20

Defining subgroups of patients with a stiff and painful shoulder: an analytical model using cluster analysis

Brian Pease & Michael Ross

DISABILITY AND REHABILITATION
https://doi.org/10.1080/09638288.2019.1631891

Taylor & Francis
Taylor & Francis Group

ARTICLE

Defining subgroups of patients with a stiff and painful shoulder: an analytical model using cluster analysis

Brian Pease[a] and Michael Ross[b]

[a]Body One Physical Therapy, Indianapolis, IN, USA; [b]Department of Physical Therapy, Daemen College, Amherst, NY, USA

ABSTRACT

Purpose: The primary purpose of this research was to develop a classification system for patients with stiff and painful shoulders using hierarchical cluster analysis.

Methods: Medical charts of 52 patients treated for stiff and painful shoulders were reviewed for descriptive and clinical data after completion of their rehabilitation. A clinician-reported outcome was derived from ratings of three members of the American Society of Shoulder and Elbow Therapists. Data were subjected to cluster analysis using the hierarchical method. Analysis of difference tests was performed to determine if differences between clusters could be found with either initial examination or outcome data.

Results: Two clusters emerged from the clustering process: a healthy, strong, and mobile group of 32 patients, and an unhealthy, weak, and immobile groups consisting of 20 patients. Significant differences in initial examination measures between clusters were found for the presence of co-morbidities, range of motion for shoulder flexion, abduction, external rotation, and internal rotation, and strength of the shoulder external rotators and in the empty can position. Significant differences between clusters were found for shoulder flexion, abduction, and external rotation range of motion, and clinician-reported outcome at the time of patient discharge.

Conclusion: Patients with stiff and painful shoulders in this study were classified into two distinct subgroups using hierarchical cluster analysis based on demographic attributes and initial examination findings. The findings from this study also suggest that patients who may be at risk for a poorer outcome can be identified based on initial examination measures. By identifying these patients early in rehabilitation who have a poorer prognosis, improved patient education, alternative interventions or diagnostic tests may be utilized on their behalf.

ARTICLE HISTORY
Received 1 February 2019
Revised 11 June 2019
Accepted 11 June 2019

KEYWORDS
Adhesive capsulitis; outcomes; physical therapy; frozen shoulder; shoulder pain

➤ **IMPLICATIONS FOR REHABILITATION**

- Patients with stiff and painful shoulders were classified into two subgroups using hierarchical cluster analysis based on demographic attributes and initial examination findings.
- Significant differences in mean clinician-reported outcome was also noted between clusters, with the patients who were healthier, stronger, and more mobile having a significantly better outcome than those patients who were more unhealthy, weak, and immobile.
- The findings from this study suggest that patients can be identified on initial examination who may be at risk for a poorer outcome.
- By identifying these patients early in rehabilitation who have a poorer prognosis, improved patient education, alternative interventions, or diagnostic tests may be utilized on their behalf sooner in the course of care.

Introduction

"Frozen shoulder" and "adhesive capsulitis" are commonly used as diagnostic labels to refer to patients with essentially the same clinical presentation: a stiff and painful shoulder. The lack of specificity of these diagnostic labels has resulted in confusion in adequately defining and effectively treating this group of patients. Regardless of the diagnosis label used, these patients are commonly referred to physical therapy for treatment [1–5]. While clinicians and authors often use the terms interchangeably, some have suggested that there is a need to differentiate the general condition (frozen shoulder) from the more specific condition (adhesive capsulitis) [6].

It has been proposed that within this group of patients with stiff and painful shoulders there may exist subgroups of homogenous patients having more in common with each other than with the group as a whole [2,6–9]. Neviaser and Neviaser [6] have advocated the use of diagnostic tests such as an arthrogram, or the use of arthroscopy, to clearly differentiate adhesive capsulitis from the generic stiff and painful shoulder. For this distinction to be meaningful in rehabilitation, there must be clinical signs and symptoms that can be identified to distinguish between these groups. Clinicians likely treat several similar entities under the terms stiff and painful shoulder, frozen shoulder or adhesive capsulitis, including chronic impingement and rotator cuff pathology.

Regardless of the diagnostic label, physical therapy interventions for the patients with a stiff and painful shoulder are often rendered based on impairment measures. Given this fact, whether the group of patients with stiff and painful shoulders represents

CONTACT Brian Pease bpease@bodyonept.com Body One Physical Therapy, 8902 N. Meridian St., Suite #120, Indianapolis, IN 46260, USA.

one, two, or more than two entities will only matter if distinct subgroups of patients can be identified based on impairment measures, and subsequently if there are differing clinical paths and outcomes associated with these groups. If no difference between groups exists in intervention chosen, clinical course, or outcomes, then the argument is moot. We are aware of no analytical attempt to identify subgroups or clusters within a group of patients with stiff and painful shoulders, with the diagnostic label of either "frozen shoulder" or "adhesive capsulitis". Therefore, the primary purpose of this research was to develop a classification system for patients with stiff and painful shoulders using hierarchical cluster analysis.

Methods

Design

This was a non-experimental, retrospective, study of consecutive patients with stiff and painful shoulders seen in an outpatient orthopedic physical therapy setting. Clustering of cases was performed using measurements and variables taken at the initial physical therapy examination and extracted during chart review once the individual's course of care had been completed. The measurements and variables that were utilized in this study were selected based upon their usefulness and routine use in the pragmatic clinical evaluation of a patient with a stiff and painful shoulder (Table 1) [1,2,6–9]. Validity of the resultant cluster solution was explored using outcome data extracted from the chart, and a clinician-reported outcome based on ratings of a panel of experts in shoulder rehabilitation [10,11]. The study was approved by the Committee on Research Involving Human Participants at the University of Indianapolis, Indianapolis, IN.

Subjects

This study included 52 patients treated by a single physical therapist in an outpatient orthopedic physical therapy setting. The physical therapist who treated the patients in this study was board certified in orthopedic physical therapy with 15 years of clinical experience specializing in patients with orthopedic disorders. Patients were included if they were referred to a physical therapist by a physician with a diagnostic label of "frozen shoulder" or "adhesive capsulitis" and had examination findings of a premature capsular end-feel, with active and passive motion similarly limited [2,6]. The sample included 34 women and 18 men, with a mean age of 52 years. Twenty patients were treated for right shoulder involvement, and 32 had left shoulder dysfunction, with 32 of 52 patients having their non-dominant shoulder involved.

Patients were excluded if they had: (1) a history of fracture, dislocation, cervical spine injury with radiculopathy, peripheral nerve injury, glenohumeral joint osteoarthritis, or rotator cuff tear; (2) strength of less than or equal to 3/5 with manual muscle testing in either abduction, external rotation, or the empty can position, suggesting a neurological or tendon injury; (3) a lag of more than 10 degrees between active and passive motion in any direction, suggesting that weakness or pain limited motion more than capsular restriction; or 4) less than 75% of the variables of interest available during chart review [1,4,5,11].

Procedures

Data from the initial physical therapist examination (Tables 1 and 2) were transferred to a standardized data form during chart reviews. In addition to data extracted from patient charts, a clinician-reported outcome was determined by having three physical therapist members of the American Society of Shoulder and Elbow Therapists rate each patient's outcome. The raters reviewed range of motion measures and patient self-reported functional limitations and pain at discharge to determine a clinician-reported outcome. The raters were blinded to the identity of all patients. Each case was rated by all three expert clinicians using a visual analog scale (VAS) of 10 cm length with endpoints of "unsatisfactory" (0) and "excellent" (10). The outcome rating for each patient was determined by measuring the VAS score of each rater and taking the mean of the three scores for each case.

Inter-rater reliability of the clinician-reported outcome was determined prior to inclusion of ratings in data analysis using the intraclass correlation coefficient (ICC) (3,1) model. The result of the ICC (3,1) was 0.83, with a 95% confidence interval of 0.75–0.94. A repeated measures analysis of variance also found no difference between raters 1, 2, or 3 ($F = 1.68$, $p = 0.192$) [12].

Table 1. Initial examination data.

Variable	Values
Age	Years
Gender	Male, female
Involvement of dominant shoulder	Yes, no
Presence of comorbidities (connective tissue disorders, hypertension, diabetes, cancer, hypo or hyperthyroidism, or previous frozen shoulder)	Yes, no
Duration of symptoms	Months
Pain at night or at rest	Yes, no
Active flexion	Degrees
Active abduction	Degrees
Active external rotation	Degrees
Active internal rotation (hand behind back)	Centimeters
Abduction strength (strong: 5/5 with MMT; weak: 4/5 with MMT)	Strong, weak
Abduction pain with resistance	painful, painless
External rotation strength (strong: 5/5 with MMT; weak: 4/5 with MMT)	Strong, weak
External rotation pain with resistance	Painful, painless
Empty can strength (strong: 5/5 with MMT; weak: 4/5 with MMT)	Strong, weak
Empty can pain with resistance	Painful, painless

Active range of motion was measured with a goniometer except for active internal rotation, which was measured as the difference between involved and noninvolved hand behind back measures by asking the patient to place their hand behind the back with their thumb extended and reach up the back to the highest point along the midline. The distance reached by the tip of the extended thumb was recorded and compared between involved and noninvolved upper extremities.
MMT: manual muscle test.

Table 2. Outcome data.

Variable	Values
Discharge active flexion	Degrees
Discharge active abduction	Degrees
Discharge active external rotation	Degrees
Discharge active internal rotation	Centimeters
Number of visits	Visits
Length of treatment	Weeks
Clinician-reported outcome	Visual analog scale: 0 (unsatisfactory) to 10 (excellent)

Active range of motion measured with a goniometer except for active internal rotation, which was measured as the difference between involved and noninvolved hand behind back measures.

Table 3. Analysis of differences between the two clusters at the time of initial examination.

		Sample total	Cluster 1 ($n = 32$)	Cluster 2 ($n = 20$)	Test statistic	p
Age (years)	X	52.0	52.03	51.90	$t = 0.09$	$p = 0.926$
	s	8.39	7.59	9.73		
	Range	33–71	33–66	36–71		
Length of	X	6.64	8.13	4.33	$u = 232.00$	$p = 0.130$
Symptoms	s	7.07	8.41	3.23		
(months)	Range	1.0–36.0	1–36	1–12		
Active flexion	X	110.79	121.47	93.70	$t = 8.88$	*$p = 0.000$
(degrees)	s	17.44	10.24	12.07	$u = 15.5$	*$p = 0.000$
	Range	75–145	105–145	75–110		
Active abduction	X	105.06	124.59	73.80	$t = 10.50$	*$p = 0.000$
(degrees)	s	30.08	18.43	14.27		
	Range	45–160	90–160	45–100		
Active external	X	40.00	51.19	22.1	$t = 6.94$	*$p = 0.000$
Rotation	s	19.51	10.99	16.62		
(degrees)	Range	0–75	35–75	0–50		
Active internal	X	−16.92	−14.81	−20.32	$t = 2.66$	*$p = 0.010$
Rotation	s	7.70	6.53	8.33		
(cm)	Range	−30.48 to 0	−30.48 to 0	−30.48 to 0		

Cluster 1 included patients who were healthier, stronger, and more mobile and cluster 2 included patients who were who were more unhealthy, weak, and immobile. X=mean; s=standard deviation. Active internal rotation was measured as the difference between involved and non-involved hand behind back measures. A negative value indicates that the involved hand could not reach as far as the non-involved hand. For example, a difference of −10 cm indicates that the noninvolved hand reached 10 cm farther than the involved hand.
*Statistically significant at $p<0.05$.

Data analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences program (IBM Corporation, Chicago, IL). Cluster analyses were performed to determine if subgroups of patients existed with similar profiles in terms of history and physical examination findings. Analyses were based upon a hierarchical approach, which uses minimum variance criteria to determine patient grouping [10]. The number of clusters subsequently chosen was based on the graphical display of the clusters through a dendrogram.

Following the determination of cluster membership, groups were tested for differences in initial examination findings used in the cluster solution. Continuous variables within clusters were analyzed for normality using the Shapiro–Wilk's test. Analysis of differences using appropriate tests were performed to determine whether a statistically significant difference existed across clusters for each variable in the clustering solution. Because cluster analysis is designed to maximize differences between clusters for each variable in the cluster solution, results of statistical tests for differences using these variables were used only for descriptive purposes**.** The alpha level was set at 0.05 for all tests of differences.

Finally, clinical relevance was determined by inspecting mean values for outcome variables in each cluster to determine whether the clusters formed were representative of different clinical subgroups. Outcome measures were assessed for normality prior to statistical analysis using the Shapiro–Wilk's test. The statistical assessment of clinical relevance consisted of an analysis of differences between clusters for outcome measures. The alpha level was set at 0.05 for all tests of differences.

Results

Subjects

Forty-five of 52 patients reported the presence of pain at night or at rest. Thirty-one of 45 patients reported the presence of one or more comorbidities. Strength assessment revealed weak abductors in 30 of 48 patients, weak external rotators in 26 of 47 patients, and weakness in the empty can position in 29 of 45 patients. Twenty-four of 46 patients had pain with resisted abduction, 17 of 45 patients had pain with resisted external rotation, and 28 of 43 patients had pain with the resisted empty can test. Descriptive statistics for continuous variables included in the clustering solution are included in Table 3.

Two clusters emerged from the clustering process: a healthy, strong, and mobile (HSM) group of 32 patients, and an unhealthy, weak, and immobile (UWI) groups consisting of 20 patients. Figure 1 displays the dendrogram of the hierarchical clustering solution. Note that two large clusters are formed, demarcated between patient cases 10 and 3. The first cluster (above and including patient case 10) represented an unhealthy, weak, and immobile groups of 20 patients. The second cluster (below

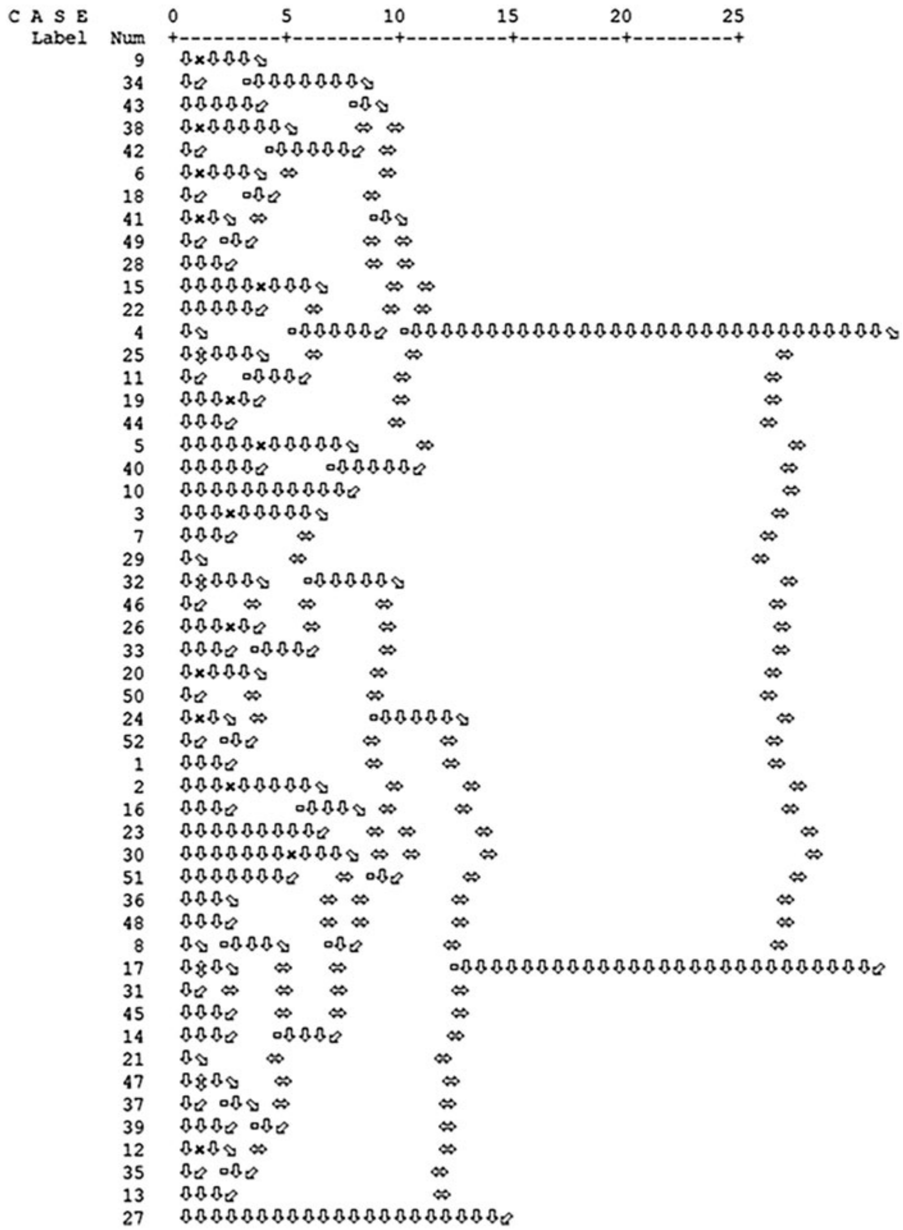

Figure 1. Dendrogram of the hierarchical clustering solution. Note that two large clusters are formed, demarcated between patient cases 10 and 3. The first cluster (above and including patient case 10) represented an unhealthy, weak, and immobile groups of 20 patients. The second cluster (below and including patient case 3) represented the healthy, strong, and mobile group of 32 patients.

and including patient case 3) represented the healthy, strong, and mobile group of 32 patients. Descriptive statistics for continuous variables in the two clusters are displayed in Table 3, while frequencies of dichotomous variables in each cluster are displayed in Table 4.

Results of tests for differences in means between clusters for initial examination variables used in the clustering solution are found in Table 3. Significant differences were found between clusters for active flexion, abduction, external rotation, and internal rotation range of motion. No significant differences in age or length of symptoms were found between clusters.

Chi-Square tests revealed statistically significant differences between clusters at the time of initial examination for the presence of co-morbidities, external rotation strength, and strength in the empty-can position (Table 4). No differences were found for gender, dominant/involved shoulder, pain at night or at rest, or abduction strength.

Results of analysis of difference tests for all outcome variables are displayed in Table 5. Although active flexion, abduction, and external rotation all improved over the intervention period for both clusters, statistically significant differences were still found between the two clusters for discharge flexion, discharge abduction, and discharge external rotation range of motion. Additionally, statistically significant differences between clusters were found for clinician-reported outcome. The distribution of clinician-reported scores for each cluster can be visualized in Figures 2 and 3. No significant differences were found between clusters for discharge internal rotation range of motion, number of visits, or length of treatment.

Discussion

The primary purpose of this research was to develop a classification system for patients with stiff and painful shoulders using

Table 4. Analysis of differences between the two clusters at the time of initial examination.

	Cluster 1 ($n = 32$)	Cluster 2 ($n = 20$)	Pearson Chi-Square	p value
Gender ($n = 52$)				
Female	21 (66%)	13 (65%)	0.002	$p = 0.963$
Male	11	7		
Involved shoulder ($n = 52$)				
Non-dominant	20 (63%)	12 (60%)	0.033	$p = 0.857$
Dominant	12	8		
Comorbidities ($n = 45$)				
None	12 (43%)	2 (12%)	4.77	*$p = 0.029$
One or more	16	15		
Pain at night/rest ($n = 52$)				
Pain	26 (81%)	19 (95%)	2.00	$p = 0.158$
No pain	6	1		
Abduction strength ($n = 48$)				
Strong	14 (48%)	4 (21%)	3.63	$p = 0.057$
Weak	15	15		
Pain with abduction ($n = 46$)				
Pain-free	12 (43%)	10 (56%)	0.708	$p = 0.400$
Painful	16	8		
ER strength ($n = 47$)				
Strong	18 (64%)	3 (16%)	10.77	*$p = 0.001$
Weak	10	16		
Pain with ER ($n = 45$)				
Pain-free	15 (56%)	13 (72%)	1.276	$p = 0.259$
Painful	12	5		
Empty can strength ($n = 45$)				
Strong	15 (56%)	1 (6%)	11.78	*$p = 0.001$
Weak	12	17		
Pain with empty can ($n = 43$)				
Pain-free	9 (35%)	6 (35%)	0.002	$p = 0.964$
Painful	17	11		

Cluster 1 included patients who were healthier, stronger, and more mobile and cluster 2 included patients who were who were more unhealthy, weak, and immobile. ER: external rotation.
*Statistically significant at $p < 0.05$.

hierarchical cluster analysis. Results of the cluster analysis revealed two subgroups of patients within a sample of patients with diagnostic labels of frozen shoulder or adhesive capsulitis. Hierarchical cluster analysis sorted patients into two groups characterized by significant differences in active range of motion in all directions, the presence of comorbidities, external rotation strength, and strength in the empty can position.

The first cluster included patients who were healthier, stronger, and more mobile (HSM) at the time of initial examination than those in the second cluster, who were more unhealthy, weak, and immobile (UWI). Patients sorted into the HSM cluster were clearly more mobile on average, with 121° of flexion, 125° abduction, 51° external rotation, and lacked 15 cm of internal rotation range of motion (measured through bilateral comparison of hand behind back motion) [13] at initial examination. Patients in the UWI cluster had an average of 94° flexion, 74° abduction, 22° external rotation, and lacked 20 cm of internal rotation. Winters et al. [11] found similar results in their cohort of patients with shoulder complaints in general practice, noting that the percentage of patients having limitations of both active and passive range of motion measures were significantly different across clusters.

Patients in the UWI cluster were significantly different than those in the HSM cluster in terms of the percentage of patients with weakness at initial examination. External rotation weakness was noted in 84% of those in the UWI cluster compared to 36% of those in the HSM group. Weakness in the empty can test position was found in 94% of patients in the UWI group compared to 44% of the HSM group. The finding of differences in the percentage of patients having weak external rotators and weakness in the empty can position suggest that this weakness may be associated with the lack of range of motion in the UWI cluster. It is unclear whether weakness precedes or follows the loss of range of motion in these patients. An alternative explanation is that the larger percentage of weakness found in the UWI group was due to pain. This conclusion seems unlikely given the fact that there was no significant difference found in the frequency of patients with pain on resisted testing of external rotators or in the empty can position between groups.

There are different “stages” of adhesive capsulitis and these stages may have substantial variation in the amount of pain, strength, and the degree of available movement seen on physical examination. No statistically significant differences between clusters were found in the current study for length of symptoms, although the HSM cluster was characterized by patients with a longer duration of symptoms (mean of 8.13 months) than the UWI cluster (mean of 4.33 months). It may be possible that patients falling into these two clusters were simply patients at different stages of the disease, which could certainly influence strength and mobility. Winters et al. [11] found significant differences between the percentage of patients with persistent symptoms between clusters, although their reporting of percentages of patients with persistent symptoms rather than the actual length of symptoms made further comparisons with this study difficult.

Interestingly, patients in the UWI cluster had greater changes in range of motion compared to patients in the HSM cluster. For example, changes in range of motion for the UWI cluster versus the HSM cluster were as follows: flexion: 29° versus 18°; abduction: 61° versus 38°; external rotation: 27° versus 14°. However, despite the changes in range of motion favoring the UWI group, the HSM group was characterized by greater range of motion at discharge in flexion, abduction, and external rotation when compared to the UWI group, which likely influenced clinician-reported outcome. When comparing the HSM and the UWI groups, clinically and statistically significant differences were noted in discharge flexion (139° versus 123°, $p = 0.001$), discharge abduction (163° versus 135°, $p = 0.004$), and discharge external rotation (65° versus 40°, $p = 0.0001$). Although groups were sorted based in part on initial examination range of motion, there was no reason to believe that these differences would remain at discharge.

The finding of differences between clusters in the frequency of patients reporting the presence of comorbities was consistent with previous literature [1]. In this study, patients in the UWI cluster had both an increased frequency of patients with comorbidities as well as a less successful outcome as measured by both impairment and clinician-reported outcome. These findings suggest that these patient’s shoulder conditions may have resulted from or been exacerbated by one or more co-morbid conditions. An alternative explanation is simply that patients who are less healthy may be expected to have a less satisfactory response to rehabilitation.

Much of the literature relating to the stiff and painful shoulder discusses the prevalence of comorbid conditions [2,6,14,15] and

Table 5. Analysis of differences between the two clusters at the time of discharge.

		Sample total	Cluster 1 ($n = 32$)	Cluster 2 ($n = 20$)	Test statistic	p value
Discharge	X	132.62	138.94	122.50	$u= 144.50$	$^*p= 0.001$
Flexion	s	16.66	8.81	21.06		
(degrees)	Range	75–165	117–165	75–150		
Discharge	X	152.17	162.81	135.15	$u= 168.50$	$^*p= 0.004$
Abduction	s	30.45	15.05	40.29		
(degrees)	Range	60–182	125–182	60–175		
Discharge ER	X	58.58	64.75	48.70	$t= 3.48$	$^*p= 0.002$
(degrees)	s	15.62	7.82	19.70		
	Range	0–82	50–82	0–75		
Discharge IR	X	−6.10	−4.67	−8.38	$u= 257.50$	$p= 0.235$
(cm)	s	6.71	4.52	8.86		
	Range	−25.4 to 0	−15.24 to 0	−25.4 to 0		
Visits	X	12.16	10.83	14.26	$u= 200.00$	$p= 0.080$
(cm)	s	7.24	6.59	7.89		
	Range	2–34	2–33	3–34		
Length of	X	14.02	13.3	15.16	$u= 278.00$	$p= 0.885$
Treatment	s	6.78	5.38	8.58		
(weeks)	Range	4–30	4–26	4–30		
Clinician-reported						
Outcome (0–10)	X	7.46	8.24	6.21	$u= 181.00$	$^*p= 0.009$
	s	2.34	1.47	2.90		
	Range	1.10–9.97	3.80–9.97	1.1–9.67		

Cluster 1 included patients who were healthier, stronger, and more mobile and cluster 2 included patients who were who were more unhealthy, weak, and immobile; X: mean; s: standard deviation; ER: external rotation; IR: internal rotation. Active internal rotation was measured as the difference between involved and noninvolved hand behind back measures. A negative value indicates that the involved hand could not reach as far as the noninvolved hand. For example, a difference of −10 cm indicates that the noninvolved hand reached 10 cm farther than the involved hand.
*Statistically significant at $p < 0.05$.

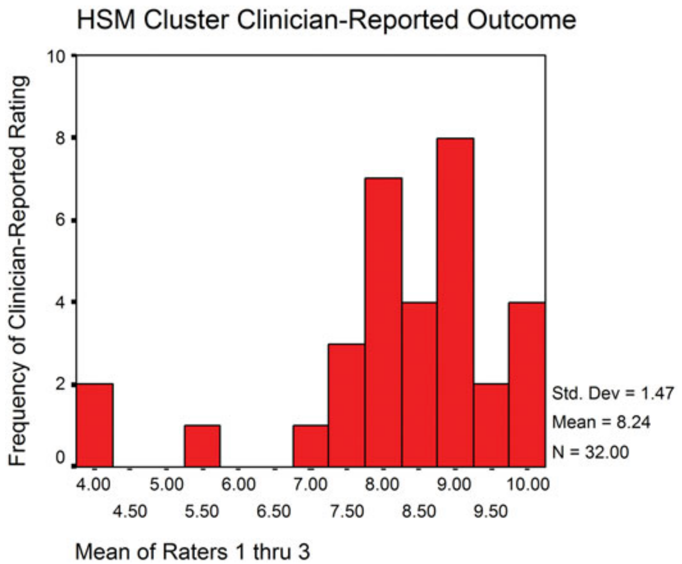

Figure 2. Clinician-reported outcome for patients in the healthier, stronger, and mobile (HSM) cluster.

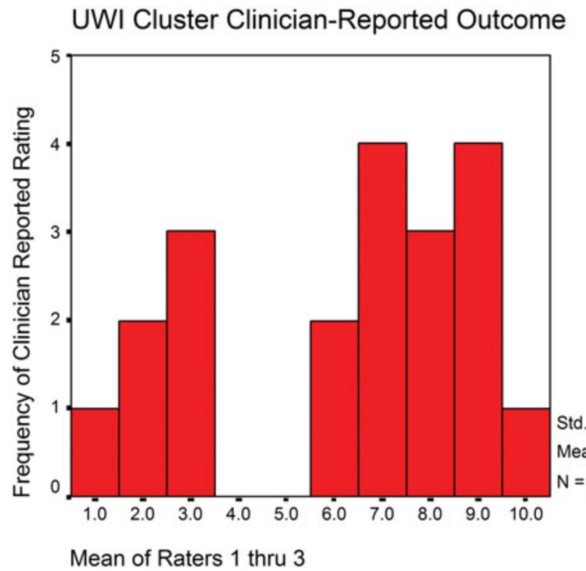

Figure 3. Clinician-reported outcome for patients in the unhealthy, weak, and immobile (UWI) cluster.

suggests that co-morbid conditions may make recovery difficult or improbable [1,2]. Several authors have determined that diabetes is a specific risk factor for idiopathic frozen shoulder [14–16]. Other comorbidities, such as cardiovascular disease, thyroid disorders, and cancer, may also be associated with frozen shoulder, but not to the same degree as diabetes [16–20]. In this study, we looked at the influence of a specific group of comorbidities: connective tissue disorders, hypertension, diabetes, cancer, hypo or hyperthyroidism, or previous frozen shoulder. Unfortunately, this approach did not allow us to look at the direct effect of risk factors that are strongly related to frozen shoulder (e.g., diabetes), compared to those comorbidities that may also be associated with frozen shoulder, but to a lesser degree (e.g., cardiovascular disease, thyroid disorders, and cancer). Nonetheless, the results of our study, as well as others, suggest that the presence of comorbid conditions may have a significant impact on the clinical presentation and outcome of interventions for patients with frozen shoulder [16]. Further study should continue to look at the prevalence of co-morbidities and their relationship to rehabilitation outcomes in patients with frozen shoulder.

Significant differences in mean clinician-reported outcome were also noted between clusters. Raters used a 10 cm VAS with a floor of "unsatisfactory" and a ceiling of "excellent" for their ratings of each case. Ratings by blinded expert clinicians resulted in a mean outcome rating for the HSM cluster of 8.24 out of 10 (range: 3.80–9.97), while the mean outcome rating of the UWI group was 6.21 of 10 (range: 1.1–9.67). Several factors relating to recovery may have influenced clinician-reported outcomes including range of motion findings, patient self-reported functional limitations, and pain at discharge. Furthermore, the finding of differences in outcomes between groups sorted by initial examination findings supports the clinical validity of the clustering solution.

The results of this investigation have clinical applicability for clinicians involved in the examination, diagnosis, and intervention of similar patients with stiff and painful shoulders. Characteristics of patient's initial active range of motion and strength might assist in sorting patients into diagnostic groups. Those with severe shoulder range of motion deficits (i.e., less than 105° of flexion, 90° abduction, or 40° external rotation) coupled with weakness and medical comorbidities at the time of initial evaluation appear to be at risk for a less successful outcome. Closely monitoring the progress of patients who are unhealthy, weak, and immobile through the initial phases of rehabilitation for strength and range of motion changes may assist in sorting those in whom weakness is secondary to immobilization from those who lack range of motion because of weakness. Patients whose range of motion and strength show signs of improvement in the first month of rehabilitation may be suffering primarily from the effects of pain, inflammation, and immobilization, while those not showing signs of responding may benefit from further diagnostic testing (e.g., radiography, ultrasonography, magnetic resonance imaging) and alterations in treatment (e.g., corticosteroid injections, manipulation under anesthesia, arthroscopic release) [3,6,19].

The physical therapist who treated the patients in this study was board certified in orthopedic physical therapy with 15 years of clinical experience specializing in patients with orthopedic disorders. Since there were no other physical therapists in this study, we could not determine if the results of this study would have differed if physical therapists with varied experience levels were also involved in this study. However, much of the literature relating to the stiff and painful shoulder suggests that a substantial lack of range and strength, as well as the presence of co-morbid conditions may make recovery difficult or improbable [1–3,20]. Therefore, while the results of our study are generally consistent with those of previous authors, having only a single physical therapist perform all the measurements and treatments in this study is a limitation that potentially influences the external validity of our results.

There were some additional limitations to this study that should also be considered. Patients selected as subjects in this retrospective study may not have been representative of patients with similar diagnoses in other settings. Additionally, a relatively small sample was analyzed in this study. Both of these potential limitations may have altered the composition of the clustering solution and the generalizability of the results. While this study found impairments to discriminate between subgroups of patients with stiff and painful shoulders, other important measures that may more fully develop the profile of each patient were not included. For example, region specific outcome tools, quality of life indices, and mental health parameters were not uniformly administered and should be included in future prospective studies to gain further knowledge on the influence of frozen shoulder.

Patients with stiff and painful shoulders were classified into two subgroups using hierarchical cluster analysis based on demographic attributes and initial examination findings. The groups were characterized by differences in active range of motion, strength, and the presence of comorbidities measured at initial examination. Significant differences were found between the groups at discharge on active flexion, abduction, external rotation, and clinician-reported outcome. These findings suggest that patients can be identified on initial examination who may be at risk for a poorer outcome. By identifying these patients early in rehabilitation who have a poorer prognosis, improved patient education, alternative interventions or diagnostic tests may be utilized on their behalf sooner in the course of care.

Acknowledgements

The authors would like to gratefully acknowledge Clyde Killian, PT, PhD, Elizabeth Domholdt, PT, EdD, and James Irrgang, PT, PhD for their assistance with this project and the three physical therapist members of American Society of Shoulder and Elbow Therapists who participated in the outcomes assessment portion of this study.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Griggs SM, Ahn A, Green A. Idiopathic adhesive capsulitis. A prospective functional outcome study of nonoperative treatment. J Bone Joint Surg Am. 2000;82-A:1398–1407.

[2] Grubbs N. Frozen shoulder syndrome: a review of literature. J Orthop Sports Phys Ther. 1993;18:479–487.

[3] Kelley MJ, McClure PW, Leggin BG. Frozen shoulder: evidence and a proposed model guiding rehabilitation. J Orthop Sports Phys Ther. 2009;39:135–148.

[4] Jain TK, Sharma NK. The effectiveness of physiotherapeutic interventions in treatment of frozen shoulder/adhesive capsulitis: a systematic review. J Back Musculoskelet Rehabil. 2014;27:247–273.

[5] Fernandes MR. Patient-reported measures of quality of life and functional capacity in adhesive capsulitis. Rev Assoc Med Bras. 2017;63:347–354.

[6] Neviaser RJ, Neviaser TJ. The frozen shoulder. Diagnosis and management. Clin Orthop Rel Res. 1987;223:59–64.

[7] Lundberg BJ. The frozen shoulder. Clinical and radiographical observations. The effect of manipulation under general anesthesia. Structure and glycosaminoglycan content of the joint capsule. Local bone metabolism. Acta Orthop Scand Suppl. 1969;119:1–59.

[8] Murnaghan JP. Frozen shoulder. In: Rockwood CA, Matsen FA, editors. The shoulder. Philadelphia: W.B. Saunders Company; 1990.

[9] Reeves B. The natural history of the frozen shoulder syndrome. Scand J Rheumatol. 1975;4:193–196.

[10] Aldenderfer MS, Blashfield RK. Cluster analysis. Sage University Paper Series on Quantitative Applications in the Social Sciences 07-044. Beverly Hills, CA: Sage Publications; 1984.

[11] Winters JC, Groenier KH, Sobel JS, et al. Classification of shoulder complaints in general practice by means of cluster analysis. Arch Phys Med Rehabil. 1997;78:1369–1374.

[12] Crocker L, James A. Introduction to classical & modern test theory. New York, NY: Holt, Rinehart and Winston, Inc; 1986.

[13] Ross M, Paterno G. Reliability of the Apley's range of motion test and dominant and nondominant upper

extremity differences. Eur J Phys Rehabil Med. 1999;8: 166–169.

[14] Huang YP, Fann CY, Chiu YH, et al. Association of diabetes mellitus with the risk of developing adhesive capsulitis of the shoulder: a longitudinal population-based followup study. Arthritis Care Res (Hoboken). 2013;65:1197–1202.

[15] Lo SF, Chu SW, Muo CH, et al. Diabetes mellitus and accompanying hyperlipidemia are independent risk factors for adhesive capsulitis: a nationwide population-based cohort study (version 2). Rheumatol Int. 2014;34: 67–74.

[16] Arkkila PE, Kantola IM, Viikari JS, et al. Shoulder capsulitis in type I and II diabetic patients: association with diabetic complications and related diseases. Ann Rheum Dis. 1996; 55:907–914.

[17] Milgrom C, Novack V, Weil Y, et al. Risk factors for idiopathic frozen shoulder. Isr Med Assoc J. 2008;10:361–364.

[18] Pedersen AB, Horváth-Puhó E, Ehrenstein V, et al. Frozen shoulder and risk of cancer: a population-based cohort study. Br J Cancer. 2017;117:144–147.

[19] Tamai K, Akutsu M, Yano Y. Primary frozen shoulder: brief review of pathology and imaging abnormalities. J Orthop Sci. 2014;19:1–5.

[20] Ando A, Sugaya H, Hagiwara Y, et al. Identification of prognostic factors for the nonoperative treatment of stiff shoulder. Int Orthop. 2013;37:859–864.