# Predicting Functional Outcomes of Open Latarjet Surgery Patients

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**ABSTRACT**

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This thesis aims to explore the predictive ability of pre-operative patient characteristics on functional outcomes following an open Latarjet procedure for shoulder instability. A prospective cohort analysis of patients who had received an open Latarjet procedure from September 2009 to February 2021 was conducted. Potential predictors included general patient information (age, number of dislocations, sport level before surgery, joint hypermobility), pre-operative scores on QuickDASH and WOSI questionnaires, and pre-operative measurements of shoulder ROM, strength, and proprioception. Data was collected during a pre-operative evaluation, and follow-up measures were gathered at 6- and 12-months after surgery. Data analysis included one-way ANOVAs to determine if outcomes improved over the follow-up periods; univariate and multivariate analyses identified predictive variables of function and quality of life measures.

For general patient information and pre-operative functional scores, results identified joint hypermobility, sport level, and pre-operative WOSI scores as predictors of post-operative function and quality of life. Regarding shoulder ROM, strength, and proprioception, there appears to be a relationship in their predictive ability of post-operative functional outcomes. However, a larger sample size is needed to substantiate these results.

These results could carry important clinical implications, as the significant predictors of surgical outcomes have the potential to be modified or improved upon prior to surgery. Using these predictors, surgeons would be able to make predictions regarding the individual needs of their patient. By incorporating preoperative functional measures that can be altered, patients may be able to reduce their levels of preoperative dysfunction yielding a better outcome from their surgery.

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ES and DR performed the surgical stabilization procedures and were responsible for the original grant application, conception, and design of the study. KT collected the pre-operative and post-operative measures and constructed the database. GD participated in the conception and design of the study, interpretation of the statistical analysis, and helped to draft the manuscript. MF assisted in the interpretation of the statistical analysis. SM completed the database reduction, performed the statistical analysis, and helped to draft the manuscript. All authors read and approved the final manuscript. Note: This is based on the journal requirements for Knee Surgery, Sports Traumatology, Arthroscopy (KSSTA) for the manuscript presented in Chapter 2.

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## Introduction

The glenohumeral joint is the most commonly dislocated joint in the body and places a significant strain on the patient and healthcare systems (~70 000 in the U.S. annually) [26, 49]. Shoulder injury and disability from these dislocations harm the patient's quality of life, extending into daily activities such as work or sports involvement [41, 66]. The use of non-operative treatments can result in high rates of injury recurrence, particularly in patients with high-risk characteristics [51]. As a result, surgical intervention has become more cost-effective to stabilize the joint and reduce rates of recurrence [26]. The two most common procedures used in treating anterior shoulder instability are the arthroscopic Bankart and the open Latarjet [15, 17, 49]. Although the Bankart procedure is still often used, recent evidence highlights that the Latarjet procedure has lower revision and shoulder dislocation recurrence rates, as well as satisfactory shoulder range of motion (ROM) and scores on patient-reported instability measures [13, 15, 17, 49, 53]. The open Latarjet procedure has been recommended for treating patients with significant glenoid bone loss, engaging Hills-Sachs lesions, and for patients engaged in contact sports [1, 9, 15, 78].

The ability of healthcare professionals to predict surgical outcomes based on varying patient factors has substantial benefits in a clinical setting. They can select the best treatment plan for the patient's situation and operate in a way that promotes individualized care. Isolating what factors can predict surgical outcomes will also aid in identifying the patients that make good surgical candidates, and who may need additional support or treatments. The recovery process following surgical stabilization is multifactorial, so predicting surgical outcomes prior to shoulder surgeries is critical to ensure optimal post-operative function. Despite the importance of outcome prediction, there is little information currently available on predicting patient outcomes with the Latarjet procedure. Predictive factors have been identified in other shoulder pathologies, including total shoulder arthroplasties [22, 77], rotator cuff repairs [23] and the arthroscopic Bankart repair [8, 74]. However, current predictive factors are centralized around unmodifiable characteristics, including the amount of glenoid bone loss, patient age, activity, the number of dislocations, and revision surgery [15, 42]. For example, the surgeon cannot change the age or the number of times a patient has dislocated their shoulder prior to their initial examination. Since positive outcomes are more consistently being identified with the open Latarjet procedure, additional studies are required to examine what pre-operative factors can be used to predict patient outcomes, to further ensure the best possible results.

Additional factors that play important roles in the initial identification of shoulder dysfunction include proprioception, ROM, and muscle strength. Proprioception is a critical to the function of the shoulder and is a significant factor in post-operative recovery following a stabilization procedure. Pre-operative proprioception in the shoulder and knee has been shown to be predictive of post-operative proprioception values in total shoulder arthroscopy patients [47], and poorer proprioception was found to predict shorter hop test length and worse subjective functional ratings in anterior cruciate ligament (ACL) injury patients [63]. ROM and muscle strength assessments of the shoulder are often used for diagnostic classification and determining the level of functional impairment [19]. Despite the importance of ROM, strength, and proprioception on the recovery of functional outcomes after various shoulder surgeries, there is little research on ROM, strength, and proprioception predicting outcomes after the Latarjet procedure. There is minimal consensus regarding post-operative rehabilitation following the open Latarjet. Research in favour of the "slow-and-steady" approach identify the subscapularis as a weak point and likely target of impaired strength and proprioception [28, 58]. However, other authors suggest the initial fixation strength as a supporting factor of accelerated rehabilitation, shown through surgeon confidence [12]. Further knowledge regarding pre-operative values of ROM, strength, and proprioception is needed to build a more comprehensive understanding of the influence these factors carry regarding shoulder function in the open Latarjet procedure. Establishing the predictive ability of these pre-operative measures and incorporating these relationships into the conceptualization of treatment plans, may allow patients to experience better surgical outcomes.

Few studies have examined the short-term recovery process of the open Latarjet procedure and the specific point at which we may see a considerable increase or decrease in functioning. More research is needed regarding visible short-term improvement markers which allow both patients and healthcare professionals to have a better idea of how the patient is progressing following their surgery. Inspecting multiple periods in the first year of recovery can determine if there is a critical point in the recovery process where one should expect improvement. An example of this critical recovery period was identified in rotator cuff repair patients, where a 75% functional recovery rate based on clinical outcomes was identified 6-

months following surgery [23]. Similar exploration into recovery rates would be beneficial for patients undergoing an open Latarjet procedure. Identifying key points in recovery will allow for adjustments to be made to the treatment plan, ensuring that patients have the best chance at an optimal recovery by preventing stagnation in their progression of restoring shoulder function.

This study investigated pre-operative patient factors and their ability to predict post-operative outcomes following an open Latarjet procedure at multiple follow-up periods in the first year after surgery. The factors to be investigated include patient demographic information, pre-operative scores of function and quality of life patient-reported measures, and pre-operative measures of ROM, proprioception, and muscle strength. We expected scores on patient-reported measures to improve following surgery, and that predictors of post-operative function and quality of life would be identified. The results of the investigation using pre-operative patient demographic information and pre-operative scores of function and quality of life patient-reported measures to predict surgical outcomes are in the manuscript presented in Chapter 2, which we are targeting to submit to the Knee Surgery, Sports Traumatology, Arthroscopy (KSSTA) research journal.

# Chapter 1: Literature Review

The shoulder is the most commonly dislocated joint in the body, with anterior dislocations having a reported incidence of 1-2% of the general population [41, 49, 70]. The initial treatment of this injury can create several different pathways of recovery with varying levels of success and cost. A patient that proceeds with a non-operative treatment may be successful, but they may also fail to see results based on their circumstance of health and require surgery or additional therapy [26]. A patient could experience a successful surgical procedure, or they could suffer from postoperative complications, requiring additional medications or corrective procedures [73]. Repeating procedures and incorporating other treatment modalities following complications is guaranteed to increase the overall cost of restoring the patient's shoulder from a predicted budget.

Beyond the added financial stress on the healthcare system and insurance companies, complications will require more time from healthcare professionals to carry out these modifications. A patient's effective use of the shoulder following injury impacts their level of function required for daily living, and by prolonging the treatment time, patients will experience functional deficits for longer than necessary [36, 44, 50]. There are multiple factors that facilitate improvement in function, with the potential to create discrepancies in the anticipated versus actual recovery time following injury to the shoulder. A large body of research has focused on determining which patient characteristics are useful to predict whether an individual will face recurrent shoulder instability following an initial dislocation.

## I. Predicting Injury Recurrence in Non-Operative Patients

The ability to predict someone's risk for injury recurrence has enormous potential for benefitting a clinical setting. Understanding how the recovery process may fluctuate between individuals will better equip healthcare professionals to address the specific needs of their patients and adapt their treatment plan accordingly. Generally, non-operative treatment has been the initial course for shoulder dislocation patients, and many patients are not good candidates for surgical repair, due to underlying health conditions or personal choice. Investigating the factors that influence recurrence without surgery also builds a foundation for further discussion when considering a surgical intervention treatment. The following studies explore various factors that may place an individual at a higher risk for injury recurrence after an initial dislocation.

Robinson et al. [64], conducted a 5-year prospective cohort study to investigate what risk factors influence injury recurrence and function following an initial dislocation in a younger age group. The variables they considered through a univariate analysis include age, sex, presence of a greater tuberosity fracture, general laxity via the Beighton score, participation level and type of sport, presence of nerve palsy, whether the patient returned to work/full activity in six weeks, and if the patient returned to their sport in the first year after initial dislocation [64]. The Beighton score is a value out of nine assigned by the presence or absence of the criteria outlined in Table 1.

| Beighton Scale Item | Highest Possible Score[a] | Criteria for a Positive Sign |
|---|---|---|
| Passive hyperextension of the fifth finger | 2 | >90° |
| Passive thumb opposition to the forearm | 2 | Thumb touches forearm |
| Elbow hyperextension | 2 | >10° |
| Knee hyperextension | 2 | >10° |
| Standing trunk flexion with knees fully extended | 1 | Both palms flat on floor |

[a] Each item is scored bilaterally, except for standing trunk flexion.

**Table 1.** Beighton criteria used to assess joint hypermobility [20].

A survival analysis was used to examine the probability of developing recurrent instability over time concerning each variable [64]. Results showed that all the previously listed variables have an influence on the recurrence rate and function of the shoulder except for sport level-, sports return- and work-related analyses, meaning that returning to work within 6-weeks or returning to sport within one year of the initial dislocation did not significantly increase the recurrence rate [64]. An age analysis split the participants into groups of a 5-year age span (15-20, 21-25, 26-30, 31-35), and results showed that the participants of the two youngest groups had the highest percentage of instability throughout the follow-up period [64]. Male participants were reported to have a higher percentage of instability compared to female participants, although this may be affected in part by the difference in sample size, with the male group having 225 people and the female group having 27 people [64]. Despite the generally low female sample size, Robinson et al. [64] reported that the risk of recurrent instability for females was lower at all age groups.

The group of patients without a greater tuberosity fracture had higher instability than those with a greater tuberosity fracture, as well as the patients with an absence of nerve palsy [64]. The group of participants with greater general laxity, as indicated with a Beighton score greater than 4, had a higher percentage of instability compared to those with less laxity [64]. Those who participated and engaged in contact or overhead sports had higher instability percentages than both the group who participated in non-contact sports and the group with no sport participation [64]. For the multivariate analysis that followed, only age and gender continued to carry significance in predicting recurrent instability two years after a primary dislocation [64].

Robinson et al. [64] also conducted a functional assessment as a part of their study, separating their participants into groups of patients who did not experience recurrent instability and the patients who had their instability treated with surgical stabilization. The measures included in the functional assessment were the Short-Form 36 Questionnaire (SF-36), the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, the Western Ontario Shoulder Instability Index (WOSI), and range of motion [64]. Both groups had similar scores on the SF-36 at two years, and there was no significant improvement in functional scores or range of motion in either group at the one- and two-year follow up assessments [64]. Despite the similarity in functional outcome scores, Robinson et al. [64] noted that the WOSI was able to detect greater functional deficits specific to shoulder instability than the DASH questionnaire. The group that had undergone surgical stabilization saw decreased ranges of motion in all directions compared to the stable shoulder group, but only the movement of external rotation reached significance, which may be a result of the surgical technique used [64]. Concurrent shoulder pathologies, general laxity, age, and sex carry influence on predicting shoulder instability, placing patients that present with these characteristics in a higher risk category. The group similarities in functional scores at the two-year period suggests that if someone with shoulder instability proceeds with surgical stabilization, they are likely to have functional outcomes similar to those without shoulder instability. The similarity in functional outcomes is promising as regaining function is the goal of treating the shoulder instability, although it would be interesting to see if the similarity is observable in functional outcomes earlier than two years.

Kralinger et al. [41], carried out a similar study to predict which patients are at high risk for injury recurrence following primary shoulder dislocation so that they can consider surgical stabilization as a treatment option. The study was done by comparing a group with first-time dislocations to a group with recurrent shoulder instability using the following parameters: age, Rowe score, athletic activity type before and after dislocation, radiologic features (such as Hills

Sachs lesions), active range of motion, duration and method of immobilization, and if physical therapy was done [41]. The Rowe score is a measure of shoulder instability, where a high score indicates greater stability than a low score. The first-time dislocation group was separated further into patients with a concomitant fracture of the greater tuberosity and those without a fracture. For patients without a concomitant fracture, age was a significant predictor of injury recurrence, with those aged 21-30 having the highest recurrence rate [41]. In an age-adjusted regression model, it was shown that the type of sport following the initial trauma did not influence injury recurrence and in all age groups younger than 70 there was a significant number of patients that had changed their sport activity to one that reduced shoulder strain [41]. The age-adjusted model also showed that participation in physical therapy did not have a significant influence on the recurrence rate [41]. In patients with a concomitant fracture, age had no significant influence on injury recurrence, and physical therapy did not influence recurrence or the well-being according to the [41]. For radiological features, the grade of the Hills Sachs lesions significantly influenced the recurrence rate of injury with grade III lesions having higher rates than both grades I and II lesions [41]. The associated conditions of shoulder dislocation (fracture of the greater tuberosity, Bankart lesions) did not correlate with the age of the patient at the initial dislocation [41]. The results of the Rowe score, a measure of shoulder instability, show that the majority of patients experience either excellent results (51.8% of the sample) or poor results (26.5% of the sample) [41]. These results continue to establish the high-risk criteria for shoulder instability by separating patients based on the presence of concomitant fractures, where age carries significance in the sample without the fracture. The distribution of the Rowe score is interesting in this study, where ~52% of patients experienced excellent results. The Rowe score distribution could be explored further as to why the remaining 48% of patients did not have similar results. It could be that the patients who do not see excellent results have underlying factors beyond involvement in athletic activity that hinder their ability to recover following their injury.

Vermeiren et al. [73], also examined what influences the rate of recurrence following a traumatic shoulder dislocation. Patients were contacted retrospectively following their initial dislocation, and follow-up periods ranged from one to nine years [73]. Information was collected on each patient's mechanism of injury for the primary dislocation, their profession, if there was an immobilization period or physiotherapy done, and the eventual outcome of the injured shoulder [73]. There was a significant rate of recurrence in those under the age of 30 years (54%)

compared to a 12% rate in people over the age of 30 years [73]. More concurrent fractures were observed in the group of patients that did not experience recurrent dislocations, most of these fractures being to the greater tuberosity [73]. In 92% of the cases, the mechanism of injury was a direct blow or fall onto the shoulder, and a forced movement during sport was responsible for 8% of the injuries [73]. Regarding occupation, manual labourers had an injury recurrence rate of 31% compared to other professions (students, retired people and housewives) who had a recurrence rate of 24% [73]. Occupation did not produce statistically significant results in this study; however, this may be due to the large difference in the group sample sizes, as the manual labourers sub-group had 26 individuals, and the other group had 128 individuals. Comparing occupation in similar group sizes, or different groupings altogether may produce a different conclusion [73]. Explanations for this finding include the younger average age in the instability group and the lack of concurrent fractures [73].

Age and concurrent fractures continue to be supported as influencers of injury recurrence, as well as bringing one's occupation and the participation in physiotherapy into the discussion. Individuals whose work involves manual labour use their shoulders more, so the higher recurrence rate among this group makes intuitive sense as they are exposed to repeated strain. The number of physiotherapy sessions is interesting, as they suggest that the patients who experience recurrent instability were unable to complete as many sessions as the group of patients without recurrent instability. The variables influencing recurrence may play an underlying role in the successful completion of physiotherapy or slow down the recovery process. It will be beneficial to continue the investigation of the influence of occupation on shoulder instability and explore what else may affect patient involvement in physiotherapy.

Eshoj et al. [29], compared the function between a group of people with a non-operated primary anterior dislocation and a group with recurrent anterior shoulder dislocations, and what may influence function between these groups. Demographic and historical information was collected on age, sex, employment status, mechanism of injury, prior shoulder treatments, and if they had been physically active before their most recent dislocation [29]. Self-reported measures were collected using the WOSI score, the Tampa Scale of Kinesiophobia (TSK), a visual analog scale (VAS) to assess health-related quality of life, and the Numeric Pain Rating Scale [29]. Additional measures include generalized joint hypermobility assessed with the Beighton tests, anterior shoulder instability assessed with apprehension, relocation, and surprise tests, the constant-Murley shoulder score (CMS), and shoulder joint position sense for flexion and abduction [29]. The CMS is a measure of one's pain and ability to carry out daily activities, where a higher score indicates better functioning than low scores.

The patient groups had similar a mean age, were male-dominated, and in most cases, the mechanism of injury was the result of a fall onto the arm [29]. There was no difference between groups in terms of self-reported shoulder function, as both reported a function of less than 50% compared to the healthy shoulder with the Emotion and Lifestyle subscales giving the lowest functional scores [29]. Each group showed a very high fear of reinjury, with TSK scores above 37 in 97% of the primary dislocation group and 96% of the recurrent instability group [29]. A larger number of patients with recurrent instability presented with joint hypermobility, but there was no group difference in measures of shoulder instability [29]. Both groups showed similar scores on the CMS and had a similar absolute error in the joint position sense tasks for flexion and abduction [29]. Patients present with poor shoulder function regardless of whether the injury is a primary or recurrent dislocation, and these group similarities carry a large impact on emotional and fear-related conditions. We can conclude that most patients with a shoulder dislocation fear re-injury and addressing this fear could be important in facilitating a successful injury treatment plan. Fear of re-injury may influence and prevent the development of other areas crucial to recovering from an injury, and such relationships should be explored.

Cameron et al. [20], investigated the relationship between age, sex, and general joint hypermobility and a history of shoulder instability among a group of young, physically active individuals and whether there is a pattern of hypermobility in this population. The average age of the male participants was 18.7 years, and for the female participants, 18.8 years [20]. Hypermobility was assessed using the Beighton criteria, and shoulder instability were determined with a questionnaire containing items about the nature of the event, arm dominance, and the mechanism of injury [20]. The group of patients with a history of shoulder instability had higher total Beighton scores than the group without shoulder instability, and when this relationship was controlled for age and race a significant correlation was noted for shoulder instability and a Beighton score of 2 or greater [20]. Participants with a Beighton score greater than two were 2.48 times as likely to have shoulder instability, a trend observed in both the male and female participants [20].

For the individual Beighton score criteria, the most common sign of general joint hypermobility was standing trunk flexion with the knees extended, observed in 14.1% of the male participants and 46.4% of the female participants [20]. A significant relationship between sex and the individual Beighton score was identified for all criteria except for hyperextension of the metacarpophalangeal joint of the 5th finger bilaterally [20]. In all other criteria for the Beighton score, the percentage of females with a positive sign for each criterion was higher than the percentage of males [20]. Most of the participants in the study did not exhibit signs of general joint hypermobility. Seventy-eight percent of the participants had a total Beighton score of 0, and only 11 people met the universal consensus cut-off point of 4 or greater, which is why a cut-off point of 2 was used in this study [20]. These results demonstrate how joint hypermobility could influence shoulder instability and the difference in hypermobility between the sexes. Healthcare professionals can take note of patients who meet these criteria of joint hypermobility and use this information when building or adapting a treatment plan. It is important to note that this study was conducted on active young individuals, so a similar relationship should be investigated in different ages and activity levels to make this finding relevant to a larger population.

Olds et al. [54], conducted a systematic review and meta-analysis to identify the risk factors that predispose someone to recurrent shoulder instability following a primary dislocation. Inclusion criteria for the review consisted of radiological or clinical evidence of dislocation or subluxation, had a follow-up period of at least one year, and published before July 1st, 2014 [54]. The Scottish Intercollegiate Guidelines Network (SIGN) checklist assessed the internal validity of the study as part of the quality assessment done for each article reviewed [54]. The following information was extracted from each study, where applicable: patient demographics, rate of injury recurrence, the mechanism of injury, and pathological or other factors associated with recurrent instability [54]. Ten studies comprised the final review.

In all ten studies age was examined, and an association was found between age and recurrent shoulder instability [54]. In patients under the age of 40 years, there is an increased recurrence rate of 44% compared to an 11% recurrence rate in those over 40 years [54]. The effect of sex on recurrent instability was examined in six studies, discovering that males were at a 3.18 times greater risk than females for recurrent instability of the shoulder [54]. Mechanism of injury was reported in nine studies, and the most common mechanism of the primary dislocation was a direct blow or a fall, usually occurring through an athletic activity [54]. The patients with a concomitant pathology of a greater tubercle fracture (OR = 0.13), a bony Bankart lesion (OR = 0.51), or nerve palsy (OR = 0.40) were less likely to experience injury recurrence, while those with a Hill Sachs lesion (OR = 1.55) were more likely to experience recurrence than someone without a concomitant pathology [54]. People with hyperlaxity were 2.68 times more likely to experience injury recurrence than those without hyperlaxity [54]. Patient occupation influenced injury recurrence, a concept that was previously discussed through the work of Vermeiren et al. [73] and will be expanded on in Section III when discussing the work of Sachs et al. [66].

This section illustrated that the factors of age, sex, concurrent pathologies, hyperlaxity, and occupation can be used to predict one's likelihood of injury recurrence. It is also evident that there is a common mechanism leading to these injuries, a direct blow or fall. Knowing these predictor variables can assist healthcare professionals in choosing the best treatment for their patients. If they are at risk for recurrent shoulder instability through a non-operative treatment, they can consider a surgical procedure as an alternative.

## II. Comparing Surgical Intervention Techniques

The function of the shoulder deteriorates with every subsequent dislocation, which is why surgical techniques are often used to prevent re-dislocation [45]. The ability to use patient characteristics to predict if someone will require surgery may spare the individual the pain and deteriorated function resulting from a recurrent injury, as well as decreasing the loss of time from daily activities [66]. Beyond predicting whether surgical intervention is a suitable option of treatment, there is a growing body of research as to which patient characteristics can determine recovery outcomes following surgery, such as the length of recovery and function of the shoulder after a recovery period. There are several options for surgical plans that can stabilize the shoulder, and prior research has sought which method is the best for limiting recurrence and giving patients the best possible outcome. Part of determining which technique to use depends on what the surgical indications are for the shoulder injury, and if multiple techniques are suitable, the personal preference of the surgeon plays a role in the decision-making process [16].

Stabilization of the shoulder joint is a crucial component to the success of these surgeries in limiting recurrence rates and shoulder instability, and these surgical techniques are becoming more favoured in first-time dislocations for the active young population [4]. The importance of stabilization is shown in the study conducted by te Slaa et al. [70], who performed a prospective study on patients receiving arthroscopy of the shoulder without a stabilization procedure. The objective was to determine the incidence of recurrence and instability over several follow-up periods and whether intra articular pathology of the shoulder could predict recurrence rates in a younger cohort [70]. Data was collected for age, arm dominance, the side affected, mechanism of injury, reduction technique, presence of neurological complications, the intra articular pathology found during arthroscopy, the Rowe score and the constant score [70].

Follow up of arthroscopy patients without stabilization at 1 year, 2 years, and at 5 years indicated an increase in dislocation recurrence and instability rates [70]. Instability rates were higher in those under the age of 25 years at all follow-up periods compared to those over the age of 25 years [70]. Three of the participants of this study (~10%) opted for a stabilization procedure during the follow-up period [70]. Rates of instability for females in the 5-year follow-up period was 75% compared to 52% in the male group, but the results of the female group are likely inflated as the sample had only four participants [70]. As such, the presence or absence of shoulder instability for one female will change the expected group outcome by a larger amount than the addition of one male for their respective groups [70]. The findings from the arthroscopy showed that the most common pathology was a Hill Sachs lesion, observed in 29 participants, followed by a Baker III lesion in 19 patients [70]. The Rowe score was useful in predicting recurrent instability at the 5-year follow-up, as the stable shoulder group has a mean score of 99, and the unstable shoulder group had a mean score of 77 [70]. Rates of instability increased over time when the shoulder was not stabilized during the arthroscopic procedure, shown by the lower Rowe score at the 5-year period. While the rates of recurrence and instability following arthroscopy without stabilization are shown, these rates should be explored in procedures involving the stabilization of the shoulder.

A surgical procedure that stabilizes the shoulder joint allows its patients to participate in their rehabilitation program more effectively, improving their function and reducing their rate of recurrence over time [44]. The two most common stabilization surgeries for anterior shoulder instability are the open Bristow-Latarjet and the arthroscopic Bankart repair [16, 17, 49]. The open procedure involves the transfer of the coracoid muscle to the anterior aspect of the glenoid to obtain stability of the joint, often used in patients with recurrent instability after a failed soft tissue repair or those with significant bone loss in the glenoid [49]. The arthroscopic procedure consists of stabilizing the shoulder through tensioning of the capsule and repairing the lesion in the labrum [16]. The criteria used to determine the technique used include the condition of the bony defect, the sporting demands required, and the quality of the shoulder complex [17]. Both procedures report as cost-effective, with the average arthroscopic procedure costing USD 20,382 and the average open procedure costing USD 21,389 [49]. Those who favour the open Latarjet procedure claim that there are lower recurrence rates and a higher return to sport, especially in collision sports [15, 49]. Those who prefer the arthroscopic Bankart procedure claim that the anatomy of the shoulder is restored, and range of motion preserved [16, 24, 49]. Prior research has investigated which technique can provide the best post-operative functioning following stabilization of the shoulder, and what factors may contribute to the success of the surgery.

Cole et al. [24] compared the effectiveness of a method to select an arthroscopic or open surgical procedure based on the findings during the operation. All patients were examined while under anesthesia for translation in the anterior, inferior, and posterior directions using a scale of 0 to +3, indicating the degree of movement [24]. Patients were given an open procedure if they had both anterior and inferior translation scores of +2 or +3, and patients were given an arthroscopic procedure if they presented with an anterior translation of +2 or +3 but an inferior translation of +1 or less [24]. Patients also completed an arthroscopic evaluation, where the joint was assessed for evidence of a concomitant injury or capsular laxity [24]. The patients who exhibited laxity in the glenohumeral ligaments and had a Bankart lesion were selected for an open procedure, patients with a Bankart lesion but intact ligaments proceeded with the arthroscopic procedure [24]. The criteria of laxity as an indication for an open procedure was also shared by Pötzl et al. [60], whose study on the surgical influence on proprioception included both open and arthroscopic techniques. The open and arthroscopic groups had similar mean ages, length from injury to surgery, follow-up length, percentage of operations on the dominant side, and sex [24]. Interestingly, most of the patients with work-related mechanisms of initial instability (13/16) were selected for the arthroscopically treated group. The criteria used to assign patients to this group may provide clues as to which structures are affected in these work-related injuries. Participants were also asked to complete the Rowe score questionnaire, the American Shoulder and Elbow Surgeons (ASES) score, and the SF-36 as well as provide information on their limitations regarding return to sport.

There was no significant difference between the open or arthroscopic procedure in terms of injury recurrence, apprehension, range of motion, Rowe score, ASES score, SF-36, and return to sport limitations [24]. In both procedure types, the operated shoulder demonstrated a loss of external rotation when the arm was at the patient's side, reported as a loss of 9° +/- 12° arthroscopically and a loss of 10° +/- 11° in the open-repair [24]. The failure rate of the procedures was 24% in the arthroscopic group and 18% in the open repair group, but this was also not significant in the study [24]. Given the right criteria to decide the best surgical procedure, an arthroscopic or open-repair technique can be very similar in the result produced in terms of injury recurrence, patient-reported outcomes, and limitations to the shoulders range of motion and sport-related functioning. Fairly high failure percentages for both procedures were observed, but since the failure rates are not significantly different between the surgical techniques, there may be another variable influencing this finding. The results reflect the importance of considering the patient characteristics that can influence surgical technique selection and the outcome-based success of the procedure.

The main area of concern when deciding to proceed with surgical stabilization is the patient's ability to regain a level of function similar to what they are used to carry out the activities of their daily living. Many patient factors that are indicators of recurrent instability of the shoulder, discussed in Section I, may continue to provide indications of a successful surgical procedure, such as hyperlaxity, occupation, and the participation type and level in sports. In a matched-pair multicenter study, Blonna et al. [16] compared the open Latarjet procedure to the arthroscopic Bankart repair to determine which method provided a better return to sport. Return to sport was measured subjectively by the patients, and patients for each procedure were matched according to age, the number of dislocations before surgery, and level of the sport before the shoulder instability [16]. The results report a higher return to sport, higher subjective shoulder value scores, and a greater range of motion in external rotation at 90° abduction in those who had received the arthroscopic

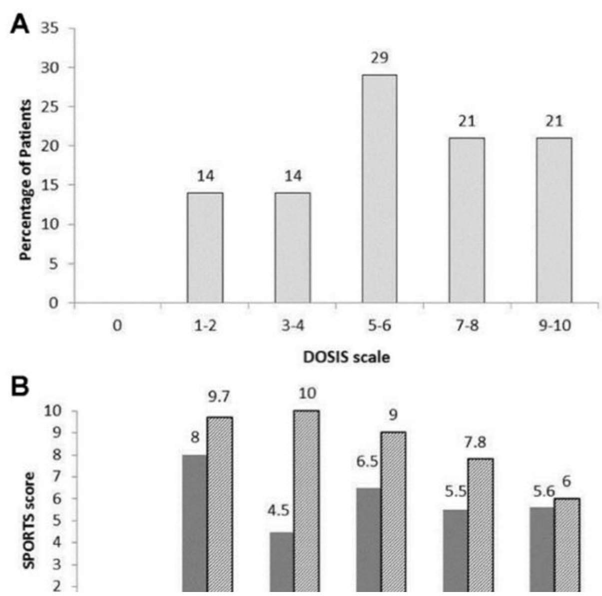


**Figure 1.** Comparison of return to sport for arthroscopic Bankart and open Latarjet [16].

*(A) Pre-operative DOSIS scores; (B) Relationship between DOSIS scores and SPORTS score for surgical techniques*

procedure (Figure 1) [16]. These are novel findings, and a potential explanation for this is that the previous studies did not include a measure dedicated to the return to sport; in this study, that measure was the Degree of Shoulder Involvement in Sports (DOSIS) scale [1615]. The open Latarjet procedure was reported to be significantly more efficient than the arthroscopic Bankart procedure, with a decreased surgical time of approximately 25 minutes [16].

Despite the higher return to sport, there was no significant difference shown between function, measured with the WOSI score, or the number of recurrent dislocations [16]. The study states that although the level of return to sport was higher for the arthroscopic technique, more than 80% of the patients returned to their sport after both repair techniques [16]. An important limitation of the study is that it fails to address the time taken to return to sport following surgery, a factor that is of high consideration for athletes, which is something that should be investigated to make predictions of recovery [16]. Potential differences are highlighted in sports return between the surgical procedures, where the patients with high sports demands may be better candidates for an arthroscopic stabilization. Future consideration should look to other areas, such as occupation return, as a variable that may predict successful surgical stabilizations as the current research is focused largely on sports return. It is also important to explore the length of time it takes to return to one's previous level of activity following surgery, as this will carry significance into the patient's recovery and daily living.

Based on the research comparing surgical techniques, it appears that when the proper criteria are used to select the best technique, the outcomes between procedures are comparable. Slight advantages may be given to arthroscopy when considering sports performance while open procedures are more efficient and report a lower, although insignificant, rate of failure. The sections that follow discuss specific categories of patient factors that could be useful in predicting shoulder stabilization outcomes, allowing healthcare professionals to make calculated decisions regarding their patient's treatment.

## III. Patient Demographics and Activity Level Predicting Surgical Outcomes

In Section I, the factors predicting injury recurrence were discussed in a non-operative patient cohort. Next, under investigation are the factors that can predict the success of a surgical procedure through various outcomes. The presence or absence of these patient factors can be useful in the decision-making process of the surgical techniques used, as discussed in Section II, the post-operative treatment plan, or whether surgical intervention is the best option for the patient. Patients are incredibly diverse in their demographic factors, such as concurrent conditions or history, as well as their daily activities through sport and occupation. The following studies explore how these variables can influence and predict surgical outcomes.

Ranalletta et al. [61], sought to determine if the incidence of generalized joint laxity is higher in a group with recurrent shoulder instability than in a control group. The study was conducted on males that had been treated arthroscopically, as not enough females were treated during the data collection period, and the control group was age-matched [61]. Generalized joint laxity was assessed using the Beighton criteria, and the results showed that both groups presented with similar rates of hypermobility, with 13% of the instability group and 9% of the control group scoring above the cut-off point [61]. Ranaletta et al. [61] opted to use a score of six to indicate hypermobility, meaning this higher cut-off point from the standard score of four could be a possible explanation for why they did not find a statistically significant relationship between hypermobility and recurrent shoulder instability. While this study does not present the expected relationship of hyperlaxity influencing shoulder instability, it is important that this finding is investigated further by using the standard Beighton score of four as the cut-off point for joint hypermobility since this is the value that most healthcare professionals will use during their clinical assessment. The relationship should also be explored in females, although this study did not have a large enough sample size during the data collection, there is an opportunity for future research to consider a potential influence.

The level of activity associated with one's daily living has the potential to influence the ability to restore function following surgical repair of the shoulder. Work-related musculoskeletal diseases account for over 33% of occupational illness in the United States, and physical risk factors for the neck and shoulder region may include heavy physical work, awkward static and dynamic working posture and repetitive work [72]. A study by Sachs et al. [66] investigated if it is possible to predict whether someone will need stabilization surgery for their shoulder based on the differences in patient characteristics between individuals requesting surgery and those who do not request surgery. This was a prospective study with a follow-up time ranging from two to seven years with patient contact occurring every six months [66]. Of the 131 patients included in the study, 29 had surgery over the follow-up period (20 patients for a

Bankart procedure and nine for a rotator cuff repair), with most of these procedures occurring within the first two years of follow-up [66].

Results showed a significant difference in recurrent dislocation between age groups. Forty-three percent of those under 40 years experienced recurrence, whereas only 10% of those over 40 years experienced recurrence [66]. The group of participants that chose to have surgery were not significantly different from the group of those who did not have surgery in terms of sex, hyperlaxity signs, mechanism of injury and time spent immobilized in a sling [66]. Occupations involving the use of upper limbs above chest height are an extrinsic risk factor for shoulder instability, and these individuals are 5.76 times more likely to suffer from recurrent instability [66]. Furthermore, the patients whose occupations involved upper limb usage above chest height were significantly younger than the group whose occupation did not [66]. The functional scores of the patients, assessed with the WOSI, Constant-Murley scale, and ASES, showed that patients with a successful non-operative treatment had similar functional scores to those with a successful surgical intervention and patients who chose to cope with their shoulder instability had significantly lower functional scores [66]. Sachs et al. [66] did not find any factors that predicted an immediate need for surgery since only 65% of the patients considered high-risk for recurrence elected to have surgery. Patients that presented initially with high pain scores were generally the patients that chose to have surgery (Figure 2) [66].

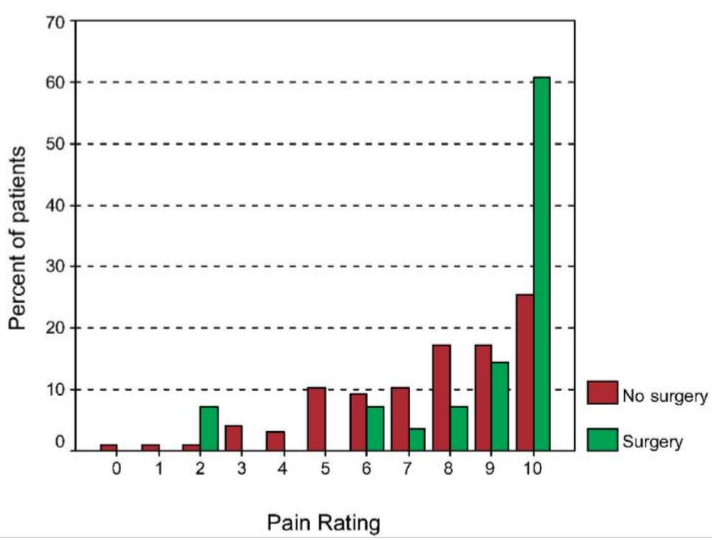


**Figure 2.** Pain rating at first time dislocation and choice to have surgery [66].

The factors of age and occupation discussed in Section I continue to be supported by this study as predictors of injury recurrence, while none of the variables significantly predicted a need for surgery. For functional outcomes, the patient scores depended on the success of the treatment plan, whether it was through surgical or non-operative means. While using patient factors may not be able to accurately predict the immediate necessity of a surgical procedure, it can be considered as a useful guideline for healthcare professionals as this study still had the majority of high-risk patients choose surgical treatment. These patients also demonstrated high levels of pain during their initial visit, which could be a further indication of when surgery should be recommended.

**IV. Sport Level and Participation Predicting Surgical Outcomes**

Shoulder function in patients with postoperative recurrence is also related to the activity level in sport. Overall, surgical stabilization is an effective intervention to lower the risk of injury recurrence and allow people to return to sport [16]. However, individuals who participate in high demanding sports involving the shoulder generally see a lower activity level when returning to sport following their surgical repair [16, 34]. This was the finding of the study conducted by Buckup et al. [17], who sought to determine if it is possible to return to one's original level of the sport following arthroscopic revision surgery. Retrospective scores were recorded for all patients for the time before their first dislocation and the time following their surgery, and participants were categorized into one of four subgroups for sport type: non-collision/non-overhead sports, high impact/collision sports, overhead sports, and martial arts sports [17]. Participants were organized further in a separate analysis by their level of sports activity: competitive sport greater than two times per week, non-competitive sport greater than two times per week, health-related sport participation greater than one time per week, and no sports participation [17].

Seventy percent (of a 20-patient sample) returned to the same level of the sport following their surgical revision, but 90% of these patients experienced limitations in their shoulders when engaged in a sporting activity [17]. The limitations in performance were reported as a result of pain or functional limitations [17]. The sport type affected the ability to return to the same level as patients engaged in overhead or martial arts sports, as well as those participating in competitive activities more than twice per week, had the lowest chance of returning to the same level and type of sport. [17] From a clinical point of view, the operated shoulder demonstrated good to excellent stability and functional scores [17]. The type of sport and the level of participation before the first dislocation can predict how sports involvement may change following surgery. It is clear that while the operated shoulder may present as functional and stable in a clinical setting, this may not translate to a restored ability in the patient's daily activities. This study focused on arthroscopic repairs only, so it will be worth investigating other techniques to see if a similar relationship is presented. By further investigating the patient factors that could influence surgical outcomes, it may be possible to identify an underlying variable that is affecting one's ability to return to their sports level and participation frequency.

This section explored patient demographics and their potential influence on the surgical outcomes of injury recurrence and returning to sport, with common variables being hyperlaxity, age, sex, occupation, and the activity level before surgery. These variables are useful in predicting which patients are at a high-risk for injury recurrence following surgery, allowing healthcare professionals to monitor patient progress and provide individualized care for the patient's goals. Often, these goals are returning to a normal lifestyle that the patient had before their injury, such as engagement in sports or related activities. Buckup et al. [17], suggested two factors that determined the ability to return to sport: the complete regeneration of external rotation capability and proprioception, which will be the focus of the next section.

## V. Proprioception of the Shoulder in Non-Operative Treatment Protocols

Proprioception is a key factor in the restoration of shoulder function following injury and surgical repair, as deficits in this area are linked to the persistence of impairments and physical limitations [1]. Proprioceptive abilities are another variable that is very individualized based on one's prior involvement in an activity requiring bodily awareness or a limited range of motion. Lephart et al. [44] suggested that a reduction in proprioceptive acuity is related to the laxity of the glenohumeral capsule. Joint laxity is observed in individuals with recurrent shoulder dislocations or those with a hyper-lax glenohumeral joint, and these individuals may find their daily movements are less fluid due to the impairment of joint position sense [36, 42]. The compromised sensory feedback may lead to decreased muscle coordination, increased instability and increased risk of additional injury [44]. Several studies have focused on proprioception in a non-operative setting for various shoulder pathologies, which are discussed below.

Anderson and Wee [4], conducted a study on proprioceptive acuity in a sample of chronic rotator cuff pathology patients using an active ipsilateral matching task at 40° and 100° of abduction. Pain measurements were collected using a visual analog scale [4]. Results showed that in a higher angle of abduction in the scapular plane, 100° in this case, there was significantly more pain than in a lower angle, which was 40° (Figure 3) [4]. At the lower angle of 40°, the group with a chronic rotator cuff pathology had a significantly different relative error value in both the affected shoulder (RE = -2.1 +/- 3.8) and unaffected shoulder (RE = -3.0 +/-4.7) compared to the control group error value (RE = 1.9 +/- 2.8) [4]. The group with the chronic rotator cuff pathology had a significantly higher absolute error at 100° on the affected limb compared to the control group, indicating poorer proprioceptive acuity [4].

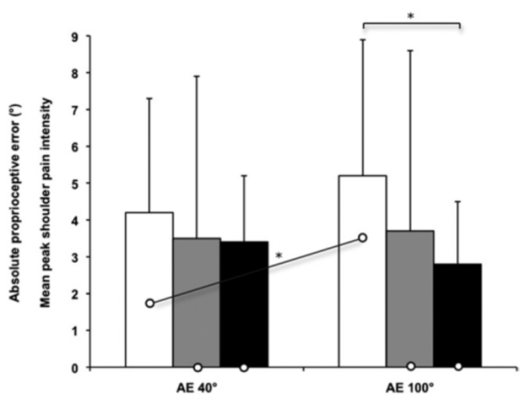


**Figure 3.** Mean proprioception absolute error and shoulder pain intensity at test angle [4].

Note: Affected limb (white); unaffected limb (grey); control group (black)

The control group did not report significantly different levels of pain at the angles tested, suggesting that the elevated pain of the shoulder impingement may have influenced the ability of the chronic rotator cuff pathology group to accurately reproduce the target angle [4]. We can see that depending on the angle being tested, a difference in proprioceptive error is present. The group of patients with shoulder instability usually undershot the target angle compared to the control group, who usually overshot the target. The results also point to how proprioception has a two-way relationship with other areas of patient recovery, in this case, pain. The patients experiencing pain had impairments of proprioceptive acuity in pain-inducing movements. Addressing and mediating the pain of the patient may be crucial to success in proprioception regeneration and, therefore, recovery.

Following the study by Anderson and Wee [4], one would expect that if the experience of pain is minimized or improved in the shoulder, proprioceptive acuity would also improve. However, this is contradicted in a study conducted by Mörl et al. [51]. A 12-week intervention study was performed to determine if the type of rehabilitation programming affected pain relief and proprioception [51]. Pain significantly reduced over the 12-week training period for both intervention groups, one of which used a flexible foil for their rehabilitative exercises and one which used flexible bands [51]. It is interesting to note that the flexible foil group had a significant reduction in pain at the 6-week mark, but the flexible bands' group did not see significant reductions until the 12 weeks [51]. Despite an overall reduction in pain, this did not translate to an improvement in an active angle replication task, as the initial significantly poorer proprioception performance in the intervention group carried through to the 12 weeks [51]. Several explanations are provided for the lack of a significant finding. The participants included in the study had not undergone surgery, which allows for the tightening of the surrounding structures in the shoulder, and the exercises used during the intervention aimed at affecting the muscles in their typical lengths [51]. We can see that many variables influence proprioception and stabilizing the shoulder joint through surgical means can alter the patient's experience of pain or tighten the shoulder for more effective rehabilitation. Considering what other variables are playing a role in proprioception regeneration will be crucial to administering an effective treatment plan following surgery on the shoulder.

There are notable differences in the research between males and females when discussing proprioception, as reported in the study by Vafadar et al. [72]. In terms of injury prevalence, women experience higher rates of work-related musculoskeletal disorders in the neck and shoulder, and this can be attributed to differences in anthropometry and neuromuscular control [72]. In the neck/shoulder region, it has been shown that women have weaker and smaller necks compared to men of a similar height and have a different shape of the glenoid fossa [72]. The focus of the study by Vafadar et al. [72] was the exploration of differences in neuromuscular control between males and females. The study was done using a cross-sectional study design to compare the joint position sense acuity in males and females [72]. In an active angle reproduction task, participants were asked to recreate their previous shoulder angle, which fell within a 10° range above or below the target angle [72]. Both sexes demonstrated a higher absolute error in the lower range of angles (55° +/- 10°) than the mid (90° +/- 10°) to high (125° +/- 10°) range of angles [72]. Examining constant error, females tended to overestimate the target angle and males both underestimated and overestimated the target angle, whereas, for variable error, males had larger error values than females [72]. It was suggested that there might be a difference in neuromuscular control systems between the sexes as an explanation for the fact that "women overshot the target 81% of the time compared to 55% of the time in males", such as the use of different repositioning strategies [72]. It can be estimated that patients may have accuracy difficulties in activities involving the lower range of the shoulder. Impairments to proprioception can be observed in males or females at various target angle ranges, but the type of error observed is different between the sexes. The difference in sexes for proprioceptive error could have implications for developing treatment plans for males versus females, as there may be a reason as to why these differences are present.

Lubiatowski et al. [46], conducted a study focused on investigating both bilateral proprioception and joint position sense. For the proprioception task, participants were instructed to actively reproduce the target angles of 30°, 60°, and 90° for flexion and abduction, and 30°, 45°, and 90° for internal and external rotation [46]. All measurements were repeated five times, and the absolute error was recorded for each, generating a mean absolute error for each of the target angles [46]. The errors for the instability group were assigned further to the affected and unaffected shoulders for comparison to each other, and the unaffected shoulder was compared to the proprioception error of a control group [46]. Unlike Vafadar et al. [72], a significant difference in the absolute error of proprioception regarding sex was not found in this study. The lack of a significant difference between sexes in the study by Lubiatowski et al. [46] may be due to their inclusion of more movements and different angles in their protocol, while Vafadar et al. [72] only used flexion for data collection. Also, Lubiatowski et al. [46] had the target angle passively demonstrated while Vafadar et al. [72] had the participant actively move to the target angle during the demonstration.

Poorer proprioceptive acuity was observed in both the stable and unstable shoulders compared to the control group, with a higher absolute error for most target angles of flexion and abduction as well as external rotation for 45° and 60° [46]. The largest difference noted was for 60° abduction, where the unstable shoulder had an error of 9.5°, the stable shoulder had an error of 8.3°, and the control group had a much lower error of 5.1° [46]. A decrease in error was observed as the target angle increased for flexion and abduction movements in both the unstable and stable shoulders, with statistically significant differences between 60° versus 90° as well as 60° versus 120° [46]. These differences are supported by a significant negative correlation between error and arm position for flexion and abduction [46]. For the control group, there was a significant negative correlation between error and arm position for flexion, which suggests that this improvement in flexion can be expected regardless of the condition of the shoulder [46]. In the lower movement ranges, there is a larger deficit in proprioceptive acuity and that this deficit can be observed in both shoulders of the group with instability. The deficit may affect performance in activities requiring the use of the shoulder in this range and hinder the rehabilitation process of the injured shoulder.

**VI. Proprioception of the Shoulder in Surgical Protocols**

Decreased proprioception in unstable shoulders is shown to improve following surgical repair, which will be the focus of this section. A suggested explanation for the improvement is that the surgical procedure tightens the glenohumeral joint and surrounding structures, allowing them to respond to sensory feedback with greater accuracy [51]. A study conducted by Zuckerman et al. [79], involved the collection of proprioceptive data pre- and post-operatively in the same group of patients with unilateral anterior glenohumeral instability that had sustained multiple dislocations. Data collection occurred 1-week preoperatively and at 6- and 12-months postoperatively, as patients had completed their rehabilitation program at this time [79]. Joint position sense was tested passively using an apparatus, and the movements of interest were flexion, abduction, and external rotation for both the involved and uninvolved shoulders [79].

For the preoperative measurement, the affected shoulder had significantly lower accuracy than the unaffected shoulder in the three movements tested, and this relationship continued into the 6-month testing period [79]. One year following surgical repair, there were no significant differences in position sense accuracy for the movements tested, indicating that position sense had been recovered to a point comparable to the unaffected side [79]. One can expect that following shoulder surgery, joint position sense improves at some point between the six month and one-year follow-up time frame. The timeframe of improvement is important knowledge to keep in mind for both patients and healthcare professionals, as it will help set a recovery timeline and when improvements can be expected. If there is no progress in proprioception regeneration during this time, we can then look to other variables that may be affecting the process.

Pötzl et al. [60], conducted a similar study to investigate the long-term changes that occur in proprioception following surgical repair to the shoulder. Similar to Zuckerman et al. [79], this study collected proprioceptive data pre- and post-operatively in the same group of patients, but the follow-up period extended to a minimum of 5-years [60]. The joint position task consisted of an active angle replication at a low-, mid-, and high-range target angle for flexion, abduction, internal rotation and external rotation [60]. The pre-operative measurement was taken 1-week before surgery, and the average time of follow-up was 5.9 years, at which time the second measurement was taken [60]. Results showed that the average joint position sense difference from the target angle for each movement improved by ~ 4°, and significant improvements were also observed in the uninvolved shoulder for abduction and rotation (Figure 4) [60].

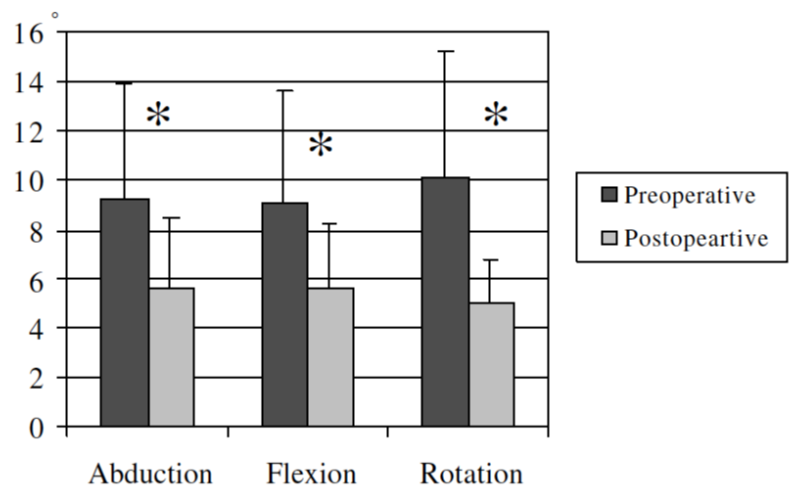


**Figure 4.** Active JPS mean difference in from the target position for the involved shoulder before and after surgery [60].

The follow-up angle reproduction tests for flexion and abduction had correlations with the Rowe score, constant score, and ASES; the strongest correlations between abduction with the constant score (-0.662) and flexion with the Rowe score (-0.775) [60]. These correlations mean that the smaller the difference is to the abduction and flexion target angles, the higher the constant and Rowe scores, respectively. The correlation findings reflect that proprioceptive acuity, especially in flexion and abduction, contributes to shoulder stability and improved daily living. The improvement is observable at the five-year timeframe but may present itself earlier in the recovery process, perhaps at a similar period that improvements were reported by Zuckerman et al. [79]. Incorporating other measures, like the Rowe and constant scores, will let one assess how proprioception can shape the progression of other facets in recovery. It will be valuable to incorporate other measures of surgical outcomes in the assessment of proprioception regeneration, such as functional measures.

Thorough surgical repair, improvements in proprioception can be observed given a period of recovery. The improvement in proprioceptive acuity is likely affected by one's experience of pain, perhaps through a reduction in activity level as a moderator of pain [33]. The effect of pain on proprioception is shown in other bodily joints, such as the knee, where it is suggested that decreased activity because of pain may lead to a decrease in proprioceptive abilities about the joint [46]. Differences in proprioception may be observable between the sexes, but previous literature has yet to form a strong conclusion and is based on non-operative treatment protocols. Further investigation should be done to expand on this relationship in a surgical context. Proprioception of the shoulder is a large aspect of post-operative recovery because its regeneration allows one to return to the level of function required for daily activities such as bringing a cup to the mouth or picking up a pencil [51]. Therefore, it is also crucial to monitor patient functioning following surgical stabilization of the shoulder.

**VII. Long-term Functional Outcomes of Shoulder Surgery Patients**

If there are factors that contribute to impaired function such as patient variables discussed in Sections I and II or poor proprioception discussed in Section IV, then identifying these factors can help predict functional outcomes following surgery. These functional outcomes must be considered for the pre-operational levels of functioning, speaking again to the necessity of an individualized treatment plan. The following studies address what factors can predict function in various shoulder pathologies over a long period.

Jain et al. [38], conducted a study to investigate what can predict longitudinal post-operative pain and function in patients with rotator cuff tears. The sample group of the study consisted of patients aged 45 years and older undergoing treatment for a rotator cuff injury [38]. The measures collected include patient demographics, comorbidities, symptoms, smoking and alcohol consumption habits, patient expectations, if manual labour was performed in their current (or last) occupation, the Fear-Avoidance and Beliefs Questionnaire (FABQ), the Mental Health Inventory (MHI-5), and the Should Pain and Disability Index (SPADI) [38]. Higher FABQ scores indicate elevated fear-avoidance behaviour concerning the shoulder, an MHI-5 score under 68 indicates a probable mood disorder, and a lower SPADI score indicates better shoulder functioning and less pain [28]. Strength testing was conducted using a dynamometer in shoulder abduction, internal and external rotation for the affected and unaffected shoulders [38]. A medical report documented the repair technique used, and diagnostic imaging reported the presence, size, and thickness of tears, as well as fatty infiltration that had occurred [38]. Patients' assessment occurred at a baseline period, and follow-up periods of 3-, 6-, and 12-months [38].

The sample size was male dominated (62%), the mean age was 59 years, and most patients' occupations involved light or no manual labour [38]. By assessing the interactions between the variables, it was found that the FABQ physical activity score and alcohol consumption were significant predictors of SPADI scores [38]. Patients consuming alcohol 1-2 times per week had lower SPADI scores, i.e., better functioning than patients consuming alcohol 2-3 times or less per month, an effect that was greatest at three months and then tapering off [38]. Higher FABQ physical activity score predicted higher SPADI scores, i.e., worse functioning, and this difference was also the most pronounced at the 3-month follow-up [38]. No other variables were found to significantly predict shoulder functioning and pain through the SPADI score [38]. The influence of alcohol use on function demonstrates how patient factors and measures of function can be used to predict surgical outcomes. In this case, the habit of alcohol consumption and fear towards physical activity were linked to shoulder functioning and pain. That information can be used to make lifestyle changes or address fear-related concerns to promote recovery of the shoulder. The relationship should be further explored in other pathologies of the shoulder, paying special attention to the 3-month postoperative period where the greatest change can be anticipated.

A relationship often explored in rotator cuff repair surgeries is the degree of fatty infiltration in the muscle and the impact it has on functional outcomes. Gladstone et al. [34], investigated the effect of muscle quality on functional outcome measures, pain, strength, and structural integrity following surgical repair [34]. The sample consisted of a subset of patients in a larger prospective study who had a full-thickness rotator cuff tear that was surgically repaired

[34]. The measures collected include ROM and strength testing, the Constant score, the ASES survey, and a VAS pain score [34]. Fatty infiltration and muscle atrophy of the supraspinatus and infraspinatus were assessed pre-operatively and at a minimum follow-up of one year [34]. Assessment was done using MRI scans and graded based on severity [34]. Fatty infiltration grading was based on the extent of fatty streaks within the muscle belly using the T1-weighted coronal MRI sequences [34]. Grades of fatty infiltration are assigned values ranging 0-4, with 0 indicating no presence of fatty streaks and 4 indicating a greater presence of fat than muscle [34]. Muscle atrophy was graded as none, mild, moderate, or severe using the oblique sagittal plane images [34]. Numeric grades were assigned to the muscle atrophy criteria ranging 0-3, with 0 representing no atrophy and 3 representing severe atrophy [34]. For all analyses, the grading systems for fatty infiltration and muscle atrophy were dichotomized [34]. Stepwise linear regression was performed to determine if fatty infiltration and muscle atrophy are predictive of functional outcomes following rotator cuff repair [34]. Progression of fatty infiltration and muscle atrophy was assessed using the Wilcoxon signed rank test [34].

Results of the study indicated a statistically significant improvement in functional measures and forward elevation strength [34]. Atrophy of the infraspinatus was found to be a significant predictor of ASES score, Constant score, and forward elevation strength [34]. Fatty infiltration of the infraspinatus predicted ASES scores [34]. Supraspinatus atrophy predicted forward elevation strength, while supraspinatus fatty infiltration was predictive of external rotation strength [34]. Supraspinatus fatty infiltration and atrophy as well as infraspinatus atrophy had significant correlations with post-operative cuff integrity [34]. In terms of predicting post-operative integrity of the rotator cuff with regression modeling, the size of the tear was the only statistically significant predictor [34]. For both the supraspinatus and infraspinatus muscles, fatty infiltration and muscle atrophy significantly progressed from the pre-operative to follow-up measures [34]. Several suggestions were given to explain the seemingly greater importance of the infraspinatus on functional outcomes. Tears extending into or involving the infraspinatus are much larger leading to ineffective muscle function and an impact on joint biomechanics [34]. Another explanation was that the infraspinatus may have some degeneration without experiencing a direct tear, a result of traction from supraspinatus atrophy or chronic retraction [34]. The results of the study highlight the importance of muscle quality in functional outcomes after a rotator cuff repair, as well as the necessity of using pre-operative measures to predict surgical outcomes.

Oh et al. [54] evaluated the correlation between functional and anatomical measures involving the rotator cuff and determine which pre-operative measures can be used to predict outcomes after a rotator cuff repair. All patients in the sample had a full thickness tear and received surgery with a minimum follow-up time of one year [54]. Measures included demographic information, anatomic variables (acromion shape and thickness, presence of spurs, and degree of fatty infiltration) assessed with pre-operative radiographs and magnetic resonance arthrography (MRA) [54]. The fatty infiltration grading criteria previously outlined in the study by Gladstone et al. [34] was used, however a T1-weighted oblique sagittal MRA sequence was used in this study [54]. In addition, the global fatty degeneration index (GFDI) was calculated by averaging the grades of fatty infiltration for the subscapularis, supraspinatus, and infraspinatus muscles [54]. Before surgery, all patients were tested for symptomatic degenerative arthritis of the acromioclavicular joint [54]. During surgery, information was collected regarding the size of the tear and associated lesions [54]. Outcome evaluation, collected pre-operatively and at follow-up, included the following: VAS for pain and patient satisfaction, Constant score, simple shoulder test (SST), and ASES [54]. Correlation coefficients were calculated between clinical variables and final functional and anatomical outcomes [54]. Stepwise linear regression was used to identify independent variables that affect outcomes [54].

Results of the study suggested a significant improvement in all functional measures from the pre-operative to follow-up measurement period [54]. Post-operative functional outcomes did not have a statistically significant correlation with the integrity of the rotator cuff [54]. Females and older patients reported lower SST scores, and post-operative ASES scores were negatively correlated with the size of the tear [54]. In terms of anatomic outcomes, older age, more fatty degeneration of the supraspinatus and infraspinatus, and greater size and retraction of the tear were associated with poorer outcomes [54]. Regression analysis using these parameters identified fatty degeneration of the infraspinatus as the most powerful independent predictor of successful anatomic outcomes [54]. The importance of the infraspinatus in predicting outcomes was previously discussed in the work of Gladstone et al. [34], and further considering how patient factors impact healing and reinjury will be beneficial.

Bedeir et al. [10], conducted a study to assess patient satisfaction in those with a shoulder pathology and determine what disease- or patient-related factors may impact satisfaction levels, as this is becoming increasingly important to improve patient compliance to a treatment plan. The sample of the study included patients receiving follow-up or post-operative care for a shoulder complaint. Information was collected through the following measures: patient demographics, the Pain Catastrophizing Scale (PCS), pain and a function VAS, the Patient-Reported Outcomes Measurement Information System (PROMIS), and the Clinician and Group Consumer Assessment of Healthcare Providers and Systems (CGCAHPS) [10]. The PROMIS survey is a questionnaire measuring pain, fatigue, and physical function, and the CGCAHPS is a tool to measure patient perceptions of care from a provider [10]. Univariate and multivariate regression analyses were performed, the latter done by separating patients into groups of less satisfied and more satisfied [10].

None of the patient demographic information was shown to correlate with patient satisfaction. For the univariate analysis, the function VAS score and the PROMIS score significantly influenced patient satisfaction, while pain measured through the PCS and the pain VAS did not [10]. A function VAS score of less than five, and a PROMIS score of less than 30 was related to lower satisfaction levels [10]. This trend of significance continued for only the function VAS score into the multivariate analysis [10]. The odds of having a score of less satisfaction were 5.5 times greater in patients with a function VAS score of lower than five than in patients with a score of five or higher [10]. The PROMIS score was shown to correlate with the QuickDASH questionnaire, allowing for possible questionnaire substitution depending on the time available [10]. A suggested explanation for the absence of a relationship of pain with satisfaction is the time frame of questionnaire completion. If this is done during early post-operative care, the patient may expect pain, and it will not influence their satisfaction as severely [10]. The persisting significance of the function VAS score stresses the importance of restoring post-operative function, as this was the most important factor in determining patient satisfaction [10]. The importance of patient perception and satisfaction in the recovery process is apparent, as a lower self-reported score of function was correlated with low satisfaction levels. Awareness of how the patient perceives their injury and the recovery process following surgery can foster stronger communication between the healthcare team, so it is valuable to be aware of what factors may develop into a decreased level of satisfaction.

Owens et al. [56], investigated the long-term results for a group of young athletes that had received arthroscopic stabilization for a primary shoulder dislocation. The following measures were collected to assess current shoulder function: the Single Assessment Numeric Evaluation (SANE), the subjective portion of the Rowe score, the ASES, the WOSI, the Simple Shoulder Test (SST), the SF-36 Physical component, current function as a percentage of preinjury function, and whether they would have surgery again through a 1-10 scale [56]. Patient history was documented, patient activity measured using the Tenger scale, and shoulder functional status assessed using the Army Physical Fitness Test (APFT) [56].

The mean follow-up length was 11.7 years with a male-dominated sample (37 out of 39) [56]. At this time following surgical repair of the shoulder, all measures used to assess current shoulder function were in the upper end of the scoring range indicating good functioning [56]. The patient-reported percentage of function compared to a preinjury level was 93.3%, and the mean score of whether they would have surgery again was a 9.1, meaning they are very likely to [56]. The mean Tegner score was 6.5, and the mean number of push-ups performed in two minutes reduced to 72.8 compared to a preinjury amount of 77.7 [56]. Five of the patients experienced recurrent dislocations, and three of these patients opted for revision surgery [56]. Without the baseline values for comparison, it is difficult to determine whether the surgical procedure significantly improved their function compared to a pre-operative period. Regardless, the high shoulder outcome scores are promising in terms of long-term shoulder function following a surgical stabilization. It should also be noted that all of the patients received an arthroscopic procedure, so there would be a benefit in exploring if a similar relationship is present in other surgical techniques for shoulder stabilization. Expanding the investigation to other procedures could assist in updating the criteria for when one technique is preferred over another, which will ensure that the patient is receiving the best option for their circumstance.

Ha et al. [34], investigated the surgical outcomes of patients who received an arthroscopic repair of an anterocapsular lesion for a follow-up period ranging from 2-6 years. The preoperative evaluation consisted of patient history, a physical exam, and magnetic resonance imaging (MRI) scans with a 1.5T scanner [34]. Under anesthesia, the patient's shoulder was examined for anteroposterior translation of the humerus and assigned a grade of 0 to +3, depending on the severity of movement [34]. The inferior translation was assessed by the presence and length of a subacromial sulcus, with a grade of 0 to +3 [34]. The arthroscopic evaluation assessed the condition of the anterior labrum while looking for pathological changes in the shoulder, including Bankart lesions, Hill Sachs lesions, capsular laxity, and the extent of the glenoid defect [34]. The Bankart lesion was repaired arthroscopically, and the patient underwent a post-operative rehabilitation period [34]. The measurements used to monitor shoulder outcomes include the University of California at Los Angeles (UCLA) shoulder score, the ASES, and the Rowe scale [34]. The range of motion in the affected shoulder for external rotation at 90° abduction was collected and compared to the contralateral shoulder [34]. The remaining data collected are a VAS evaluating function compared to the preinjury level and return to activity through five different levels where Grades 0-II are satisfactory, and Grades III-IV are unsatisfactory [34].

The mean follow-up period was 44-months, and all the measurements of shoulder outcomes significantly improved following surgical repair, indicating an improvement in function (Table 2) [34].

| Variable | Preoperative* | Follow-up* | P Value |
|---|---|---|---|
| Shoulder score *(points)* | | | |
| UCLA† | 18.7 ± 3.0 (18.3-19.2) | 33.3 ± 2.2 (33.0-33.6) | <0.001 |
| ASES‡ | 49.1 ± 8.3 (47.8-50.4) | 91.9 ± 7.2 (90.8-92.9) | <0.001 |
| Rowe§ | 40.1 ± 15.5 (37.3-42.5) | 92.3 ± 9.6 (90.8-93.7) | <0.001 |
| Range-of-motion deficit | | | |
| Forward elevation *(deg)* | 2.0 ± 2.8 (1.5-2.4) | 2.2 ± 3.0 (1.7-2.7) | 0.187 |
| External rotation at side *(deg)* | 1.8 ± 3.0 (1.3-2.3) | 2.0 ± 4.0 (1.4-2.6) | 0.376 |
| External rotation at 90° of abduction *(deg)* | NA | 2.2 ± 4.4 (1.6-2.9) | NA |
| Internal rotation behind back *(vertebral level)* | 0.2 ± 0.5 (0.1-0.3) | 0.2 ± 0.5 (0.1-0.3) | 0.221 |
| Activity *(percent of preinjury level)* | | | |
| Overall | 47 ± 17 (44-49) | 96 ± 8 (95-97) | <0.001 |
| Patients not participating in sports (n = 46) | 60 ± 14 (56-64) | 95 ± 4 (97-100) | <0.001 |
| Patients participating in sports (n = 121) | 42 ± 15 (39-44) | 95 ± 9 (93-97) | <0.001 |
| Contact sports (n = 89) | 41 ± 14 (38-44) | 95 ± 10 (93-97) | <0.001 |
| Overhead sports (n = 17) | 34 ± 15 (26-41) | 94 ± 8 (90-98) | <0.001 |
| Other sports (n = 15) | 53 ± 13 (45-60) | 94 ± 11 (88-100) | <0.001 |

**Table 2.** Results comparing functional scores before and after arthroscopic repair of anterocapsular lesion [34].

Patient activity levels significantly increased after surgery, and 91% of the patients rated their shoulder function as 90% or higher of their preinjury function levels [34]. Although patients who were involved in overhead sports had worse functioning before surgery, these individuals returned to a level of activity similar to other sports [34]. The degree of the defect in the glenoid significantly influenced the risk of surgery failure through injury recurrence, where patients with a defect greater than 30% of the glenoid circumference were at a higher risk than patients with a defect less than 20% [34]. For the cases that experienced injury recurrence, the function was related to activity level as patients with high demanding activities had a lower return to sport than individuals who were not engaged in sports activity [34]. In patients that had recurrent instability, the frequency of recurrence was much smaller compared to a pre-operative frequency [34]. While the significant improvement demonstrated in this study and the study by Owens et al. [56] is incredible for the patients involved, it would be beneficial to see these functional improvements in a shortened period. The study presents activity level of the patient before surgery as a useful predictor of functioning and injury recurrence and highlights the defect of the glenoid as a predictor of surgery failure. These variables can be used during patient assessments to predict their surgical success and outcomes.

## VIII. Summary and Significance of Proposal

Shoulder function was found to be influenced by several patient factors, such as fear and prior activity levels, and there is an opportunity to examine additional variables and other shoulder pathologies [34, 38]. Understanding the multifactorial nature of patient factors influencing surgical outcomes will aid healthcare professionals in their decision-making process, making modifications to ongoing treatment plans, and individualizing their patient care. In addition, patient perception and satisfaction of their recovery process can influence their functional outcomes [10]. Informing patients of their risk level for injury recurrence or potential surgical outcomes will allow patients to make educated decisions regarding their daily habits and activities. If injury recurrence does occur in high-risk patients, they will be less surprised and may be more likely to maintain their level of satisfaction and trust in their healthcare provider.

Outcome prediction prior to shoulder surgery is critical to ensure optimal post-operative function, yet there is little information currently available on predicting patient outcomes with the open Latarjet procedure. Current factors that influence the surgeon's decision to operate are very similar to the previously mentioned predictors of injury recurrence, with focus being placed on patient factors and anatomy of the shoulder that cannot be altered or improved upon prior to surgical intervention. Notable factors influencing surgical decisions include glenoid bone loss, patient age, activity, the number of dislocations, and whether the surgery is a primary or revision procedure [15, 42]. The identification of modifiable predictors of surgical outcomes could aid surgeons in making predictions and better-informed decision regarding the needs of their patient and whether surgery is the correct intervention at that time.

In addition, previous studies suggest that surgical stabilization is effective at improving joint position sense for patients with shoulder instability [79, 60]. ROM, muscle strength, and proprioception in the shoulder significantly impact daily living [32, 36, 51], therefore stressing the importance of restoring these qualities following shoulder surgery. Despite the influence of ROM, muscle strength, and proprioceptive variables on the recovery of functional outcomes after shoulder surgery, little investigation has been done with respect to the open Latarjet procedure. As ROM, strength, and proprioception are variables that also be altered or improved, establishing their predictive ability and incorporating potential relationships into the design of a treatment plan may allow patients to yield better surgical outcomes.

Therefore, the purpose of this study is to comprehensively investigate which pre-operative patient factors in those with a shoulder dislocation influence functional outcomes following the open Latarjet procedure. These findings will carry great clinical importance, as they will assist in the identification of good surgical candidates and candidates that may require additional support prior or after surgery during their recovery process based on their pre-operative assessment.

The objectives of the proposed study are:

- Determine what pre-operative patient factors influence the post-operative outcomes following an open Latarjet procedure.
- Determine the relationship between range of motion, proprioception, muscle strength and functional improvement after an open Latarjet procedure.

We hypothesize that:

- Factors that are predictive of injury recurrence will be strong predictors of post-operative functional outcomes, such as age, number of dislocations and sports involvement.
- Functional outcomes will improve following surgical stabilization, and preoperative patient-reported outcomes would be predictive of clinically important outcomes following surgery.

- Proprioceptive acuity, strength and range of motion values in the affected shoulder will be predictive of post-operative functional scores.

# Chapter 2: Pre-operative quality of life assessed by WOSI score prior to Laterjet procedure is related to higher quality of life at 6 months and at 1 year follow-up

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## Abstract

Purpose: To determine if preoperative patient-reported quality of life and function measures can predict outcomes at 6-months and 12-months following an open Latarjet procedure for shoulder instability.

Methods: Fifty-five patients who received an open Latarjet procedure for shoulder instability between September 2009 to February 2021 were assessed for eligibility. Patient-reported data collected prior to surgery included demographic information, hyperlaxity assessed with Beighton criteria, patient-reported quality of life using the Western Ontario Shoulder Instability Index (WOSI) score, and shoulder function using the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) scale. WOSI and QuickDASH scores were collected again at 6-months and one-year follow-up after Latarjet surgery. Linear regression analyses were performed to identify variables that were predictive of WOSI and QuickDASH scores at 6- and 12-month follow-up. The patient characteristics with a univariate p-value<0.20 were incorporated into the multivariate analysis models for WOSI and QuickDASH scores at 6- and 12-month follow-up. Predictive variables with a p-value<0.05 and identified confounding variables were retained in the final models.

Results: Thirty-seven patients met the inclusion criteria out of the fifty-five patients who received an open Latarjet procedure for shoulder instability. Patients experienced a significant improvement in WOSI scores (p<0.001) and there was a trend towards the QuickDASH scores improving (p=0.096) at 6 and 12-month follow-up. Pre-operative WOSI scores (p=0.008) and Beighton scores (p=0.03) were predictive of 6-month WOSI scores in the multivariate regression. Pre-operative WOSI scores (p=0.008) were predictive of WOSI scores at one-year follow-up. Beighton score (p=0.007) and playing a competitive sport prior to surgery (p=0.04) are predictors of QuickDASH scores at 6-month follow-up.

Conclusion: Our results indicate that pre-operative WOSI scores predicted quality of life improvement as measured by the WOSI at 6- and 12-months after Laterjet surgery. In addition, Beighton scores, and the level of sport played prior to surgery can be used to predict functional outcomes at 6-months and one-year. Incorporating pre-operative quality of life and function

measures can be useful to clinicians in determining surgical candidacy and patient outcomes. More research is needed to determine if pre-operative rehabilitation and improvement of instability can further improve function post-surgery.

**Level of Evidence:** II; prospective cohort study

**Keywords:** Shoulder instability; Latarjet procedure; Outcome predictors; Patient-reported outcomes; Function

**Pre-operative quality of life assessed by WOSI score prior to Latarjet procedure is related to quality of life at 6 months and at 1 year follow-up**

## Introduction

Shoulder dislocation resulting in joint instability is a frequent pathology in the young athletic population, and it is often addressed through surgical intervention [9]. Although the Bankart procedure is still commonly used, recent evidence suggests that the Latarjet procedure has lower revision and shoulder dislocation recurrence rates, as well as satisfactory shoulder range of motion (ROM) and scores on patient-reported instability measures [5, 8, 9, 34, 39]. In particular, the open Latarjet procedure has been recommended for treating patients with significant glenoid bone loss, engaging Hills-Sachs lesions, and for patients engaged in contact sports [1, 3, 7, 49]. Since positive outcomes are more consistently being identified with the open Latarjet procedure, additional studies are required to examine what factors can be used to predict patient outcomes, to further ensure the best possible results.

Predicting surgical outcomes for prior to shoulder surgeries is critical to ensure optimal post-operative function, yet there is little information currently available on predicting patient outcomes with the Latarjet procedure. Previous studies examining surgical outcomes have been conducted in other shoulder pathologies, and predictive factors have been identified for the total shoulder arthroplasties [13, 48], rotator cuff repairs (RCR) [14], and the arthroscopic Bankart repair [2, 44]. A number of patient characteristics have been identified in the literature as predictors of surgical outcomes, typically identified as the recurrence of injury or surgical success. These factors include young age [44], male sex [32], joint hyperlaxity [12, 16, 24, 44], participation in competitive sport [2, 3], bone graft osteolysis and graft positioning [16, 24, 38], Hill-Sachs lesions [2, 37, 44], and the degree of glenoid bone loss [7, 29]. However, what is important to note is that these factors can rarely be addressed or changed before surgery. The surgeon for example is unable to change the age or the number of times a patient has dislocated their shoulder prior to the initial examination.

Identifying modifiable predictors of surgical outcomes could carry several important clinical implications. Primarily, surgeons would be able to make predictions and better-informed decision regarding the needs of their patient and whether surgery is the correct decision at that time. Current factors that influence the surgeon's decision to operate are very similar to the previously mentioned predictors of injury recurrence, with focus being placed on variables that cannot be altered or improved upon prior to surgical intervention. Notable factors include glenoid bone loss, patient age, activity, the number of dislocations, and revision surgery [7, 29].

By incorporating preoperative functional measures that can be improved upon when making surgical decisions, patients may be able to reduce their levels of preoperative dysfunction, yielding a better outcome from their surgery. A similar strategy of using preoperative rehabilitation has previously been applied to the lower extremity, specifically the knee and hip joints. Patients who completed a rehabilitation program before surgery saw greater functional improvements and return to sport [20], as well as quicker discharge times [41], when compared to patients who did not complete a preoperative program. Similar improvements in the shoulder could be made through preoperative rehabilitation, an intervention that has not been frequently used in the past despite its potential for symptom management before surgery [45]. To substantiate the idea of using preoperative rehabilitation to improve surgical success, it is necessary to determine if measures of shoulder function and instability prior to surgery can be used to predict the same outcome following surgical intervention.

Therefore, the purpose of this study is to determine if preoperative patient-reported function and instability measures can be used to predict shoulder function and instability following an open Latarjet procedure. We hypothesized that preoperative patient-reported outcomes would show the ability to be predictive of clinically important outcomes following surgery.

## Methods

The study consisted of a prospective cohort analysis of patients who had received an open Latarjet procedure for shoulder instability. All patients provided written, informed consent, and the study was approved by the institution ethics boards.

### Measures

*Demographic information*

General patient information including age, sex, height, weight, body mass index (BMI), smoking/alcohol consumption, the mechanism of injury (MOI), insurance status, and occupation were recorded. Patient smoking status and alcohol consumption were documented through a yes/no response. MOI information was recorded in the following groups: sport, auto accident, fall from a height, bicycle accident, hit by a car, low velocity drop, lifting a heavy object, and "other". Insurance status was obtained originally in four groups: personal insurance, coverage through workers compensation (CSST) or automobile insurance (SAAQ), or no insurance coverage. A difference in functional outcomes has been observed depending on insurance status, where patients with workers' compensation had significantly poorer functional scores than patients with personal insurance [42]. Due to potential outcome differences and a limited sample of patients insured through CSST and SAAQ, these patients were excluded from the study. Occupation status was recorded into three groups including: active employed, sedentary employed and a third group of unemployed/student. We noted if the shoulder had been immobilized and had patients self-report the number of dislocations they had suffered before their surgery. Sport participation level of the patient following their initial dislocation but before their surgery was documented, grouped as: competitive, recreational, or no participation. We measured general joint hyperlaxity, which was assessed using the Beighton criteria [4]. Beighton criteria gives a series of nine positive/negative tests resulting in a score ranging from 0-9, with a higher score indicating greater joint mobility [19]. The Beighton score is a highly reliable assessment of hypermobility demonstrating high to excellent interrater (ICC=0.71-1.0) and intrarater reliability (ICC=0.89-0.98) for raters of varying backgrounds and experience levels [9].

*Functional shoulder instability – Western Ontario Shoulder Instability Index (WOSI)*

To assess quality of life related to shoulder instability, the Western Ontario Shoulder Instability Index (WOSI) was used. The WOSI consists of 21 questions spanning four domains: Physical Symptoms, Sports/Recreation/Work, Lifestyle, and Emotions. The questionnaire utilizes a visual analog scale (VAS) where a score for each domain, as well as an overall score, are expressed as a value out of 2100 or a percentage out of 100 to quantify the amount and quality of pain [47]. The WOSI measurement tool has been established as a disease-specific and quality of life focused, validated method of assessment for patients with shoulder instability with a high reliability (Cronbach a = 0.96, ICC = 0.87-0.98) [27, 47].

*Shoulder function – QuickDASH*

To assess shoulder function, the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) was used. The QuickDASH is a condensed version of the full-length DASH questionnaire that produces similar results while taking less time to complete and interpret (ICC=0.90) [21, 33]. The questionnaire consists of a 5-point Likert scale ranging from 1-5, where a higher score indicates reduced functioning of the shoulder [33]. The French version of the QuickDASH is also reported to be a reliable and valid instrument for measuring shoulder functioning [21].

*Surgical technique*

Patients were installed in the beach chair position for all procedures performed. A 4 to 5cm length incision was made from the tip of the coracoid process toward the axillary fold. The cephalic vein was identified, retracted and the medial branches were ligated. The anterior fibres of the deltoid were split to expose the coracoid process. The coracoacromial ligament was detached approximately 1cm distal from the insertion site, releasing the coracohumeral ligament. The arm was placed into adduction and internal rotation, and the pectoralis minor was detached from the medial coracoid. A graft of approximately 3cm was harvested by performing an osteotomy with an oscillating saw. The undersurface of the coracoid was sculpted to obtain a flat and bleeding surface. Two holes were drilled into the bone block, approximately 1cm apart from each other. The subscapularis was split horizontally at the junctions of the upper two-thirds and lower one-third, the same level as the future graft location. The capsule was incised longitudinally with electrocautery. Following the excision of the anteroinferior labrum and preparation of the anterior glenoid neck to achieve a bleeding bone bed, the graft was fixed with two 3.5-mm cancellous or cortical screws to the anterior glenoid. The capsule was repaired to the coracoacromial ligament stump with the arm in external rotation followed by standard wound closure [1, 6].

*Rehabilitation protocol*

Patients were instructed to rest for the six weeks following their surgery. The arm was placed in a single splint with internal rotation, and ROM exercises for the elbow, hand, and wrist were to be performed four times daily. Daily hygiene with active-assisted movement was permitted. At six weeks, active-assisted exercises were incorporated. Exercises included: anterior flexion, adduction, and abduction (external rotation 0° and 90°) at will, maximum external rotation to 30°, internal rotation without going behind the back. Isometric strengthening of the deltoid was performed at this time. From weeks 12 to 24, patients were to complete a program focused on strengthening the rotator cuff and scapular stabilization. Posture and proprioception exercises were performed, along with a gradual return to work and sport under guidance of the surgeon. Six months following the surgery, patients were permitted to return to contact sports.

**Procedures**

All patients were evaluated preoperatively one week prior to surgery. Demographic information and pre-operative WOSI and QuickDASH scores were recorded during the evaluation period. The surgical procedure was then performed by one of six orthopedic surgeons. Patients were given rehabilitation instructions as outlined above. During the 6-month and one-year follow-up appointments, WOSI and QuickDASH scores were collected as post-operative measures of shoulder function and patient quality of life.

**Statistical Analysis**

Descriptive statistics were calculated using mean and standard deviation for continuous variables and count for categorical variables. One-way ANOVAs were used to determine if there was a significant change in WOSI and QuickDASH scores for the pre-operative, 6-month, and one-year follow-up measurement periods.

Univariate linear regression analyses were performed to identify variables that were predictive of WOSI and QuickDASH scores at 6- and 12-month follow-up. The predictive univariate variables were included in the multivariate regression model for the respective follow-up period. Patient characteristics with a univariate p-value $< 0.20$ were entered into the multivariate analysis models as potential predictors and confounding variables.

Multivariate linear regression was conducted for both dependent variables at 6- and 12-month follow-up. Only variables with a p-value $< 0.05$ were retained in the final models. Confounding was assessed and variables leading to a 15% change in the beta coefficients of significant variables were included in the multivariate model. All analyses were performed using SPSS (version 27.0 IBM, Armonk, NY, USA).

**Results**

During the period from September 2009 to February 2021, 55 patients were treated for shoulder instability with an open Latarjet procedure. Of the patients treated, 37 patients met the inclusion criteria for analysis, details of which are outlined in Figure 1. The females who had received an open Latarjet procedure had much better WOSI scores than males for both the 6-month and one-year follow-up periods. Although the pre-operative WOSI and QuickDASH scores were similar between males and females, only four patients were female. The number of female patients was not high enough to complete a group comparison analysis, so they were removed from the sample for further analysis. In addition to the differing post-operative functional scores, sex-based differences have been identified with respect to shoulder instability, pre-operative functional scores and Beighton criteria scores [16, 32]. Magnuson et al. [32] also reported higher rates of Hill-Sachs lesions and anterior glenoid defects in males, both of which are indicators for the open Latarjet procedure. The female demographic information and scores for the WOSI and QuickDASH are provided in the Appendix. For male patients the demographic information, along with the means and standard deviations for additional variables included in the analysis, are presented in Table 1. There is some variation in sample size due to some missing data on some of the measures. Mean values for WOSI and QuickDASH scores recorded before surgery, at six months and at one-year, are also reported in Table 1.

There was a statistically significant difference in WOSI score between the measurement periods of pre-operative, 6-months, and one-year follow-up as determined by one-way ANOVA ($F(2,94) = 25.51$, $p < 0.001$, $\eta^2 = 0.350$). A Tukey post-hoc test revealed that patient shoulder instability significantly improved from the pre-operative measure (63.81 ± 20.02) to both the 6-month follow-up (34.95 ± 19.51, $p < 0.001$) and the one-year follow-up (29.68 ± 24.30, $p < 0.001$). While WOSI scores did improve from the 6-month to one-year follow-up measurement period, this score improvement was not statistically significant ($p = 0.61$).

While there was a consistent improvement in QuickDASH scores from the pre-operative measure to the 6-month and one-year follow-up measures, the difference in score was not statistically significant ($p = 0.094$). There is a trend toward a statistically significant improvement in shoulder function following the open Latarjet procedure at 6 months and 1 year.

**Model 1: What predicts WOSI score at 6 months after surgery**

The univariate analysis indicated several variables that were associated with a higher WOSI score at six months after surgery. A higher WOSI score at six months follow-up was associated with a higher Beighton score, younger age, and greater pre-operative QuickDASH and WOSI scores as assessed through a univariate linear regression analysis. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 54.9% of the variance in WOSI scores, showed that Beighton scores (p=0.03) and pre-operative WOSI scores (p=0.001) are predictors of the WOSI score at six months follow-up. Greater pre-operative shoulder instability can be used as a predictor of patient quality of life related to shoulder instability six months following surgery.

**Model 2: What predicts WOSI score at 1 year after surgery**

The univariate analysis indicated several variables that were associated with a higher WOSI score at one-year after surgery, presented in Table 3: Model 2. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 24.6% of the variance in WOSI score, showed that only pre-operative WOSI scores (p=0.008) were predictive of the WOSI score at one-year follow-up. Greater pre-operative shoulder instability can be used as a predictor of patient quality of life related to shoulder instability six months following surgery.

**Model 3: What predicts QuickDASH scores at 6 months after surgery**

The univariate analysis indicated several variables that were associated with a higher QuickDASH score at six months after surgery, presented in Table 4: Model 3. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 49.5% of the variance in QuickDASH scores, showed that the Beighton score (p=0.007) and playing a competitive sport prior to surgery (p=0.04) are predictors of high QuickDASH scores at six months follow-up.

**Model 4: What predicts QuickDASH scores one year after surgery**

The univariate analysis indicated several variables that were with higher QuickDASH scores at one-year after surgery, presented in Table 5: Model 4. The associated variables were incorporated into a multivariable model, but no variable reached statistical significance as a predictor of QuickDASH scores at one-year follow-up.

## Discussion

The most important finding of the present study was determining that pre-operative WOSI scores are predictive of patient quality of life related to shoulder instability at 6- and 12-months following an open Latarjet procedure. The consistently small p-values present in both our univariate and multivariate analysis demonstrates the robustness of the relationships highlighted. The use of pre-operative patient-reported measures, such as the WOSI, may have substantial clinical implications when considering that these measures can be modified and improved prior to surgical intervention. In addition, patients that demonstrate a significantly higher WOSI score during a pre-operative evaluation may affect the surgeons decision to operate immediately. Future studies are needed in this area, but it is possible through rehabilitation to lower pre-op WOSI scores which could improve both willingness to operate and outcomes after surgery.

Several studies have been conducted focused on what may influence a surgeon's decision to operate on their patient, as well as factors that influence patient willingness to undergo a procedure. Lau et al. [29] sought to determine which factors influence a surgeon's decision to perform a bony versus a soft tissue procedure for recurrent anterior shoulder instability. The predominant factors included the amount of glenoid bone loss, patient age and activity demands [29]. The results from Lau et al. [29] build on the study conducted by Bishop et al. [7], who also sought to investigate preoperative factors that influence surgical treatment selection. Factors that were predictive of surgical decision-making included symptom duration, number of dislocations, revision surgery, and the amount of bone loss present [7]. Considering the Latarjet procedure, predictive factors included high-risk sport, glenoid bone loss, and revision surgery [7]. In both previously described studies, all the factors assessed centralized around shoulder anatomy and unmodifiable patient characteristics, such as age, sex, occupation and hand dominance [7, 29]. It should be noted that in the study performed by Bishop et al. [7], patient outcome data was collected prospectively for future but was not included in the mentioned study. As patient care shifts towards a more personalized process with shared decision-making [29], it becomes increasingly important to consider the patient perspective and how their assessment of function and instability can carry over into surgical success.

Weekes et al. [45] assessed the factors that influence a patient's decision to undergo a RCR. Results showed that limited shoulder function and the recommendation of the surgeon as the top two patient factors, while patient activity level and the risk of tear progression were the top two surgeon factors for a RCR [45]. Under half (45.8%) of the patients used preoperative physical therapy prior to their procedure. The patients who did engage in preoperative physical therapy reported worse postoperative shoulder functioning, however, the difference in score did not exceed the minimal clinically important difference [45]. It is important to note when interpreting this result that both the preoperative physical therapy group and group without physical therapy reported significant improvements on the American Shoulder and Elbow Surgeons Shoulder Score (ASES), reported as an improvement from a cumulative pre-operative score of 42.7 to post-operative scores of 80.8 and 87.1, respectively [45]. Pre-operative physical therapy had a significant negative correlation with shoulder function; however, the correlation value was quite small ($r = -0.21$) [45]. In addition, poorer outcomes that may have resulted from preoperative physical therapy did not exceed the minimal clinically important difference (MCID) of 12 points [45]. The combination of improving ASES scores and group difference remaining within the MCID suggests that the inclusion of preoperative rehabilitation did not have an overtly detrimental effect on surgical outcomes.

Weekes et al. [45] further noted the low preoperative physical therapy numbers as a potential area of improvement in patient care, as physical therapy can be used for symptom management and contribute to reduced failure rates. Additional research would be needed to explore the relationship of preoperative rehabilitation and shoulder function in other shoulder pathologies and their surgical interventions. Additional measures used in shoulder assessment, such as the WOSI score, should also be incorporated to build a comprehensive understanding of preoperative rehabilitation and its influence on surgical outcomes.

There are several physiologic suggestions in the literature attempting to explain why shoulder instability and dysfunction may persist following surgical stabilization. One explanation considers the damage done to the capsulolabral glenoid complex and that the extent of damage increases with subsequent dislocations of the shoulder joint [22]. Damage to proprioceptive fibres with consecutive shoulder dislocations and surgical treatment may also play a role, as any remaining deficit in proprioceptive ability could impair daily functioning and a reduced ability to engage in activity [9]. A delay between the initial dislocation and surgical intervention increases the chances of developing shoulder arthropathy, with an increased number in dislocations as a suggested cause [29]. Lädermann et al. [29] highlight age as a risk factor for shoulder arthropathy following surgery, where older patients may have poorer cartilage properties and decreased capacity for repair leading to extended cartilage damage in the shoulder joint. In addition, Lädermann et al. [29] reported a higher number of patients that felt their shoulder was unstable than patients who sustained a redislocation, suggesting patient apprehension to account for the discrepancy. Subscapularis tendon management has influence on strength recovery after the Latarjet procedure, with subscapularis tenotomy being associated with reduced strength and higher instability rates compared to subscapularis split [49]. The subscapularis tenotomy technique has been reported as inferior in terms of biomechanics, functional scores, and post-operative stability [18].

Graft osteolysis has been reported as a potential cause of shoulder instability following the Latarjet procedure, a concern that depending predominately on the positioning of the coracoid graft region [16]. The distal portion of the coracoid graft is least involved in osteolysis and shows better bone healing, potentially due to improved bone contact and blood supply [16]. Using an open Latarjet procedure instead of an arthroscopic technique is suggested to improve graft positioning, allow for better orientation of the screws during surgery, and provide greater exposure during the more technical aspects of the procedure [1]. Di Giacomo et al. [16], suggests that the graft osteolysis may not be the leading cause of anterior shoulder instability, as their sample experienced no injury recurrence or instability despite a large amount of osteolysis in the coracoid. Scapula positioning, shoulder hyperlaxity and bony defects were proposed as explanatory factors [16].

Graft positioning is supported as one of the critical aspects of the Latarjet procedure. Medial positioning of the graft may contribute to shoulder instability [24] while lateral positioning could lead to degenerative changes, due to friction with the humeral head [38]. Biomechanically, the ideal graft position is at 4 o'clock to prevent anterior dislocation [24, 38]. Superior placement can contribute to injury recurrence and inferior placement increases the risk of non-union [24, 25, 46]. Graft positioning and osteolysis rates were not considered in the present study, as our focus was establishing predictors of shoulder instability that could be modified prior to surgical intervention.

In the open Latarjet procedure, the placement of the bone block graft on the glenoid is suggested to have an impact in patients with shoulder hyperlaxity [38]. Placing the bone block higher on the glenoid could be done to increase the sling effect of the coraco-biceps tendon on the inferior subscapularis muscle [50]. Modifications to graft placement during the procedure may be a contributor to a more favourable outcome in open Latarjet patients with shoulder hyperlaxity compared to an arthroscopic Bankart procedure.

Pre-operative WOSI scores have been shown to be predictive of other concerns in shoulder anatomy. Cronin et al. [16], reported an increased probability of a large labral tear with increasing WOSI scores, quantified as an estimated 16.9% odds ratio increase for a 100-point increase in WOSI values. Although the concept of using preoperative patient reported measures to predict postoperative functional outcomes has received minimal attention with respect to the open Latarjet procedure, it has been explored in total shoulder arthroplasty procedures. Preoperative patient-reported scores of mental health, physical function and pain were able to predict postoperative achievement of surgical outcomes, determine which patients would see a greater benefit from surgery, and aid in the decision-making process [13, 48].

Currently established predictors in the literature of postoperative shoulder instability are primarily focused on the anatomy of the shoulder and other characteristics that cannot be altered prior to surgical intervention. Balg and Boileau [2], reported superior Hill-Sachs lesions in external rotation and a loss of contour of the inferior glenoid as predictors of an increased injury recurrence rate. Voos et al. [44], reported the volume of the Hill-Sachs lesion, age under 25 years, and ligamentous laxity as predictors of recurrent anterior instability. It should be noted that the studies conducted by Balg and Boileau [2] and Voos et al. [44] were performed on arthroscopic Bankart repair patients. Regarding open Latarjet procedures, Mook et al. [37] identified measurements of the glenoid track, notably coracoid size, glenoid width, and Hill-Sachs lesion location, as predictors of postoperative shoulder stability.

Results from the present study show that general joint hypermobility assessed with Beighton's criteria is predictive of shoulder function and instability 6-months following an open Latarjet procedure. General joint hypermobility based on the Beighton criteria has been previously established to have a relationship with glenohumeral joint instability [12]. Yang et al. [49], had a similar finding to our study through identifying the Beighton score as a predictor of worse WOSI scores in patients who had received a modified Latarjet procedure. The present study contrasts in terms of follow-up length, the influence of joint hypermobility was observed 6-months into the recovery process compared to the average 3.5-year follow-up by Yang et al. [49]. The persisting relationship of the Beighton score and WOSI score highlights the importance of joint hypermobility and its influence on patient quality of life in those with shoulder instability. The finding of the present study supports that hyperlaxity continues to be an important factor in the discussion of shoulder function and instability following open Latarjet surgery.

Shoulder hyperlaxity has been previously reported in the literature as a risk factor for recurrent instability in multiple pathologies [17, 24]. Voos et al. [44] identified an association of ligamentous laxity in the shoulder with recurrent instability after an arthroscopic Bankart repair. Kim et al. [26] identified higher rates of injury recurrence in patients with excessive joint laxity, assessed with the Beighton criteria, who had received an arthroscopic Bankart repair. Bessière et al. [5] compared outcomes between the arthroscopic Bankart and the open Latarjet procedures. Relevant findings include that shoulder hyperlaxity, assessed through passive external rotation $> 85°$ in the uninjured shoulder, was predictive of injury recurrence for the Bankart procedure and not the Latarjet [5]. The group differences in favour of the open Latarjet regarding hyperlaxity provide some explanation to the limited hyperlaxity-based research available for the open Latarjet procedure.

Results of the present study also showed improvement in patient quality of life related to instability of the shoulder at 6- and 12-months following an open Latarjet procedure. A statistically significant difference in WOSI scores from the pre-operative measure to both the 6-month and one-year follow-up periods was observed. While the trend of improvement continued when comparing the 6-month and one-year scores, this score difference was not statistically significant. Regarding the MCID of the WOSI, distribution-based and effect size-based calculation methods led to values of 7.2 and 2.9 on the 100-point scale, respectively [40]. The improvement in mean WOSI score from the pre-operative measure to 6-months follow-up was 28.86 points on the 100-point scale, far exceeding both of the previously listed MCID values. The WOSI score difference between 6-months and one-year follow-up is 3.59, falling in between the MCID values and preventing us from concluding whether this score improvement is clinically significant. The blatant improvement in WOSI score during the first 6-months of recovery is comparable to recovery rates in rotator cuff repairs, where a 75% functional recovery rate was identified 6-months following the surgical procedure [14].

Although the improvement in score did not translate into a statistically significant relationship in QuickDASH score, a trend towards statistical significance was indicated. The lack of a statistically significant finding may be due in part to the low sample size and large standard deviation in QuickDASH scores. It should also be noted that the mean pre-operative QuickDASH score was fairly low, suggesting that the patient sample had relatively good function in their shoulder prior to the open Latarjet procedure. A lower mean pre-operative score left little room for a statistically significant improvement in the follow-up measurement periods. When interpreting the improvement in score, it is important to consider the MCID of the measurement tool. The MCID for the QuickDASH was identified as an eight percent change in score, corresponding to a 4-point difference in the summation of the questions [35]. For the present study, the mean difference in QuickDASH score from the pre-operative period to the 6-month follow-up period is 6.44, exceeding the MCID previously stated. The improvement from 6-months to one-year did not exceed the MCID, as the difference in means was 3.59. Observing a clinically significant improvement in QuickDASH scores is promising finding, as it suggests that the first 6-months after surgery is a key period in regaining shoulder function.

Participation in a competitive sport prior to surgery was found to be predictive of shoulder function, measured with the QuickDASH, 6-months following an open Latarjet procedure. Sport participation level and type are both well-established as a predictors of injury recurrence in various shoulder pathologies. Balg and Boileau [2], found competitive sports participation to be significantly related to injury recurrence in patients receiving an arthroscopic Bankart repair. Regarding open Latarjet procedures, Baverel et al. [3] reported in their group comparison between competitive and recreational athletes that the group of competitive athletes had better postoperative WOSI scores. Sport differences in WOSI scores were not significant findings from the current study, but it should be noted that the mean follow-up length for competitive and recreational athletes was 44- and 49- months, respectively [3].

The main focus when analyzing sports is the patient's ability to return to sport after surgery. However, there was insufficient data available to analyze this variable in the present study. Buckup et al. [10] reported that patients who compete in competitive sport more than twice per week have smaller chances of returning to sport at their pre-injury level. In addition, 90% of the patient sample reported shoulder-related limitations and attributed it to pain or function concerns [10]. It should be noted that the patients received a revision arthroscopic Bankart procedure [10], yet similar results have been identified in primary procedures as well. Blonna et al. [8] assessed return to sport in both open Bristow-Latarjet procedures and arthroscopic Bankart procedures. Pre-operative scores on the Degree of Shoulder Involvement in

Sport (DOSIS), the type of surgery, and the number of dislocations before surgery were predictive of one's ability to return to sport at a follow-up of 5.3 years [8]. Regarding arthroscopic Latarjet procedures, Buckup et al. [9] found that 89.4% of the patients were able to return to their original sport after an average of 4.6 months, with overhead and martial arts athletes demonstrating lower rates of return. The results presented by Buckup et al. [9] support the notion that important clinical findings can be observed within the first 6 months of surgical follow-up regarding functional outcomes and sport.

An interesting concept when analyzing return to sport is patient psychology and the influence it carries during recovery. Tjong et al. [43] found that in patients who had received an arthroscopic Bankart, kinesiophobia was a prevalent theme among patients who had decided not to return to sport following their surgery. For arthroscopic stabilization procedures, it appears that return to sport depends more on patient fear and motivation rather than perceived function of the shoulder. Kee et al. [28] assessed return to sport in open Latarjet patients and reported that while all patients returned to sport within one year of surgery, most patients were unable to return to their pre-injury level of play. In patient interviews, memories were reported of pain and instability prior to their surgery that delayed their return to sport, supporting a psychological component to the recovery process [28]. Differences in return to sport were found depending on the type of sport played, with collision sport athletes showing a significantly lower level of return to sport [28].

Further research would be needed to explore the concept of pre-operative rehabilitation with respect to the open Latarjet procedure. Failla et al. [20] reported that a group of patients who performed preoperative rehabilitation had higher, more clinically meaningful function and a greater return to sport two years following anterior cruciate ligament (ACL) repair compared to a group who did not receive a preoperative intervention. Rooks et al. [41] found that patients who participated in a 6-week long exercise program prior to a total hip or knee replacement were discharged home rather than to an inpatient rehabilitation facility in comparison to patients who did not receive the exercise intervention. Determining the influence of a preoperative exercise program on surgical outcomes in the shoulder could set patients up for greater long-term success in their recovery.

There are several limitations that should be considered when interpreting the results of this study. The sample size was limited, primarily due to the exclusion criteria regarding the presence and type of surgical intervention. Despite the limited number of patients, the sample size is comparable to similar studies focused on predicting shoulder surgery outcomes. Due to a limited sample of females who met the inclusion criteria, these patients were excluded from analysis, hindering the generalizability of the results between sexes. Future consideration should be given to exploring the prediction of Latarjet outcomes in females. The follow-up periods of 6- and 12- months could be considered as a limitation, however, several studies suggest that the bulk of functional recovery and the greatest risk of injury recurrence are within the first year of the Latarjet procedure [23, 39]. Similar rates of recovery have been noted in rotator cuff repair patients, as Cho et al. [14] reported a 60% improvement in functional outcomes at 3-months and 75% recovery at 6-months after rotator cuff repair.

The present study has shown that pre-operative WOSI scores, Beighton score, and the level of sport played prior to surgery can be used to predict functional outcomes at 6-months and one-year following the open Latarjet procedure in males. In addition, the first 6-months following the open Latarjet procedure appears to be where the greatest returns in shoulder function and stability can be made. We believe that the consideration of preoperative function and instability scores can be useful to clinicians in determining surgical candidacy, when surgical intervention is appropriate, and informing patients of expected surgical outcomes. Future research should be directed towards predictive characteristics in females, and the effectiveness of a preoperative rehabilitation phase to improve functional scores prior to surgical intervention.

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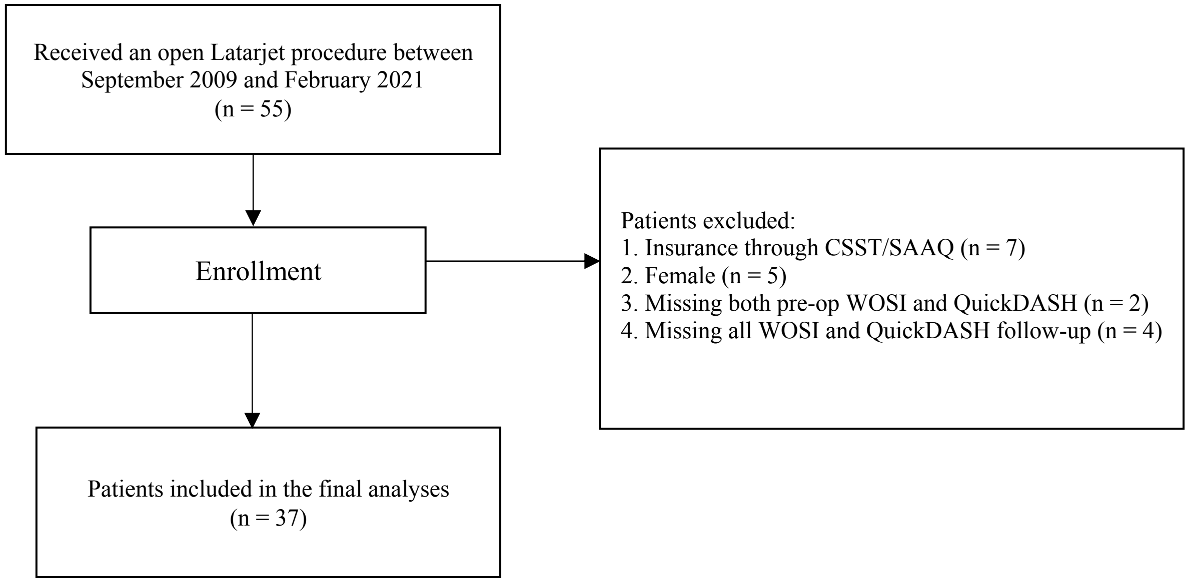


**Figure 1.** Consort diagram illustrating the inclusion and exclusion of patients treated for shoulder instability.

| Characteristic | n | Mean ± SD or count |
|---|---|---|
| Height (in) | 37 | 70.54 ± 3.34 |
| Weight (lb) | 37 | 180.89 ± 38.46 |
| BMI | 37 | 25.25 ± 4.41 |
| Age at surgery | 37 | 25.47 ± 5.55 |
| Smoking | 37 | |
| Yes | | 10 |
| No | | 27 |
| Alcohol | 37 | |
| Yes | | 16 |
| No | | 21 |
| MOI | 36 | |
| Sport | | 22 |
| Auto accident | | 1 |
| Fall from height | | 2 |
| Bicycle accident | | 1 |
| Hit by a car | | - |
| Low velocity drop | | 3 |
| Lifting a heavy object | | - |
| Other | | 7 |
| Missing | | 1 |
| Occupation | 37 | |
| Active Employed | | 9 |
| Sedentary/Employed | | 10 |
| Student/Unemployed | | 18 |
| Insurance | 37 | |
| Personal | | 23 |
| None | | 14 |

| | | |
|---|---|---|
| Immobilization<br>Yes<br>No<br>Missing | 34 | <br>25<br>9<br>3 |
| # of Dislocations | 37 | 26.81 ± 34.36 |
| Sport level before<br>Competitive<br>Recreational<br>None | 37 | <br>22<br>10<br>5 |
| Hyperlaxity | 34 | 2.15 ± 2.16 |
| Pre-op WOSI | 37 | 63.81 ± 20.02* |
| 6M Follow up WOSI | 30 | 34.95 ± 19.51* |
| 1Y Follow up WOSI | 30 | 29.68 ± 24.30* |
| Final WOSI score | 20 | 25.93 ± 22.26 |
| Pre-op QuickDASH | 36 | 29.67 ± 18.08 |
| 6M Follow up QuickDASH | 27 | 23.23 ± 16.62 |
| 1Y Follow up QuickDASH | 31 | 19.64 ± 21.60 |
| Final QuickDASH score | 21 | 14.29 ±20.43 |

**Table 1.** Demographic, function, and all shoulder information of male patients receiving an open Latarjet surgery and included in the 6 month and 1 year follow-up.

*p-value <0.05 in one-way ANOVA

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| No. of dislocations | 30 | 0.039 (-0.180, 0.258) | 0.72 | | | | |
| Hyperlaxity | 27 | 4.634 (1.210, 8.058) | **0.01** | Hyperlaxity | 24 | 3.295 (0.302, 6.288) | **0.03** |
| Age at surgery | 30 | -0.821 (-2.072, 0.430) | **0.19** | | | | |
| Sport before accident | 30 | -6.403 (-17.192, 4.386) | 0.23 | | | | |
| Pre-op QuickDASH | 25 | 0.342 (-0.082, 0.765) | **0.11** | | | | |
| Pre-op WOSI | 26 | -0.706 (-1.075, -0.3370 | **0.001** | Pre-op WOSI | 24 | -0.589 (-0.909, -0.270) | **0.001** |

**Table 2: Model 1.** Preoperative variables that were used to predict WOSI scores at 6 months after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis. Hyperlaxity and pre-operative WOSI scores are predictive of 6-month WOSI scores.

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| No. of dislocations | 30 | -0.061 (-0.374, 0.251) | 0.69 | | | | |
| Hyperlaxity | 27 | 0.146 (-4.302, 4.593) | 0.95 | | | | |
| Age at surgery | 30 | 1.056 (-0.496, 2.609) | **0.17** | | | | |
| Sport before surgery | 30 | -4.719 (-17.583, 8.144) | 0.46 | | | | |
| Pre-op QuickDASH | 27 | 0.223 (-0.320, 0.766) | 0.41 | | | | |
| Pre-op WOSI | 27 | -0.606 (-1.043, -0.169) | **0.008** | Pre-op WOSI | 27 | -0.606 (-1.043, -0.169) | **0.008** |

**Table 3: Model 2.** Preoperative variables that were used to predict WOSI scores one-year after shoulder surgery. Any variable with p < 0.2 in the univariate analysis was included in the multivariate analysis. Only pre-operative WOSI score was predictive of one-year WOSI scores.

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| No. of dislocations | 27 | 0.018 (-0.161, 0.197) | 0.84 | | | | |
| Hyperlaxity | 23 | -4.981 (-8.204, -1.758) | **0.003** | Hyperlaxity | 23 | -4.597 (-7.760, -1.434) | **0.007** |
| Age at surgery | 27 | 0.827 (-0.248, 1.901) | **0.13** | | | | |
| Sport before surgery | 27 | 8.989 (0.610, 17.367) | **0.04** | Sport before surgery | 23 | | |
| | | | | Competitive | 14 | -21.278 (-41.112, -1.435) | **0.04** |
| | | | | Recreational | 7 | -12.264 (-33.966, 9.438) | 0.251 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pre-op QuickDASH | 25 | -0.399 (-0.840, 0.042) | **0.07** | | | | |
| Pre-op WOSI | 24 | -0.054 (-0.363, 0.256) | 0.72 | | | | |

**Table 4: Model 3.** Preoperative variables that were used to predict QuickDASH at 6 months after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis. Hyperlaxity and sport level are predictive of 6-month QuickDASH scores.

| Univariate analysis | | | |
|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value |
| No. of dislocations | 31 | -0.205 (-0.427, 0.017) | **0.07** |
| Hyperlaxity | 29 | 0.597 (-3.283, 4.478) | 0.75 |
| Age at surgery | 31 | -0.641 (-1.954, 0.672) | 0.32 |
| Sport before surgery | 31 | -4.029 (-15.322, 7.263) | 0.47 |
| Pre-op QuickDASH | 28 | 0.297 (-0.163, 0.757) | **0.19** |
| Pre-op WOSI | 27 | -0.094 (-0.522, 0.334) | 0.65 |

**Table 5: Model 4.** Preoperative variables that were used to predict QuickDASH one year after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis were considered in the multivariate analysis.

**Author Contribution**

ES and DR performed the surgical stabilization procedures and were responsible for the original grant application, conception, and design of the study. KT collected the pre-operative and post-operative measures and constructed the database. GD participated in the conception and design of the study, interpretation of the statistical analysis, and helped to draft the manuscript. MF assisted in the interpretation of the statistical analysis. SM completed the database reduction, performed the statistical analysis, and helped to draft the manuscript. All authors read and approved the final manuscript.

## List of Abbreviations

American Shoulder and Elbow Surgeons Shoulder Score (ASES)

Anterior cruciate ligament (ACL)

Body mass index (BMI)

Commission de la Santé et de la Sécurité du travail – Workers compensation (CSST)

Mechanism of injury (MOI)

Minimal clinically important difference (MCID)

Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH)

Range of motion (ROM)

Rotator cuff repair (RCR)

Société de l'assurance automobile du Québec – Automobile insurance (SAAQ)

Visual analog scale (VAS)

Western Ontario Shoulder Instability Index (WOSI)

# Appendix

| Participant | Pre-op WOSI | 6M Follow up WOSI | 1Y Follow up WOSI | Pre-op QuickDASH | 6M Follow up QuickDASH | 1Y Follow up QuickDASH |
|---|---|---|---|---|---|---|
| Female #1 | - | 10.76 | 11.52 | 15.91 | 9.09 | 4.5 |
| Female #2 | 74.29 | 16.45 | 20.86 | 45.45 | 11.36 | - |
| Female #3 | 51.76 | 27.21 | 12.10 | 13.64 | 34.09 | 22.73 |
| Female #4 | 54.05 | - | 9.33 | 47.73 | - | 18.18 |

**Table 6.** WOSI and QuickDASH scores for females who received an open Latarjet procedure.

| | Females | | Males | |
|---|---|---|---|---|
| Characteristic | n | Mean ± SD or count | n | Mean ± SD or count |
| Pre-op WOSI | 3 | 60.03 ± 12.40 | 37 | 63.81 ± 20.02 |
| 6M Follow up WOSI | 4 | 18.14 ± 8.36 | 30 | 34.95 ± 19.51 |
| 1Y Follow up WOSI | 3 | 13.45 ± 5.08 | 30 | 29.68 ± 24.30 |
| Final WOSI | 3 | 13.62 ±6.15 | 20 | 25.93 ± 22.26 |
| Pre-op QuickDASH | 3 | 30.68 ± 18.42 | 36 | 29.67 ± 18.08 |
| 6M Follow up QuickDASH | 4 | 18.18 ± 13.82 | 27 | 23.23 ± 16.62 |
| 1Y Follow up QuickDASH | 3 | 15.14 ± 9.49 | 31 | 19.64 ± 21.60 |
| Final QuickDASH | 3 | 3.03 ± 5.25 | 21 | 14.29 ±20.43 |

**Table 7.** Comparison of WOSI and QuickDASH scores for females and males receiving the open Latarjet procedure.

| Characteristic | n | Mean ± SD or count |
|---|---|---|
| Height (in) | 4 | 66.00 ± 4.97 |
| Weight (lb) | 4 | 140.50 ± 35.49 |
| BMI | 4 | 22.51 ± 4.29 |
| Age at surgery | 4 | 24.80 ± 6.29 |
| Smoking | 4 | |
| Yes | | - |
| No | | 4 |
| Alcohol | 4 | |
| Yes | | 2 |
| No | | 2 |
| MOI | 3 | |
| Sport | | 2 |
| Auto accident | | - |
| Fall from height | | - |
| Bicycle accident | | 1 |
| Hit by a car | | - |

| | | |
|---|---|---|
| Low velocity drop | | - |
| Lifting a heavy object | | - |
| Other | | - |
| Missing | | 1 |
| Occupation | 4 | |
| Active Employed | | - |
| Sedentary/Employed | | 2 |
| Student/Unemployed | | 2 |
| Insurance | 4 | |
| Personal | | 2 |
| None | | 2 |
| Immobilization | 3 | |
| Yes | | 1 |
| No | | 2 |
| Missing | | 1 |
| # of Dislocations | 4 | 11.50 ± 8.10 |
| Sport level before | 4 | |
| Competitive | | 4 |
| Recreational | | - |
| None | | - |
| Hyperlaxity | 3 | 4.33 ± 2.31 |
| Pre-op WOSI | 3 | 60.03 ± 12.40 |
| 6M Follow up WOSI | 4 | 18.14 ± 8.36 |
| 1Y Follow up WOSI | 3 | 13.45 ± 5.08 |
| Final WOSI | 3 | 13.62 ±6.15 |
| Pre-op QuickDASH | 3 | 30.68 ± 18.42 |
| 6M Follow up QuickDASH | 4 | 18.18 ± 13.82 |
| 1Y Follow up QuickDASH | 3 | 15.14 ± 9.49 |
| Final WOSI | 3 | 3.03 ± 5.25 |

**Table 8.** Demographic, function, and all shoulder information of female patients receiving an open Latarjet surgery.

# Chapter 3: Range of Motion, Muscle Strength, and Proprioception as Predictors of Surgical Outcomes

## Introduction

Daily activity, such as raising a glass to your mouth or writing with a pen, requires the ability to accurately coordinate movement of the upper limb for success [36, 51]. Individuals who experience recurrent shoulder dislocations, or those with a hyperlax glenohumeral joint, may find that the fluidity of their movements are affected by impaired proprioception [36, 43]. This impairment results from damage to the shoulders capsuloligamentous, muscular, and cutaneous receptors responsible for providing sensory feedback [4]. Understanding the structural damage and resulting dysfunction of the shoulder joint are prevalent themes in the literature when discussing dislocations of the shoulder and resulting joint instability.

There are several methods of assessment regarding proprioception; the two most common are kinesthesia and joint position sense (JPS) [1]. Kinesthesia is measured through establishing a threshold to detect passive motion or limb movement [4] and JPS refers to the angle and position of joints relative to one another [60]. JPS is further assessed with a breakdown into active and passive tasks, where active task replication requires the individual to move their own limb and passive protocols consist of another person or device relocating the limb in space. Active JPS tasks are generally preferred to passive protocols, as they stimulate both joint and muscle receptors and better represent the actual functioning of the joint [1, 4]. In terms of measuring JPS, a common unit used is error, or the distance from the target angle. Two popular forms of error measurement are absolute error and constant error. Absolute error identifies the magnitude of error while discounting direction, while constant error measures the deviation from the target while taking direction into account [72]. Most studies use absolute error when measuring JPS, but including constant error provides key sensorimotor information by reflecting how accurately the target is represented in the nervous system [72]. In other words, constant error indicates whether a person is typically overshooting or undershooting their target.

Following an injury to the shoulder joint, the resulting compromised sensory feedback may contribute to additional ligamentous strain and decreased muscle coordination, increasing the risk of additional injury [4, 44]. Surgical intervention allows for the tightening of surrounding shoulder structures, allowing them to receive and respond to sensory feedback with greater accuracy [51]. Aydin et al. [5] compared proprioception in healthy and surgically repaired shoulders using the mean error of an active JPS task. Results suggested that there were no significant differences in mean error in terms of arm dominance or surgical status, meaning that the operated shoulder had similar error to the contralateral limb [5]. Only internal and external rotation were assessed in the study with the rationale that these movements are frequently performed in overhead activities [5]. Following surgical repair, improvement in active JPS was reported by both Zuckerman et al. [79] and Pötzl et al. [60], as the mean differences from the perceived angle and the actual target angle became significantly smaller following surgical stabilization in both studies. Zuckerman et al. [79] showed that improvements in joint position sense were significant one year after surgery, while Pötzl et al. [60] showed that the improvements were sustained until their follow-up period of 5-years. These studies show that surgical stabilization is effective at improving joint position sense for patients with shoulder instability.

The return of accurate proprioception in the shoulder is a key point in post-operative recovery, as it allows one to return to regain the level of function required for daily living. In a study conducted by Maier et al. [47], pre-operative function was found to be predictive of post-operative proprioception following a total shoulder arthroscopy. Patients were subdivided into three groups based on their constant-murley score, and results showed that lower pre-operative constant-murley scores are a negative predictor for post-operative proprioception [47]. A lower, i.e., better, constant-murley score predicted a better postoperative outcome in terms of proprioception for patients [47]. It would be interesting to see if the inverse relationship of pre-operative proprioception predicting functional outcomes is present. Such a relationship has been investigated in the knee following anterior cruciate ligament (ACL) injury by Roberts et al. [63], who found that poorer proprioception was related to shorter length on a hop test and worse subjective functional ratings.

In addition to proprioception, range of motion (ROM) and muscle strength assessments are often used for diagnostic classification and determining the level of functional impairment [19]. As these shoulder characteristics already play such an important role in the initial identification of shoulder dysfunction, and demonstrate a relationship with scores on functional measures, it is possible that their measurements can also be used to predict the likelihood of a positive outcome following surgical intervention. Establishing the predictive ability of ROM, strength, and proprioception, and incorporating these relationships into the design of a treatment plan, may allow patients to yield better surgical outcomes. Patients who experience limitations in terms of ROM, strength, and proprioceptive acuity may benefit from an intervention aimed towards improving these measures prior to their surgical procedure, setting the stage for higher levels of functioning after surgery.

Despite the established importance of ROM, strength, and proprioception on the recovery of functional outcomes after shoulder surgery, little formal research has been conducted on the open Latarjet procedure with respect to these variables. Considering post-operative rehabilitation, guidelines provide no clear consensus. One camp of thought highlights the need for gradual regaining of ROM to allow for appropriate healing of the subscapularis muscle and the anterior capsule [28, 58]. The subscapularis is a likely target of impairments to force production and proprioception, therefore, rehabilitation must target regaining proprioceptive acuity and muscle strength in the upper and lower portions of the subscapularis [28, 58]. In contrasting opinion, Belestsky et al. [12] report a shorter immobilization period compared to the arthroscopic Bankart procedure, with the hypothesis that surgeons utilizing the open Latarjet are confident in the initial fixation strength allowing for an accelerated rehabilitation process. Fox et al. [32] outlined their protocol aiming to compare the outcomes of the arthroscopic Bankart and the open Latarjet procedure by assessing shoulder joint neuro-mechanics, ROM, strength, and patient-reported function and health status. The results of this study will be important in filling the gap present in the literature, but a direct analysis of open Latarjet outcomes is also warranted. Further research needed to explore the post-operative outcomes of the open Latarjet in terms of regaining ROM, strength, and proprioception. In addition, more knowledge regarding pre-operative values of ROM, strength, and proprioception is needed to build a more comprehensive understanding of the influence these factors carry regarding shoulder function in the open Latarjet procedure.

The purpose of this study is to determine if preoperative measures of ROM, muscle strength, and proprioceptive acuity can be used to predict shoulder function and instability following an open Latarjet procedure. We hypothesize that ROM, muscle strength, proprioceptive acuity, and functional outcome scores will improve following surgery and significant predictors will be identified.

## Methods

The study consisted of a prospective cohort analysis of 55 patients who had received an open Latarjet procedure for shoulder instability. All patients provided written, informed consent, and the study was approved by the institution ethics boards.

### Measures

*Demographic information*

General patient information was recorded, including age, sex, height, weight, body mass index (BMI), smoking/alcohol consumption, the mechanism of injury (MOI), insurance status, and occupation. Smoking status and alcohol consumption were documented through a yes/no response. MOI was recorded in the following groups: sport, auto accident, fall from a height, bicycle accident, hit by a car, low velocity drop, lifting a heavy object, and "other". Insurance status was obtained originally in four groups: personal insurance, coverage through workers compensation (CSST) or automobile insurance (SAAQ), or no insurance coverage. Differing functional outcomes have been observed depending on patient insurance status, where individuals with workers' compensation had significantly poorer functional scores than those with personal insurance [67]. Due to potential outcome differences and a limited sample of patients insured through CSST and SAAQ, these patients were excluded from the study. Occupation status was recorded into three groups including: active employed, sedentary employed and a third group of unemployed/student. We noted if the shoulder had been immobilized and patients self-reported the number of dislocations they had suffered before their surgery. Sport participation level of the patient following their initial dislocation but before their surgery was documented, grouped as: competitive, recreational, or no participation. We measured general joint hyperlaxity using the Beighton criteria [11]. The Beighton criteria gives a series of nine positive/negative tests resulting in a score ranging from 0-9, with a higher score indicating greater joint mobility [29]. In addition, the Beighton score is a highly reliable assessment of hypermobility for raters of varying backgrounds and experience levels demonstrating a high interrater (ICC = 0.71-1.0) and intrarater reliability (ICC = 0.89-0.98) [17].

*ROM, force, and proprioception*

Active shoulder ROM was measured bilaterally using a goniometer. The goniometer is reported to have excellent reliability (ICC = 0.85-0.99), with slightly higher accuracy than an inclinometer [25]. The shoulder movements measured include flexion, abduction, external rotation (ER) at 0° abduction, and internal (IR) and external rotation at 90° abduction. Flexion, abduction, external rotation at 0° abduction movements were measured with the patient sitting. While in the sitting position, the patient was instructed to remain in an upright posture and avoid arching the back. External and internal rotation at 90° abduction active ROM was measured with the patient lying in a supine position with the shoulder abducted and elbow flexed to 90°.

Shoulder strength of both shoulders was assessed for the movements of flexion, abduction, and internal and external rotation at 90° abduction. A hand-held dynamometer was used for strength measurement, as it is reported to be a reliable tool for strength assessment in patients with shoulder joint injuries (ICC = 0.79-0.99) [19, 37]. For flexion and abduction movements the patient was seated; for internal and external rotation, the patient was lying in a supine position. Sitting and supine positions are preferred when performing strength testing, as other positions yield large differences in muscle strength performance [25]. The patient was asked to perform the movements against the resistance of the dynamometer to a maximum voluntary effort, holding this effort for a period of five seconds. The examiner maintained the dynamometers position by matching the force exerted by the patient.

Proprioception in the shoulder was evaluated as the patient's ability to actively reproduce a joint position. Both the healthy and affected shoulder were measured. A goniometer was also used for the proprioception assessment. The positions used include 90° flexion, 90° abduction, 30° external rotation, 30° internal rotation. For proprioception testing, the patient lying in supine position with their eyes closed. The protocol consisted of a passive demonstration of the arm positioning for reference, followed by an active replication of the position. The process was repeated for three trials per reference position. The angle produced was recorded for each the three trials, from which the mean absolute error and mean constant error for each movement was calculated.

*Functional shoulder instability – Western Ontario Shoulder Instability Index (WOSI)*

To assess patient quality of life related to shoulder instability, the Western Ontario Shoulder Instability Index (WOSI) was used. The WOSI consists of 21 questions spanning four domains: Physical Symptoms, Sports/Recreation/Work, Lifestyle, and Emotions. The questionnaire utilizes a visual analog scale (VAS) where a score for each domain, as well as an overall score, are expressed as a value out of 2100 or a percentage out of 100 to quantify the amount and quality of pain [76]. The WOSI measurement tool has been established as a disease-specific, quality of life focused, and validated method of assessment for patients with shoulder instability [39]. The WOSI is reported to have high internal consistency and test-retest-reliability, indicated by a Cronbach a value of 0.96 and an ICC ranging from 0.87-0.98, respectively [76].

*Shoulder function – QuickDASH*

To assess patient shoulder function, the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) was used. The QuickDASH is a condensed version of the full-length DASH questionnaire that produces similar results while taking less time to complete and interpret (ICC=0.90) [31, 50]. The questionnaire consists of a 5-point Likert scale ranging from 1-5, with higher score indicating reduced functioning of the shoulder [50]. The French version of the QuickDASH is also reported to be a reliable and valid instrument for measuring shoulder functioning [31].

*Surgical technique*

Patients were installed in the beach chair position for all procedures. A 4 to 5cm length incision was made from the tip of the coracoid process toward the axillary fold. The cephalic vein was identified, retracted and the medial branches were ligated. The anterior deltoid fibres were split to expose the coracoid process. The coracoacromial ligament was detached approximately 1cm distal from the insertion site, releasing the coracohumeral ligament. The arm was placed into adduction and internal rotation, and the pectoralis minor was detached from the medial coracoid. A graft of approximately 3cm was harvested by performing an osteotomy with an oscillating saw. The undersurface of the coracoid was sculpted to obtain a flat and bleeding surface. Two holes were drilled into the bone block, approximately 1cm apart from each other. The subscapularis was split horizontally at the junctions of the upper two-thirds and lower one-third, the same level as the future graft location. The capsule was incised longitudinally with electrocautery. Following the excision of the anteroinferior labrum and preparation of the anterior glenoid neck to achieve a bleeding bone bed, the graft was fixed to the anterior glenoid with two 3.5-mm cancellous or cortical screws. The capsule was repaired to the coracoacromial ligament stump with the arm in external rotation followed by standard wound closure [2, 14].

*Rehabilitation protocol*

Patients were instructed to rest for the six weeks following their surgery. During this period, the arm was placed in a single splint with internal rotation, and range of motion (ROM) exercises for the elbow, hand, and wrist were to be performed four times daily. Daily hygiene with active-assisted movement was permitted. Beginning at six weeks, active-assisted exercises were incorporated. These exercises included: anterior flexion, adduction, and abduction (external rotation 0° and 90°) at will, maximum external rotation to 30°, internal rotation without going behind the back. Isometric strengthening of the deltoid was performed at this time. From weeks 12 to 24, patients were to complete a program focused on rotator cuff strengthening and scapular stabilization. Postural and proprioceptive exercises were performed, along with a gradual return to work and sport under guidance of the surgeon. Patients were permitted to return to contact sport six months following their surgery.

**Procedures**

All patients were evaluated preoperatively one week prior to surgery. Demographic information and pre-operative WOSI and QuickDASH scores were recorded during the evaluation period. Pre-operative measurements of patient ROM, force, and proprioception were also collected for the affected shoulder during the evaluation period. The surgical procedure was then performed by one of six orthopedic surgeons. Patients were given rehabilitation instructions as outlined above. During the 6-month and one-year follow-up appointments, WOSI and QuickDASH scores were collected as post-operative measures of shoulder function and instability. During the one-year follow-up appointment, measurements of patient ROM, force, and proprioception were collected for the affected shoulder.

**Statistical Analysis**

Descriptive statistics were calculated using mean and standard deviation for continuous variables and count for categorical variables. One-way ANOVAs were used to determine if there was a significant change in WOSI and QuickDASH scores for the pre-operative, 6-month, and one-year follow-up measurement periods.

Univariate linear regression analyses were performed to identify variables regarding ROM, force, and proprioception of the affected shoulder that were predictive of WOSI and QuickDASH scores at 6- and 12-month follow-up. The predictive univariate variables were included in the multivariate regression model for the respective follow-up period. Patient characteristics with a univariate p-value $< 0.20$ were entered into the multivariate analysis models as potential predictors and confounding variables.

Multivariate linear regression was conducted for both dependent variables at 6- and 12-month follow-up. Only variables with a p-value $< 0.05$ were retained in the final models. Confounding was assessed and variables leading to a 15% change in the beta coefficients of significant variables were included in the multivariate model. All analyses were performed using SPSS (version 27.0 IBM, Armonk, NY, USA).

## Results

During the period from September 2009 to February 2021, 55 patients were treated for shoulder instability with an open Latarjet procedure. Of the patients treated, 39 patients met the inclusion criteria for analysis, details of which are outlined in Figure 5. Demographic information and mean values for WOSI and QuickDASH scores recorded before surgery, at six months and at one-year, are presented in Table 3. Pre-operative and one-year follow up values for ROM, force, and proprioceptive error in the affected shoulder are reported in Tables 4, 5, and 6, respectively. Pre-operative and one-year follow up values for ROM, force, and proprioceptive error in the healthy shoulder are presented in Tables 7, 8, and 9, respectively.

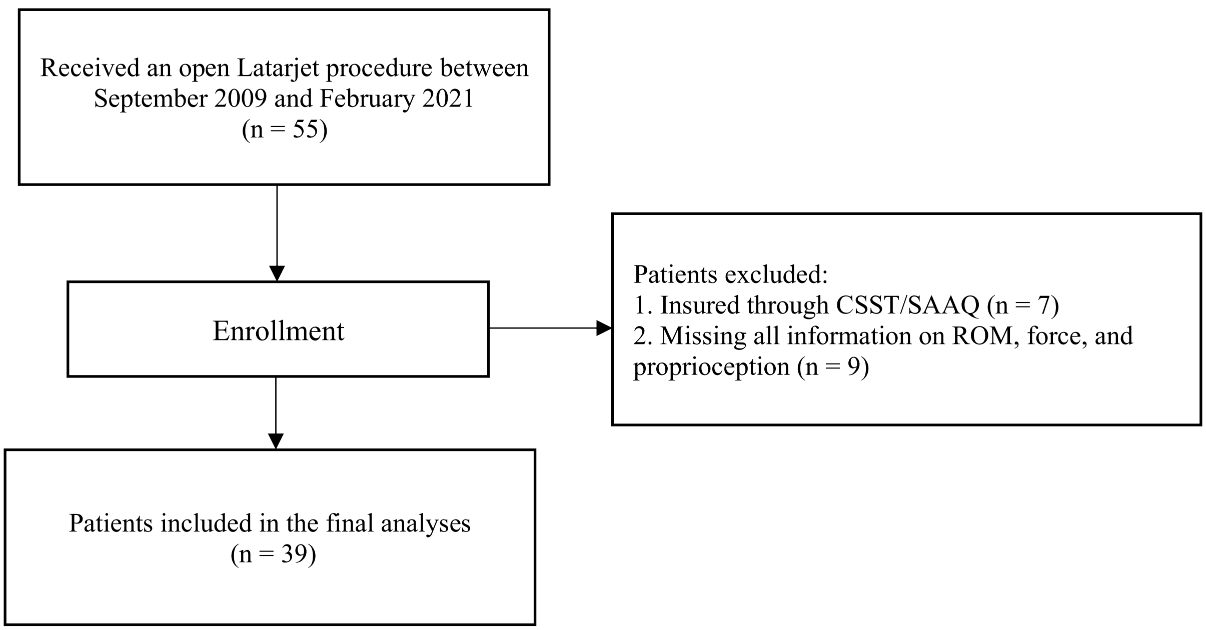


**Figure 5.** Consort diagram illustrating inclusion and exclusion criteria.

| Characteristic | n | Mean ± SD or count |
|---|---|---|
| Sex | 39 | |
| Male | | 35 |
| Female | | 4 |
| Height (in) | 39 | 70.36 ± 3.66 |
| Weight (lb) | 39 | 182.15 ± 42.48 |
| BMI | 39 | 25.51 ± 4.78 |
| Age at surgery | 39 | 25.80 ± 5.54 |
| Smoking | 39 | |
| Yes | | 8 |
| No | | 31 |

| | | |
|---|---|---|
| Alcohol | 39 | |
| Yes | | 20 |
| No | | 19 |
| MOI | 37 | |
| Sport | | 23 |
| Auto accident | | - |
| Fall from height | | 1 |
| Bicycle accident | | 2 |
| Hit by a car | | - |
| Low velocity drop | | 2 |
| Lifting a heavy object | | - |
| Other | | 9 |
| Missing | | 2 |
| Occupation | 39 | |
| Active Employed | | 7 |
| Sedentary/Employed | | 15 |
| Student/Unemployed | | 17 |
| Insurance | 39 | |
| Personal | | 14 |
| None | | 25 |
| Immobilization | 33 | |
| Yes | | 21 |
| No | | 12 |
| Missing | | 6 |
| # of Dislocations | 49 | 27.23± 33.41 |
| Sport level before | 38 | |
| Competitive | | 25 |
| Recreational | | 9 |
| None | | 4 |
| Missing | | 1 |
| Hyperlaxity | 36 | 2.50 ± 2.38 |
| Pre-op WOSI | 37 | 63.66 ± 18.87* |
| 6M Follow up WOSI | 25 | 37.07 ± 23.23* |
| 1Y Follow up WOSI | 26 | 28.70 ± 23.96* |
| Final WOSI | 20 | 25.62 ± 23.93 |
| Pre-op QuickDASH | 38 | 31.94 ± 18.87* |
| 6M Follow up QuickDASH | 24 | 21.97 ± 15.51 |
| 1Y Follow up QuickDASH | 25 | 16.99 ± 18.85* |
| Final QuickDASH | 21 | 13.64 ± 19.97 |

**Table 3.** Demographic, function, and all shoulder information of patients receiving an open Latarjet surgery and included in the 6 month and 1 year follow-up.

*p-value <0.05 in one-way ANOVA

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Affected ROM flexion | 35 | 166.85 ± 24.72 | 12 | 179.58 ± 1.44 |
| Affected ROM abduction | 35 | 159.09 ±31.49 | 12 | 180.00 ± 0.00 |
| Affected ROM ER 0 | 31 | 59.54 ± 22.83 | 12 | 53.33 ± 23.09 |
| Affected ROM ER 90 | 32 | 68.00 ± 21.20 | 11 | 61.55 ± 11.32 |
| Affected ROM IR 90 | 32 | 70.50 ± 15.33 | 11 | 61.64 ± 11.32 |

**Table 4.** Mean and standard deviation for affected shoulder ROM collected at pre-op and one-year follow-up.

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Affected force abduction | 26 | 25.97 ± 9.89 | 10 | 30.81 ± 8.17 |
| Affected force flexion | 27 | 31.01 ± 11.70 | 10 | 39.10 ± 11.76 |
| Affected force IR 90 | 27 | 24.03 ± 8.64 | 10 | 26.90 ± 9.10 |
| Affected force ER 90 | 27 | 22.21 ± 8.49 | 10 | 26.08 ± 9.00 |

**Table 5.** Mean and standard deviation for affected shoulder force (lbs) collected at pre-op and one-year follow-up.

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Affected Prop Flex 90 Abs Err | 14 | 5.74 ± 3.76 | 9 | 4.52 ± 3.29 |
| Affected Prop Flex 90 Con Err | 14 | -0.50 ± 6.77 | 9 | 0.30 ± 5.49 |
| Affected Prop Abd 90 Abs Err | 14 | 7.98 ± 5.26 | 9 | 5.11 ± 3.39 |
| Affected Prop Abd 90 Con Err | 14 | -1.36 ±8.98 | 9 | -1.70 ± 4.43 |
| Affected Prop ER 30 Abs Err | 12 | 12.53 ± 7.86 | 7 | 5.29 ± 2.31 |
| Affected Prop ER 30 Con Err | 12 | 12.36 ± 8.01 | 7 | 1.76 ± 5.41 |
| Affected Prop IR 30 Abs Err | 14 | 9.52 ± 6.93 | 9 | 16.33 ± 9.92 |
| Affected Prop IR 30 Con Err | 14 | 6.86 ± 8.51 | 9 | 12.11 ± 15.04 |

**Table 6.** Mean and standard deviation for affected shoulder proprioceptive error collected at pre-op and one-year follow-up.

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Healthy ROM flexion | 34 | 178.09 ± 7.98 | 11 | 180.00 ± 0.00 |
| Healthy ROM abduction | 34 | 177.35 ± 9.39 | 11 | 180.00 ± 0.00 |
| Healthy ROM ER 0 | 33 | 68.52 ± 19.75 | 12 | 76.50 ± 17.80 |
| Healthy ROM ER 90 | 32 | 88.16 ± 16.34 | 8 | 94.38 ± 17.32 |
| Healthy ROM IR 90 | 32 | 70.50 ± 15.33 | 8 | 57.75 ± 13.23 |

**Table 7.** Mean and standard deviation for healthy shoulder ROM collected at pre-op and one-year follow-up.

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Healthy force abduction | 27 | 29.93 ± 11.72 | 8 | 29.08 ± 9.18 |
| Healthy force flexion | 27 | 37.83 ± 16.12 | 8 | 41.45 ± 12.92 |
| Healthy force IR 90 | 27 | 28.72 ± 12.12 | 8 | 28.16 ± 9.04 |
| Healthy force ER 90 | 28 | 29.59 ± 12.08 | 8 | 29.63 ± 10.68 |

**Table 8.** Mean and standard deviation for healthy shoulder force (lbs) collected at pre-op and one-year follow-up.

| | Pre-Op | | One-Year Follow-Up | |
|---|---|---|---|---|
| | n | Mean ± SD | n | Mean ± SD |
| Healthy Prop Flex 90 Abs Err | 15 | 5.93 ± 3.62 | 8 | 5.29 ± 2.00 |
| Healthy Prop Flex 90 Con Err | 15 | 0.47 ± 6.34 | 8 | -0.29 ± 5.11 |
| Healthy Prop Abd 90 Abs Err | 15 | 7.31 ± 6.35 | 8 | 8.63 ± 7.19 |
| Healthy Prop Abd 90 Con Err | 15 | -3.36 ± 8.78 | 8 | -6.46 ± 9.24 |
| Healthy Prop ER 30 Abs Err | 15 | 15.76 ± 8.24 | 8 | 15.13 ± 7.28 |
| Healthy Prop ER 30 Con Err | 15 | 12.33 ± 12.71 | 8 | 15.13 ± 7.28 |
| Healthy Prop IR 30 Abs Err | 15 | 8.78 ± 5.84 | 8 | 8.71 ± 6.70 |
| Healthy Prop IR 30 Con Err | 15 | 5.31 ± 9.22 | 8 | 5.46 ± 9.88 |

**Table 9.** Mean and standard deviation for healthy shoulder proprioceptive error collected at pre-op and one-year follow-up.

There was a statistically significant difference in WOSI score between the measurement periods of pre-operative, 6-months, and one-year follow-up as determined by one-way ANOVA ($F(2,85) = 22.88$, $p < 0.001$, $\eta^2 = 0.350$). A Tukey post-hoc test revealed that patient shoulder instability significantly improved from the pre-operative measure (63.66 ± 18.87) to both the 6-month follow-up (37.07 ± 23.23, $p < 0.001$) and the one-year follow-up (28.70 ± 23.96, $p < 0.001$). While WOSI scores did improve from the 6-month to one-year follow-up measurement period, this score improvement was not statistically significant ($p = 0.35$).

There was a statistically significant difference in QuickDASH score between the measurement periods of pre-operative, 6-months, and one-year follow-up as determined by one-way ANOVA ($F(2,85) = 5.63$, $p = 0.005$, $\eta^2 = 0.118$). A Tukey post-hoc test revealed that patient shoulder function significantly improved from the pre-operative measure (31.94 ± 18.87) to the one-year follow-up measure (16.99 ± 18.85, $p = 0.005$). While there was a consistent improvement in QuickDASH scores from the pre-operative measure to the 6-month follow-up measure (p=0.091), and the 6-month follow-up measure to the one-year follow-up measure (p = 0.598), the differences in scores were not statistically significant.

**Model 1: What predicts WOSI score 6 months after surgery**

The univariate analysis indicated several variables that were associated with a higher WOSI score at six months after surgery. WOSI score at six months follow-up was associated with flexion ROM and proprioception constant error in abduction. The associated variables were incorporated into a multivariable model, but no variable reached statistical significance as a predictor of WOSI score at 6-months follow-up.

| Univariate analysis | | | |
|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value |
| Pre-op Affected ROM flexion | 25 | -0.319 (-0.707, 0.069) | **0.10** |
| Pre-op Affected ROM abduction | 23 | -0.202 (-0.503, 0.127) | 0.22 |
| Pre-op Affected ROM ER 0 | 25 | 0.229 (-0.184, 0.642) | 0.26 |
| Pre-op Affected ROM ER 90 | 21 | 0.226 (-0.267, 0.719) | 0.35 |
| Pre-op Affected ROM IR 90 | 22 | 0.144 (-0.489, 0.777) | 0.64 |
| Pre-op Affected force abduction | 17 | -0.073 (-1.454, 1.308) | 0.91 |
| Pre-op Affected force flexion | 18 | -0.168 (-1.114, 0.779) | 0.71 |
| Pre-op Affected force IR 90 | 18 | -0.032 (-1.807, 1.743) | 0.97 |
| Pre-op Affected force ER 90 | 18 | -0.912 (-2.749, 0.925) | 0.31 |
| Pre-op Affected Prop Flex 90 Abs Err | 10 | 1.608 (-3.189, 6.404) | 0.46 |
| Pre-op Affected Prop Flex 90 Con Err | 10 | 0.812 (-1.576, 3.200) | 0.46 |
| Pre-op Affected Prop Abd 90 Abs Err | 10 | 0.142 (-3.190, 3.474) | 0.92 |
| Pre-op Affected Prop Abd 90 Con Err | 10 | 1.132 (-0.730, 2.995) | **0.19** |
| Pre-op Affected Prop ER 30 Abs Err | 8 | -0.614 (-3.249, 2.020) | 0.59 |
| Pre-op Affected Prop ER 30 Con Err | 8 | -0.581 (-3.178, 2.016) | 0.60 |

| | | | |
|---|---|---|---|
| Pre-op Affected Prop IR 30 Abs Err | 10 | 0-0.747 (-3.100, 1.606) | 0.49 |
| Pre-op Affected Prop IR 30 Con Err | 10 | 0.053 (-1.898, 2.003) | 0.95 |

**Table 10: Model 1.** Preoperative variables that were used to predict WOSI scores at 6 months after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis.

**Model 2: What predicts WOSI score at 1 year after surgery**

The univariate analysis indicated several variables that were associated with a higher WOSI score at one-year after surgery, presented in Table 11: Model 2. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 92.6% of the variance in WOSI score, showed that pre-operative abduction absolute error (p = 0.02), external rotation constant error (p = 0.02), and internal rotation constant error (p = 0.007) were predictive of the WOSI score at one-year follow-up.

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| Pre-op Affected ROM flexion | 24 | -0.347 (-0.713, 0.018) | **0.06** | | | | |
| Pre-op Affected ROM abduction | 24 | -0.035 (-0.347, 0.277) | 0.82 | | | | |
| Pre-op Affected ROM ER 0 | 22 | -0.043 (-0.555, 0.468) | 0.86 | | | | |
| Pre-op Affected ROM ER 90 | 20 | -0.080 (-0.669, 0.510) | 0.78 | | | | |
| Pre-op Affected ROM IR 90 | 21 | 0.131 (-0.617, 0.880) | 0.72 | | | | |
| Pre-op Affected force abduction | 18 | -0.410 (-1.719, 0.898) | 0.52 | | | | |
| Pre-op Affected force flexion | 18 | -0.122 (-1.069, 0.824) | 0.79 | | | | |
| Pre-op Affected force IR 90 | 18 | -0.399 (-2.132, 1.334) | 0.63 | | | | |
| Pre-op Affected force ER 90 | 18 | 0.027 (-1.486, 1.541) | 0.97 | | | | |
| Pre-op Affected Prop Flex 90 Abs Err | 9 | 2.391 (-3.555, 8.337) | 0.38 | | | | |
| Pre-op Affected Prop Flex 90 Con Err | 9 | 0.139 (-3.564, 3.842) | 0.93 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pre-op Affected Prop Abd 90 Abs Err | 9 | -3.260 (-6.984, 0.464) | **0.08** | Pre-op Affected Prop Abd 90 Abs Err | 7 | -4.889 (-7.973, -1.805) | **0.02** |
| Pre-op Affected Prop Abd 90 Con Err | 9 | 1.283 (-1.276, 3.842) | 0.28 | | | | |
| Pre-op Affected Prop ER 30 Abs Err | 7 | 2.524 (-0.975, 6.023) | **0.12** | | | | |
| Pre-op Affected Prop ER 30 Con Err | 7 | 0.245 (-0.928, 5.837) | **0.12** | Pre-op Affected Prop ER 30 Con Err | 7 | -7.686 (-12.697, -2.675) | **0.02** |
| Pre-op Affected Prop IR 30 Abs Err | 9 | 1.477 (-2.855, 5.809) | 0.48 | | | | |
| Pre-op Affected Prop IR 30 Con Err | 9 | 2.489 (0.014, 4.964) | **0.049** | Pre-op Affected Prop IR 30 Con Err | 7 | 7.129 (3.702, 10.556) | **0.007** |

**Table 11: Model 2.** Preoperative variables that were used to predict WOSI scores one-year after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis.

## Model 3: What predicts QuickDASH scores at 6 months after surgery

The univariate analysis indicated several variables that were associated with a higher QuickDASH score at six months after surgery, presented in Table 12: Model 3. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 51.9% of the variance in QuickDASH scores, showed that abduction ROM ($p = 0.009$) is predictive of QuickDASH scores at six months follow-up. External rotation force was a confounding variable in the final model.

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| Pre-op Affected ROM flexion | 24 | -0.168 (-0.439, 0.103) | 0.21 | | | | |
| Pre-op Affected ROM abduction | 22 | -0.223 (-0.442, -0.003) | **0.047** | Pre-op Affected ROM abduction | 17 | -0.408 (-0.699, -0.117) | **0.009** |
| Pre-op Affected ROM ER 0 | 24 | -0.007 (-0.291, 0.278) | 0.96 | | | | |
| Pre-op Affected ROM ER 90 | 20 | 0.135 (-0.197, 0.466) | 0.40 | | | | |
| Pre-op Affected ROM IR 90 | 21 | -0.006 (-0.460, 0.447) | 0.98 | | | | |
| Pre-op Affected force abduction | 16 | -0.289 (-1.331, 0.753) | 0.56 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pre-op Affected force flexion | 17 | -0.241 (-0.917, 0.434) | 0.46 | | | | |
| Pre-op Affected force IR 90 | 17 | -0.185 (-1.413, 1.043) | 0.75 | | | | |
| Pre-op Affected force ER 90 | 17 | -1.415 (-2.585, -0.245) | **0.02** | Pre-op Affected force ER 90 | 17 | -0.816 (-1.858, 0.226) | 0.115 |
| Pre-op Affected Prop Flex 90 Abs Err | 11 | 0.560 (-2.021, 3.142) | 0.64 | | | | |
| Pre-op Affected Prop Flex 90 Con Err | 11 | -0.086 (-1.458, 1.286) | 0.89 | | | | |
| Pre-op Affected Prop Abd 90 Abs Err | 11 | -0.070 (-1.839, 1.700) | 0.93 | | | | |
| Pre-op Affected Prop Abd 90 Con Err | 11 | 0.349 (-0.690, 1.388) | 0.47 | | | | |
| Pre-op Affected Prop ER 30 Abs Err | 9 | 0.137 (-1.293, 1.566) | 0.83 | | | | |
| Pre-op Affected Prop ER 30 Con Err | 9 | 0.136 (-1.269, 1.542) | 0.83 | | | | |
| Pre-op Affected Prop IR 30 Abs Err | 11 | -0.301 (-1.598, 0.995) | 0.61 | | | | |
| Pre-op Affected Prop IR 30 Con Err | 11 | 0.002 (-1.087, 1.091) | 0.99 | | | | |

**Table 12: Model 3.** Preoperative variables that were used to predict QuickDASH scores at 6 months after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis.

**Model 4: What predicts QuickDASH scores one year after surgery**

The univariate analysis indicated several variables that were associated with a higher QuickDASH score one-year after surgery, presented in Table 13: Model 4. The associated variables were incorporated into a multivariable model. Multivariate analysis results, which explained 88.3% of the variance in QuickDASH scores, showed that external rotation absolute error ($p = 0.02$) is predictive of QuickDASH scores at one-year follow-up. Abduction absolute error was a confounding variable in the final model.

| Univariate analysis | | | | Multivariate analysis | | | |
|---|---|---|---|---|---|---|---|
| Variable | n | B coefficient (95% CI) | *p* value | Variable | n | B coefficient (95% CI) | *p* value |
| Pre-op Affected ROM flexion | 23 | -0.154 (-0.457, 0.150) | 0.31 | | | | |
| Pre-op Affected ROM abduction | 23 | -0.006 (-0.252, 0.241) | 0.96 | | | | |
| Pre-op Affected ROM ER 0 | 21 | -0.118 (-0.541, 0.305) | 0.57 | | | | |
| Pre-op Affected ROM ER 90 | 19 | -0.087 (-0.587, -0.412) | 0.71 | | | | |
| Pre-op Affected ROM IR 90 | 20 | 0.168 (-0.430, 0.766) | 0.56 | | | | |
| Pre-op Affected force abduction | 17 | -0.235 (-1.428, 0.959) | 0.68 | | | | |
| Pre-op Affected force flexion | 17 | -0.169 (-1.008, 0.671) | 0.67 | | | | |
| Pre-op Affected force IR 90 | 17 | -0.207 (-1.851, 1.437) | 0.79 | | | | |
| Pre-op Affected force ER 90 | 17 | -0.025 (-1.386, 1.336) | 0.97 | | | | |
| Pre-op Affected Prop Flex 90 Abs Err | 8 | 0.303 (-6.006, 6.612) | 0.91 | | | | |
| Pre-op Affected Prop Flex 90 Con Err | 8 | 0.900 (-2.615, 4.415) | 0.55 | | | | |
| Pre-op Affected Prop Abd 90 Abs Err | 8 | -3.459 (-6.626, -0.292) | **0.04** | Pre-op Affected Prop Abd 90 Abs Err | 6 | -1.335 (-4.553, 1.883) | 0.28 |
| Pre-op Affected Prop Abd 90 Con Err | 8 | 0.663 (-1.920, 3.244) | 0.55 | | | | |
| Pre-op Affected Prop ER 30 Abs Err | 6 | 3.912 (1.994, 5.831) | **0.005** | Pre-op Affected Prop ER 30 Abs Err | 6 | 3.349 (0.916, 5.783) | **0.02** |
| Pre-op Affected Prop ER 30 Con Err | 6 | 3.773 (1.848, 5.698) | **0.006** | | | | |
| Pre-op Affected Prop IR 30 Abs Err | 8 | 2.302 (-1.332, 5.937) | **0.17** | | | | |
| Pre-op Affected Prop IR 30 Con Err | 8 | 2.608 (0.823, 4.393) | **0.01** | | | | |

**Table 13: Model 4.** Preoperative variables that were used to predict QuickDASH scores one-year after shoulder surgery. Any variable with $p < 0.2$ in the univariate analysis was included in the multivariate analysis.

## Discussion

From the preliminary results, improvements can be observed in shoulder ROM for the movements of flexion and abduction from the pre-operative measure to the one-year follow-up measure. Flexion and abduction are frequently used movements in daily activity, as most tasks require a form of humeral elevation [52]. Similarly, Ali et al. [2] did not find significant losses in range for flexion and abduction in their assessment of the open Latarjet procedure. Perhaps the frequent movement of the arm in flexion and abduction allows for a quicker return of joint ROM measures. A loss in ROM from pre-operative measures to the one-year follow-up was observed for the movements of IR and ER. Restriction in ER is reported in other studies following the open Latarjet [3, 6]. Despite the observable loss in ER for patients in the present sample, literature shows that Bankart repairs demonstrate significantly greater restriction of ER following surgery [3]. In addition, the amount of humeral rotation needed is dependent on the task and the position of the arm in space. Depending on how individuals approach their tasks, the deficit in IR and ER may not significantly impair daily functioning [52].

Shoulder strength improved after surgery, but the proprioception results were varied. Measures of force improved for all movements examined from the pre-operative period to the one-year follow-up. It is possible that the surgical stabilization and subsequent rehabilitation would allow for the shoulder musculature to heal and be able to produce greater force than an injured shoulder waiting for surgical intervention. Proprioception, which was reported with absolute and constant error measurements, shows more variation between the pre-operative measure to the one-year follow-up. It appears that the error measurements generally improved with the exception of IR. The lack of improvement in error for IR may result from the target angle of 30° that was used. Lubiatowsi et al. [46] found greater error values during lower testing angles in a JPS task, and that the IR error values improved with increased deviation from a neutral position. When interpreting the above changes in shoulder ROM, strength, and proprioception it is important to consider the low sample size at the one-year follow-up, as these values may be different with a larger number of patients.

In terms of predicting surgical outcomes, it appears that ROM, strength, and proprioception have a relationship with shoulder function and patient quality of life at 6-months and one-year following the open Latarjet procedure. Specifically, ROM for abduction and flexion and proprioceptive acuity for abduction, IR and ER were related to QuickDASH and

WOSI scores. The weight of these findings is somewhat impacted by the low sample size, a limitation caused by the later incorporation of proprioceptive data collection into a larger database project. Additional data is needed to determine if ROM, strength, and proprioceptive information can remain significant predictors of open Latarjet outcomes with a more robust sample size. Although the present results are not strong enough to confidently contribute to the knowledge surrounding surgical outcome prediction, the influence of ROM, strength, and proprioception has been explored in other studies.

The ability of the shoulder joint to accurately coordinate and produce movement affects the proper functioning of the entire upper limb, including the elbow and wrist joints. The impact of poor proprioception and ROM in the shoulder affects humeral movement which can propagate to the elbow and wrist, resulting in their overcompensation or dysfunction [51]. As an extension, problems that stem in the shoulder can continue down the arm and impact smaller movements such as writing or orienting a cup to one's mouth [51]. Addressing poor proprioception and joint ROM in the shoulder may induce a snowball effect and correct the overcompensation done by the elbow and wrist in daily movements, translating to better overall function of the upper limb.

There is little current information directly assessing ROM, strength, and proprioception for the open Latarjet procedure and the impact of these qualities on shoulder functioning. A recent protocol by Fox et al. [32] aims to compare the outcomes of the arthroscopic Bankart and the open Latarjet procedure by assessing shoulder joint neuro-mechanics, ROM, strength, and patient-reported function and health status. The open Latarjet procedure requires subtle variations in terms of graft placement, graft orientation, and subscapularis management [13, 32]. Minimal investigation has been done on the changes in joint load during movement following a procedure such as the open Latarjet [32]. The results of this study will allow for a better understanding of how joint loading and stability relates to daily functioning, aiding the design of rehabilitation strategies that meet individual needs [32]. Caubère et al. [21] analyzed the post-operative status of the subscapularis muscle following the open Latarjet procedure and its effect on shoulder function, as the coracoid bone block transfers through the muscle. After a mean follow-up period of one-year, results showed that the subscapularis retained satisfactory function, minimal fatty infiltration, and normal amounts of atrophy [21]. Considering isokinetic shoulder strength, deficits in concentric and eccentric contractions were observed for IR and ER, although the ratio of rotator strength remained unchanged [21]. The deficit in shoulder strength had a weakly significant correlation with patient WOSI score, but these results were not expanded upon due to a low sample size of 20 patients [21]. Finally, Caubère et al. [21] found significantly greater fatigability during IR compared to the healthy shoulder. Acknowledging that ROM, strength, and proprioception impact functioning, it is logical to consider the role they may play in the multifactorial nature of patient recovery.

The bulk of research assessing proprioception in the surgically stabilized shoulders has a focus of improving proprioceptive values following an intervention. The rationale of surgical stabilization improving proprioception is that the procedure tightens the glenohumeral joint and surrounding structures, allowing them to respond to sensory feedback with greater accuracy [51]. Several of these studies have been previously mentioned. Zuckerman et al. [79], found that one-year following an anterior capsulorrhaphy with capsulolabral detachment repair, joint position sense in the affected shoulder had improved to a comparable point with the unaffected side. At the 6-month follow-up period, the shoulders had different accuracy in position sense, suggesting that improvements in proprioception continue throughout the first year of recovery [79]. Pötzl et al. [60] also identified improvements in proprioception five-years following surgical intervention using the Bankart technique (10 open, 4 arthroscopic). Strong correlations were identified with proprioceptive acuity and better Rowe scores [60], supporting that accuracy in shoulder movements contributes to joint stability and functioning. The study has a low sample size of 14 patients, so further consideration with a larger number of patients would benefit knowledge in this area.

There is also minimal research available for the shoulder in terms of using proprioception values to make direct predictions of surgical outcomes. However, the influence of proprioception and strength on joint function has been assessed in the knee. Roberts et al. [63] sought to explore proprioceptive deficits, muscle strength, and joint laxity following ACL injury and the potential connection to functional disability and outcomes. It should be noted that these patients did not receive surgical intervention in the study. Results showed that poorer proprioception significantly predicted shorter hop length and poorer subjective function [63]. Strength was not a predictor of outcomes in the study, explained by acknowledging that patients underwent a neuromuscular rehabilitation program with an emphasis on hamstring strength and coordination [63]. Further research is needed on this area in the shoulder joint, as the use of strength and proprioception measures as predictors of surgical outcomes will increase the options available to clinicians and patients in deciding the best treatment option given their unique circumstance.

Considering muscle strength, Rhee et al. [62] aimed to compare the open and arthroscopic Bankart procedures in terms of muscle strength recovery, as the open procedure places the subscapularis tendon at risk of atrophy and fatty infiltration. The mean isometric strength values were different between the two groups 6-weeks following surgery, with the open Bankart group having weaker muscle strength than the arthroscopic Bankart group [62]. The same trend was observed 3-months after surgery, but only for shoulder flexion, as muscle strength for internal and external rotation were not significantly different between groups [62]. For the remaining follow-up periods of 6-, 9-, and 12-months, muscle strength was similar between groups [62]. The 12-month follow-up period reported muscle strength values of 97% in the open group and 99% in the arthroscopic group compared to the unaffected shoulder [62]. The explanation given for the slower strength recovery in flexion for the open Bankart group is the healing time of the subscapularis tendon [62]. The tendon is incised and reattached during the open procedure, and since it acts as a stabilizer during scapular plane elevation, strength may be affected until the structure is fully healed [62]. While open procedures may translate to an initially slower return in muscle strength, it appears that by the 6-month period patients can see comparable results to an arthroscopic procedure.

The sample included in the present analysis saw statistically significant improvements in both QuickDASH and WOSI scores. Despite relatively low pre-operative scores, a statistically significant improvement was present when compared to the one-year follow-up measurement, as well as a trend towards statistical significance when comparing the pre-operative measure to the 6-month follow-up. As previously discussed, the minimal clinically important difference (MCID) for the QuickDASH is a 4-point change in the summation of the questions [50]. The mean differences in QuickDASH score from the pre-operative period to the 6-month period, and from the 6-month period to the one-year period, are 9.97 and 4.98, respectively. A clinically significant improvement in QuickDASH scores was observed through each time period.

Similar statements can be made for the change in WOSI score throughout each measurement period. Statistically significant differences in WOSI scores from the pre-operative measure to both the 6-month and one-year follow-up periods were observed. Improvement was noted from the 6-month to one-year measurement periods, however, the change in WOSI score was not statistically significant. The mean differences in WOSI score from the pre-operative period to the 6-month period, and from the 6-month period to the one-year period, are 26.59 and 8.37, respectively. Both values exceed the MCID of the WOSI score, which are 7.2 through distribution-based calculations and 2.9 through effect size-based calculations on the 100-point scale [57]. A large jump in WOSI score was once again observed in the first 6-months of recovery, continuing to suggest that the majority of function return is made during this period.

The present study has shown that measures of shoulder ROM, strength, and proprioception are related to functional outcomes at 6-months and one-year following the open Latarjet procedure. In addition, the first 6-months following the open Latarjet procedure appears to be in restoring patient quality of life. The consideration of preoperative measures of ROM, strength, and proprioception can be useful to clinicians when determining surgical candidacy, when surgical intervention is appropriate, and informing patients of expected surgical outcomes. Future research should be directed towards identifying predictive factors with a larger sample size to substantiate the relationships identified in this study.

## Chapter 4: General Discussion

As discussed in Chapter 2, most pre-established predictors of surgical outcomes in the shoulder are unmodifiable with a focus on anatomy of the shoulder and patient characteristics. By assessing pre-operative measures that could be modified, we identified the WOSI score as predictive of patient quality of life at 6-months and one-year after the open Latarjet procedure. Pre-operative WOSI scores have been used to predict other areas of concern within the shoulder, such as the increased probability of a labral tear with increasing WOSI scores [27]. Patients that demonstrate a significantly higher pre-operative WOSI scores may affect the surgeon's decision to operate immediately or pursue non-operative means of treatment in order to lower WOSI scores before surgery.

The results of Chapter 2 also built upon previously reported predictors of surgical outcomes, joint hyperlaxity and the level of sport played. General joint hypermobility assessed with Beighton's criteria was shown to be predictive of shoulder function and patient quality of life 6-months following an open Latarjet procedure, a finding that corroborates the results of Yang et al. [78] at an early point in the recovery process. Participation in a competitive sport prior to surgery was found to be predictive of shoulder function 6-months following an open Latarjet procedure. Baverel et al. [9] reported differences in WOSI scores related to sport level, where competitive athletes had better scores than recreational athletes. The patient sample in the study by Baverel et al. [9] had a large concentration of professional and national team athletes, so it makes sense that quality of life measures would improve when these individuals are able to return to a significant portion of their daily routine. Although the results in Chapter 2 did not identify a relationship between sport level and WOSI score, it is possible that a longer follow-up period would have allowed patients to return to their routine and lower WOSI scores would be reflected. Joint hyperlaxity and sport level should be considered when making predictions about the surgical outcomes of the open Latarjet procedure.

Additional pre-operative measures that could be modified include shoulder ROM, muscle strength, and proprioception; these measures that are often used for the diagnostic classification and assessment of functional impairment of the shoulder [19]. Seeing that these measures are already incorporated into the evaluation process, they present as a logical option for predicting surgical outcomes and were the focal point in Chapter 3. The results of Chapter 3 present a general improvement in the measures of shoulder ROM, strength, and proprioception. Regarding outcome prediction, ROM, strength, and proprioception seem to have a relationship with surgical outcomes following the open Latarjet procedure. These results are tempered by a small sample size, but previous research on ACL injuries indicate that poor proprioception is predictive of functional outcomes in the knee [63]. Addressing poor proprioception and joint ROM in the shoulder may help in mitigating some dysfunction that could be experienced in the elbow and wrist, a result of overcompensation to complete a task [51]. By correcting poor proprioception and ROM in the affected shoulder, one may see greater precision in humeral movements allowing for better overall limb functioning [51]. The ROM, strength, and proprioception of the shoulder joint are key players in restoring function and improving patient quality of life following the open Latarjet procedure.

The importance of identifying modifiable predictors of surgical outcomes cannot be understated, carrying potential to aid surgeons in making well-informed decisions regarding treatment plans and whether pre-operative interventions would be beneficial to the patient's surgical success. The recovery process following surgical stabilization is multifactorial, so the prediction of surgical outcomes allows surgeons to provide an individualized treatment approach, giving each patient the best outcome possible. By using pre-operative values to predict the likelihood of a positive surgical outcome, an opportunity presents itself to improve these measures prior to surgery. The improvement would be done through a pre-operative rehabilitation program, focused on muscle strengthening, improving joint position sense, and patient-reported measures of function. The use of pre-operative physical therapy is a potential area of improvement in patient care, as physical therapy can be used for symptom management and contribute to reduced failure rates [75]. As previously discussed, the concept of pre-operative rehabilitation has not yet been explored in the open Latarjet procedure, but positive outcomes have been reported by Failla et al. [30] and Rooks et al. [65] in the lower extremity. Further research is needed to explore the relationships identified in this study, as they will be able to contribute to the knowledge surrounding outcome prediction and the role played by ROM, strength, and proprioception in the shoulder.

Although it was not addressed in the present study, a key factor for future consideration when using pre-operative patient measures to predict surgical outcomes is the influence of psychosocial factors. Specifically, pain catastrophizing is reported be a contributing factor in prolonged or incomplete recovery following a shoulder dislocation [58]. Catastrophizing is a multifaceted negative mental state during actual or anticipated painful experiences, subdivided into elements of rumination, magnification, and helplessness [68].

The predictive value of catastrophizing has in explored in previous studies. Sullivan et al. [68] sought to determine whether prospective catastrophizing scores could predict physical function through activity intolerance during exercise. The results showed that for movements which did not cause pain, catastrophizing was not significantly associated with impaired physical function or with reduced motivation to perform physical maneuvers [68]. During movement associated with pain, catastrophizing appeared to contribute a deficit in force production, i.e., a reduction in the maximal weight that participants are able or willing to lift [68]. In a multivariate analysis aimed at predicting the deficit in force, it was found that the Pain Catastrophizing Scale (PCS) was a statistically significant predictor and contributed an additional 10% of variance to the overall force deficit model [68]. Relating these findings to shoulder surgery, catastrophizing patients may be less likely to fully participate in a pre-operative or post-operative rehabilitation phase for their shoulder out of fear that they will experience pain. In the event that a catastrophizing patient does participate in a rehabilitation program, it is possible that the individual will avoid pain-inducing movements or perform at a reduced capacity regarding force production.

Patients who experience high amounts of catastrophizing may not see an ideal outcome following shoulder surgery compared to patients who do not display high catastrophizing, due to the previously mentioned factors of activity avoidance and impact on functional tasks [68]. Regarding surgical intervention, Kibler et al. [39] investigated the use of patient reported measures and pain catastrophizing to determine the effects on outcomes in patients treated for scapular muscle detachment. The authors hypothesized that high catastrophizing patients would report poorer patient-reported outcomes, and patients were divided into high catastrophizing and low catastrophizing groups [39]. Both groups reported improved ASES scores from the pre-operative to follow-up assessments, however, degree of improvement is where the group differences become apparent [39]. Results showed that high PCS scores, indicating higher catastrophizing, were associated with inferior total ASES scores, as well as inferior scores on the pain and function subscales [39]. The poorer outcomes in the high catastrophizing group translated to overall patient satisfaction, as 90% of the patients in this group reported that they were not satisfied or moderately satisfied [39]. The relationship identified by Kibler et al. [39]

between PCS scores and patient-reported outcomes related to shoulder surgery highlights the negative influence catastrophizing can play in the recovery process. Although both groups of patients improved, the group with lower catastrophizing had a greater, statistically significant improvement in ASES scores, indicating better a more optimal outcome [39]. Pain catastrophizing, and other psychosocial factors, will be important to further investigate in terms of shoulder surgery outcome prediction and identifying the optimal pre-operative intervention tailored to the individual needs of each patient.

The purpose of this study was to identify predictors of functional outcomes in the open Latarjet procedure that can be modified, allowing clinicians more options in determining surgical candidacy, when surgical intervention is appropriate, and informing patients of expected surgical outcomes. Improvements in QuickDASH and WOSI scores were observed in patients receiving an open Latarjet procedure for a one-year follow-up period. It is a very positive result to see significant improvements related to shoulder function and patient quality of life within the first year of recovery, as the primary goal of shoulder stabilization procedures such as the open Latarjet is giving the patient the best outcome possible. Continuing to build on patient factors that are predictive of surgical outcomes will allow patients to have a greater understanding of what they can expect after the open Latarjet procedure, likely contributing to overall long-term patient satisfaction.

Regarding pre-operative functional scores and patient characteristics, pre-operative WOSI scores, Beighton score, and the level of sport played prior to surgery were found to be predictive of surgical outcomes in males. In addition, the first 6-months following the open Latarjet procedure appears to be where the greatest returns in shoulder function and stability can be made. Future research should be directed towards predictive characteristics in females, and the effectiveness of a preoperative rehabilitation phase to improve functional scores prior to surgical intervention.

It appears that ROM, muscle strength, and proprioception have a relationship with functional outcomes at 6-months and one-year after the open Latarjet procedure, although these results are weakened due to a low sample size. Further research is needed to determine whether ROM, muscle strength, and proprioception can be used to predict functional outcomes in the shoulder surgery patients with a larger sample size. Once a predictive ability is established, further research will need to evaluate if a pre-operative rehabilitation program aimed at improving ROM, strength, and proprioceptive acuity translates to an overall improvement in patient functional outcomes following surgical stabilization of their shoulder.

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