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PhD THESIS

Subacromial pain syndrome

Terminology, diagnosis and clinical presentation

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Cover page: Adapted from ‘The Shoulder’ (1934) by E.A. Codman

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1 TITLES OF PAPERS

PAPER I

Terminology and diagnostic criteria used in studies investigating patients with subacromial pain syndrome from 1972 to 2019: a scoping review *British Journal of Sports Medicine* Published Online First: 22 February 2023. doi: 10.1136/bjsports-2022-106340

Adam Witten, Karen Mikkelsen, Thomas W. Mayntzhusen, Mikkel Bek Clausen, Kristian Thorborg, Per Hölmich and Kristoffer Weisskirchner Barfod.

PAPER II

Prevalence of shoulder diagnoses in patients presenting with signs and symptoms of SAPS. A cross-sectional study in a secondary care setting.

Adam Witten, Mikkel Bek Clausen, Kristian Thorborg, Per Hölmich and Kristoffer Weisskirchner Barfod.

PAPER III

Bilateral ultrasonographic findings in patients with unilateral subacromial pain syndrome and intact rotator cuff tendons.

Adam Witten, Mikkel Bek Clausen, Kristian Thorborg, Per Hölmich and Kristoffer Weisskirchner Barfod.

2 THESIS AT A GLANCE

	AIM	METHODS	RESULTS	CONCLUSION
I	To create an overview of the terminology and the diagnostic criteria used in studies investigating patients with SAPS.	Scoping review of original studies investigating patients with SAPS. Electronic databases were searched for inception to June 2020.	27 unique terms for SAPS were identified. The diagnostic criteria were often based on a cluster of physical examination tests. 146 different test combinations were identified. 9% of the studies included patients with full-thickness supraspinatus tears and 46% did not.	Studies investigating SAPS are heterogeneous to an extent that makes it difficult, and often impossible, to compare them.
II	To investigate the prevalence of shoulder diagnoses in patients presenting with signs and symptoms of SAPS	Patients were systematically screened for SAPS and for concomitant diagnoses using standardized diagnostic criteria	408 were diagnosed with SAPS. 172 (42%) had at least one type of concomitant diagnosis. In total, 21 different variations of concomitant diagnoses were observed.	Patients with SAPS constitute a heterogenic group that often present with concomitant shoulder diagnoses.
III	To compare subacromial measurements between affected and unaffected shoulders in patients with unilateral SAPS.	Ultrasonographic measurements of supraspinatus thickness, subacromial bursa thickness, AHD and impingement were performed in patients with unilateral SAPS.	58 patients were included. Ultrasonographic impingement was more frequent in affected shoulders compared to unaffected (87% vs 35%). There were no significant differences in supraspinatus thickness and subacromial bursa thickness or AHD between affected and unaffected shoulders.	Ultrasonographic impingement is more frequent in affected shoulders, compared to unaffected, in patients with SAPS.

3 ABBREVIATIONS

AC	Acromioclavicular
ASD	Arthroscopic subacromial decompression
AHD	Acromio-humeral distance
GH	Glenohumeral
MRI	Magnetic resonance imaging
OA	Osteoarthritis
RCT	Randomized controlled trial
ROM	Range of motion
SAPS	Subacromial pain syndrome
UL	Ultrasonography

4 BRIEF DEFINITIONS

In the context of this thesis, the following terms and definitions are used.

ISOLATED SAPS

SAPS (subacromial pain syndrome) and no concomitant diagnoses.

SAPS AND CONCOMITANT DIAGNOSES

Patients with SAPS in addition to one or more of the following concomitant diagnoses: Acromioclavicular osteoarthritis, full-thickness supraspinatus tears, long head biceps tendon pathology, SLAP lesion, minor shoulder instability, calcified tendinopathy, and major shoulder instability.

CONFLICTING SHOULDER-RELATED DIAGNOSES

Patients with a conflicting shoulder-related diagnosis could not receive a SAPS diagnosis. Systemic musculoskeletal disease, inflammatory joint disease (e.g. rheumatoid arthritis), symptomatic cervical pathology, frozen shoulder, glenohumeral osteoarthritis, fibromyalgia, previous surgery, fractures or radiotherapy in the shoulder girdle were considered to be conflicting shoulder-related diagnoses.

IMPINGEMENT AND ULTRASONOGRAPHIC IMPINGEMENT

Impingement is used to describe the (theoretical) phenomenon of subacromial structures impinging between the humeral head and the acromion. The term *ultrasonographic impingement* is used when referring to the (practical) ultrasonographic evaluation of impingement.

5 ENGLISH SUMMERY

BACKGROUND: There is room for improvement in the current handling of patients with subacromial pain syndrome (SAPS). Only approximately half of patients benefit satisfactorily from a non-surgical approach, and the therapeutic effect of arthroscopic subacromial decompression has been questioned. Increased knowledge of potential heterogeneity, in patients with SAPS, could be an important first step towards a more individualized approach, potentially improving treatment outcomes.

AIM: To increase the knowledge of heterogeneity in patients with SAPS, and investigate the role of impingement in SAPS.

METHODS: Study I was a scoping review investigating terminology and diagnostic criteria in studies investigating SAPS. Study II was a cross-sectional study investigating the prevalence of other shoulder diagnoses in patients presenting with signs and symptoms of SAPS. Study III was a cross-sectional study comparing ultrasonographic subacromial measurements and impingement between the affected and the unaffected shoulder in patients with unilateral SAPS.

RESULTS: Study I found that there is a considerable heterogeneity in terminology and diagnostic criteria in studies investigating SAPS. Study II found a high prevalence of other diagnoses in patients presenting with signs and symptoms of SAPS. Study III found no significant differences in thickness of the subacromial structures between affected and unaffected shoulders, but found a higher prevalence of ultrasonographic impingement in affected shoulders.

CONCLUSION: The heterogeneity across studies makes it difficult to compare studies. Patients with SAPS are heterogeneous in terms of concomitant diagnoses. Ultrasonographic impingement is more frequent in affected shoulders compared to unaffected.

6 SAMMENFATNING PÅ DANSK

BAGGRUND: Den er rum til forbedring i den nuværende håndtering af patienter med subakromialt smertesyndrom (SAPS). Kun cirka halvdelen af patienterne oplever et tilfredsstillende resultat fra en ikke-kirurgisk tilgang, og den terapeutiske effekt af artroskopisk subakromial dekompression er tvivlsom. Øget viden om potentiel heterogenitet, blandt patienter med SAPS, kan være et vigtigt første skridt mod en mere individualiseret tilgang, der potentielt kan forbedre behandlingsresultaterne.

FORMÅL: At øge viden om heterogenitet blandt patienter med SAPS og undersøge betydningen af impingement ved SAPS.

METODE: Studie I var en oversigtsartikel, der undersøgte terminologi og diagnostike kriterier i studier om SAPS. Studie II var et tværsnitsstudie, der undersøgte forekomsten af andre skulderdiagnoser hos patienter med tegn og symptomer på SAPS. Studie III var en tværsnitsstudie, der sammenlignede ultrasonografiske målinger af subakromiale strukturer og impingement mellem den symptomatiske og den asymptomatiske skulder hos patienter med unilateral SAPS.

RESULTATER: Studie I viste, at der er betydelig heterogenitet i terminologi og diagnostiske kriterier i studier om SAPS. Studie II fandt en høj forekomst af konkomitante diagnoser hos patienter, der viste tegn og symptomer på SAPS. Studie III fandt ingen signifikante forskelle i tykkelsen af subakromiale strukturer mellem den symptomatiske og asymptomatiske skulder, men fandt en højere forekomst af ultrasonografisk impingement i de symptomatiske skuldre.

KONKLUSION: Heterogeniteten på tværs af studier gør det vanskeligt at sammenligne dem. Patienter med SAPS er heterogene med hensyn til konkomitante diagnoser. Ultrasonografisk impingement er hyppigere i symptomatiske skuldre, sammenlignet med asymptomatiske skuldre.

7 INTRODUCTION

7.1 TERMINOLOGY USED IN THIS THESIS

There is not consensus regarding the terminology used to describe patients with subacromial pain syndrome (SAPS) [1–3]. Accordingly, several different terms exist, and these are often used interchangeably [1–3]. In addition to SAPS, some of the more commonly used terms are: subacromial impingement, shoulder impingement, rotator cuff syndrome, rotator cuff tendinopathy and rotator cuff impingement. Throughout this thesis, 'SAPS' is used to describe *the population* of interest, while 'impingement' is used to describe *the phenomenon* of the subacromial structures impinging between the humeral head and the acromion. In this thesis, impingement is investigated as a phenomenon occurring within the entity of SAPS.

7.2 THE SHOULDER – ANATOMY AND FUNCTION

The shoulder joint, also known as the glenohumeral joint, is a synovial joint that connects the humeral head to the glenoid socket of the scapula [4]. The articulating surfaces of the humeral head and the glenoid socket are covered with hyaline cartilage to reduce friction and facilitate smooth movement within the joint. The labrum, a ring of fibrocartilage, surrounds the glenoid socket, effectively increasing its surface area and depth, providing a more secure fit for the larger humeral head. The joint is surrounded by a relatively loose capsule that is reinforced by the superior, middle, and inferior glenohumeral ligament which provide additional stability. The capsule has an inner synovial layer, that produces synovial fluid, which lubricates the joint and nourishes the cartilage. The joint is unique in having an intraarticular tendon, the long head biceps tendon. It originates from the

supraglenoid tubercle, runs through the joint and passes into the intertubercular groove of the humerus. The bony prominence acromion projects anterolaterally from the scapular spine, extending over the shoulder joint. The coracoacromial ligament connects the anterolateral aspect of the acromion to the coracoid process of the scapula. In conjunction with the acromion, the coracoacromial ligament forms the coracoacromial arch, a roof-like structure that acts as a superior constraint of shoulder joint. The subacromial bursa is the largest bursa in the body. It extends in the subacromial space, between the acromion and the rotator cuff tendons. The function of the shoulder depends on these anatomical structures.

The shoulder joint is a highly complex and versatile joint that allows for a wide range of highly coordinated movements. In addition to the articulation between the humerus and the scapula, the scapula articulates with the thorax (scapulothoracic joint) and the clavicle (acromioclavicular joint), and the clavicle articulates with the sternum (sternoclavicular joint). Together with their contralateral counterparts, these joints create the shoulder girdle. In total, eighteen muscles act on the shoulder [4].* The attainment of a fully functional shoulder depends on harmonious coordination and intricate interplay of all the anatomical structures. The rotator cuff is particularly vital. The rotator cuff is comprised of four muscles, namely supraspinatus, infraspinatus, teres minor and subscapularis. They all originate from the scapula and insert on the humeral head in close conjunction. The rotator cuff not only facilitates movement but also provide dynamic stability, ensuring the humeral head stays centered within the glenoid socket during shoulder movement. When the arm is raised or rotated, the rotator cuff tendons glide under the coracoacromial arch. The rotator cuff tendons, and the subacromial bursa, should be able glide freely to achieve full shoulder function, pain-free.

** Musculus trapezius, latissimus dorsi, rhomboideus major, rhomboideus minor, levator scapulae, serratus anterior, pectoralis major, pectoralis minor, subclavius, deltoideus, supraspinatus, infraspinatus, teres minor, teres major, subscapularis, coracobrachialis, biceps brachii and triceps brachii* [4]

Normal Motions of the Shoulder Joint

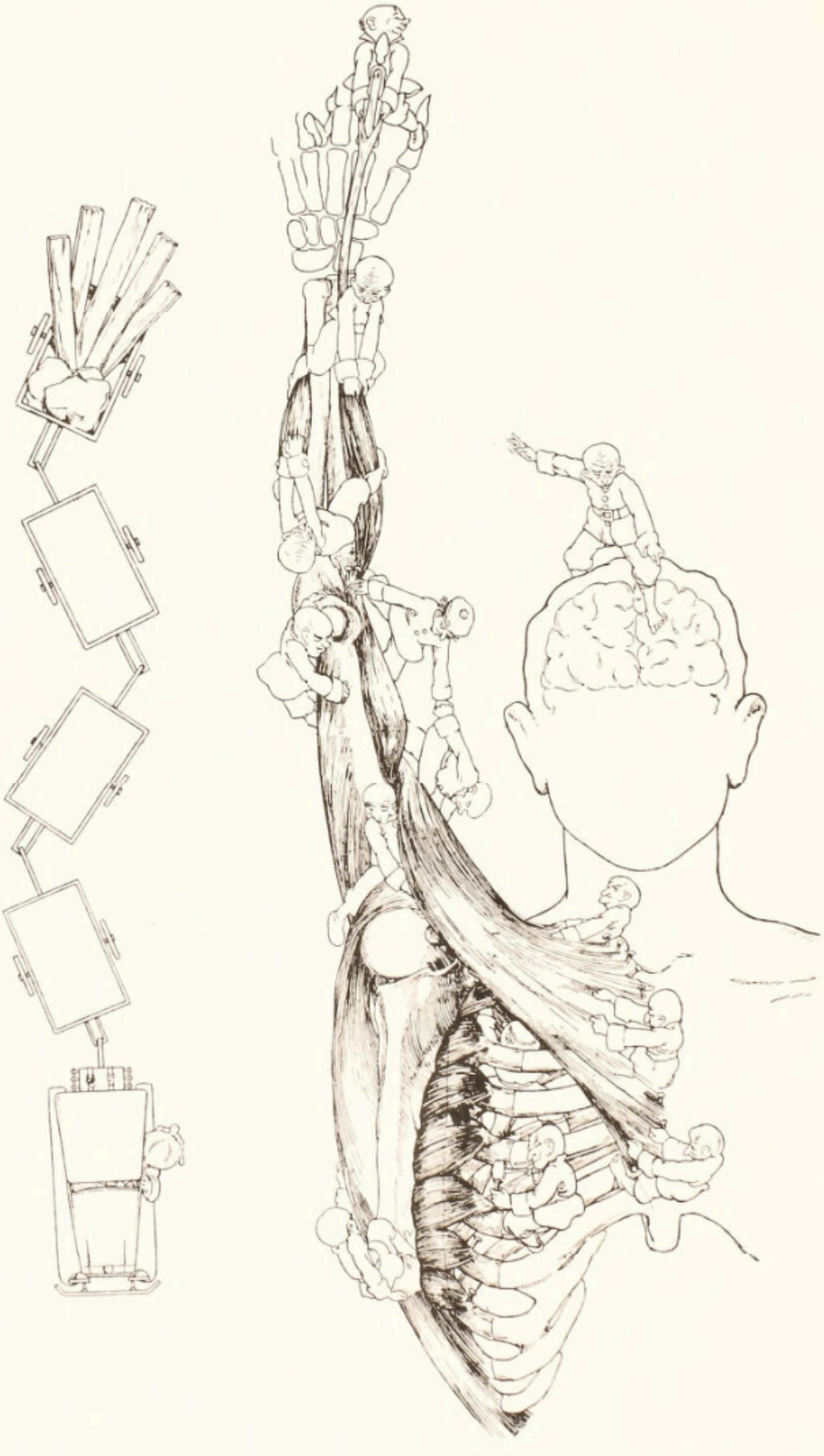


Plate I. Coöperation of All Muscles

FIGURE 1: COOPERATION OF ALL MUSCLES

From ‘The Shoulder’ (1934) by E.A. Codman [5]: A man can undoubtedly raise his arm until he has reached a point as high as seems to him possible, and then with an effort he can push directly upward against that point. We may compare the mechanics of this process with the automobile and trailers shown in this diagram. Even if a driver succeeded in backing these trailers as accurately as suggested, we cannot conceive of his getting them in a line sufficiently straightened to enable him to push backward on some other object. Yet man can, without effort or strain, perform this miracle by the alignment of the bones of his arm in such a manner that a further contraction of his muscles will straighten the line of his bones and transmit the force directly away from its base. The right-hand figure suggests a comparison with the work of a rigger who is erecting a complicated arrangement of spars, which at the final moment he can raise to a vertical position by the unanimous cooperative efforts of the crew in charge of each portion of the structure. When we consider that in each muscle, the gnomes at work are thousands, each operating a special muscle fiber, it fills the mind with admiration of the accomplishments of evolution, but with humility with regard to man's ability to undertake to know in detail such a delicate mechanism. Have we even a right to attempt gross adjustments?

7.3 SHOULDER PAIN – A SOCIATAL AND AN INDIVIDUAL PROBLEM

Shoulder pain has a high prevalence and is often longstanding [6–8]. Due to this, shoulder pain is a considerable socioeconomic challenge. In Denmark alone, the annual cost of shoulder pain is estimated to be €1.21 billion [9]. SAPS is recognized as the most common cause of shoulder pain with an incidence reported to be 832 per 100,000 person-years [9–13]. SAPS surpasses all other shoulder disorders, both in terms of causing sick leave and in terms of societal economic expenses. [9].

7.4 SUBACROMIAL PAIN SYNDROME

There is universally accepted diagnostic criteria for SAPS, but generally, SAPS is recognized as a clinical diagnosis characterized by insidious onset of shoulder pain [14–17]. Patients with SAPS typically complain of shoulder pain on the anterolateral aspect of the shoulder, but the pain can also radiate down the anterior aspect of the arm [14]. Pain aggravated by shoulder activity, especially repetitive overhead activities, is considered suggestive of SAPS [14]. Patients often experience decreased active range of motion (ROM), making it difficult to reach behind the back or elevate the arm fully [18,19]. They can also encounter weakness of the shoulder, further contributing to the functional limitations [20–24]. These physical impairments can impact various aspects of daily life, including self-care, work tasks, recreational activities, and participation in sports. The consequences of SAPS extend beyond physical limitations alone. Persistent symptoms and functional limitations may lead to sleep disturbances and decreased overall quality of life [21,24–27].

7.5 THEORIES OF SUBACROMIAL PAIN SYNDROME

The etiology and exact pain-generating mechanism of SAPS are not fully understood [1,28,29]. The enigmatic nature of SAPS has been the center of debate

for years, fueling a discussion of differing viewpoints expressed in high-ranking journals [1,30]. While the exact mechanism is not understood, the pain is believed to originate from the subacromial structures, namely the subacromial bursa and the supraspinatus tendon. With reference to these structures, numerous efforts have been made to identify and describe the pathological characteristics of SAPS, through various methods of clinical tests, muscle testing, radiographs, ultrasound, CT, MRI, electromyography, anatomical dissection, histological analyses and more [29,31–38]. The perplexity surrounding SAPS is further illustrated by the many different approaches, and terms, that have been utilized to try to encapsulate it: e.g. a structure-specific approach (focus on: subacromial bursa, supraspinatus tendon, acromion and coracoacromial ligament) [39–41], a pathophysiological approach (focus on: tendinopathy, bursitis, inflammation) [31,34,35], a mechanistic approach (focus on: impingement of the subacromial structures) [39,42,43], and a non-specific approach that recognizes SAPS as a syndrome [44]. It has also been proposed that the pain-generating mechanism of SAPS might not be solely nociceptive, and that central sensitization/hypersensitivity could be a contributing factor [45,46]. The many findings, from these different methods and approaches, have resulted in numerous different theories of SAPS [1], along with a multitude of proposed contributing pathophysiological mechanisms and factors [1,28,38,44,47,48,29,31–37]. Overall, the proposed pathophysiological mechanisms and factors for SAPS can be divided into two main categories, an *intrinsic* mechanism theory, and an *extrinsic* mechanism theory. The intrinsic theory proposes that the pain in SAPS originates from degenerative alterations occurring *within* the supraspinatus tendon [32–36], whereas the extrinsic theory suggests that the pain arises from mechanical compression of the supraspinatus tendon against the acromion [49,50]. The latter is popularly referred to as the impingement theory, one of the most predominant and debated theories.

7.6 THE IMPINGEMENT THEORY

In 1972, the renowned orthopedic surgeon Charles S. Neer II (1917-2011) published his famous paper ‘Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report’ [50], one of the most cited orthopedic papers in history. Neer is commonly acknowledged as the progenitor of the impingement theory, and he is usually cited as such with reference to that paper. However, Neer actually uses the first sentence in his paper by referencing the impingement theory to a much earlier work by the surgeon Ernest Amory Codman (1869-1940) from 1931 [51]. Codman has been credited as the first American doctor to systematically follow-up on his patients, a pioneering and somewhat provocative idea at the time [52]. In his own words: *"(…) merely the common-sense notion that every hospital should follow every patient it treats, long enough to determine whether or not the treatment has been successful, and then to inquire 'if not, why not?' with a view to preventing a similar failure in the future.”* [52]. Codman meticulously described his surgical cases, and, in particular, reported the cases he considered to be failures. The two cases presented below illustrate some of the earliest descriptions of impingement as a concept, published in 1934 [5]:

	Preoperative Diagnosis	Operative Findings
1	"The history and symptoms are typical of a ruptured supraspinatus tendon in the right shoulder, with some adhesions of the bursa, or blocking of the motion by the remains of the torn tendon **impinging** on the acromion. I think the latter."	“The base of the bursa was deeply congested and swollen, but there was no demonstrable tear of the tendon of the supraspinatus. There were light adhesions in the bursa which were broken up with the finger. The short rotators and capsule were greatly contracted and were slowly stretched until full external rotation and abduction could be attained, and the wound closed."
2	“I feel that the diagnosis of subacromial bursitis is correct, but that the underlying cause of the bursitis was a ruptured supraspinatus tendon. This has now partially healed - enough to renew the power of abduction but not enough to make the point of rupture smooth. The result is an irregularity on the base of the bursa which in abduction **impinges** on the acromion and acromio-clavicular ligament."	“On opening the bursa the ruptured supraspinatus tendon was beautifully demonstrated, the tendon having been torn from the tuberosity, leaving none of the original attachment on the bone. It had retracted about a half inch and the torn end could be seized with a tenaculum."

While Codman was one of the first to publish on the idea of impingement, there is no doubt that Neer popularized the concept and brought it to a broader audience. Neer described impingement as a painful shoulder disorder in the continuum from ‘edema and hemorrhage’ to ‘complete tears of the supraspinatus tendon and long biceps tendon’ attributable to impingement of the subacromial structures *“(…) against the anterior edge and undersurface of the anterior third of the acromion, the coracoacromial ligament and, at times, the acromioclavicular joint...”* [49,50]. Neer developed and used two tests to identify patients with SAPS: Neer’s test[1] and the

[1] Originally called Neer’s sign [49]

subacromial injection test[2] [49]. Neer also described a targeted surgical procedure, subacromial decompression, and a method to identify patients that would benefit from it [49,50]. In other words, Neer presented a simple explanation for a distinguishable disorder and he provided a simple, logical surgical procedure as treatment. The impingement theory was centred around a mechanical solution (subacromial decompression) for a mechanical problem (impingement).

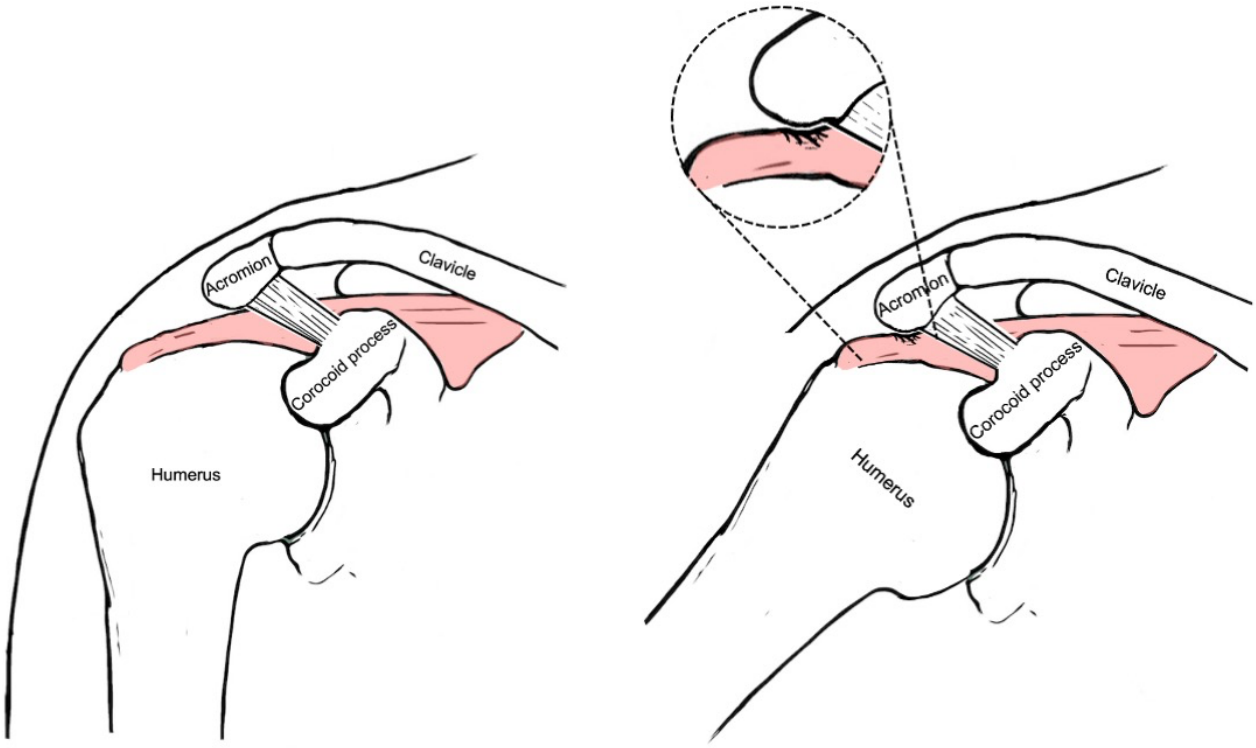
7.7. EXTERNAL VS INTERNAL IMPINGEMENT

Neer's definition of impingement is sometimes referred to as 'external' impingement, as opposed to 'internal' impingement. The concept of internal impingement was introduced later as a distinctively different condition from external impingement [53,54]. Internal impingement refers to shoulder pain believed to arise from the contact (impingement) between the posterosuperior glenoid and the undersurface of the supraspinatus and infraspinatus, particularly during a throwing position (cocking phase). 'External impingement' should not be confused with the 'extrinsic mechanism' theory, and 'internal impingement' should not be confused with the 'intrinsic mechanism' theory (section 7.5). Internal impingement is not discussed further in this thesis.

[2] Originally called Neer's test [49]

FIGURE 2: IMPINGEMENT

Left: the shoulder with the arm in resting position. **Right:** when the arm is raised, the supraspinatus tendon and the subacromial bursa (not depicted) impinges on the undersurface of the acromion and the coracoacromial ligament.

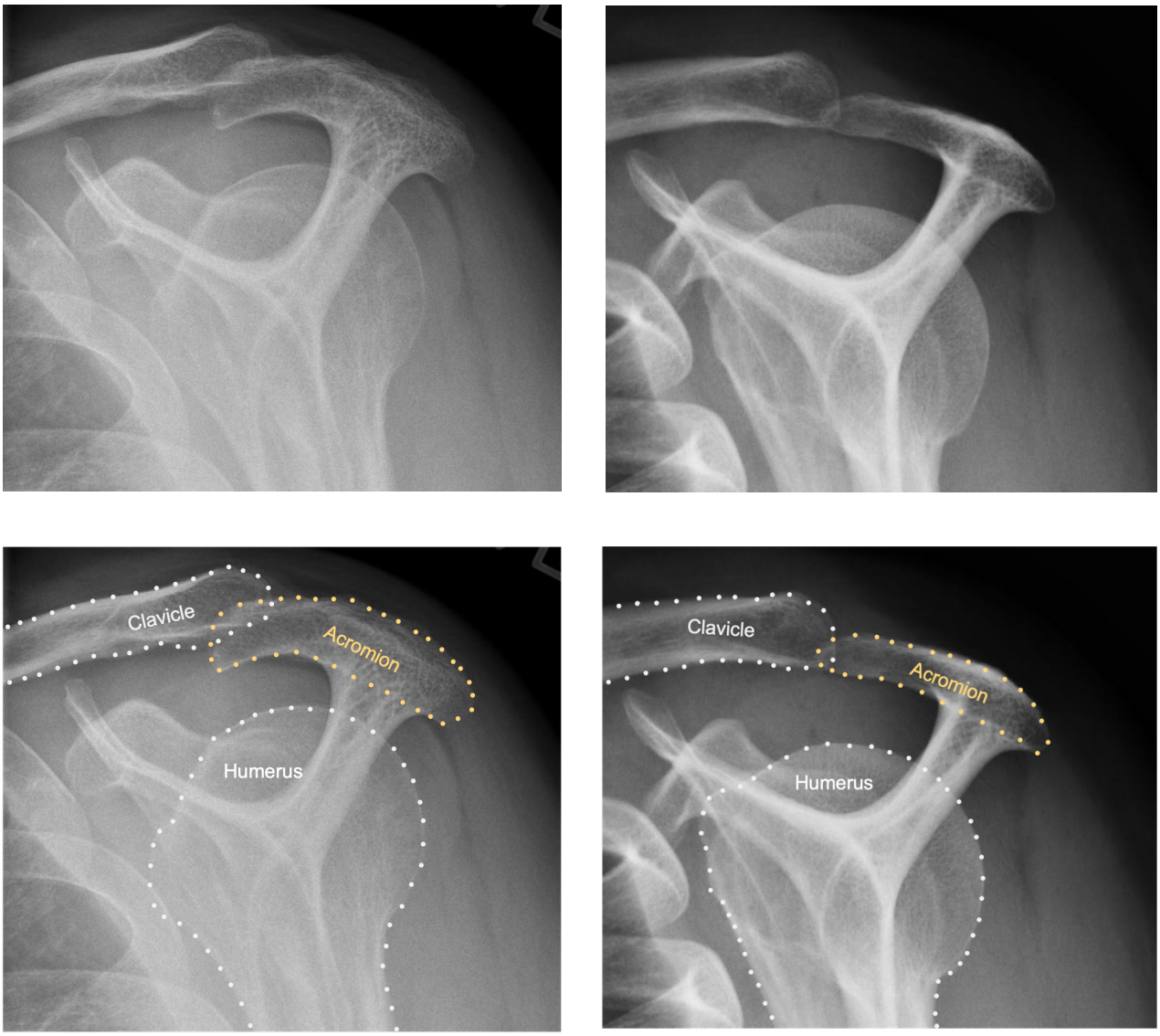


7.8 ARTHROSCOPIC SUBACROMIAL DECOMPRESSION

Subacromial decompression (or acromioplasty) is now performed as an arthroscopic procedure, known as arthroscopic subacromial decompression (ASD). The rationale of ASD is to create a larger space for the subacromial structures to move, thus relieving painful impingement of the supraspinatus tendon, subacromial bursa, and the long head biceps tendon. This is achieved by resecting and flattening the undersurface of the acromion, removing the subacromial bursa, releasing the coracoacromial ligament, and removing potential osteophytes from the acromioclavicular joint (co-planning). There is a large individual variation in the acromial shape [55]. Some have a relatively “flat” acromial undersurface, whereas other have a more hook-shaped acromion (figure 3). The latter has generally been theorized to be associated to SAPS, as a more hook-shaped acromion theoretically reduces the subacromial space leading to impingement of the subacromial structures. [56,57].

FIGURE 3: RADIOGRAPHS WITH DIFFERENCES IN ACROMIAL MORPHOLOGY

Left: Radiographs (outlet views) showing a hook-shaped acromion.
Right: Radiographs (outlet views) showing a flatter acromion.
The radiographs are standardized in accordance with the Copenhagen Supraspinatus Outlet View Criteria (CSOV criteria) [55].



7.9 SCEPTICISM TOWARDS THE IMPINGEMENT THEORY

Neer's impingement theory was broadly accepted for many years. The concept of impingement gained wide acceptance and grew to become one of the most frequent orthopedic diagnoses. The targeted surgical procedure, ASD, accompanied this growth, and became one of the most frequently performed orthopedic procedures worldwide [58,59]. Prospective studies have reported good short and long-term outcomes from ASD [60–65], indirectly lending validation to Neer's impingement theory.

Neer's theory stood largely unchallenged until findings, that seemingly did not align with the impingement theory, began to emerge. Accordingly, studies reported that partial-thickness supraspinatus tears more frequently occurred on the articular side, not the bursal side of the tendon [66–68]. This has been used as a counterargument against the impingement theory hypothesizing that tears developing from mechanical friction (impingement) of the bursal side against the undersurface of the acromion. Studies also reported a high number of asymptomatic rotator cuff tears [69–71], which also has been laid out as a contraintuitive finding to the proposed pathophysiological mechanism. Another series of subsequent studies reported that exercise treatment could be just as effective as ASD [62,65,72], and that ASD was no more effective than bursectomy (removal of the subacromial bursa, but not altering acromial morphology) [73]. Such findings, seemingly counterintuitive, have given rise to an increasing scepticism towards Neer's impingement theory. The debate was fuelled further in 2017 and 2018, when Beard et al. and Paavola et al. published the first two (and currently only) randomized controlled trials that compared ASD to placebo (investigational arthroscopy) [74,75]. Both RCT's found no clinically relevant effect of ASD compared to diagnostic arthroscopy. This has brought forth arguments for the discontinuation of ASD [76,77], while others claim that patients can benefit from ASD, if selected more carefully [14]. As the whole rationale of ASD was nested within the impingement theory, the findings of the RCT's have led to further scepticism towards Neer's theory. Some believe that Neer's theory is inadequate to

encompass the entire population of SAPS [1], while others advocate for the complete abandonment of the term impingement [77,78].

7.10 THE DIFFICULTIES OF HANDLING PATIENTS WITH SAPS

Exercise-based physiotherapy has generally proven equally effective as ASD, and has been shown to reduce the need for surgery in patients on the waiting-list for ASD [62,65,72,79]. With reference to these findings, there is consensus that patients with SAPS should be offered a structured physiotherapy regimen as first line of treatment [14]. However, only half of the patients experience satisfactory symptom relief from this [80,81]. This means, that, with the present state of evidence-based knowledge, approximately half of the patients diagnosed with SAPS are left with unacceptable symptoms, and no further treatment options, if the current surgical treatment is discontinued without implementing a different approach.

It has been suggested that the treatment outcome for SAPS can be improved through a more individualized approach, appraising potential heterogeneity in patients with SAPS [1,28,29,82,83], but currently there is little knowledge of this. Increased knowledge of potential heterogeneity in patients with SAPS could be an important first step towards the development of a more individualized treatment approach for patients with SAPS.

8 AIM AND OBJECTIVES

8.1 OVERALL AIM

To increase the knowledge of heterogeneity in patients with SAPS, and investigate the role of impingement in SAPS.

8.2 INDIVIDUAL STUDY OBJECTIVES

STUDY I

To create an overview of the terminology and the diagnostic criteria used in studies investigating patients with SAPS.

STUDY II

To investigate the prevalence of shoulder diagnoses in patients presenting with signs and symptoms of SAPS.

STUDY III

To compare bilateral ultrasonographic subacromial measurements in patients with unilateral isolated SAPS and intact rotator cuff tendons.

9 SUBJECTS AND METHODS

This thesis is based on three studies investigating terminology, diagnosis, and clinical presentation of patients with SAPS. This chapter summarizes the subjects and methods for each of the studies in the thesis. A detailed description of the studies are presented in the individual manuscripts.

9.1 OVERVIEW OF STUDIES

Study I was as a scoping literature review mapping the terminology and the diagnostic criteria used in original studies investigating patients with SAPS.

Study II was a cross-sectional study. Based on standardized physical examination tests, radiographs and ultrasonography, patients presenting with signs and symptoms of SAPS were screened for the presence of conflicting shoulder-related diagnoses and concomitant diagnoses.

Study III was a cross-sectional study comparing bilateral ultrasonographic measurements (subacromial bursa, supraspinatus tendon, AHD and impingement) in patients with unilateral, isolated SAPS.

The patients included in **study II** comprised the population from which the eligible patients for **study III** were found. The overall flow of patients for **study II** and **III** are presented in figure 4.

9.2 STUDY I (SCOPING REVIEW)

9.2.1 DATACOLLECTION

Eligible studies: Peer-reviewed studies investigating SAPS.

Inclusion criteria: Subacromial impingement, shoulder impingement, rotator cuff syndrome, rotator cuff tendinopathy/ tendinitis/tendinosis, rotator cuff impingement or subacromial pain in title or abstract.

Exclusion criteria: Studies with less than ten participants, studies investigating SAPS with another specified disease; fewer than ten participants; language other than English, Danish, Swedish, or Norwegian.

Data collection: Electronic databases were systematically searched. Two reviewers screened titles and abstracts, three reviewers screened full-text versions, and one reviewer extracted data.

Information sources and search: MEDLINE, Embase, CINAHL and SPORTDiscus were searched from inception to June 10, 2020. A biomedical librarian assisted in the development of the search strategy.

Selection of sources of evidence: Records not containing any of the terms subacromial impingement, shoulder impingement, rotator cuff syndrome, rotator cuff tendinopathy/tendinitis/-tendinosis, rotator cuff impingement or subacromial pain in title or abstract were considered to be irrelevant and removed by computerized automation in Endnote (version X8.2). Two reviewers screened titles and abstracts and three reviewers screened full-texts. Data were extracted by one reviewer.

9.2.2 SYNTHESIS OF RESULTS

Terminology: Terms from title, abstract and manuscript, but not the reference list, were extracted. Similar terms were merged (e.g., rotator cuff tendinopathy and rotator cuff tendinitis).

Diagnostic criteria: Diagnostic criteria were described within the following categories: patient inclusion criteria, patient exclusion criteria, use of imaging, and (full-thickness) supraspinatus tears.

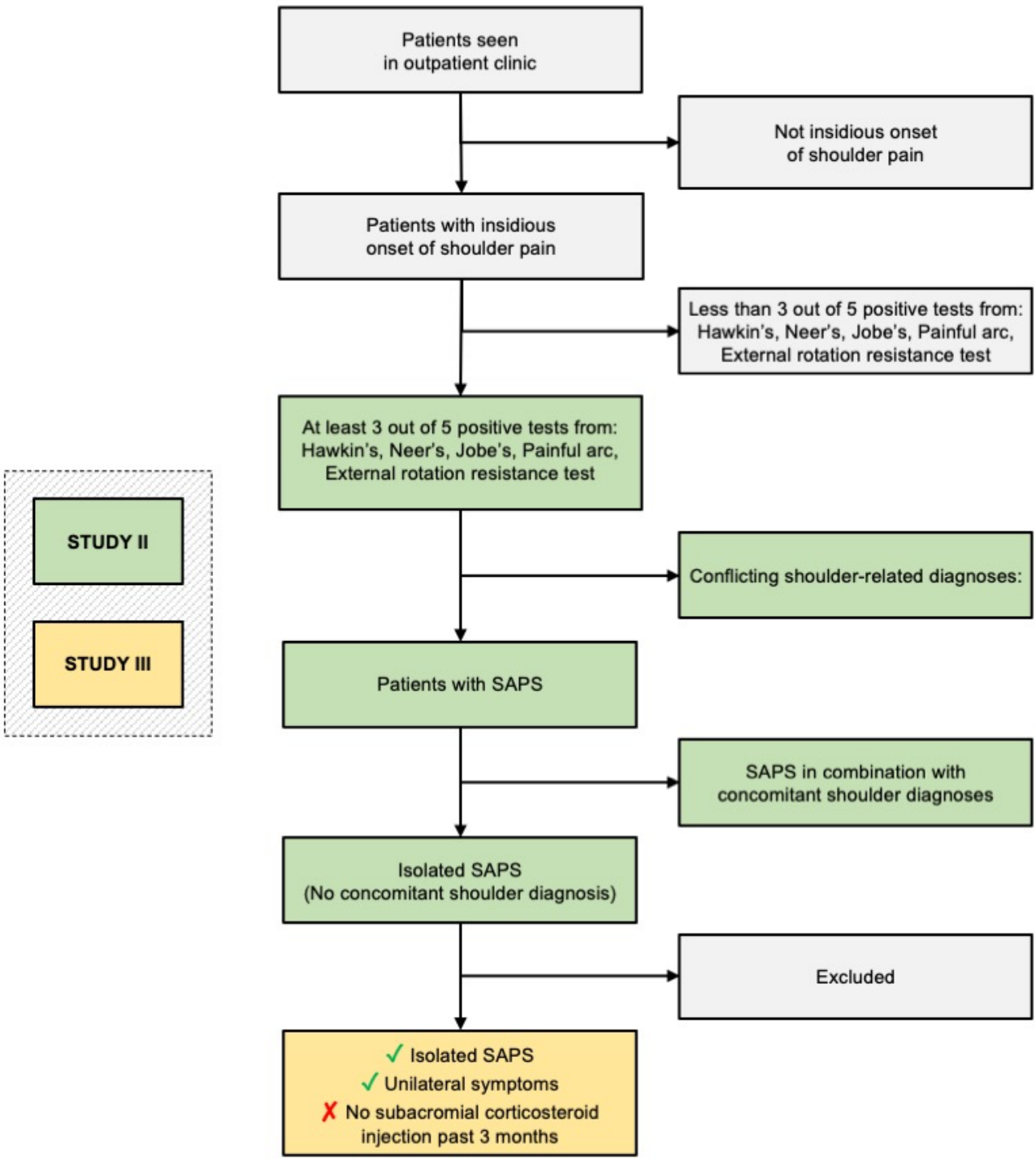
Imaging: The use of imaging modalities in each study were registered within the following categories: to rule in SAPS, exclude other shoulder pathology, a combined use, or a non-specified purpose.

Full-thickness supraspinatus tears: A full-thickness tear was defined as a tear extending through the full thickness of the tendon, thus creating a communication between the bursal side and the articular side.

9.3 OVERALL COHORT FOR STUDY II AND III

Participants were recruitted consecutively from the outpatient clinic, Arthroscopic section, Orthopaedic Department, Copenhagen University Hospital, Hvidovre, Denmark, between Sep 1, 2020 and Dec 31, 2022. All adult patients (at least 18 years) referred with insidious onset of shoulder pain to the orthopaedic outpatient clinic were eligible for inclusion. Eligible patients were identified through a systematic screening of all patients referred to the outpatient clinic in the inclusion period. Screening was conducted by orthopaedic shoulder specialists. On daily basis, the orthopaedic shoulder specialists each received a folder containing an individual screening page designated each of their eligible shoulder patients for the day. The orthopaedic shoulder specialist registered the results for each patient on the screening page according to the standardized testing procedure (section 9.3.2). If information was missing, the screening pages were returned to the orthopaedic shoulder specialist to be filled out. Eligible patients underwent a **clinical examination** with standardized physical examinations tests (table 2), ultrasonography, and radiography. Patients were first screened for conflicting shoulder-related diagnoses that could mimic the symptoms of SAPS. Patients diagnosed with a conflicting shoulder-related diagnoses could not be diagnosed with SAPS. Patients diagnosed with SAPS were further screened for the presence of concomitant shoulder diagnoses according to predefined criteria: full-thickness rotator cuff tears, calcified tendinopathy, long head biceps pathology, acromioclavicular osteoarthritis, SLAP lesions, major shoulder instability, and minor shoulder instability. The patients with SAPS and no concomitant diagnosis (isolated SAPS) were screened for eligibility for inclusion in **study III.** Eligible patients for **study III** were invited to an **extended clinical examination** in the outpatient clinic (section 9.6). This extended clinical examination included a bilateral shoulder ultrasonography measurements according to a standardized protocol [84]. The overall flow of patients is presented in figure 4.

FIGURE 4: FLOW OF PATIENTS IN STUDY II AND III



9.4 INCLUSION AND EXCLUSION CRITERIA FOR STUDY II AND III

Inclusion and exclusion criteria for **study II and III** are presented in table 1.

TABLE 1: INCLUSION AND EXCLUSION CRITERIA FOR STUDY II AND III

	STUDY II	STUDY III
INCLUSION CRITERIA		
Insidious onset of shoulder pain No indirect or direct trauma	X	X
At least 3 out of 5 positive tests Hawkin's test, Neer's test, Jobe's test, painful arc, and external resistance test	X	X
Isolated SAPS No biceps tendon pathology, SLAP lesion, full-thickness rotator cuff tears, calcified tendinopathy, acromioclavicular osteoarthritis, minor shoulder instability or major shoulder instability		X
EXCLUSION CRITERIA		
Subacromial corticosteroid injection During the past 3 months		X
Bilateral shoulder symptoms No episode of insidious shoulder pain in other shoulder during the past 3 months		X
Insufficient Danish		X
Severe medical illness ASA score higher than or equal to 4	X	X
Conflicting shoulder-related diagnosis Systemic musculoskeletal disease, Inflammatory joint disease, Symptomatic cervical spine pathology, Thoracic outlet syndrome, Frozen shoulder, glenohumeral osteoarthritis, Previous surgery, fracture, or radiotherapy in the affected shoulder region	X	X

9.5 CLINICAL EXAMINATION (STUDY II AND III)

The clinical examination of eligible patients was performed by orthopaedic shoulder specialists in the outpatient clinic. It served the purpose of identifying patients with SAPS, and screen for predefined concomitant diagnoses: isolated SAPS, biceps tendon pathology, SLAP lesion, full-thickness rotator cuff tears, calcified tendinopathy, acromioclavicular osteoarthritis (OA), minor shoulder instability or major shoulder instability.

The clinical examination included 17 standardized physical examination tests. Ultrasonography was used routinely as an adjuvant in the diagnostic process. Patients also underwent standardized radiographs of the glenohumeral and acromioclavicular joint to systematically screen for glenohumeral OA and acromioclavicular OA (table 2). A written guide of the diagnostic criteria and the physical examination tests was available to the orthopedic shoulder specialists in the outpatient clinic at all times.

TABLE 2: PHYSICAL EXAMINATION TESTS AND IMAGING MODALITIES USED TO IDENTIFY AND SUBGROUP PATIENTS WITH SAPS.

(Figure from paper II)

PHYSICAL EXAMINATION TEST	USED TO IDENTIFY
Hawkin's	SAPS
Neer's	SAPS
Jobe's	SAPS
Painful arc	SAPS
External rotation resistance test	SAPS
Apprehension	Major shoulder instability
Relocation	Major shoulder instability
Surprise	Major shoulder instability
Jerk	Major shoulder instability
Castagna's	Minor shoulder instability
O'brien's	SLAP lesion
Speed's	Biceps tendon pathology
Long head biceps tendon palpation pain	Biceps tendon pathology
Cross-over	Acromioclavicular OA
Acromioclavicular joint palpation pain	Acromioclavicular OA
Passive external shoulder rotation	Frozen shoulder
Passive shoulder flexion	Frozen shoulder

IMAGING MODALITY	USED TO IDENTIFY
Radiography (glenohumeral joint)	Glenohumeral OA
	Calcified tendinopathy
	Acromioclavicular OA
Ultrasonography	Full-thickness rotator cuff
	Calcified tendinopathy
	Biceps tendon rupture

9.6 DEFINITION OF DIAGNOSES (STUDY II)

The diagnoses, used in the present study, are defined below. Patients presenting with signs and symptoms of SAPS were screened for the presence of conflicting shoulder-related diagnoses, which ruled out a SAPS diagnosis. Patients diagnosed with SAPS were further screened for the presence of concomitant diagnoses. It was possible for patients with SAPS to be diagnosed with more than one concomitant diagnosis.

9.6.1 SAPS

· Insidious onset of shoulder pain
· At least 3 out of 5 positive tests from the following: Hawkin's test, Neer's test, Jobe's test, painful arc and external resistance test (section 11.2)
· No *conflicting shoulder-related* diagnosis (such as frozen shoulder or glenohumeral osteoarthritis)

9.6.2 ISOLATED SAPS

Patients with SAPS, and no concomitant shoulder diagnosis, were diagnosed as having isolated SAPS.

9.6.3 CONFLICTING SHOULDER-RELATED DIAGNOSES

There is consensus that diagnoses that can exhibit signs and symptoms similar to SAPS, but require a different treatment, should be ruled out before a SAPS diagnosis can be given [85]. In this thesis, the following diagnoses were labelled as conflicting shoulder-related diagnoses and ruled out before patients could be diagnosed with SAPS: Systemic musculoskeletal disease, inflammatory joint disease (e.g. rheumatoid arthritis), symptomatic cervical pathology, frozen shoulder, glenohumeral osteoarthritis, fibromyalgia, previous surgery, and fractures or radiotherapy in the shoulder girdle. A detailed description of these diagnoses can be found in the appendix.

9.6.4 CONCOMITANT SHOULDER DIAGNOSES

Calcified tendinopathy

Defined as a calcification in the supraspinatus or infraspinatus tendon larger than 5 x 5 mm, in any dimension, as seen on ultrasound and/or X-ray.

Rotator cuff tears

Ultrasonography or MRI were used to diagnosed rotator cuff tears [86]. Full-thickness tears (communication between bursal side and articular side) were considered to be a distinct concomitant diagnosis, whereas partial-thickness tears were not.

Biceps tendon pathology

Biceps tendon pathology included patients with biceps tendinopathy and patients with a rupture of the long head biceps tendon. The combination of point tenderness in the bicipital groove and a positive Speed's test have been shown to have a high correlation to histological tendinopathy changes in the biceps tendon [87]. The diagnosis of biceps tendinopathy was defined as these two findings being present.

Superior Labrum Anterior and Posterior (SLAP)

The diagnosis did not rely on MRI as asymptomatic SLAP lesions are a normal age-related finding [13]. Instead, the diagnosis of a SLAP lesion [11] was based on a positive O'Briens test [12].

Acromioclavicular osteoarthritis

Acromioclavicular joint osteoarthritis was defined as a positive cross-over test (cross-body adduction test) [88], palpable acromioclavicular joint pain, and radiological evidence of osteoarthritis.

Shoulder instability

Shoulder instability was divided into minor and major instability.

Minor shoulder instability

Pain from the Apprehension test or Castagna's test [89], *but* no signs of major instability.

Major shoulder instability

Anterior instability was defined as a positive Apprehension test [90] or Surprise test [91], and a positive Relocation test [90]. 'Posterior instability' was defined as a positive jerk test [92].

9.7 RECRUITMENT PROCEDURE FOR STUDY III

The patients with isolated SAPS included in **study II** were screened for eligibility for **study III.** Eligible patients were contacted via phone or e-mail. Patients, agreeing to participate, were invited to an extended examination in the outpatient clinic at the earliest convenient time.

9.8 EXTENDED EXAMINATION (STUDY III)

The extended examination included a standardized ultrasonographic examination, and shoulder radiographs of the acromioclavicular joint and the glenohumeral joint, had they not been acquired before.

9.9 ULTRASONOGRAPHIC EXAMINATION (STUDY III)

The following measurements were conducted: subacromial bursa thickness (two positions), supraspinatus tendon thickness (two positions), acromio-humeral

distance (AHD) (one position), and evaluation of ultrasonographic impingement. The ultrasonographic examination were applied in accordance with a previously described method reporting good to excellent intra- and interrater reliability of all measurements [84]. Ultrasonography was performed on a Hitachi Arrieta V70. The scanning positions and measurements are summarized in table 3.

TABLE 3: OVERVIEW OF ULTRASONOGRAPHIC MEASUREMENTS IN STUDY III

(Figure from paper III)

Measurement	Scanning position	Transducer position	Evaluation
Supraspinatus tendon	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Supraspinatus tendon	Hand behind the back *(internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Subacromial bursa	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Subacromial bursa	Hand behind the back (internal rotation)	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Acromio-humeral distance	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	At the most anterolateral aspect of the acromion, measuring the shortest distance to the humeral head in the longitudinal axis.	Distance (mm)
Ultrasonographic Impingement	Dynamic abduction and internal rotation	At the most anterolateral aspect of the acromion (longitudinal axis)	Yes / no

FIGURE 5: ULTRASONOGRAPHIC VISUALIZATION OF THE SUBACROMIAL BURSA AND THE SUPRASPINATUS TENDON (LONGITUDINAL VIEW)

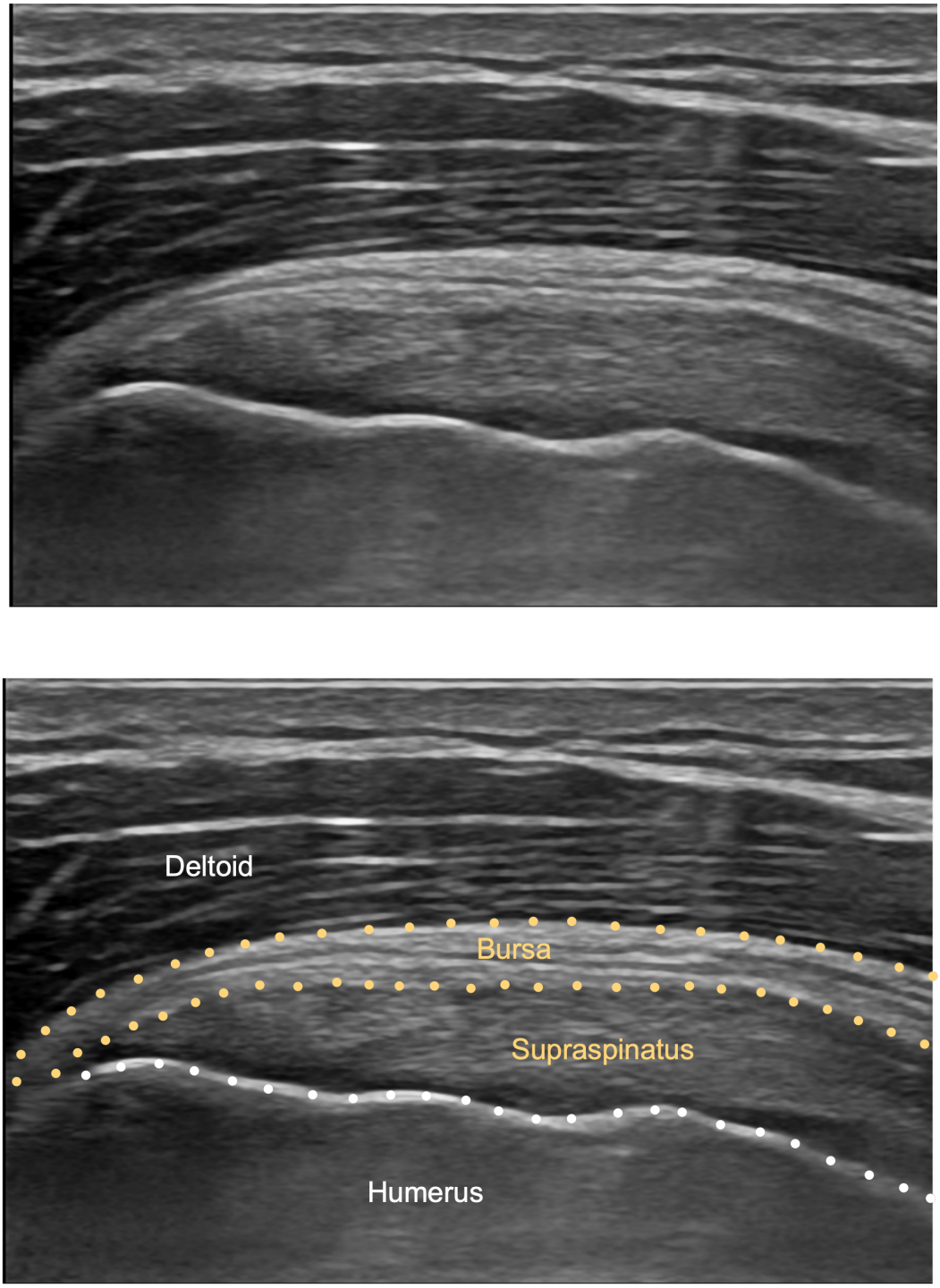
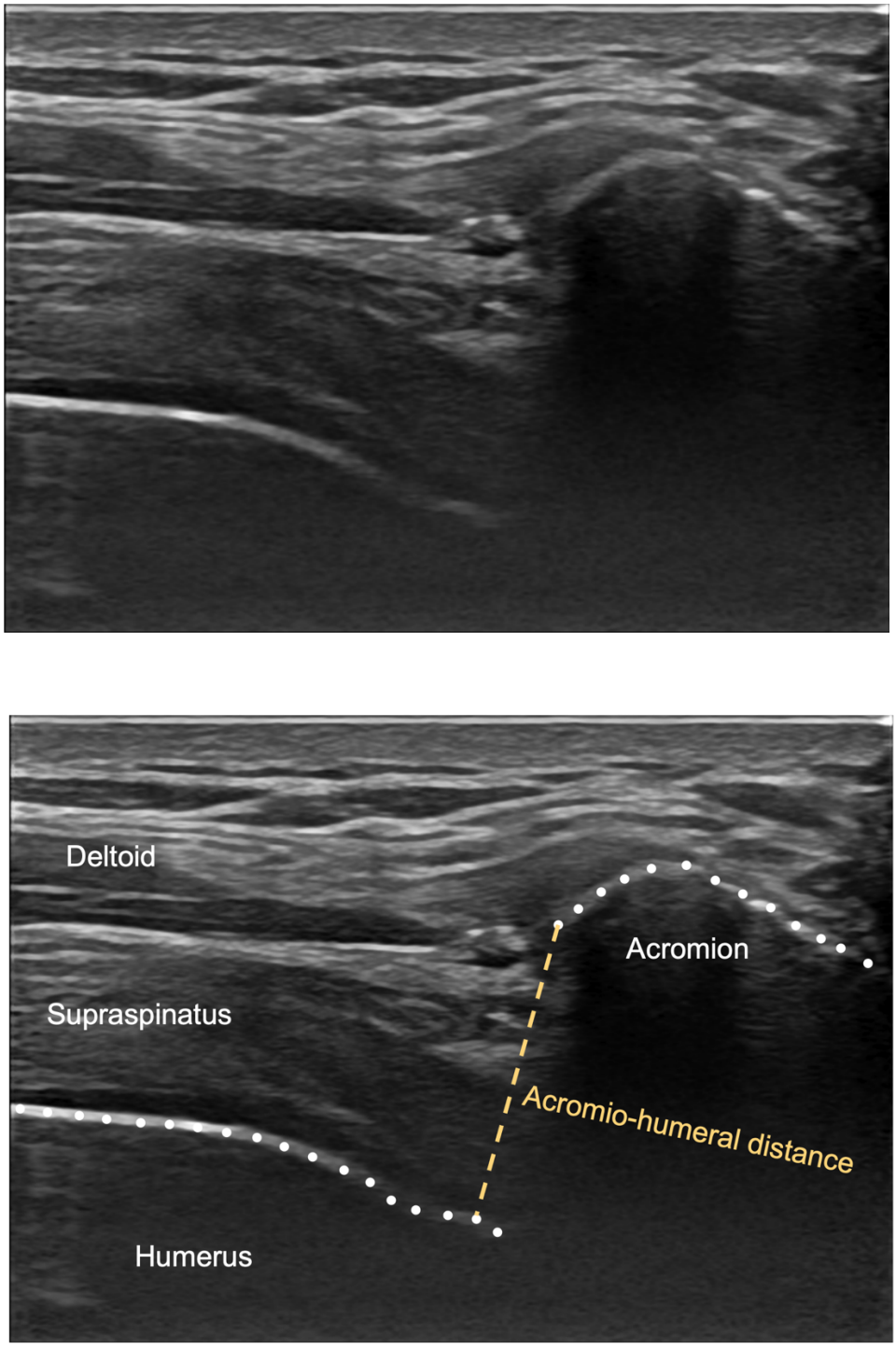


FIGURE 6: ULTRASONOGRAPHIC VISUALIZATION OF THE ACROMIO-HUMERAL DISTANCE

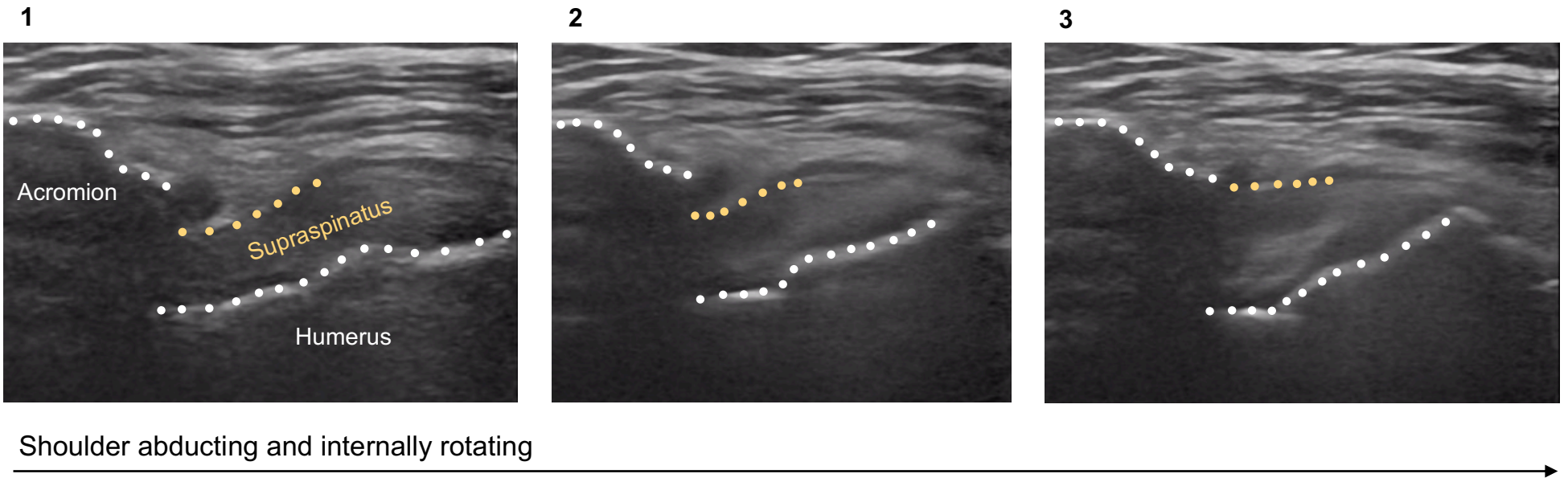


9.10 DEFINITION AND EVALUATION OF ULTRASONOGRAPHIC IMPINGEMENT (STUDY III)

Presence of ultrasonographic impingement was evaluated with the patient sitting on a chair with the shoulder in neutral position and the elbow flexed to 90 degrees. The examiner placed the ultrasound transducer at the anterolateral acromion, visualizing acromion, the supraspinatus tendon and the subacromial bursa with a longitudinal view. The patient was instructed to slowly elevate the arm while internally rotating the shoulder while the transducer was kept in place. Impingement was defined as visual bulging of the subacromial bursa against the acromion and rated as present/not present (figure 7).

FIGURE 7: ULTRASONOGRAPHIC IMPINGEMENT

Subsequent series of pictures depicting a case of ultrasonographic impingement.
The pictures show an increasing elevation of the supraspinatus tendon (superior border marked by dotted orange line) and the subacromial bursa as the shoulder is abducted and internally rotated. Picture 1 shows the supraspinatus tendon and the subacromial bursa being just below the lateral border of acromion. Picture 2 shows the supraspinatus tendon and the subacromial bursa nearing the lateral border of acromion. Picture 3 shows the supraspinatus tendon and the subacromial bursa impinging on acromion, with the subacromial bursa bulging as a result. In a shoulder without ultrasonographic impingement, the supraspinatus tendon and the subacromial bursa glides freely/smoothly under the acromion.



10 STATISTICS AND SAMPLE SIZE CONSIDERATIONS

STUDY I

Descriptic statistics were used to summarize findings within the predefined domains. There was no sample size calculation.

STUDY II

SAMPLE SIZE CONSIDERATIONS

Based on a pilot study, the following distribution of patients was assumed; isolated SAPS: 40%, supraspinatus tears: 20%, long head biceps tendon pathology: 8%, SLAP lesions: 8%, acromioclavicular osteoarthritis: 8% major shoulder instability: 8%, minor shoulder instability: 8%. A total of 125 patients were needed to include 10 patients in the smallest group.

STATISTICS

Descriptive statistics were used to summarize the prevalence of conflicting shoulder-related diagnoses and concomitant shoulder diagnosis in patients presenting with signs and symptoms of SAPS. Descriptive statistics were also used to summarize patient demographics.

STUDY III

SAMPLE SIZE CALCULATION

The two-sided paired-samples T-test was used for continuous data, while the one-sided chi-square test was used for categorical data. With a power of 0.9, a significance level of 0.05 and an effect size of 0.5, 44 patients were needed for the analyses of continuous data. Based upon previous findings, the estimated proportions of ultrasonographic impingement were assumed to be 0.5 and 0.08 in affected and unaffected shoulders, respectively [134]. With a power of 0.8, and a significance level of 0.05, 46 patients were needed for the analyses for categorical data.

STATISTICS

Normal distribution for continuous data was visually confirmed by histograms. The paired samples t-test was used for continuous data, while the chi-square test was used for nominal data. An alpha-level of 0.05 was used. All analyses were handled in IBM SPSS Statistics for Windows, Version 28.0.

11 METHOLOGICAL CONSIDERATIONS

11.1 METHODOLOGICAL CONSIDERATIONS FOR STUDY I

DECIDING ON THE TYPE OF REVIEW

Reviews are fundamental components in research. They play a crucial role in consolidating and synthesizing existing knowledge and contribute to evidence-based decision-making. There exists a multitude of review types, each serving a distinct purpose. The various types of reviews have emerged to meet the specific objectives and requirements for different research questions. Systematic reviews with meta-analyses are generally regarded as the highest level of evidence [93–95], but over the past decade, there has been a growing recognition of the value and utility of scoping reviews [96]. While systematic reviews and scoping reviews both serve the purpose of synthesizing evidence, they differ in their objectives and applicability. Systematic reviews follow a predetermined set of criteria to identify, assess, and synthesize knowledge from the included studies. Scoping reviews take on a broader and more exploratory approach compared to systematic reviews. Their primary objective is to map the existing literature and identify the key concepts, sources, and gaps within a particular research area [96]. By encompassing a wide range of studies, scoping reviews can provide a more comprehensive understanding of the breadth and depth of a research topic, aiding researchers in identifying research priorities and knowledge gaps. This could serve as a platform for the initiation and planning of a subsequent systematic review. As the primary purpose of **Study I** was to create an overview of the existing literature investigating patients with SAPS, a scoping review approach was chosen.

We chose not to include grey literature[3], and articles that was not peer-

[3] Grey literature encompasses information that is not formally published in conventional academic outlets [142].

reviewed, because we wanted to create an overview of the evidence from which we base recommendations and guidelines on, namely clinical studies. The inclusion of grey literature would likely also have skewed the results towards an unjustified increased heterogeneity.

While the overall aim was to present data transparently and objectively, the study may have been influenced by cognitive biases. The search strings were developed around known terms for SAPS. Though the aim was to encompass a broad view of SAPS, there is a risk that the predetermined search terms could have restricted the pool of available studies, which could have led to seemingly more uniform findings. Moreover, data was presented within four main categories: patient inclusion criteria, patient exclusion criteria, use of imaging and full-thickness supraspinatus tears. While the intention was to present data as objectively as possible, it could be argued there was other way to present it. This could also have affected the findings.

11.2 METHODOLOGICAL CONSIDERATIONS FOR STUDY II

The concepts of pathology and diagnoses are closely intertwined. While pathology refers to the alterations, structural or functional, outside the normal spectrum [97], diagnoses are often based on the finding of such alterations. The definition of “normal” is the crucial aspect. The scientific community sometimes define "normal" but this isn't always the practice, as is the case with SAPS. However, even when having defined “normal”, it can still be difficult to agree when alterations represent pathology, as many of these occur along a continuum. Some alterations also become more prevalent with age and can be considered a normal age-related finding [98,99]. The boundary between normal variation, and pathology, can be further blurred. In some cases, individuals may exhibit alterations outside the normal spectrum, but do not display any symptoms, raising the question of whether such alterations should be classified as pathology. On the other hand, some

individuals may experience symptoms without any detectable alterations. Some diagnoses are based on very specific pathological alterations, with an universally accepted definition, for instance hypertension [100]. Others are not. Therefore, the definition of pathology, and the accompanying diagnosis, can be a matter of debate. With no universally accepted diagnostic criteria for either SAPS or the concomitant diagnoses, as defined in this thesis, the diagnostic criteria for these were developed prior to the inclusion period in an iterative process between the study group and the orthopaedic shoulder specialists, working in the participating department, with the aim of reflecting clinical practice in the closest possible way.

INVESTIGATING A DIAGNOSIS THAT DOES NOT HAVE RECOGNIZED DIAGNOSTIC CRITERIA

Although SAPS is the most common diagnosis in the spectrum of shoulder disorders, there are no universally recognized diagnostic criteria for SAPS. Consequently, multiple diagnostic approaches exist. Some studies define SAPS from imaging alone, others from clinical tests, and some from a combination of both [29,37,38]. This lack of universally recognized diagnostic criteria to define SAPS poses a challenge, as it hinders comparability and generalizability of research findings. This can be somewhat countered by using a transparent methodology. Reproduceable diagnostic criteria are a prerequisite for this. Systematic reviews have investigated the predictive value of different physical examination test clusters to diagnose SAPS [101–103]. However, a Cochrane review concluded that there were insufficient evidence to give any recommendations, on which tests to use, due to *extreme* diversity in the performance and interpretation of tests among studies [103]. The definition of SAPS, in this thesis, was based on the recommendation of a systematic review, that found the combination of Painful arc, Hawkin's, Neer's, Jobe's and the external rotation resistance test, from which at least three needed to be positive, to have the highest diagnostic accuracy for diagnosing SAPS [102]. This test cluster was found to have a sensitivity and specificity of 75% and 74%,

respectively, for diagnosing SAPS when compared to surgical findings in 55 patients [38]. The study defined SAPS from any of the following: *"a visually enlarged bursa, fibrotic appearing bursa, or degeneration of the supraspinatus tendon at the superficial aspect."* [38].

Surgical findings, obtained through procedures like arthroscopy, are often considered the gold standard in diagnostic studies, due to their direct visualization of intra-articular structures. However, the designation of surgical findings as the gold standard for diagnosing SAPS can be contested. With no clear pathophysiological explanation of SAPS, it seems difficult to emphasize specific intraarticular findings as being pathognomonic for SAPS. Furthermore, individual variations in shoulder anatomy, and normal age-related alterations, makes it difficult to determine when an observation can be categorised as pathological. Nevertheless, the approach utilizing a combination of physical examination tests, is recommended by experts, reviews and guidelines [14–17], which is why such an approach was adopted in this thesis.

CONFLICTING SHOULDER-RELATED DIAGNOSES

SAPS is recognized as a clinical diagnosis, often synthesized from a combination of physical examination tests aimed towards eliciting a familiar pain response in the patient [14–17]. Physical examination tests can also elicit a positive response in the presence of other shoulder-related diagnoses, such as systemic musculoskeletal disease, inflammatory joint disease (e.g. rheumatoid arthritis), symptomatic cervical pathology, frozen shoulder, glenohumeral osteoarthritis and fibromyalgia. As opposed to SAPS, the pain-generating mechanisms of these conditions are not believed to originate from the subacromial structures, and in clinical practice these diagnoses are clearly differentiated from SAPS, especially in terms of treatment. Surgery and fractures alter the innate anatomy and caries the risk for development of unpredictable pain patterns with multiple different pain-generating foci. While it can be argued that SAPS can exist in patients with previous surgery and/or

fractures, these diagnoses undoubtedly introduce an unknown complexity. Due to these reasons, all the above-mentioned diagnoses were categorised as *conflicting shoulder-related diagnoses* in this thesis.

DEFINING DIAGNOSTIC CRITERIA FOR THE CONCOMITANT DIAGNOSES

Full-thickness rotator cuff tears and calcified tendinopathy were diagnosed with ultrasonography, which have been shown to have a high sensitivity and specificity [84,86,104]. Asymptomatic findings of acromioclavicular osteoarthritis are common [98,105]. For this reason, the definition of acromioclavicular osteoarthritis was based on both clinical and paraclinical findings. The diagnosis of SLAP and biceps tendinopathy (included under biceps tendon pathology) was based on clinical findings, with the gold standard being visual confirmation under arthroscopy. The latter would have allowed for a much higher specificity but would not be ethical or practically feasible. We could have chosen to base the diagnosis on MRI findings, which likely would have resulted in a higher sensitivity. However, pathological changes on MRI are a normal age-related finding [84], which increases the risk of over-diagnosing. Major shoulder instability is a well-defined diagnosis that can be established through clinical test and patient history [85,86], as used in this thesis. Minor shoulder instability has only been investigated sparsely but has been defined as a painful shoulder without any history of subluxation or dislocation, and a positive Castagna's test [65,87]. The same definition was used in this thesis.

11.3 METHODOLOGICAL CONSIDERATIONS FOR STUDY III

ULTRASONOGRAPHIC EVALUATION OF THE SUBACROMIAL STRUCTURES

Ultrasonography has been proven a valuable tool for the quantitative evaluation of subacromial structures, with several studies demonstrating its high reliability in this regard [75,77,95]. Previous studies have primarily concentrated on assessing

unilateral subacromial measurements, using healthy controls as a reference [34,35,37,97]. While a control group can be effectively matched for recognized confounding factors, it is inherently difficult to account for unforeseen or undetected confounders. The potential existence of significant individual variations in subacromial structures between patients, and the potential confounding effect of such, remains uncertain. To mitigate the risk of such confounding, it was chosen to compare the findings to the unaffected contralateral shoulder, as opposed to healthy controls. Conversely, this approach could introduce a bias by the potential inclusion of a higher number of patients with the dominant shoulder affected, though it is unclear if, and how, this might influence the outcomes.

The concept of impingement, as an observable phenomenon, has only been investigated sparsely. Studies have primarily tried to visualize impingement with ultrasonography, but the definitions are inconsistent [106–109]. Theoretically, dynamic MRI could also be utilized to visualize impingement, but this was not feasible in the place of investigation. Moreover, the evaluation of ultrasonographic impingement has been proven reliable [110], whereas MRI has not.

BLINDING OF ULTRASONOGRAPHIC MEASUREMENTS

Blinding is a method employed to reduce bias by withholding certain information from patients and researchers (investigators), or both. For obvious reasons, it was not possible to blind the patients from which shoulder that was affected and unaffected. It was also not possible to blind the investigator due to several obstacles in the setup. Firstly, the investigator, for practical and administrative reasons, had to know which shoulder that was affected, e.g., when referring the patient to radiography. Secondly, certain scanning positions, necessary for the ultrasonographic investigation, were visually challenging, and occasionally unattainable, for the patients due to their symptoms. To address the first obstacle, one potential solution could have involved assigning an additional investigator responsible for administrative tasks. However, even with this approach, the second obstacle would remain unresolved since the visual difficulties, experienced by

certain patients, would still be apparent. In theory, it would have been possible to administer a potent analgesic to the patients. However, it would be unethical and contrary to good clinical practice to administer it to all patients indiscriminately. Alternatively, it could have been selectively given to patients who required it, but this approach would have significantly prolonged the examination time due to the time required for the analgesic to take effect. Additionally, the analgesic's impact could potentially influence the results, particularly of the dynamic assessment, thus introducing another bias.

12 SUMMARY OF RESULTS

12.1 STUDY I (SCOPING REVIEW)

Eleven thousand and fifty-six records were identified in the electronic databases. In total 535 studies were included. Twenty-seven unique terms for SAPS were identified across all studies. Through the past 50 years, the use of terminology has been inconsistent. Subacromial impingement syndrome and shoulder impingement syndrome have been the most used terms, but in recent years SAPS have been used increasingly (figure 8).

Studies primarily used physical examination tests to diagnose SAPS (table 5). Accordingly, 68% of studies used at least one shoulder test to diagnose SAPS, while 41% used a cluster of physical examination tests. In total, 146 different test combinations were identified. A combination from the following tests were often used: Hawkin's, Neer's, Jobe's, painful arc, injection test and isometric shoulder strength tests..

75% of studies listed specific conditions as patient exclusion criteria, but only 19% described how the conditions were defined. Rotator cuff tears, shoulder instability, cervical disorders, frozen shoulder, inflammatory arthritis, and acromioclavicular joint pathology were the most used exclusion criteria (table 6).

The most used imaging modalities were radiography, MRI, ultrasonography, which were primarily used to exclude other shoulder pathology, rather to diagnose SAPS (table 7).

Patients with full-thickness supraspinatus tears were excluded in 46% of studies, and actively included in 10%, meaning that 44% did not report whether they included these patients or not.

FIGURE 8: Terminology used in the period 1972–2019 to describe patients with subacromial pain syndrome.
587 terms were registered across 519 studies as some studies used more than one term.
Figure reprinted from Witten et al. [85] in accordance with the guidelines of the British Journal of Sports Medicine/BMJ.

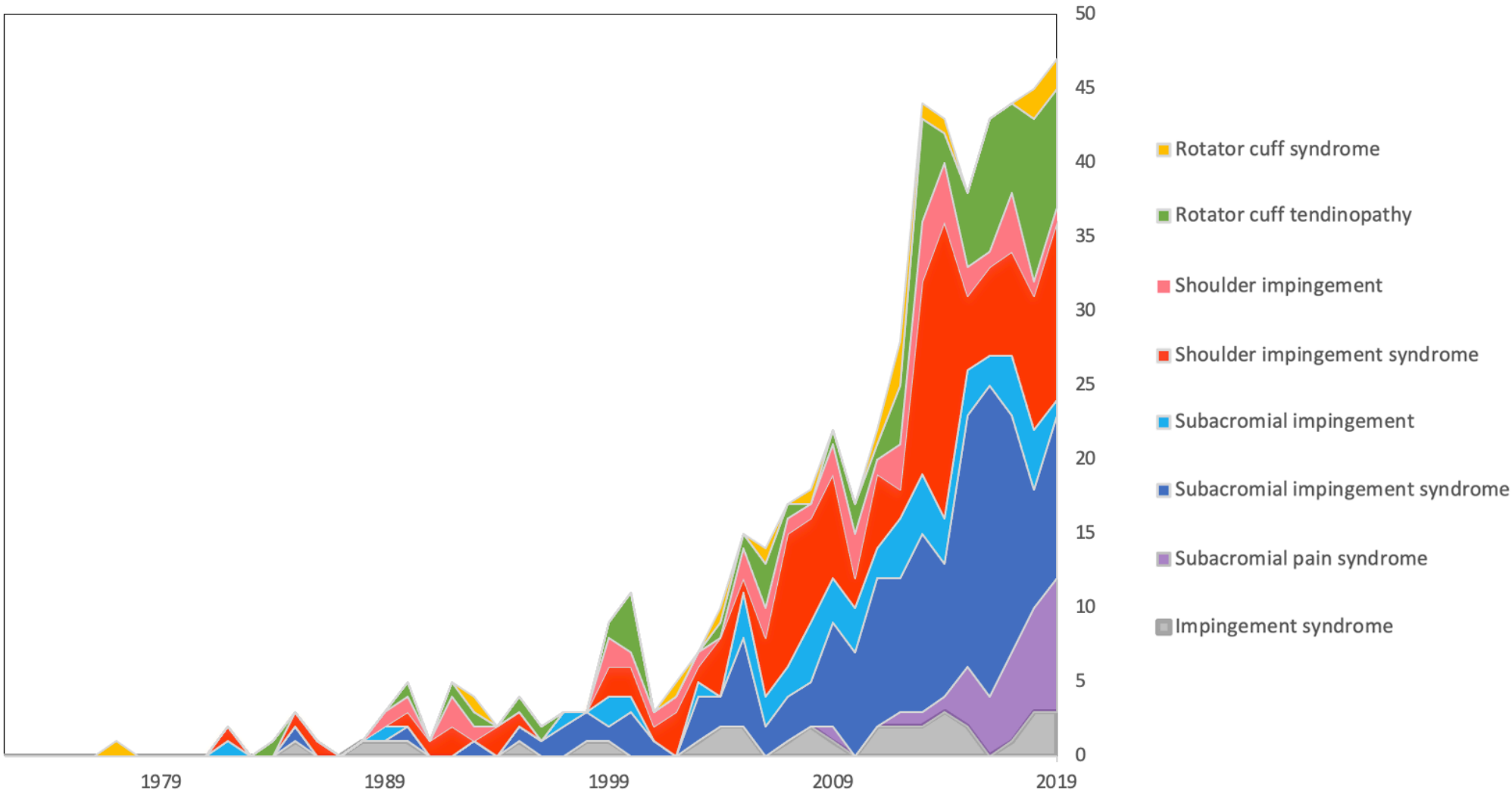


TABLE 4: TERMS USED TO DESCRIBE PATIENTS WITH SAPS

Term	n	%
Impingement (summarized)	***454***	***75***
Subacromial impingement syndrome	167	31
Shoulder impingement syndrome	135	25
Subacromial impingement	52	10
Shoulder impingement	43	8
Impingement syndrome	35	7
Impingement	4	1
Rotator cuff impingement	4	1
Chronic impingement syndrome	3	1
Rotator cuff impingement syndrome	3	1
Subacromial shoulder impingement	2	< 1
Cuff impingement	1	
Internal shoulder impingement	1	
Subacromial impingement disease	1	
Shoulder outlet impingement syndrome	1	
Impingement tendinopathy	1	
Chronic shoulder impingement	1	
Tendinopathy/tendon-related	***79***	***15***
Rotator cuff tendinopathy	74	14
Supraspinatus tendinitis	4	1
Supraspinatus tendon disease	1	< 1
Pain/disease/syndrome (summarized)	***71***	***12***
Subacromial pain syndrome	36	7
Rotator cuff syndrome	16	3
Rotator cuff disease	7	1
Subacromial pain	6	1
Subacromial shoulder pain	3	1
Rotator cuff related syndrome	1	< 1
Painful shoulder syndrome	1	
Rotator cuff related shoulder pain	1	

27 unique terms were registered across 535 studies. A total of 604 terms were registered as some studies used more than one term. *Table reprinted from Witten et al. [85] in accordance with the guidelines of the British Journal of Sports Medicine/BMJ.*

TABLE 5: PHYSICAL EXAMINATIONS TESTS AND IMAGING MODALITIES USED TO DIAGNOSE SAPS

Name of test	Studies using test
Hawkin's	268 (54%)
Neer's	263 (53%)
Painful arc	155 (31%)
Jobe's	136 (28%)
Isometric – External shoulder rotation	104 (21%)
Injection test	75 (15%)
Isometric – Shoulder abduction	67 (14%)
Pain from palpation of rotator cuff tendon(s)	57 (12%)
Active shoulder elevation pain	29 (8%)
Isometric test - Internal shoulder rotation	21 (6%)
Speed's	11 (2%)
Pain from Shoulder Apprehension test	9 (2%)
Yocum's	8 (2%)
Gerber's	8 (2%)
Drop arm	7 (1%)
Isometric – Shoulder flexion	6 (1%)
Shoulder relocation test	6 (1%)
Cross-body adduction test	5 (1%)
Lift off	5 (1%)
Patte's (Hornblower's test)	5 (1%)
Full can	5 (1%)
Yergason's	3 (1%)
Resisted elbow flexion	2 (<1%)
Shoulder apprehension	2
External shoulder rotation lag sign	1
MRI	31 (6%)
Ultrasonography	20 (4%)
Radiography	10 (2%)

Use of physical examination tests (across 493 studies) and imaging modalities (across 529 studies) to diagnose patients with SAPS. A study can contribute with multiple (or no) tests and imaging modalities. *Table reprinted from Witten et al. [85] in accordance with the guidelines of the British Journal of Sports Medicine/BMJ.*

TABLE 6: SHOULDER PATHOLOGY USED TO EXCLUDE PATIENTS FROM HAVING SAPS

Shoulder pathology	Studies reporting pathology as an exclusion criterion	Studies reporting how pathology was diagnosed
Rotator cuff tear	237 (49%)	68 (14%)
Shoulder Instability	204 (40%)	70 (14%)
Cervical disorder	190 (37%)	18 (3%)
Frozen shoulder	145 (29%)	30 (6%)
Inflammatory arthritis	134 (28%)	0
Acromioclavicular joint	115 (23%)	8 (2%)
Glenohumeral	91 (18%)	0
History of shoulder trauma	87 (17%)	-
Neurological disorder	83 (16%)	0
Calcified tendinitis	72 (14%)	0
Labral injury	21 (4%)	2 (<1%)
Fibromyalgia	20 (4%)	0
Biceps tendon pathology	13 (3%)	3 (<1%)
Os acromiale	7 (1%)	0

483 studies were included in the analyses for rotator cuff tears and 513 studies were included in the remaining analyses. A study can contribute with multiple (or no) shoulder pathologies. *Table reprinted from Witten et al. [85] in accordance with the guidelines of the British Journal of Sports Medicine/BMJ.*

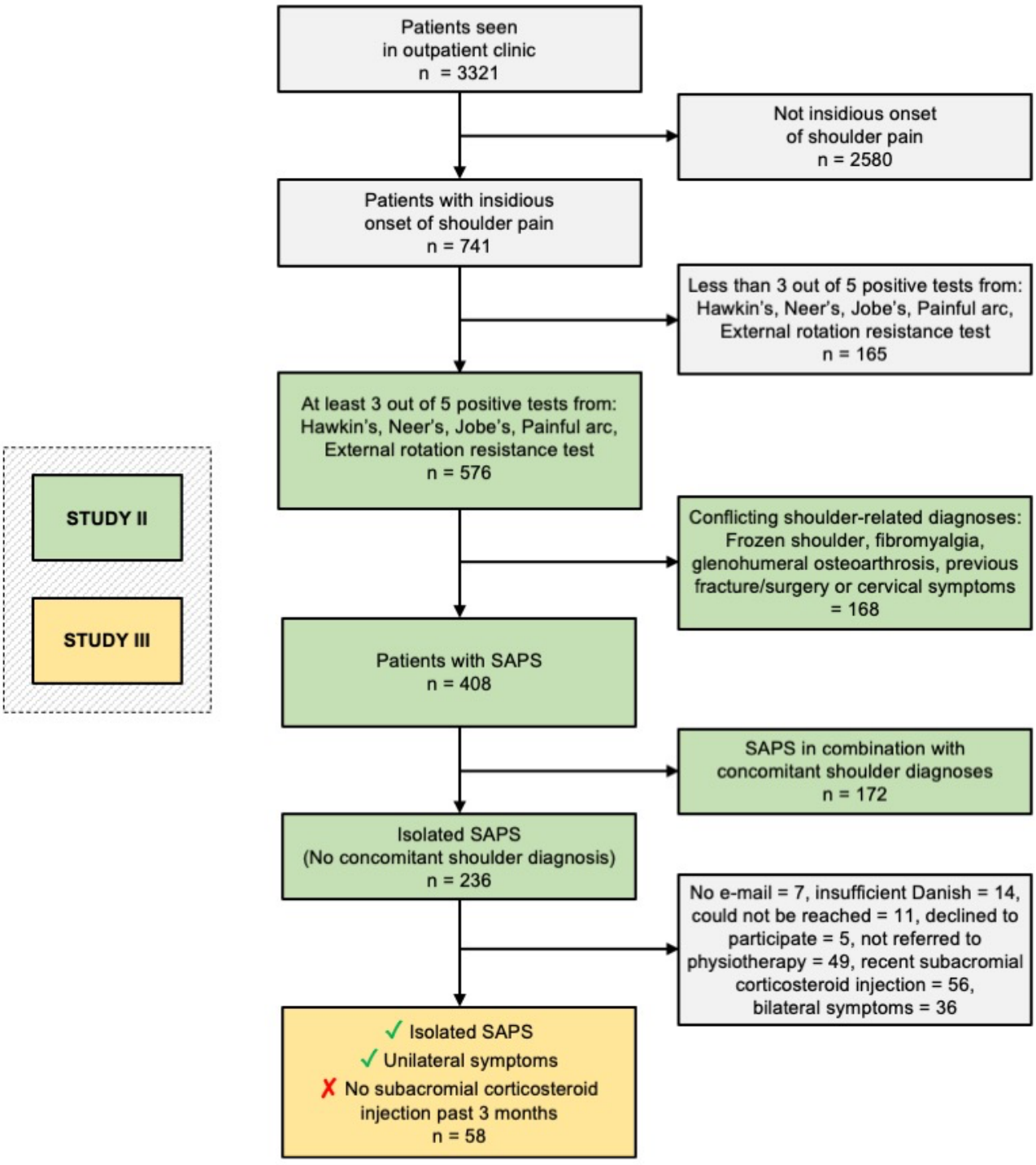
TABLE 7: USE OF IMAGING MODALITIES

Modality	To rule in SAPS	To exclude other pathology	To rule in SAPS, and to exclude other pathology	Purpose not specified	Total
Radiograph	6 (1%)	65 (12%)	4 (1%)	79 (15%)	154
MRI	20 (4%)	37 (7%)	11 (2%)	75 (14%)	143
Ultrasound	13 (2%)	42 (8%)	7 (1%)	71 (13%)	133
Arthrography	0	7 (1%)	0	11 (2%)	18 (3%)
CT	0	0	0	3 (1%)	3 (1%)

Studies using a specific image modality to either rule in SAPS, exclude other pathology (such as osteoarthritis, rotator cuff tears, and labral injury), or to rule in SAPS and exclude other pathology at the same time. Some studies did not specify the purpose of the image modality. 529 studies were included in the analyses. *Table reprinted from Witten et al. [85] in accordance with the guidelines of the British Journal of Sports Medicine/BMJ.*

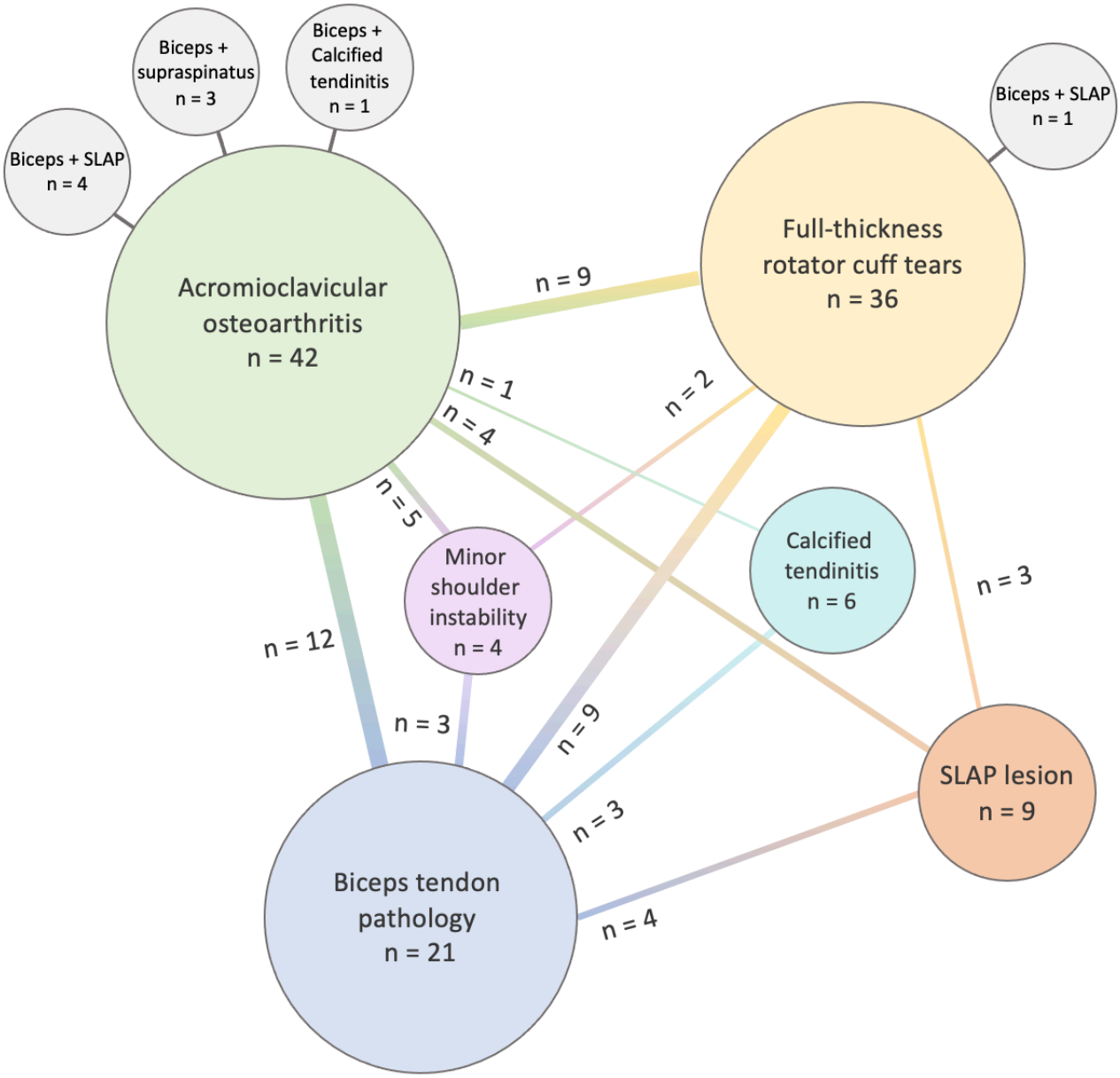
12.2 STUDY II

FIGURE 9: OVERALL INCLUSION OF PATIENTS IN STUDY II AND III



During the inclusion period, 3321 patients referred to the outpatient clinic during were systematically screened (figure 9). From those, we identified 741 patients referred with insidious onset of shoulder pain, and of whom 576 fulfilled the inclusion criteria for SAPS. A total of 168 patients had a conflicting shoulder-related diagnosis, and was thus, not diagnosed with SAPS. The most common of these were: frozen shoulder, fibromyalgia, glenohumeral osteoarthritis, and combinations hereof. The remaining 408 patients were diagnosed with SAPS and investigated further for signs of concomitant shoulder diagnoses. Of these patients, 42% had at least one type of concomitant pathology. The most common were acromioclavicular osteoarthritis, full-thickness supraspinatus tears and long head biceps tendon pathology. SLAP lesion, minor shoulder instability and calcified tendinopathy were also observed, though less frequently. None of the included patients had signs of major shoulder instability. A combination of concomitant diagnoses, with two or more different types, were seen in 32% of patients the patients with SAPS (figure 10). In total, 22 different variations of concomitant pathology were observed. The mean age of patients with SAPS was 56 years. 57% were women.

FIGURE 10: COMBINATIONS OF CONCOMITANT DIAGNOSES IN PATIENTS WITH SAPS.
Colored circles represent the number of SAPS patients with one concomitant diagnosis. Combinations, with two types, of concomitant pathologies are represented by connecting lines and adjacent numbers. The smaller circles represent combinations with three types of concomitant diagnoses. 172 patients are represented in the figure. *(Figure from paper II)*



12.3 STUDY III (BILATERAL ULTRASONOGRAPHIC MEASUREMENTS)

Ninety-four patients with SAPS and no recent corticosteroid injection were found eligible for inclusion. Of these, 36 patients had bilateral symptoms and where excluded. In total, 58 patients were included in the study. Six patients had so pronounced symptoms that they were unable to put their arm behind the back or participate in the dynamic evaluation. Five patients could not obtain the intended scanning position with the hand on the hip due to their visceral body composition. In these cases, the corresponding ultrasonographic measurements were not obtained. Demographics are presented in table 8, while ultrasonographic measurements are presented in table 9.

TABLE 8: DEMOGRAPHICS OF STUDY III

Number of patients	58
Age	51.4 (SD ±11.8)
Women	64%
BMI	26.8 (SD ±4.96)
Dominant shoulder affected	71%
Symptom duration	32 months (SD ±44), median: 18 months

Values are presented as mean, unless stated otherwise.

(Table from paper III)

TABLE 9: ULTRASONOGRAPHIC MEASUREMENTS COMPARING AFFECTED AND UNAFFECTED SHOULDERS

(Table from paper III)

		Shoulder		P-value	
	N	**Affected**	**Unaffected**	**One-sided**	**Two-sided**
Supraspinatus tendon Position: Hand on hip	53	5.46 mm (SD ±1.11)	5.47 mm (SD ±1.03)	n.s.	n.s.
Supraspinatus tendon Position: Hand behind back	52	5.42 mm (SD ±1.12)	5.50 mm (SD ±0.92)	n.s.	n.s.
Subacromial bursa Position: Hand on hip	53	2.03 mm (SD ±0.53)	1.93 mm (SD v0.53)	n.s.	n.s.
Subacromial bursa Position: Hand behind back	52	1.91 mm (SD ±0.55)	1.86 mm (SD ±0.54)	n.s.	n.s.
Acromio-humeral distance Position: Neutral, relaxed	58	11.16 mm (SD ±2.03)	11.06 mm (SD ±2.10)	n.s.	n.s.
Impingement Dynamic scan	52	Present: 45 Not present: 7	Present: 18 Not present: 34	P = 0.04	

13 DISCUSSION

The overall aim of this thesis was to increase the knowledge of heterogeneity in patients with SAPS, and investigate the role of impingement in SAPS. This was conducted through one review (**study I**) and two cross-sectional studies (**II and III).** **Study I and II** deals with terminology, diagnosis, and clinical presentation of patients with SAPS, whereas **study III** deals with the role of ultrasonographic impingement in patients with SAPS.

HETEROGENEITY ACROSS STUDIES IN THE USE OF TERMINOLOGY AND DIAGNOSTIC CRITERIA

Study I shows that terminology and diagnostic criteria, used to identify patients with SAPS, varies significantly across studies. Looking across all studies, it appeared that the terminology used did not affect the diagnostic criteria. This indicates that *impingement* and *SAPS* are generally used to convey the same in the literature. The heterogeneity in terminology poses challenges for clinicians who aim to deliver a diagnosis that can be easily comprehended and effectively communicated by all healthcare providers. This situation also leads to potential confusion among patients who may encounter multiple terms referring to the same condition.

The heterogeneity in diagnostic criteria was present across several domains, including patient inclusion criteria, patient exclusion criteria, use of imaging, and whether full-thickness supraspinatus tears were included within the entity of SAPS. This makes it difficult, sometimes nearing impossible to interpret and compare findings across studies due to differences in patient populations. The most influential randomized controlled trials concerning the treatment of SAPS also have differences in the diagnostic criteria [60,62,74,75,111,112]. When evidence from studies is compiled, the potential diversity in diagnostic criteria is frequently

overlooked or not given specific attention. Consequently, many guidelines, recommendations, and reviews tend to disregard these variations in diagnostic criteria [113–116], even though acknowledging them could carry substantial implications for how the findings are understood and applied, especially regarding generalizability. The findings of **study I** indicate there is a need for an increased awareness on potential heterogeneity across patient populations. Guidelines and reviews should consider employing population heterogeneity as a domain according to the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) guidelines [117].

PATIENTS PRESENTING WITH SIGNS AND SYMPTOMS OF SAPS ARE HETEROGENEOUS

Study I further showed that SAPS is a diagnosis that, from a scientific perspective, typically is synthesized from a combination of physical examination tests. Most often a combination, from Hawkin's, Neer's, Jobe's, painful arc and isometric shoulder strength tests, was used. This is in line with a systematic review, highlighting the test cluster of Hawkin's, Neer's, Jobe's, painful arc and isometric external shoulder rotation, from which at least 3 needs to be positive, to have the highest predictive value of SAPS [16]. Adopting this approach**, Study II** investigated the prevalence of other shoulder diagnoses in patients presenting with SAPS.

Before patients can be classified as having SAPS, it is widely agreed that other shoulder-related diagnoses that may exhibit signs and symptoms similar to SAPS, but require a different treatment, shoulder be ruled out [85]. In **study II** these diagnoses were labelled *conflicting shoulder-related diagnoses*. Of the 576 patients presenting with signs and symptoms of SAPS, a substantial number (n = 168, 29%) received a conflicting shoulder-related diagnosis instead of SAPS. Most of these patients were diagnosed with a frozen shoulder or glenohumeral osteoarthritis, highlighting these as important differential diagnoses in patients otherwise presenting with signs and symptoms of SAPS.

Of the 408 patients that was diagnosed with SAPS, 171 (42%) received at least one concomitant shoulder diagnosis. Acromioclavicular osteoarthritis, full-thickness supraspinatus tears and long head biceps tendon pathology were the most common. SLAP lesions, minor shoulder instability, and calcified tendinopathy were also observed, though less frequently. No patients displayed signs consistent with major shoulder instability, suggesting that this does not regularly provoke signs and symptoms of SAPS.

ULTRASONOGRAPHIC IMPINGEMENT IN PATIENTS WITH SAPS

Study III investigated a subgroup of patients with isolated SAPS to compare ultrasonographic subacromial measurements between the affected and unaffected and shoulders. We found that ultrasonographic impingement was more frequent in affected shoulders, compared to unaffected, but in contrast we did not detect any significant group differences in measurements of supraspinatus tendon thickness, subacromial bursa thickness or acromio-humeral distance (AHD). These findings suggest that ultrasonographic impingement could be a contributing factor for SAPS, unrelated to measurable variations of the thickness of the subacromial structures. This nuance the current understanding of SAPS. The findings seemingly fits well with Neer's original theory [49,50], but are contrary to popular belief that thickened subacromial structures are a pathognomonic finding in patients with SAPS [40,41,43,107].

Though ultrasonographic impingement was observed significantly more in affected shoulders (87%), a notable portion of the unaffected shoulders (35%) were also observed with ultrasonographic impingement. This compares reasonable with a previous study, reporting a prevalence of ultrasonographic impingement in 7-25% (depending on the definition of impingement) of asymptomatic controls [106]. There is no clear explanation for this, but it could be that ultrasonographic impingement occurs as a normal phenomenon, but nevertheless, predisposes to development of SAPS. It could also be that ultrasonographic impingement develops before

symptoms, as a prodromic sign. Prospective studies, capturing the transitioning of asymptomatic shoulders to symptomatic, are needed to elucidate this further. Because the only observable difference, between affected and unaffected shoulder, was seen during elevation of the arm, the overall findings seem to suggest that the symptoms of SAPS arise, at least in part, from altered glenohumeral kinematics. A possible explanation for this could be that pain arises independent of structural changes and leads to altered glenohumeral kinematics which then causes ultrasonographic impingement. The presence of impingement could, in turn, potentially be an independent pain-generating factor, thus creating a self-perpetuating cycle, maintaining prolonged symptoms.

IMPLICATIONS FOR INTERPRETATION OF THE LITTERATURE

This thesis shows there is a considerable heterogeneity in terminology, diagnostic criteria, and clinical presentation of patients with SAPS. It further shows that (ultrasonographic) impingement seems to be more frequent in affected shoulders than unaffected shoulders in patients with isolated SAPS.

The heterogeneity of SAPS extends across multiple dimensions. While study I showed that the heterogeneity was present across patient populations, in terms of how SAPS was defined and identified, study II showed that heterogeneity was also present within the same patient population, in terms of the prevalence of concomitant diagnoses. Even though SAPS do not have any recognized diagnostic criteria, potential heterogeneity have received little attention in the discussion about SAPS. Acknowledgement of heterogeneity in patients with SAPS represents a new, or at the very least, an overlooked perspective in the current understanding of SAPS.

A consensus statement, from European and American shoulder experts, a multidisciplinary review from Dutch Orthopaedic Association, a guideline in the

BMJ[4] and a systematic review in the BJSM[5], all recommend using a combination of physical examination tests to diagnose SAPS [14–17]. These publications recommend combinations that include some of the following physical examination tests: Hawkin's, Neer's, Jobe's, painful arc and the isometric shoulder external rotation test. It can be argued that this represents a fairly conventional diagnostic approach for SAPS, or at least one that is appraised by many different stakeholders. Nonetheless, reviews, guidelines, and commentaries, concerning the treatment of SAPS, seldom assess or evaluate the diagnostic approach when findings are interpreted [24,100–102]. The most influential trials, concerning the treatment of SAPS [60,62,74,75,111,112], also have considerable variations in the diagnostic criteria. The acknowledgement of differences in patient populations could have significant implications for the interpretation of the current literature, especially when studies are compared, and when evidence from multiple studies are summarized.

Furthermore, **study II** shows that if patients are diagnosed with SAPS from a combination of Hawkin's, Neer's, Jobe's, painful arc and the isometric shoulder external rotation test, more than half (59%) would have a conflicting shoulder-related diagnosis (such as frozen shoulder or glenohumeral osteoarthritis) or a concomitant diagnosis (such as acromioclavicular osteoarthritis or a full-thickness supraspinatus tear). **Study I** showed that this approach is far from adopted by all studies, but it is likely that conflicting shoulder-related diagnoses and concomitant diagnoses can be present in other studies that do not specifically screen for this. Most studies did not report whether they excluded such patients, with conflicting shoulder-related - or concomitant diagnoses, and if they did, they seldom reported how the screening was conducted (table 6). The cumulative findings of **study I and II** indicate that there is a pressing need for an increased focus on this matter, to be able to interpret findings in a nuanced manner.

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[4] British Medical Journal

[5] British Journal of Sports Medicine

THE IMPINGEMENT THEORY REVISITED

A little more than 50 years ago, Neer popularly introduced the diagnosis of impingement syndrome (now referred to as SAPS) [49,50]. The term was aptly named, as it directly referred to the then-held pathophysiological explanation: impingement of the subacromial structures against the undersurface of the acromion. [49,50]. Neer also introduced two diagnostic tests, Neer's test[6] and the subacromial injection test[7] [49,50]. In summary, there was one term in use to describe the patient population, and one single method for identifying them. The findings of this thesis make it evident that this is no longer the scenario. Today, there are numerous terms and diagnostic criteria in existence, and the term 'impingement' is gradually falling out of use, while SAPS is gaining more frequent use. This shift, in terminology and diagnostic criteria, illustrates the increasingly held opinion that SAPS includes a wide range of pathophysiological causes that extend beyond impingement [1]. Neer initially defined SAPS based on certain symptoms and tests. Today, most studies use different diagnostic criteria, if any at all. Yet, there is a growing acceptance that the impingement theory is incorrect, or at least not comprehensive enough to encapsulate SAPS [1,78]. A possible explanation for this could be that the entity of SAPS has evolved and expanded to encompass a variety of conditions beyond Neer's original definition. In recent years, there has been a notable rise in both the frequency of diagnoses and the number of ASD procedures performed, hinting that this might be the situation [10,58,78]. A counterargument would be that the notable rise could be due to an increased awareness of SAPS. However, in Denmark, the prevalence of SAPS rose 465% from 1996 to 2013, according to a large nationwide epidemiological register study [10], and it improbable that such a significant rise can be solely attributed to increased awareness. Some studies estimate SAPS to constitute more than 70% of all shoulder cases [12,118], and it has been expressed that "the label" SAPS

[6] Originally called Neer's sign [49]

[7] Originally called Neer's test [49]

perhaps has become too large and heterogenous to be of reasonable clinical value [1]. Perhaps the question is not so much whether Neer's theory was correct, but rather how we *chose* to define SAPS today. If SAPS is defined according to Neer's original theory, then SAPS most likely has expanded to include patients without impingement. If SAPS is defined according to the present (heterogeneous) use of diagnostic criteria, then Neer's theory most likely is inadequate to encapsulate all patients with SAPS. This thesis undeniably shows that studies have deviated far from Neer's original diagnostic criteria. The question emerges whether studies employing alternative diagnostic criteria, or none at all, can be used to challenge Neer's impingement theory.

Study III also used a slightly different diagnostic approach compared to Neer, by referring to a more contemporary understanding of SAPS, in which a combination of physical examination tests is recommended [14–17], leaving out routine use of a diagnostic subacromial injection [49,50]. **Study III** adds to the currently sparse literature on impingement as an observable phenomenon. The findings indicate that impingement, as defined in this thesis, is frequent in affected shoulders of patients with isolated SAPS. However, as impingement also was found in a considerable portion of the unaffected shoulders, and not all affected shoulders, no firm conclusion on the exact role of impingement in SAPS, can be made.

14 CONCLUSION

STUDY I

Studies investigating SAPS are heterogenous to an extent that makes it difficult, and often impossible, to compare them. Studies should be interpreted with care bearing this in mind.

STUDY II

Patients with SAPS often present with concomitant shoulder diagnoses. The clinical importance of this remains uncertain, but the high prevalence underpins the need for further investigations on the role of concomitant diagnoses in relation to prognosis and response to current treatment paradigms.

STUDY III

In patients with unilateral isolated SAPS, we found more cases of ultrasonographic impingement in affected shoulders compared to unaffected, but no significant differences in the supraspinatus tendon thickness, subacromial bursa thickness or AHD. These findings suggest that ultrasonographic impingement has better discriminative validity than supraspinatus tendon thickness and bursa thickness.

15 PERSPECTIVES

The word *diagnosis* derives from Greek *dia-;* ‘apart’ and *gignōskein;* ‘recognize, know’, with *diagignōskein* meaning “to know thoroughly” or “know apart (from another)” [119,120]. Diagnoses involve the process of identifying a disease or disorder through signs, symptoms, medical history, and diagnostic tests. According to the World Health Organization (WHO) diagnoses should be: *“specific, unambiguous, as self-descriptive and simple as possible, and based on cause wherever feasible.”* [121] Diagnoses are essentially a way for healthcare professionals to organize their patients. A certain diagnosis ideally should be accompanied by a specific course of treatment. That way, diagnoses become essential for effective treatment and communication between healthcare professionals, patients, and other stakeholders. Ideally, when a patient is given a diagnosis, all healthcare professionals should know how to approach the patient in terms of treatment and information. Throughout the history of medicine, diagnoses have consistently evolved in response to the unearthing of new scientific breakthroughs and discoveries.

POTENTIAL SUBGROUPING OF PATIENTS WITH SAPS

Full-thickness supraspinatus tears, calcified tendinopathy, labral lesions, long head biceps tendon pathology, acromioclavicular osteoarthritis, and shoulder instability are diagnoses that may present in patients otherwise diagnosed with SAPS [17,20,122–124]. Opposing arguments can be made as to whether these concomitant diagnoses have a direct causal relationship to the symptoms of SAPS, or if they can coexist with SAPS independently. Regardless of this, from a surgical perspective, these diagnoses are clearly differentiated for SAPS, as they are approached in a substantially different manner.

The heterogeneity among patients with SAPS offers a new possible direction, for the treatment of SAPS, nested within the potential of a more individualized approach. The impact of concomitant diagnoses, in the treatment of SAPS, has not yet been established, but it is plausible that treatment exclusively focused on the subacromial structures may lead to inferior outcomes in patients with concomitant pathology, such as acromioclavicular osteoarthritis. The best treatment strategy for such patients (SAPS and concomitant diagnoses) may involve addressing structures beyond the subacromial, through tailored interventions based on individual pathophysiological findings. Further studies are needed to elucidate this.

ARE ONE SURGICAL PROCEDURE THE PANACEA FOR THE MAJORITY OF SHOULDER PATIENTS?

The symptoms of SAPS are believed to originate from the subacromial structures. Consequently, the surgical procedure for SAPS (ASD) is aimed towards modifying acromial morphology and resecting the subacromial bursa, whereas the other diagnoses entail surgical procedures directed at different anatomical structures. In contrast, concomitant diagnoses, as defined in this thesis, involve surgical procedures directed at other anatomical structures. Therefore, it is possible that the effect of ASD could be negatively affected by the presence of concomitant shoulder diagnoses, that are not affected by this approach. There are some indication of this in the literature, though only from retrospective studies [125,126]. They reported a higher number of failures (unsatisfactory results) from ASD in patients with rotator cuff tears, calcified tendinopathy, instability, and in patients with misdiagnosed cervical pathology. It can be argued that this is somewhat obvious and most surgical trials already take this into consideration by adding a list of such diagnoses as exclusion criteria. While this can be said to be true, the findings of **study I** show that there is still a large discrepancy in studies, between the reported/listed exclusion criteria (without further explanation) and clarification for how screening for these diagnoses were performed.

The RCT's respectively from Beard [74] and Paavola [75] are some of the most important and influential studies concerning the treatment of SAPS. These studies have served as the primary foundation for guidelines, recommendations and opinions that advocate the discontinuation of ASD [30,114,127,128]. Both the incidence of SAPS and the use of ASD had risen dramatically up until the inception of the two RCT's [10,59]. The RCT's timely asked the right question when they sought to answer if the current use of ASD was supported. Without delving further into the methodology of the RCT's, their findings indeed raise doubts about the current application of ASD. However, this thesis raise question as to whether it is justified to extrapolate the findings of the RCT's to all patients with SAPS, as potential concomitant diagnoses could have influenced the findings. This concern has also been expressed in a BMJ editorial [124].

It is difficult to believe that one surgical procedure can be the panacea for the majority of shoulder patients. If the term SAPS is used negligently, it may have led to an overuse of ASD, thus diluting its potential effect. The remaining question now seems to be: Does ASD serve its intended purpose within the population it was designed for, namely patients with isolated SAPS who are non-responders to non-operative treatment?

IF WE DO NOT AGREE ON THE PROBLEM, WE CANNOT AGREE ON A SOLUTION. A CONSENSUS IS NEEDED.

This thesis shows there is a considerable heterogeneity within terminology and diagnostic criteria for SAPS. SAPS have been studied for approximately a century, but it appears the path to a solution is more complex than ever. We need to agree on basic definitions if we are to interpret findings nuancedly. There is a pressing need for a consensus on this.

While this thesis shows there is a considerable heterogeneity within terminology, it nevertheless, introduces new terms (concepts): 'isolated SAPS' and 'SAPS and concomitant diagnoses'. While this represent a new approach, the

actual clinical value of this is unknown. The existence of these concepts is only merited if they are correlated to something of importance, e.g. differences in prognoses. Otherwise, it will just add to the confusion. Future studies are needed to determine this.

16 EPILOGUE

Throughout a long career as a practicing surgeon and by dissecting postmortem specimens, Codman had studied the shoulder intensely, in particular the subacromial bursa and the rotator cuff. He summarized his thoughts in a book titled 'The Shoulder: Rupture of the Supraspinatus Tendon and Other Lesions In or About the Subacromial Bursa' (1934), which he described as his life work. Codman begins the chapter on 'Tendinitis of the short rotators'[8] with the following: *"THIS is a class of cases which I find it difficult to define, difficult to treat and difficult to explain from the point of view of pathology.* Now, almost a century later, many would likely still concur with this statement. It is a disheartening realization that our understanding of SAPS has not improved much during the last 100 years.

Three of the chapters in Codman's book from 1934 were titled 'Rupture of the supraspinatus tendon", "Tendinitis of the short rotators", and "The pathology of the subacromial bursa and the supraspinatus tendon". Today, many clinicians and researchers would probably argue, that these chapters could be merged into a single chapter simply called "subacromial pain syndrome" - but Codman thought it nessecary to write three distinct chapters in the same book to encapsulate the many nuances he saw in anatomy, function and pathology related to the subacromial structures. Perhaps Codman was overcomplicating things. Perhaps we, today, are simplifying things too much. One thing is certain. The concept of SAPS and impingement has evolved since their inception, and they probably will continue to do so. The concepts of SAPS and impingement, as defined in this thesis, may eventually be found to be imprecise or plainly refuted. I would consider it a compliment if someone were to undertake such a pursuit.

[8] As in 'rotator cuff'

17 ACKNOWLEDGEMENTS

I was about to finish my medical studies and needed to write my master's thesis. I remember reading an article in the newspaper mentioning the research of Per and Kristian, and I got intrigued enough to write Per. He wrote back the next day and said I should call him. I did. We arranged a meeting with him and Kristian. I remember being impressed with the interest they took in me. Since then, I have not looked back. Today, I am proud to call Per my mentor. He has guided me continuously in my career and helped me tremendously, not only as a researcher, but also in my clinical work, and when I was finding my footsteps as a young doctor. I am sure he will continue to do this. For that, I am forever grateful.

During my first research project, I was also fortunate enough to work together with Mikkel and Kristian. I believe that taught me doing research the proper way – there were no shortcuts. I am glad they decided to extend their supervision to this project.

Gradually my research endeavour sort of snowballed into a larger project that had a PhD embedded in it. At times, it was challenging to manage a PhD beside the clinical work, but ultimately, I believe it made me a better researcher and a better clinician to combine both worlds. I was glad to be able to do it mostly on my own terms. Per and Kristoffer obviously had a huge part in that. Beside from excellent academic supervision and feedback, Kristoffer also helped me immensely in my clinical work. Colleague, supervisor, mentor, friend. I am not sure which label to use. Overall, I believe I have been quite fortunate to learn from these brilliant minds. Thank you!

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19 PAPERS

PAPER I

Terminology and diagnostic criteria used in studies investigating patients with subacromial pain syndrome from 1972 to 2019: a scoping review

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ABSTRACT

Introduction There is no recognised terminology, nor diagnostic criteria, for patients with subacromial pain syndrome (SAPS). This is likely to cause heterogeneity across patient populations. This could be a driver of misconceptions and misinterpretations of scientific results. We aimed to map the literature regarding terminology and diagnostic criteria used in studies investigating SAPS.

Materials and methods Electronic databases were searched from inception to June 2020. Original peer-reviewed studies investigating SAPS (also known as subacromial impingement or rotator cuff tendinopathy/impingement/syndrome) were eligible for inclusion. Studies containing secondary analyses, reviews, pilot studies and studies with less than 10 participants were excluded.

Results 11 056 records were identified. 902 were retrieved for full-text screening. 535 were included. 27 unique terms were identified. Mechanistic terms containing 'impingement' are used less than before, while SAPS is used increasingly. For diagnoses, combinations of Hawkin's, Neer's, Jobe's, painful arc, injection test and isometric shoulder strength tests were the most often used, though this varied considerably across studies. 146 different test combinations were identified. 9% of the studies included patients with full-thickness supraspinatus tears and 46% did not.

Conclusion The terminology varied considerably across studies and time. The diagnostic criteria were often based on a cluster of physical examination tests. Imaging was primarily used to exclude other pathologies but was not used consistently. Patients with full-thickness supraspinatus tears were most often excluded. In summary, studies investigating SAPS are heterogeneous to an extent that makes it difficult, and often impossible, to compare studies.

WHAT IS ALREADY KNOWN

⇒ Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain.
⇒ There is no recognised terminology, nor diagnostic criteria, for patients with SAPS.

WHAT ARE THE NEW FINDINGS

⇒ The terminology used to describe patients with SAPS varies considerably across studies and time.
⇒ More mechanistic terms containing 'impingement' are used less than before, while SAPS is used increasingly.
⇒ Studies investigating SAPS are heterogeneous to an extent that makes it difficult, and often impossible, to compare them. Studies should be interpreted with care bearing this in mind.

INTRODUCTION

In 1972, the orthopaedic surgeon Charles S Neer, II, popularised the entity of subacromial pain syndrome (SAPS). He described it as a condition characterised by persistent subacromial pain attributable to mechanical impingement of the subacromial structures, namely the supraspinatus tendon.[1] Neer's description and theory of mechanical impingement has been questioned.[2–6] Today, many consider SAPS to have a multi-aetiological origin that does not necessarily involve mechanical impingement.[2–6] Owing to the lack of a recognised definition for SAPS, numerous terms and diagnostic approaches exist.[7] The terms in use are often used interchangeably which is also reflected in electronic databases and search engines. Accordingly, PubMed indexes the term 'subacromial impingement syndrome' interchangeably with 'rotator cuff impingement', 'shoulder impingement' along with several others.[8]

SAPS is regarded as the most common type of shoulder pain,[9–11] but despite this, there is no universally recognised terminology, nor diagnostic criteria. This is likely to cause heterogeneity within and across patient populations due to varying diagnostic approaches and use of different tests and imaging. Such heterogeneity could be an important driver of misconceptions and misinterpretations of scientific results. The question as to whether full-thickness supraspinatus tears should be included in the SAPS entity also represents an area with potential discrepancy between studies.

The patient population, and thus, the diagnostic criteria, are a crucial aspect in the design of studies. A specific treatment might work in one patient population, but not in others. Uniform diagnostic criteria are essential to be able to include the intended study participants and to interpret the scientific findings. Awareness of variations in diagnostic criteria could consequently have important implications for the interpretation of studies, especially when comparing studies.

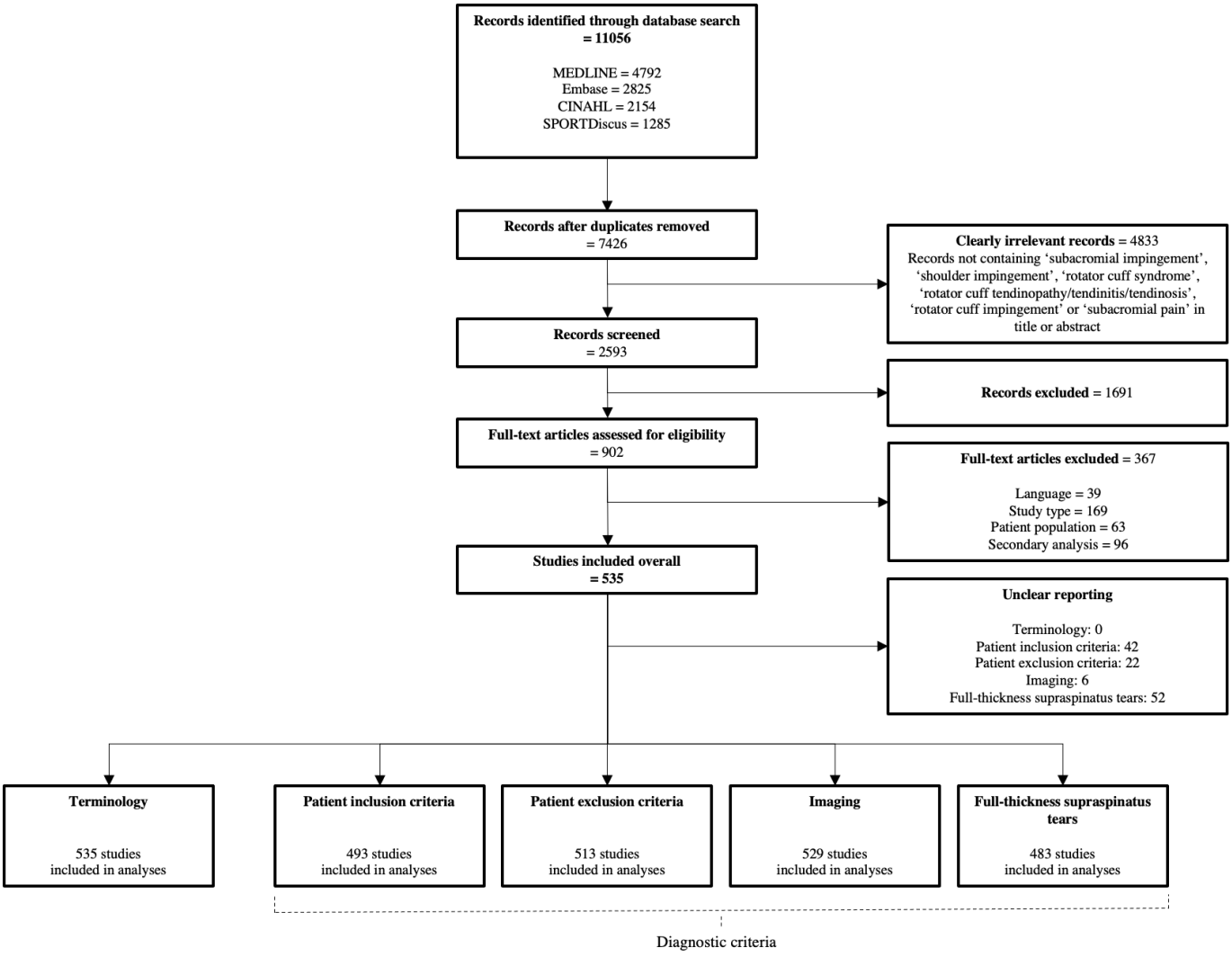

Figure 1 Flow diagram.

It is imperative to have clear and consistent terminology to communicate effectively. Terminology has shown to influence patients' perceived healthcare needs, with patients linking more mechanical terms, such as 'impingement' and 'rotator cuff tear', to an increased perceived need for surgery and imaging.[12] This emphasises the clinical importance of terminology.

The use of different terms for patients with SAPS may be reflected in the diagnostic criteria, with different terms linked to subgroups of patients with different diagnostic criteria. If so, it could explain the numerous different terms that are currently in use, although the inconsistent use of terms could also simply reflect different trends over time. An understanding of these factors could help one to navigate the literature.

The use of terminology and diagnostic criteria for patients with SAPS has not previously been mapped. Considering the high prevalence of SAPS, it is important to establish an overview of the use of terminology and diagnostic criteria to enable a more qualified and nuanced interpretation of the literature.

OBJECTIVE

The objective of this scoping review was to create an overview of (1) The terminology and (2) The diagnostic criteria used in studies investigating patients with SAPS. The specific objectives were to investigate:

1. The use of terminology across studies and time.
2. The patient-specific criteria used to include patients in the diagnosis of SAPS. *These are labelled patient inclusion criteria in this paper*.
3. The patient-specific criteria used to exclude patients from the diagnosis of SAPS. *These are labelled patient exclusion criteria in this paper*.
4. The use of imaging in diagnosing SAPS.
5. Whether patients with full-thickness supraspinatus tears are included or excluded from the diagnosis of SAPS.

METHODS

A scoping review approach was chosen because this is recommended to obtain an overview of the literature.[13] This review is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews guidelines.[14]

Eligibility criteria for the included studies

Any original study published in a peer-reviewed journal that investigated patients with SAPS was eligible for inclusion. Inclusion criteria: mentioning of subacromial impingement, shoulder impingement, rotator cuff syndrome, rotator cuff

Table 1 Terms used to describe patients with subacromial pain syndrome

Term	N	%
Impingement (summarised)	***454***	***75***
Subacromial impingement syndrome	167	28
Shoulder impingement syndrome	135	22
Subacromial impingement	52	9
Shoulder impingement	43	7
Impingement syndrome	35	6
Impingement	4	1
Rotator cuff impingement	4	1
Chronic impingement syndrome	3	< 1
Rotator cuff impingement syndrome	3	
Subacromial shoulder impingement	2	
Cuff impingement	1	
Internal shoulder impingement	1	
Subacromial impingement disease	1	
Shoulder outlet impingement syndrome	1	
Impingement tendinopathy	1	
Chronic shoulder impingement	1	
Tendinopathy/tendon-related (summarised)	***79***	***13***
Rotator cuff tendinopathy	74	12
Supraspinatus tendinitis	4	1
Supraspinatus tendon disease	1	< 1
Pain/disease/syndrome (summarised)	***71***	***12***
Subacromial pain syndrome	36	6
Rotator cuff syndrome	16	3
Rotator cuff disease	7	1
Subacromial pain	6	1
Subacromial shoulder pain	3	< 1
Rotator cuff related syndrome	1	
Painful shoulder syndrome	1	
Rotator cuff related shoulder pain	1	

27 unique terms were registered across 535 studies. A total of 604 terms were registered as some studies used more than one term.

tendinopathy/tendinitis/tendinosis, rotator cuff impingement or subacromial pain in the title or abstract. The following study types were included: prospective cohorts, retrospective cohorts, case-control studies, cross-sectional studies and case series. Protocol articles, secondary analyses from previous studies, pilot studies, reviews and in vitro studies were not included. Studies investigating SAPS within a population with another specified disease (e.g, the prevalence of SAPS in a population of paraplegic patients or patients with cancer) were also excluded, as were studies with less than 10 participants, and those presented in languages other than English, Danish, Swedish or Norwegian.

Information sources and search

The electronic databases MEDLINE (via PubMed), Embase, CINAHL and SPORTDiscus were systematically searched from inception to 10 June 2020. The search strategy was developed in cooperation with a biomedical librarian and adapted to fit the different electronic databases. The search string was built around the terms: shoulder impingement, subacromial impingement, subacromial pain, rotator cuff tendinopathy, rotator cuff impingement and rotator cuff syndrome. The specific search strings were adapted to the different databases and are available in the online supplemental appendix.

Selection of sources of evidence

All records were imported into EndNote (V.X8.2) where duplicates were identified and removed by one reviewer (AW). Records not containing the following in the title or abstract: subacromial impingement, shoulder impingement, rotator cuff syndrome, rotator cuff tendinopathy/tendinitis/tendinosis, rotator cuff impingement or subacromial pain were removed by computerised automation in EndNote. The remaining records were imported into the Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) and independently screened for title and abstracts by two reviewers (AW and KM). Full-text articles were assessed independently by two of three reviewers (AW, KM and TWM) for eligibility . Disagreements among the reviewers were resolved by dialogue. Articles were excluded in the following hierarchical order: language, study type, population, secondary analysis.

Data charting process

A data charting form was developed and tested in an iterative process before the final data extraction began.

Data items

The following data items were extracted: general study information (title, year of publication, authors and mean age of participants), terminology and diagnostic criteria.

Critical appraisal of individual sources of evidence

There was no formal assessment of study quality.

Synthesis of results

Terminology

Terms used to describe the patient population were extracted from title, abstract and manuscript, but not the reference list. Terms containing tendinopathy, tendinitis or tendinosis were merged in the same category (eg, rotator cuff tendinopathy and rotator cuff tendinitis were merged). If a study used more than one term, all terms were extracted. To establish an overview of the development in the use of terminology, the year of publication was extracted together with the terms. Studies published in 2020 were not part of this analysis (data extraction ended June 2020).

Diagnostic criteria

The diagnostic criteria were subcategorised into four categories: patient inclusion criteria, patient exclusion criteria, use of imaging and full-thickness supraspinatus tears. Studies with unclear or ambiguous reporting, within a given category, were excluded from the subsequent analyses.

Patient inclusion criteria

Patient inclusion criteria were extracted as literally as possible. Closely related criteria were merged in the same category.

Patient exclusion criteria

Specific shoulder pathology that excluded patients from study participation (patient exclusion criteria) was extracted as literally as possible. Closely related criteria were merged in the same category.

Imaging

Specified use of all types of imaging modalities were extracted. For each imaging modality, it was noted whether it was used to

rule in (e.g, a study using MRI to confirm the diagnosis), exclude other specific shoulder pathology (e.g, a study using radiographs to exclude glenohumeral osteoarthrosis), to both rule in and exclude other specific shoulder pathology (e.g, a study using ultrasound to confirm the diagnosis and exclude rotator cuff tears), or if the purpose was not specified.

Full-thickness supraspinatus tears

Supraspinatus tears were divided into partial tears and full-thickness tears. Partial tears were defined as tears not extending through the full thickness of the tendon, whereas full-thickness tears did, resulting in communication between the bursal side and the articular side.

RESULTS

Of the 11 056 records identified in the databases, 902 were retrieved for full-text screening and 535 were included in the study (figure 1). The reviewers had agreement of 88% for the title and abstract screening and 87% for the full-text screening. All disagreements were resolved by dialogue. The mean age of the included participants was 46 years.

All studies were included in the overview of terminology (figure 1). For the overview of diagnostic criteria some of the studies included had unclear or ambiguous reporting regarding patient inclusion criteria (42 studies, 8%), patient exclusion criteria (22 studies, 4%), use of imaging (six studies, <1%), and whether full-thickness supraspinatus tears were included or not (52 studies, 10%). These studies were excluded from the subsequent analyses. Thus 493 studies were included in the analyses regarding patient inclusion criteria, 513 for patient exclusion criteria, 529 for imaging and 483 for analyses on full-thickness supraspinatus tears (figure 1).

Terminology

Patients with SAPS were described with 27 unique terms across the 535 included studies. The terms could be classified under three main categories: An 'impingement category' (a mechanistic understanding), a 'tendinopathy/tendon category' (a structure-specific understanding), and a 'pain/disease/syndrome category' that does not identify pathology or mechanism. The most used term under each category was 'subacromial impingement syndrome', 'rotator cuff tendinopathy' and 'SAPS', respectively (table 1). Sixty-five (12%) studies were not consistent in their use of terminology and used two or more different terms interchangeably.

Development in the use of terminology (1972–2019)

Terminology has fluctuated (figure 2). 'Subacromial impingement syndrome' and 'shoulder impingement syndrome' have been the predominant terms used, but in recent years SAPS and 'rotator cuff tendinopathy' have been used increasingly. Since the introduction of SAPS, multiple terms have been in use continuously, and the terminology has never reached a high degree of consensus.

Diagnostic criteria

Patient inclusion criteria

Out of 493 studies, 335 (68%) reported the use of at least one shoulder test to diagnose SAPS (table 2), and 200 (41%) of the studies used a cluster of tests for the diagnosis. In total, 146 different test combinations were identified. The diagnostic criteria for the most common terms are presented in table 3. Often, a combination of physical examination tests was used, but a substantial proportion of the studies (15%–34%) did not report any diagnostic criteria. Studies that did report diagnostic criteria often used a combination of the following tests: Hawkin's, Neer's, Jobe's, painful arc, injection test and isometric

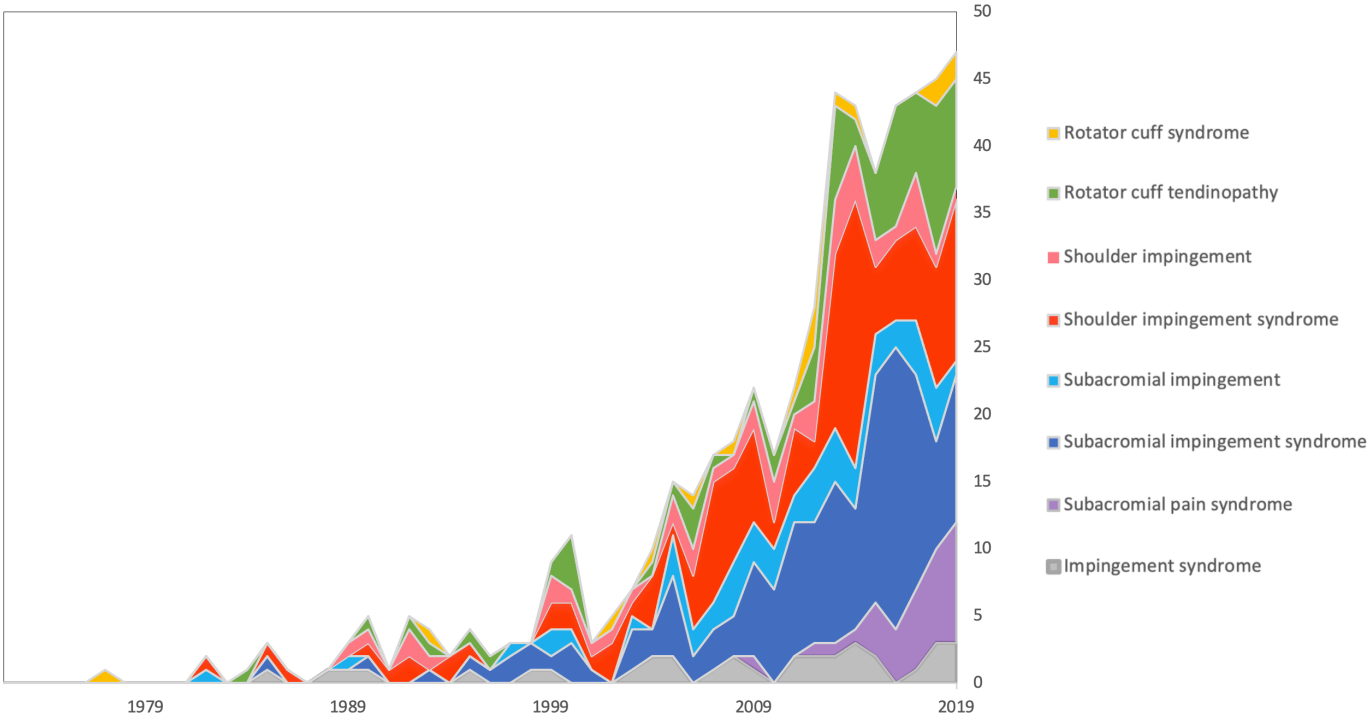

Figure 2 Terminology used in the period 1972–2019 to describe patients with subacromial pain syndrome. 587 terms were registered across 519 studies as some studies used more than one term.

Table 2 Physical examination tests and imaging modalities used to diagnose subacromial pain syndrome (patient inclusion criteria)

Name of test	Studies using test
Hawkin's	268 (54%)
Neer's	263 (53%)
Painful arc	155 (31%)
Jobe's	136 (28%)
Isometric external shoulder rotation	104 (21%)
Injection test	75 (15%)
Isometric shoulder abduction	67 (14%)
Pain from palpation of rotator cuff tendon(s)	57 (12%)
Active shoulder elevation pain	29 (8%)
Isometric internal shoulder rotation	21 (6%)
Speed's	11 (2%)
Pain from shoulder apprehension	9 (2%)
Yocum's	8 (2%)
Gerber's	8 (2%)
Drop arm	7 (1%)
Isometric shoulder flexion	6 (1%)
Shoulder relocation	6 (1%)
Cross-body adduction	5 (1%)
Lift off	5 (1%)
Patte's (Hornblower's)	5 (1%)
Full can	5 (1%)
Yergason's	3 (1%)
Resisted elbow flexion	2 (<1%)
Shoulder apprehension	2
External shoulder rotation lag sign	1
MRI	31 (6%)
Ultrasound	20 (4%)
Radiograph	10 (2%)

Use of physical examination tests (across 493 studies) and imaging modalities (across 529 studies) to diagnose patients with SAPS. A study can contribute with multiple (or no) tests and imaging modalities.

shoulder strength tests, though this varied considerably. The most used test combination was Hawkin's and Neer's, though this exact combination was only used in 19 (4%) studies.

Patient exclusion criteria

Out of 513 studies, 384 (75%) listed specific patient exclusion criteria. However, only 98 (19%) studies reported how other specific shoulder pathologies were diagnosed (table 4). The most frequently used patient exclusion criteria were rotator cuff tears, shoulder instability, cervical disorders, frozen shoulder, inflammatory arthritis and acromioclavicular joint pathology.

Imaging

Out of 529 studies, the most frequently used imaging modalities were radiography (154 studies, 29%), MRI (143, 27%) and ultrasound (133, 25%). Arthrography and CT were rarely used. The imaging modalities were primarily used to exclude other specific shoulder pathology, rather to rule in SAPS. The findings are presented schematically in table 5.

Full-thickness supraspinatus tears

Of the 483 studies, patients with full-thickness supraspinatus tears were excluded in 224 (46%) and included in 46 (10%) of the studies. Of the studies, 213 (44%) did not specify whether they included patients with full-thickness supraspinatus tears or not.

DISCUSSION

Our study shows that the terminology and the diagnostic criteria used to describe patients with SAPS varies considerably across studies and over time. Since 1972, the terminology has become increasingly heterogeneous owing to a steady introduction of new terms. In recent years, the terms SAPS and 'rotator cuff tendinopathy' seem to have overtaken the more mechanistic terms 'shoulder impingement' and 'subacromial impingement'. This, perhaps, represents a tendency to abandon Neer's mechanical impingement theory. It could also represent an evolving understanding of SAPS that leaves room for the mechanical impingement theory as one of many potential pain generating factors in play.

The heterogeneity across terms is problematic for clinicians as they attempt to provide patients with a diagnosis that is easily understood and communicated across all healthcare providers. Patients are most likely equally confused by what appears to be multiple terms for the same condition.

The diagnostic criteria used to identify patients with SAPS generally comprised physical examination tests, or combinations thereof, that provoked shoulder pain (tables 2 and 3). Hawkin's, Neer's, Jobe's, painful arc, injection test and isometric shoulder strength tests were often used in various combinations to make the diagnosis. The most used test combination (Hawkin's and Neer's) accounted for less than 4%. The diagnosis was sometimes supported by radiographs (29%), MRI (27%) and/or ultrasound (25%), primarily used to exclude other shoulder pathology (table 5). Therefore, it seems fair to conclude that SAPS is a clinical diagnosis characterised by subacromial pain with the absence of other shoulder pathology. This perspective is in line with a recent consensus paper from shoulder experts in North America and Europe.[15] However, despite this general view, a large variation in diagnostic criteria was seen across the included studies. The variation is so extensive that it can lead to contradictive use of the terms, when some studies use a specific shoulder test as a patient inclusion criterion, while other studies use the same shoulder test as a patient exclusion criterion (e.g, the drop arm-test or Speed's test). Consequently, some studies are not comparable. The most influential randomised controlled trials concerning the treatment of SAPS have considerable differences in diagnostic criteria.[16–21] When evidence is summarised across studies, potential heterogeneity in diagnostic criteria is usually not addressed specifically or given any consideration in the interpretation of the results.[22–25] Consequently, many guidelines, recommendations and reviews tend to neglect these differences in diagnostic criteria, although consideration of these could have significant implications for the interpretation and generalisability of the findings.[22–25] The findings of this study warrant an increased focus on potential population heterogeneity in future guidelines and reviews. Guidelines and reviews should consider downgrading evidence, according to the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) guidelines, [26] due to differences in diagnostic criteria.

The diagnostic criteria vary considerably *within* each of the different terms, but the diagnostic criteria do not seem to vary much *across* the different terms (table 3). This suggests that the heterogeneous terminology represents different aetiological viewpoints, or simply different traditions within scientific communities, rather than different patient populations or subgroups. The most common patient exclusion criteria were

Table 3 Diagnostic criteria for the most common terms

	Studies (n)	No diagnostic criteria	Other*	Hawkin's, Neer's, Jobe's, painful arc, external rotation resistance test	Hawkin's, Neer's, Jobe's, external rotation resistance test, tendon palpation pain	Hawkin's, Neer's, Jobe's, pain from apprehension test, relocation test	Hawkin's, Neer's, Jobe's, painful arc, isometric abduction pain, isometric external rotation pain	Hawkin's, Neer's, Jobe's, painful arc, drop arm-test, lift-off test	Hawkin's, Neer's, Jobe's	Hawkin's, Neer's, painful arc, injection test	Hawkin's, Neer's, injection test	Hawkin's, Neer's, painful arc	Hawkin's, Neer's, tendon palpation pain	Hawkin's, painful arc, injection test	Hawkin's, Neer's	Hawkin's	Painful arc, isometric abduction pain, isometric external rotation pain, isometric internal rotation pain	Isometric abduction pain, isometric external rotation pain, isometric flexion pain, isometric internal rotation pain, tendon palpation pain	Neer's, injection test	Neer's	Injection test	MR	Painful arc
Impingement (summarised)	*387*	*93 (24%)*	*175 (45%)*	*18 (5%)*	*2 (1%)*	*4 (1%)*			*11 (3%)*	*6 (2%)*	*8 (2%)*	*2 (1%)*	*3 (1%)*	*3 (1%)*	*19 (5%)*	*3 (1%)*			*7 (2%)*	*5 (1%)*	*19 (5%)*	*10 (3%)*	*2 (1%)*
Subacromial impingement syndrome	148	29 (20%)	57 (39%)	13 (9%)					6 (4%)	6 (4%)	6 (4%)				11 (7%)				4 (3%)		10 (7%)	6 (4%)	
Shoulder impingement syndrome	124	33 (27%)	66 (53%)			4 (3%)			5 (4%)				3 (2%)		5 (4%)	3 (2%)					5 (4%)		
Subacromial impingement	48	11 (23%)	22 (46%)	2 (4%)							2 (4%)	2 (4%)		3 (6%)							4 (8%)		2 (4%)
Shoulder impingement	35	9 (26%)	15 (43%)												3 (9%)				3 (9%)	5 (14%)			
Impingement syndrome	32	11 (34%)	15 (49%)		2 (6%)																	4 (13%)	
Tendinopathy/tendon-related																							
Rotator cuff tendinopathy	68	20 (29%)	34 (50%)	3 (4%)			5 (7%)										3 (4%)					3 (4%)	
Pain/disease/syndrome (summarised)	*48*	*8 (17%)*	*26 (54%)*					*2 (4%)*	*2 (4%)*	*5 (10%)*							*2 (4%)*						
Subacromial pain syndrome	33	5 (15%)	19 (58%)					2 (6%)	2 (6%)	5 (15%)													
Rotator cuff syndrome	15	3 (20%)	7 (47%)														2 (13%)	3 (20%)					

A study can be included under more than one term due to inconsistent terminology. 503 terms across 493 studies were included in the analyses.
*Less common diagnostic criteria (combined).

Table 4 Shoulder pathology used to exclude patients from having subacromial pain syndrome (patient exclusion criteria)

Shoulder pathology	Studies reporting pathology as a patient exclusion criterion	Studies reporting how the pathology was diagnosed
Rotator cuff tear	237 (49%)	68 (14%)
Shoulder Instability	204 (40%)	70 (14%)
Cervical disorder	190 (37%)	18 (3%)
Frozen shoulder	145 (29%)	30 (6%)
Inflammatory arthritis	134 (28%)	0
Acromioclavicular joint pathology	115 (23%)	8 (2%)
Glenohumeral osteoarthrosis	91 (18%)	0
History of shoulder trauma	87 (17%)	–
Neurological disorder	83 (16%)	0
Calcified tendinitis	72 (14%)	0
Labral injury	21 (4%)	2 (<1%)
Fibromyalgia	20 (4%)	0
Biceps tendon pathology	13 (3%)	3 (<1%)
Os acromiale	7 (1%)	0

483 studies were included in the analyses for rotator cuff tears and 513 studies were included in the remaining analyses. A study can contribute with multiple (or no) shoulder pathologies.

conditions characterised by shoulder pain, but it was only few of the studies that described how the conditions were diagnosed. This further hinders the generalisability of the findings, in most of the studies, and is something that should be taken into consideration. Imaging was not consistently used across studies, even though several of the patient exclusion criteria were conditions that require supportive imaging to diagnose. Studies that did use imaging most often did not specify the purpose of the use.

Interestingly, most of the studies did not include patients with full-thickness supraspinatus tears. This conflicts with Neer's original definition of SAPS as a progressive, non-traumatic condition attributable to 'mechanical impingement' and 'degenerative tendinitis' in the continuum from tendon oedema to complete rupture of supraspinatus tendon.[1] The findings of this study thereby exemplify a shift in the pathophysiological understanding of SAPS since Neer published his famous paper 50 years ago.[1] It is possible that this shift is reflected in the current use of terms, with the tendency to abandon the mechanistic terms 'subacromial impingement' and 'shoulder impingement'.

This is the first study to conduct a comprehensive review of the literature mapping the terminology and the diagnostic criteria concerning SAPS. The comprehensive search strategy was chosen to get the broadest perspective of studies investigating SAPS with as little selection bias as possible. This methodological approach adds to the overall sensitivity of the study. No formal methodological quality assessment of the included studies was performed. This could be considered a limitation, as low-quality studies might have a more diverse diagnostic approach, leading to increased heterogeneity between the included studies.

In summary, we found lack of consensus regarding the use of terminology and diagnostic criteria for SAPS. The heterogeneity is a significant scientific problem, making it very difficult, and often impossible, to compare studies, develop research and learn from the results. Considering that SAPS is one of the most common type of shoulder pain,[9–11] it is imperative to form a consensus within this area, to improve overall communication, and to improve future reporting, enabling a more qualified and nuanced interpretation of studies. Until a consensus is formed, future studies should judiciously consider their use of terminology. Potential new terms should not be introduced without good reason and careful consideration. Future studies should use a transparent diagnostic approach and a clear definition of the patient population. Studies should apply a meticulous methodological approach, especially concerning patient inclusion criteria and patient exclusion criteria, to ensure reproducibility and to aid in the interpretation and generalisability of the findings.

Implications and recommendations for studies investigating SAPS

We recommend using the term 'subacromial pain syndrome' to classify patients with subacromial pain without any identifiable pain-generating factor. The word 'subacromial pain' encapsulates the cardinal symptom of SAPS, and the word 'syndrome' recognises that the pathophysiology is not fully understood.

When classifying patients with SAPS, we recommend using a combination of physical examinations tests, and imaging, as other potential shoulder pathology, that can mimic the symptoms of SAPS, must be excluded. Common pathologies that must be excluded are glenohumeral osteoarthrosis, frozen shoulder, shoulder instability, full-thickness rotator cuff tears, and neurological and cervical disorders. We further advocate that calcified tendinitis, acromioclavicular osteoarthrosis and biceps tendinopathy are distinctively different conditions than SAPS, but can be viewed as concomitant pathology that does not exclude SAPS per se. For research purposes, we recommend using standardised and protocolised physical examination tests in combination, such as the Hawkin's, Neer's, Jobe's, painful arc, and external rotation resistance test, from which at least three must be positive, before patients can be classified as having SAPS.[27 28]

Table 5 Use of imaging modalities

Modality	To rule in SAPS	To exclude other pathology	To rule in SAPS, and to exclude other pathology	Purpose not specified	Total
Radiograph	6 (1%)	65 (12%)	4 (1%)	79 (15%)	154 (29%)
MRI	20 (4%)	37 (7%)	11 (2%)	75 (14%)	143 (27%)
Ultrasound	13 (2%)	42 (8%)	7 (1%)	71 (13%)	133 (25%)
Arthrography	0	7 (1%)	0	11 (2%)	18 (3%)
CT	0	0	0	3 (1%)	3 (1%)

Studies using a specific image modality to either rule in SAPS, exclude other pathology (such as osteoarthritis, rotator cuff tears and labral injury), or to rule in SAPS and exclude other pathology at the same time. Some studies did not specify the purpose of the image modality. 529 studies were included in the analyses.
SAPS, subacromial pain syndrome .

CONCLUSION

The terminology used to describe patients with SAPS varies considerably across studies and time. More mechanistic terms containing 'impingement' are used less than before, while SAPS is used increasingly. The diagnostic criteria were often based on physical examination tests, but many studies did not report any diagnostic criteria. Combinations of Hawkin's, Neer's, Jobe's, painful arc, injection test and isometric shoulder strength tests were the most often used, though this varied considerably across studies. Imaging was primarily used to exclude other pathologies, but was not used consistently. Patients with full-thickness supraspinatus tears were most often excluded, though many studies did not report whether they included or excluded these patients. In summary, studies investigating SAPS are heterogeneous to an extent that makes it difficult, and often impossible, to compare studies. Studies should be interpreted with care bearing this in mind.

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PAPER II

TITLE PAGE

Title

Prevalence of shoulder diagnoses in patients presenting with signs and symptoms of subacromial pain syndrome. A cross-sectional study in a secondary care setting.

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INTRODUCTION

Subacromial pain syndrome (SAPS) is recognized as the most common cause of shoulder pain [1–4]. There is consensus that patients with SAPS should be offered a structured physiotherapy regimen as first line of treatment, but it is only half of the patients that experiences satisfactorily symptom relief from this [5,6]. For patients with persisting symptoms, the surgical procedure arthroscopic subacromial decompression (ASD) can be considered. Prospective studies have generally reported good results from ASD [7–12]. However, randomized controlled trials have not found any clinically relevant effect of ASD compared to diagnostic arthroscopy [13,14]. This has brought forth arguments for the discontinuation of ASD [15,16]. With the present state of evidence-based knowledge, approximately half of the patients diagnosed with SAPS are left with unacceptable symptoms, and no further treatment options, if the current surgical treatment is discontinued without implementing a different approach.

Looking across studies investigating SAPS, there is a considerable variation in the diagnostic criteria, which could lead to heterogeneity in patients diagnosed with SAPS [12]. It has been theorized that the treatment of SAPS can be improved by appraising potential heterogeneity in patients with SAPS [19–23], but currently there is little evidence of this. Full-thickness supraspinatus tears, calcified tendinopathy, labral lesions, long head biceps tendon pathology, acromioclavicular osteoarthritis, and shoulder instability are diagnoses that may present in patients otherwise diagnosed with SAPS [4,24–27]. It can be debated whether these diagnoses have a direct causal relationship to the symptoms of SAPS, or if they can coexist with SAPS independently as concomitant diagnoses. Regardless of this, from a surgical perspective, these diagnoses are clearly differentiated for SAPS, as they are approached in a substantially different manner.

The prevalence of concomitant shoulder diagnoses, among patients with SAPS, is not known. Uncovering potential heterogeneity, among patients with SAPS, could be an important first step towards a more individualized treatment approach, improving the overall handling of these patients.

Objective

To investigate the prevalence of shoulder diagnoses in patients presenting with signs and symptoms of SAPS.

METHODS

Ethics

The study was registered and approved by the Regional Scientific Ethical Committee, Copenhagen Region (Reference no.:H-19025712). The protocol was uploaded to clinical trials (NCT05549674).

Study design

This was a cross-sectional study in a secondary care setting. Patients referred with insidious onset of shoulder pain were systematically screened for eligibility. Based on standardized physical examination tests, ultrasonography and radiographs, patients diagnosed with SAPS were systematically screened for the presence of the following *concomitant* shoulder diagnoses: biceps tendon pathology, superior antero-posterior labral tear (SLAP lesion), full-thickness supraspinatus tear, calcified tendinopathy, acromioclavicular osteoarthritis, minor shoulder instability and major shoulder instability.

Participants and inclusion procedure

Participants were recruitted consecutively from the outpatient clinic, Arthroscopic Center, Orthopaedic Department, Copenhagen University Hospital, Hvidovre, Denmark between Sep. 1, 2020 and Dec. 31, 2022. All patients (≥ 18 years) referred with insidious onset of shoulder pain to the outpatient clinic were screened for eligibility by orthopaedic shoulder specialists. Eligibility screening comprised a clinical examination with 17 standardized physical examination tests. Ultrasonography was used routinely as an adjuvant to differentiate between

diagnoses. Patients also underwent standardized radiographs of the glenohumeral and acromioclavicular joint to diagnose or exclude glenohumeral osteoarthritis, acromioclavicular osteoarthritis, and calcified tendinopathy. MRI was not used routinely.

Inclusion criteria

· Insidious onset of shoulder pain

· SAPS defined as: at least 3 out of 5 positive tests from the following: Hawkin's test, Neer's test, Jobe's test, painful arc and external resistance test.

Setting

Arthroscopic section, Orthopaedic Department, Copenhagen University Hospital, Hvidovre, Denmark employs 7 orthopaedic shoulder specialists treating shoulder patients on a regular basis (approximately 2 outpatient clinic days per week). The mean orthopaedic experience of the shoulder specialists was 14 years (range: 7-22 years) at the start of the study. The orthopaedic shoulder specialists all use shoulder ultrasonography as part of their normal clinical work. Ultrasonography was performed on Hitachi Arrieta V70 Diagnostic Ultrasound Systems.

On daily basis, the orthopaedic shoulder specialists each received a folder containing an individual screening sheet for every eligible shoulder patient on today's patient list. The orthopaedic shoulder specialist registered the results for each patient on the screening sheet according to the standardized testing procedure. If information was missing, the screening pages were returned to the orthopaedic shoulder specialist to be filled out.

Development and agreement on predefined diagnoses

The diagnostic criteria for all diagnoses were developed prior to the study in an iterative process. The study group and the orthopaedic shoulder specialists had three structured meetings over a six-month period where the diagnostic criteria were discussed and adjusted. The diagnostic criteria were adapted, based on the

orthopaedic shoulder specialists' feedback, to make sure that the diagnoses would reflect clinical practice in the closest possible way. Questions regarding the test procedure, including the performance of each physical examination test, were discussed, and resolved in agreement prior to the inclusion of patients. The physical examination tests were protocolized and standardized. A written guide of the diagnostic criteria and the physical examination tests were available to the orthopaedic shoulder specialists in the outpatient clinic.

Definition of diagnoses

The diagnoses, used in the present study, are defined below. Patients with SAPS could be diagnosed with more than one concomitant diagnosis. All tests are described in the appendix.

SAPS

· Insidious onset of shoulder pain

· At least 3 out of 5 positive tests from the following: Hawkin's test, Neer's test, Jobe's test, painful arc and external resistance test.

· No *conflicting shoulder-related diagnosis*

Patients diagnosed with SAPS were further investigated for the presence of *concomitant diagnoses.*

Conflicting shoulder-related diagnoses

Before patients can be classified as having SAPS, it is widely agreed that other shoulder-related diagnoses that may exhibit signs and symptoms similar to SAPS, but require a different treatment, shoulder be ruled out [18]. Systemic musculoskeletal disease, inflammatory joint disease (e.g. rheumatoid arthritis), symptomatic cervical pathology, frozen shoulder, glenohumeral osteoarthritis, fibromyalgia, previous surgery, fractures or radiotherapy in the shoulder girdle were considered as such, and ruled out before patients were classified as having SAPS.

A detailed description of the definition of the above-mentioned can be found in the appendix.

Isolated SAPS

Patients with SAPS, and no concomitant shoulder diagnosis, were diagnosed as having isolated SAPS.

Concomitant diagnoses in patients with SAPS

Calcified tendinopathy

A calcification in the supraspinatus or infraspinatus tendon larger than 5 x 5 mm in any dimension.

Rotator cuff tears

Rotator cuff tears were diagnosed with ultrasonography or MRI [28]. Tears were differentiated to be either partial thickness or full thickness. A partial thickness tear was defined as a lesion that did not involve the full thickness of the tendon. A full-thickness tear was defined as a tear that extended through the full thickness of the tendon (leading to an open connection between glenohumeral joint and subacromial space). Partial thickness tears were not considered a distinct diagnosis.

Long head biceps tendon pathology

The diagnosis was based on a clinical examination with findings of point tenderness in the bicipital groove and a positive Speed's test [29], a combination which have been shown to have a high correlation to histological tendinopathy changes in the biceps tendon [30]. Ultrasonographic, or clinical evidence, of a rupture of the long head biceps tendon was also registered under this category.

SLAP lesion

A SLAP lesion was defined as a positive O'Brien's test [12]. The diagnosis did not rely on MRI, as asymptomatic SLAP lesions, identified on imaging, are a normal age-related finding [13]. Patients with an acute SLAP injury (not insidious onset of shoulder pain) was not included.

Acromioclavicular osteoarthritis

Osteoarthritis of the acromioclavicular joint was diagnosed as: a positive cross-over test (cross-body adduction test) [31], recognizable pain at the acromioclavicular joint at palpation, and radiological signs of acromioclavicular osteoarthritis.

Shoulder instability

Shoulder instability was divided into two subgroups: minor shoulder instability and major shoulder instability.

Minor shoulder instability

Pain from the Apprehension test or Castagna's test [32], *but* no signs of major instability.

Major shoulder instability

'Anterior instability' was diagnosed as a positive apprehension test [33], or surprise test [34], and a positive Relocation test [33]. 'Posterior instability' was diagnosed as a positive jerk test [35].

Table 1: Physical examination tests and imaging systematically used to diagnose patients. A detailed description of the physical examination tests can be found in the appendix.

Physical examination test	Used to identify
Hawkin's	Subacromial pain
Neer's	Subacromial pain
Jobe's	Subacromial pain
Painful arc	Subacromial pain
External rotation resistance	Subacromial pain
Apprehension	Major shoulder
Relocation	Major shoulder
Surprise	Major shoulder
Jerk	Major shoulder
Castagna's	Minor shoulder
O'Brien's	SLAP lesion
Speed's	Biceps tendon
Long head biceps tendon palpation pain	Biceps tendon
Cross-over	Acromioclavicular
Acromioclavicular joint palpation pain	Acromioclavicular
Passive external shoulder rotation	Frozen shoulder
Passive shoulder flexion	Frozen shoulder
Imaging	**Used to identify**
Radiography (frontal and sagittal plane	Glenohumeral OA
	Calcified tendinopathy
	Acromioclavicular OA
Ultrasonography	Full-thickness rotator
	Calcified tendinopathy
	Biceps tendon rupture

Statistical method

Descriptive statistics were used to summarize the prevalence of concomitant shoulder diagnosis in patients presenting with signs and symptoms of SAPS. Descriptive statistics were also used to summarize patient demographics.

Sample size considerations

Based on an unpublished pilot study, the following distribution of patients was assumed; isolated SAPS: 40%, supraspinatus tears: 20%, long head biceps tendon pathology: 8%, SLAP lesions: 8%, acromioclavicular osteoarthritis: 8% major shoulder instability: 8%, minor shoulder instability: 8%. In total, 125 patients were needed to include 10 patients in the smallest group.

RESULTS

We systematically screened 3321 patients referred to the outpatient clinic during the 28 months inclusion period. We identified 741 patients referred with insidious onset of shoulder pain, of whom 576 fulfilled the inclusion criteria of at least 3/5 positive tests from the following: Hawkin's test, Neer's test, Jobe's test, painful arc and external resistance test. From these, 168 patients were diagnosed with conflicting shoulder-related diagnoses: frozen shoulder (n = 64), fibromyalgia (n = 28), glenohumeral osteoarthritis (n = 22), previous surgery (n = 15), frozen shoulder and glenohumeral osteoarthritis (n = 1), previous fracture in shoulder girdle (n = 10), cervical symptoms (n = 15), cervical symptoms and glenohumeral osteoarthritis (n = 2), cervical symptoms and fibromyalgia (n = 4), previous surgery in shoulder region and frozen shoulder (n = 2), previous surgery in shoulder region and glenohumeral osteoarthritis (n = 3), glenohumeral osteoarthritis and fibromyalgia (n = 1), previous fracture and frozen shoulder (n = 1). In total, 408 patients were diagnosed with SAPS. From these, 172 (42%) had at least one concomitant shoulder diagnosis, and 55 of those (32%) were diagnosed with multiple concomitant diagnoses. In total, 22 different combinations of concomitant

diagnoses were observed across the 172 patients. The mean age was 56 years (SD± 13), and 234 (57%) were women.

Figure 1: Flow diagram of patients

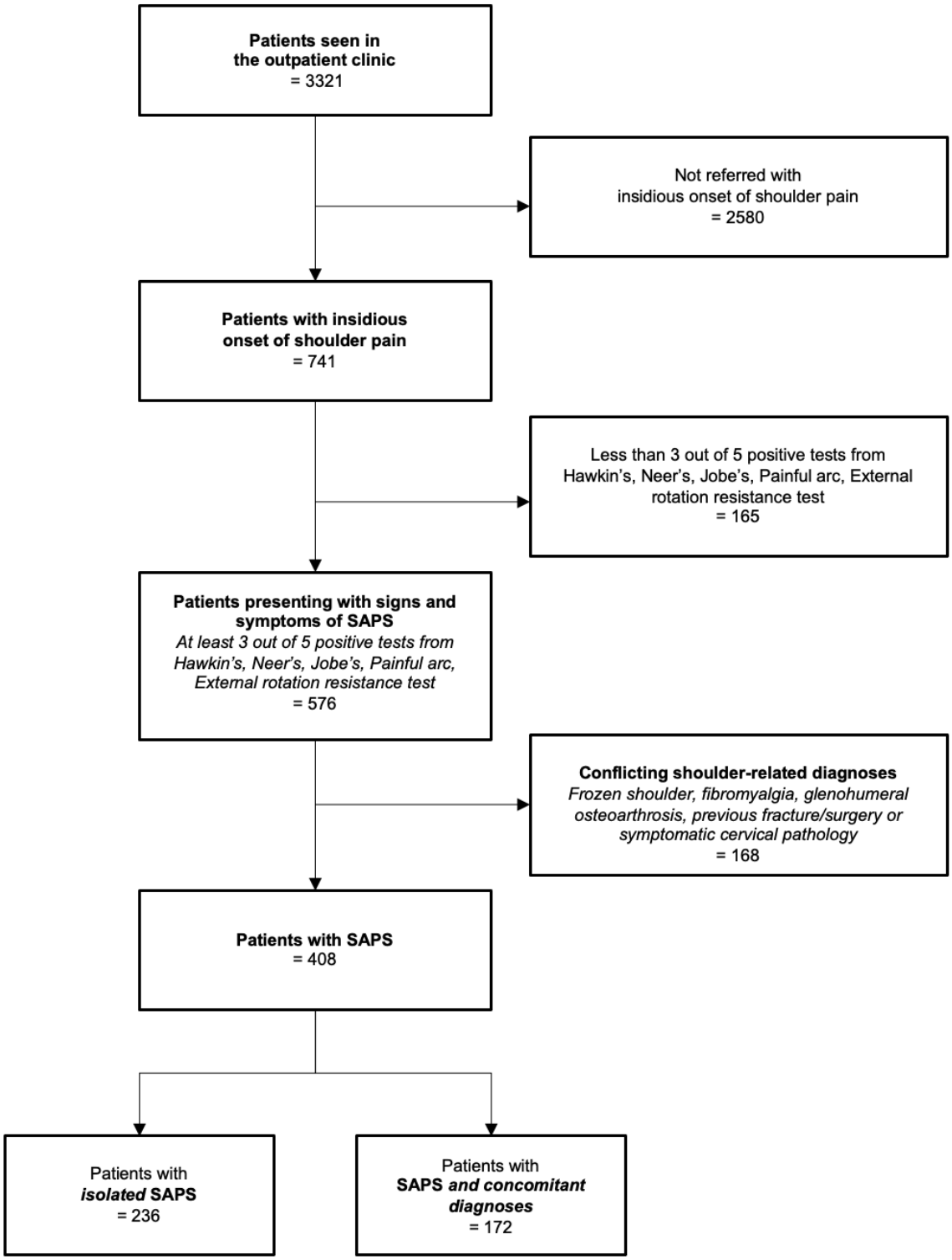


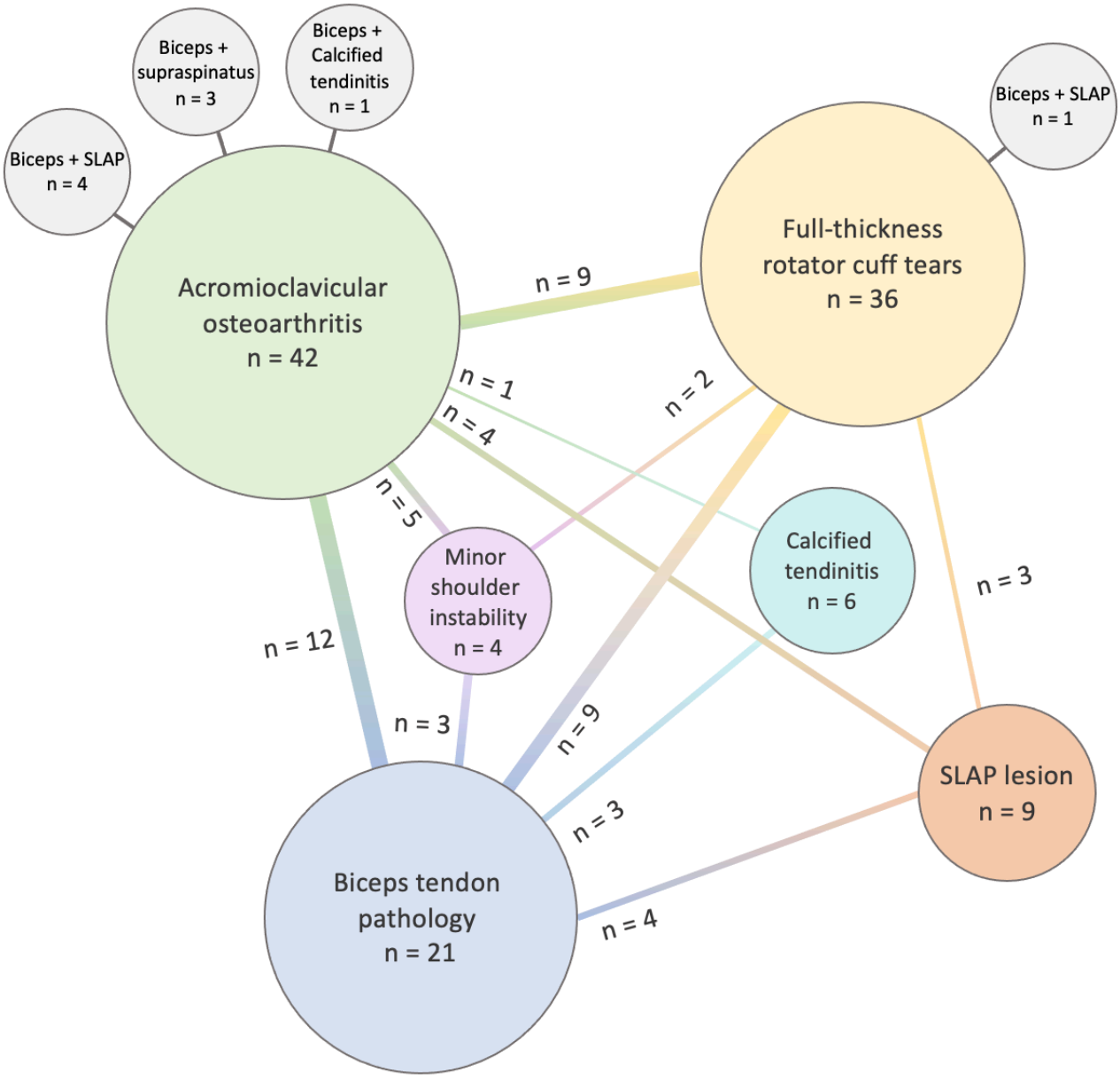
Table 2: Combinations of diagnoses in patients with SAPS

Of the 408 patients with SAPS, 236 had isolated SAPS and 172 had SAPS and at least one concomitant diagnosis. From these, 76 patients had acromio-clavicular osteoarthritis, 60 had rotator cuff tears, 57 had biceps tendon pathology, 20 had SLAP lesions, 14 had minor shoulder instability and 7 had calcified tendinopathy in total.

	n	%
Isolated SAPS	**236**	**-**
SAPS with concomitant diagnoses	**172**	**100**
Acromioclavicular osteoarthritis (OA)	42	24
Acromioclavicular OA + Biceps tendon pathology	12	7
Acromioclavicular OA + Supraspinatus tear	9	5
Acromioclavicular OA + Minor shoulder instability	5	3
Acromioclavicular OA + Biceps tendon pathology + SLAP lesion	4	2
Acromioclavicular OA + Supraspinatus tear + Biceps tendon pathology	3	2
Acromioclavicular OA + Biceps tendon pathology + Calcified tendinopathy	1	1
Rotator cuff tears (Supra* = 3; Supra + Infra* = 4; Subscap* = 1)	36	21
Rotator cuff tear + Biceps (Supra = 6; Supra + Infra = 1; Supra + Infra + Subscap = 1)	8	5
Supraspinatus tear + SLAP lesion	2	1
Supraspinatus tear + Minor shoulder instability	2	1
Supraspinatus tear + Biceps + SLAP lesion	1	1
Biceps tendon pathology (2 complete ruptures)	21	12
Biceps tendon pathology + SLAP lesion	4	2
Biceps tendon pathology + Minor shoulder instability	3	2
SLAP lesion	9	5
Minor shoulder instability	4	2
Calcified tendinopathy	6	3
Major shoulder instability	0	0

**Abbreviations: SLAP = Superior Labrum Anterior to Posterior; Supra = supraspinatus; Infra = infraspinatus; Subscap = subscapularis.*

Figure 2: Combinations of concomitant diagnoses in patients with SAPS. Coloured circles represent the number of SAPS patients with one concomitant diagnosis. Combinations, with two types, of concomitant pathologies are represented by connecting lines and adjacent numbers. The smaller circles represent combinations with three types of concomitant diagnoses. 172 patients are represented in the figure.



DISCUSSION

The most important finding was that 42% of the 408 patients with SAPS had at least one concomitant shoulder diagnosis. Patients with SAPS and concomitant diagnoses represent a heterogenous group, encompassing several potential pain-contributing foci from different anatomical structures. The impact of concomitant diagnoses, in the treatment of SAPS, has not yet been established, but it is plausible that treatment exclusively focused on the subacromial structures may lead to inferior outcomes in these patients. Inattention to concomitant diagnoses could therefore lead to underestimation of treatment effects in both non-surgical and surgical trials. The best treatment strategy, for patients with SAPS and concomitant diagnoses, may involve addressing structures beyond the subacromial space, through tailored interventions based on individual pathophysiological findings. Further research is needed to elucidate this.

In this study, we found 22 different combinations of concomitant diagnoses, in patients otherwise diagnosed with SAPS, and one in three patients were diagnosed with multiple concomitant diagnoses. This emphasizes the overall complexity of patients with SAPS and underpins the potential of establishing a more individualized approach. Acromioclavicular osteoarthritis, full-thickness supraspinatus tears and long head biceps tendon pathology were the most common concomitant diagnoses. SLAP lesion, minor shoulder instability and calcified tendinopathy were also observed, though less frequently. From the idea that concomitant diagnosis potentially requires additional treatment apart from addressing the subacromial space, patients should be screened for at least these six types of frequently present concomitant diagnoses. None of the included patients were diagnosed with major shoulder instability, suggesting that major shoulder instability does not commonly provoke signs and symptoms of SAPS.

The most observed concomitant diagnosis was acromioclavicular osteoarthritis. The suspicion of acromioclavicular osteoarthritis arises when pain is found at the acromioclavicular joint. As the subacromial bursa reaches under the acromioclavicular joint, difficulty may arise in discerning whether the symptoms

arise from the joint or the bursa. Suspected acromioclavicular osteoarthritis should therefore be confirmed by radiographs. However, the diagnosis should not rely on imaging alone as asymptomatic acromioclavicular degenerative findings are common [36].

We found a high prevalence of full-thickness rotator cuff tears in the present study, most often supraspinatus tears. This is an interesting finding as most studies, investigating patients with SAPS, aim to exclude patients with full-thickness supraspinatus tears [17,18]. While a complete rupture of a rotator cuff tendon (a full-thickness tear with no attachment at the footprint) often can be identified from physical examination tests alone, full-thickness tears with remaining attachment can be difficult to diagnose with physical examination tests alone. It is generally recommended to use ultrasonography (or MRI) to diagnose rotator cuff tears [37,38]. This should be utilized in patients with SAPS, if the aim is to identify patients with full-thickness rotator cuff tears.

Biceps tendon pathology were also observed frequently, and often in combination with other concomitant diagnoses. Complete ruptures of the long head biceps tendon can often be identified visually due to obvious muscle deformity. We identified two of such cases.

Conflicting shoulder-related diagnoses

From the 576 patients presenting with signs and symptoms of SAPS, a considerable proportion (n = 168, 29%) were diagnosed with a conflicting shoulder-related diagnosis, and thus, not diagnosed with SAPS. Most of these patients were diagnosed with a frozen shoulder (n = 72), which highlights this as an important differential diagnosis in patients presenting with signs and symptoms of SAPS. Glenohumeral osteoarthritis was seen in 5% (n = 29) of the patients presenting with signs and symptoms of SAPS. While glenohumeral osteoarthritis can be asymptomatic, it is difficult to discriminate the pain from that of SAPS. Routine use of radiographs should therefore be considered to identify patients with glenohumeral osteoarthritis. Symptomatic cervical spine pathology was seen in 4%

(n = 21) of the patients presenting with symptoms of SAPS. It was not a frequently observed pathology, but it does require a vastly different treatment approach than SAPS, and therefore, should not be missed.

Prevalence of SAPS

In this study, we found that 55% of all patients, referred with insidious onset of shoulder pain to our secondary care institution, were diagnosed with SAPS. Previous studies have found SAPS to be the most common cause of shoulder pain in the primary sector [1,39], while the prevalence of SAPS in a secondary care setting only has been investigated sparsely [3]. This study seems to confirm SAPS being the most common cause of shoulder pain in a secondary care setting. The high prevalence emphasizes the need for further research for this patient group.

The clinical importance of concomitant diagnoses in patients with SAPS remains uncertain, but the high prevalence of concomitant diagnoses underpins the need for a systematic and transparent approach, to enable a qualified interpretation of studies. Studies should consider using ultrasound and radiographs to investigate for diagnoses of concomitant diagnoses that may require a different treatment approach. Patients with concomitant diagnoses should be thoroughly accounted for to enable a qualified interpretation of findings in future studies.

Strengths and weaknesses

The strict methodology, with systematic screening of patients and predefined diagnostic criteria, is a major strength that ensures high reproducibility of the findings.

CONCLUSION

Patients presenting with signs and symptoms of SAPS have a high prevalence of other shoulder-related diagnoses. This signifies that patients suspected of SAPS should undergo systematic screening to identify potential conflicting diagnoses and concomitant diagnoses that might require alternative treatment strategies.

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PAPER III

TITLE PAGE

Title

Bilateral ultrasonographic findings in patients with unilateral subacromial pain syndrome and intact rotator cuff tendons

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INTRODUCTION

Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain [1,2]. Despite its clinical significance, the etiology is not completely understood. The etiology is hypothesized to be multifactorial, involving a complex interplay of potential structural abnormalities and pathological changes within the subacromial space [3]. Commonly proposed abnormalities are thickening of the subacromial bursa and supraspinatus tendon, narrowing of the subacromial space (acromio-humeral distance; AHD), and impingement, in which the subacromial structures impinges against the acromion during shoulder elevation [4–10].

Ultrasonography has become an increasingly valuable diagnostic tool in the evaluation of shoulder conditions, providing a non-invasive, cost-effective, and dynamic imaging modality [11]. Ultrasonography can be utilized to quantitatively assess the subacromial structures, having demonstrated a high reliability doing so [11–13]. The majority of the existing literature, investigating subacromial structures with ultrasonography, have focused on unilateral shoulder assessments with comparison to healthy controls [6,8,9,14]. This approach does not consider individual variations of the subacromial structures between patients. Utilizing the healthy contralateral shoulder as a control can minimize unrecognized individual variations of the subacromial structures, which could provide a more qualified insight into the fundamental pathophysiological characteristics of SAPS. Previous studies have primarily focused on one or two subacromial structures at a time, seldom considering all subacromial structures collectively. The interaction between the subacromial structures is poorly understood, and it is possible that relationships could be overlooked if the subacromial structures are assessed individually. This could lead to an incomplete understanding of the pathophysiological characteristics of SAPS.

It remains uncertain whether there are differences between the affected and unaffected shoulder in patients with SAPS. Elucidating the ultrasonographic manifestations of SAPS holds the potential to refine diagnostic criteria and improve

the understanding of its etiology. These insights could also provide perspectives on potential risk factors for the development of SAPS.

The aim of this study was to assess the discriminative validity of ultrasonography to identify patients with SAPS.

METHODS

Ethics

The study was registered and approved by the Regional Scientific Ethical Committee, Copenhagen Region (Reference no.:H-19025712).

Study design

This was a cross-sectional study investigating patients with unilateral, isolated SAPS (no concomitant shoulder diagnoses). Standardized ultrasonographic measurements were performed on the affected shoulder and the unaffected shoulder. The study was part of a larger cohort of patients with SAPS. None of the data in this study have previously been published.

Setting

Participants were recruited consecutively from the outpatient clinic, Arthroscopic section, Orthopaedic Department, Copenhagen University Hospital, Hvidovre, Denmark, between September 1, 2020, and December 31, 2022.

Patients and inclusion procedure

All patients (≥ 18 years) referred with insidious onset of shoulder pain to the orthopaedic outpatient clinic were screened for eligibility. Screening was conducted by orthopedic shoulder specialists. The screening consisted of a clinical examination with 17 standardized physical examination tests (described in detail in a previous study REF til PhD-studie nr. 2), shoulder ultrasonography and glenohumeral and acromioclavicular radiographs to identify potential concomitant

shoulder diagnoses. Patients with isolated SAPS, fulfilling the inclusion criteria, were invited to participate in the study. Upon agreement, a date was scheduled for the ultrasonography examination.

Inclusion criteria

Patients were eligible for inclusion based on the following criteria: Insidious onset of shoulder pain, at least 3 out of 5 positive tests from the following: Hawkin's test, Neer's test, Jobe's test, painful arc and external resistance test; insidious onset of shoulder pain (SAPS diagnosis)

Exclusion criteria

A) Terminal illness or severe medical illness (ASA score higher than or equal to 4); Systemic musculoskeletal disease; Inflammatory joint disease (e.g. rheumatoid arthritis); Symptomatic cervical spine pathology; Thoracic outlet syndrome; Frozen shoulder; Previous surgery, fracture or radiotherapy in the affected shoulder region; Glenohumeral osteoarthrosis (OA). B) Acromioclavicular OA; Full-thickness rotator cuff tears (communication between glenohumeral joint and subacromial space); Shoulder instability; Long head biceps tendon pathology; Labral lesions; Calcified tendinitis (calcifications exceeding 5 x 5 mm) C) Contralateral shoulder symptoms (no episode of non-traumatic pain in the contralateral shoulder during the past 3 months). D) Subacromial corticosteroid injection during the past 3 months. E) Examination not possible before iniation of physiotherapy.

Ultrasonographic examination

The following bilateral measurements were conducted: subacromial bursa thickness (two positions), supraspinatus tendon thickness (two positions), AHD (one positions), and presence of ultrasonographic impingement (dynamic scan). The ultrasonographic examination were applied in accordance with a previously described method reporting good to excellent intra- and interrater reliability of all measurements when performed by experienced sonographers. [12]. Accordingly,

ICC(2,3) has been reported between 0.82 and 0.99, and Kappa has been reported to be 0.96 and 0.82 for intra- and interrater reliability, respectively. The reliability has been reported to be lower in novice sonographers, ranging from poor to good [15]. All ultrasonographic examinations were performed by the first author, an arthroscopic shoulder specialist familiar with the ultrasonographic measurements. Ultrasonography was performed on a Hitachi Arrieta V70. The scanning positions and measurements are summarized in table 1.

Table 1: Overview of the ultrasonographic measurements

Legend: This table provides an overview of the ultrasonographic measurements. These were performed in accordance with a previously described method, explained in detail by Kjær et al [12].

Measurement	Scanning position	Transducer position	Evaluation
Supraspinatus tendon	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Supraspinatus tendon	Hand behind the back *(internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Subacromial bursa	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Subacromial bursa	Hand behind the back (internal rotation)	Just anterior to the anterolateral acromion, perpendicular to the tendon longitudinal axis, 2 cm from the lateral border of the supraspinatus footprint	Thickness (mm)
Acromio- humeral distance	Hand resting on hip *(approx. 45 degrees abduction and internal rotation)*	At the most anterolateral aspect of the acromion, measuring the shortest distance to the humeral head in the longitudinal axis.	Distance (mm)
Ultrasonographic impingement	Dynamic abduction and internal rotation	At the most anterolateral aspect of the acromion (longitudinal axis)	Yes / no

Background characteristics

The following background characteristics were registered: age, gender, height, weight, symptom duration and handedness.

Sample size calculation

Using a two-sided paired-samples T-test, a desired power of 0.9, a significance level of 0.05 and an effect size of 0.5, 44 patients were needed for analyses regarding continuous data. For categorical data, estimated proportions of ultrasonographic impingement were assumed to be 0.5 and 0.08 in affected and unaffected shoulders, respectively, based upon previous findings [16]. Using a one-sided chi-square test, a power of 0.8, and a significance level of 0.05, 46 patients were needed for the analyses for categorical data.

Statistics

Each patient served as their own control. It was assumed that age, gender, BMI, and symptom duration did not have a confounding effect, as it was assumed improbable that these factors would impact the measurements of affected and unaffected shoulders differentially. SAPS in the dominant shoulder was investigated for a potential confounding effect. Individual linear regression analyses were run to determine the relationship between SAPS in the dominant shoulder and each of the measurements in both affected and unaffected shoulders. There was no statistically significant relationship between SAPS in the dominant shoulder and any of the measurements. The paired samples t-test was used for continuous data, while the chi-square test was used for nominal data. Normal distribution for continuous data was visually confirmed by histograms. An alfa-level of 0.05 was used for all analyses. Statistics were handled in IBM SPSS Statistics for Windows, Version 28.0.

RESULTS

Ninety-four patients with isolated SAPS were eligible in the inclusion period. Of these, 36 patients were excluded due to bilateral symptoms. In total, 58 patients were included in the study. Six patients had so pronounced symptoms that they were unable to put the arm behind the back or participate in the dynamic evaluation. Five patients could not obtain the intended scanning position with the hand on the hip due to their visceral body composition. In these cases, the corresponding ultrasonographic measurements were not obtained. Demographics are presented in table 2. The results of the ultrasonographic measurements, and comparisons between affected and unaffected side, are presented in table 3. The proportion of ultrasonographic impingement differed significantly between affected and unaffected side (87% vs. 35%, p=0.04). No further significant differences were found.

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146 **Figure 1: Flow of patients**

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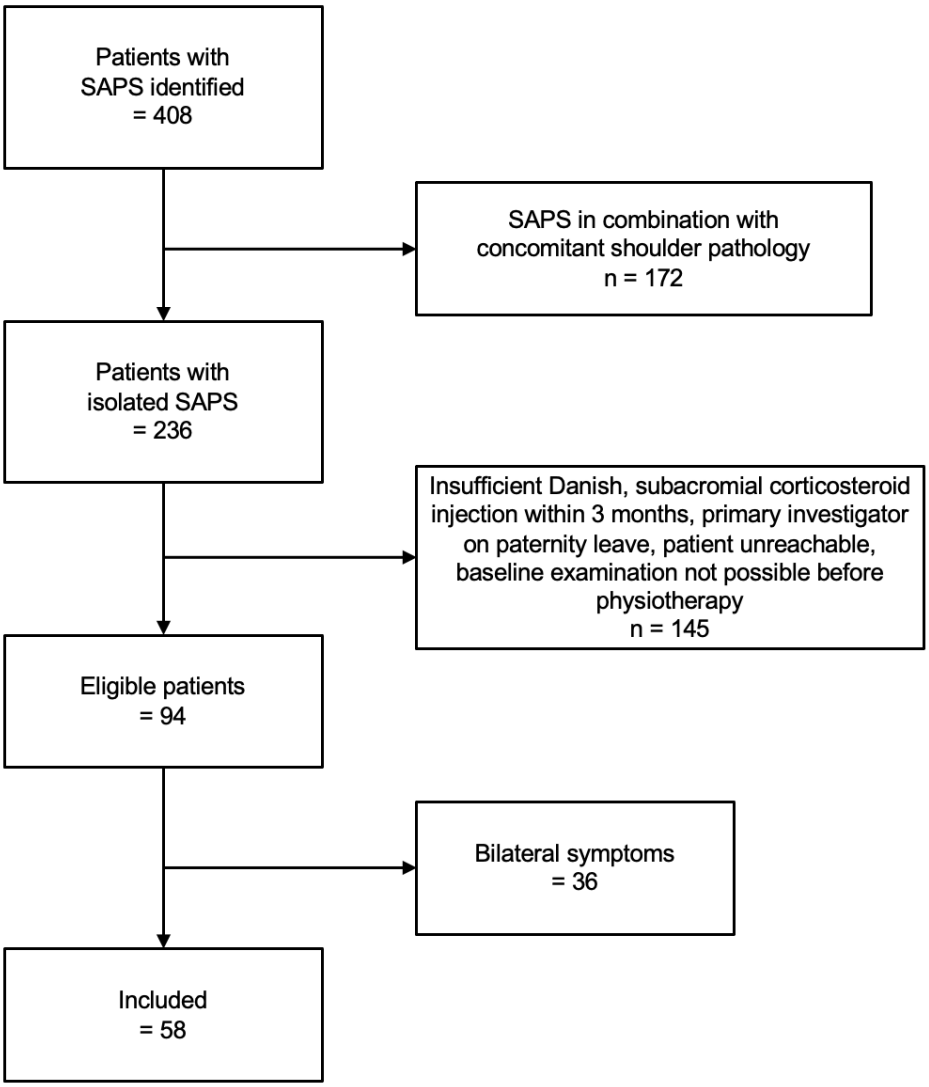

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Table 2: Demographics

Number of patients	58
Age	51.4 (SD ±11.8)
Women	64%
BMI	26.8 (SD ±4.96)
Dominant shoulder affected	71%
Symptom duration	32 months (SD ±44), median: 18 months

Values are presented as mean, unless stated otherwise.

Table 3: Ultrasonographic measurements comparing the affected to the unaffected shoulder

		Shoulder		P-value	
	N	Affected	Unaffected	One-sided	Two-sided
Supraspinatus tendon Position: Hand on hip	53	5.46 mm (SD ±1.11)	5.47 mm (SD ±1.03)	n.s.	n.s.
Supraspinatus tendon Position: Hand behind back	52	5.42 mm (SD ±1.12)	5.50 mm (SD ±0.92)	n.s.	n.s.
Subacromial bursa Position: Hand on hip	53	2.03 mm (SD ±0.53)	1.93 mm (SD ±0.53)	n.s.	n.s.
Subacromial bursa Position: Hand behind back	52	1.91 mm (SD ±0.55)	1.86 mm (SD ±0.54)	n.s.	n.s.
Acromio-humeral distance Position: Neutral, relaxed	58	11.16 mm (SD ±2.03)	11.06 mm (SD ±2.10)	n.s.	n.s.
Ultrasonographic impingement Dynamic scan	52	Present: 45 Not present: 7	Present: 18 Not present: 34	P = 0.04	

DISCUSSION

The two most important findings of this study were that ultrasonographic impingement was more frequently observed in affected shoulders compared to unaffected, and that there were no significant differences in the measurements of the subacromial bursa, supraspinatus tendon or AHD. These findings highlight ultrasonographic impingement as a possible contributing factor for SAPS, independent of measurable variations of the subacromial bursa, supraspinatus tendon and AHD.

The high prevalence of ultrasonographic impingement in affected shoulders (87%) is a notable finding. It must also be recognized that there were a considerable proportion of false-positive findings as ultrasonographic impingement was also seen in 35% of the unaffected shoulders. There are several possible explanations for this. It is possible that ultrasonographic impingement is unrelated to the development of SAPS, but nevertheless is seen more frequently in painful shoulders. This could hypothetically be attributed to changes in glenohumeral kinematics arising as a consequence of shoulder pain, regardless of its origin. Conversely, the occurrence of ultrasonographic impingement in unaffected shoulders could suggest that ultrasonographic impingement is an early phenomenon in the preclinical stage of SAPS. It is possible that shoulders could be in a prodromal phase, where impingement is present, but symptoms have not yet manifested. Few studies have investigated impingement as a pathogenetic phenomenon of SAPS, and their definitions and findings are heterogeneous [5,6,16,17]. Read et al. (1998) defined impingement as ultrasonographic bulging of the supraspinatus tendon, similar to the definition in this study. They reported high sensitivity and specificity when compared to surgical findings [5]. Bureau et al. (2006) graded impingement on a scale that ranged from “pain during movement (with no ultrasonographic impingement)” to soft-tissue impingement/upward migration of the humeral head” [16]. They found higher prevalence of impingement in patients with SAPS compared to controls, but also found asymptomatic cases (7-25% depending on the definition of impingement). This is in line with the findings of

the present study. Daghir et al. (2012) defined impingement quantitively by the amount of bursal fluid accumulating lateral to the acromion during abduction [6]. They compared patients with SAPS and healthy controls and found no difference between SAPS and controls. Soker et al. (2001) had a similar definition to Daghir, but reported a significant difference between patients with SAPS and controls [17]. As to the knowledge of the authors, no other study has used the contralateral shoulder as control before.

The lack of significant differences in the thickness of the subacromial bursa between affected and unaffected shoulders is another noteworthy finding, one that challenges the prevailing understanding of SAPS. Accordingly, thickening of the subacromial bursa, and accompanying fluid accumulation within, is generally believed to be one of the pathognomonic findings of SAPS [17]. This prevailing belief could potentially originate from the facts that full-thickness supraspinatus tears are regularly encompassed within the SAPS entity [18,19], and that the subacromial bursa have been reported to be thickened in patients with full-thickness supraspinatus tears [20–22]. It must also be noted that variations in scanning positions can influence the measured thickness of the subacromial bursa [14], and that there is a high prevalence of asymptomatic findings in shoulder ultrasonography, including large bursa thickness [23]. Consequently, the prevailing understanding of SAPS could be susceptible to an unacknowledged confirmation bias towards the commonly accepted notion of bursal thickening, as studies seldom use blinded raters.

In this study, no group differences in supraspinatus tendon thickness was found between affected and unaffected shoulders. This is an interesting finding, as the supraspinatus tendon has generally been reported to be to be thicker in patients with SAPS [8,9,14]. However, opposing findings, with decreased supraspinatus tendon thickness, have also been reported [7]. Although speculative, a possible theory for these contrasting findings could be that the thickness of the supraspinatus tendon increases in the acute stage of SAPS, but subsequently decreases over time. This could theoretically be attributed to atrophy resulting from

reduced activity owing to functional-impairing shoulder pain. Nevertheless, this does not provide an explanation for the lack of significant differences found in the present study.

No difference in AHD between affected and unaffected shoulders was found in this study. The role of AHD in SAPS is not entirely understood. Decreased AHD intuitively supports the theory of impingement as being the primary pain-generating mechanism of SAPS. However, a decrease in AHD does not intuitively align with the increased thickness of the subacromial bursa and supraspinatus tendon, that are generally reported in patients with SAPS. The findings of this study compare well to a systematic review that did not find any correlation between AHD and SAPS [24].

The findings of the present study nuance the current understanding of SAPS. Ultrasonographic impingement was more frequent in affected shoulders, but in contrast we did not detect any significant differences in measurements of subacromial structures. Because the only observable difference, between affected and unaffected shoulders, was seen during movement, the overall findings suggest that the symptoms arise, at least in part, from altered glenohumeral kinematics. A possible explanation for this could be that pain arises independent of structural changes, and leads to altered glenohumeral kinematics which causes ultrasonographic impingement. The presence of impingement could, in turn, potentially be an independent pain-generating factor, thus creating a self-perpetuating cycle, maintaining prolonged symptoms.

It must be recognized that SAPS is a complex and dynamic condition that involve multiple factors beyond structural abnormalities alone. It is plausible that these non-structural factors have a more substantial influence on the development and maintenance of symptoms, overshadowing the potential impact of subtle differences in structural changes. Longitudinal studies, capturing the transitioning of asymptomatic shoulders to symptomatic, are necessary to fully elucidate the underlying pathological mechanisms of SAPS.

Strength and weaknesses

The standardized and validated ultrasonographic measurements are a strength that increases the reproducibility and transparency of the findings. The inclusion of a homogenous patient group, systematically screened for concomitant shoulder diagnoses, is another strength that provide well-suited circumstances for exploring the presumed pathophysiological mechanisms of SAPS. The study is limited by the lack of blinding of the rater. It must also be noted that Bonferroni-correction were not made.

CONCLUSION

In this cohort of patients with isolated unilateral SAPS, we found more cases of ultrasonographic impingement in affected shoulders compared to unaffected, but no significant differences in the supraspinatus tendon, subacromial bursa or AHD. These findings question the dogma of thickened subacromial structures being one the primary etiological explanation for SAPS.

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Interrater reliability of subacromial ultrasound measures in the hands of novice sonographers. *Dan Med J 2023;70(11):A05230285*
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Interrater and intrarater reliability of four different classification methods for evaluating acromial morphology on standardized radiographs.
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Shoulder pain – you need to know the past to understand the present
BJSM blog post, April 28, 2023. https://blogs.bmj.com/bjsm/2023/04/28/shoulder-pain-you-need-to-know-the-past-to-understand-the-present/
Adam Witten, Mikkel Bek Clausen, Kristian Thorborg, Per Hölmich and Kristoffer Weisskirchner Barfod.

Clavicle fractures does not increase the incidence of later diagnosis of subacromial impingement syndrome. A case-control study of 131.838 persons
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21 APPENDIX

DETAILED DESCRIPTION OF PHYSICAL EXAMINATION TESTS

Hawkin's test

The examiner places the patient's shoulder in 90 degrees abduction with the elbow into 90 degrees flexion, in the scapular plane. The examiner internally rotates the patient's shoulder. The test is positive if recognizable shoulder pain is reproduced.

Neer's test

The examiner places one hand on the back and top of the patient's shoulder (to avoid scapular protraction and external rotation). With the other hand, the examiner then flexes the patient's shoulder from 0 to 180 degrees. The test is positive if recognizable shoulder pain is reproduced.

Jobe's test

The patient is instructed to put both shoulders in 90 degrees flexion in the scapular plane and in internal rotation (thumbs pointing down). The patient is instructed to hold the position while the examiner applies downward force on the patient's forearms. The test is positive if recognizable shoulder pain is reproduced.

Painful Arc

The patient is instructed to abduct the shoulder in the coronal plane. The test is positive if recognizable shoulder pain is reproduced with maximum pain experienced between 60 to 120 degrees abduction.

External rotation resistance test (resisted isometric external shoulder rotation)

The patient is instructed to flex both elbows to 90 degrees. The patient is thee instructed to hold the position while the examiner applies (internal rotational) force on the patient's distal forearms. The test is positive if recognizable shoulder pain is reproduced.

Apprehension test

The patient is lying supine. The shoulder is abducted to 90 degrees with the elbow in 90 degrees flexion. Using the forearm as a lever, the examiner externally rotates the patient's shoulder forcing the humeral head anteriorly. The test is positive when the patient demonstrates an apprehensive feeling. The test is negative if the patient only experiences pain.

Relocation test

The patient is lying supine. The shoulder is abducted to 90 degrees with the elbow in 90 degrees flexion. Using the forearm as a lever, the examiner externally rotates the patient's shoulder forcing the humeral head anteriorly. The examiner then applies a posterior-directed force on the humeral head. If this relieves an apprehensive feeling, the test is positive.

Surprise test

From the end position of the relocation test, the posterior-directed force on the humeral head is removed quickly without preparing the patient (examiners hand is removed from the patient's shoulder). The test is positive if the patient demonstrates an apprehensive feeling.

Castagna's test

Same position as for Jobe's apprehension test, but with the arm abducted to 45

degrees instead of 90. The test is considered positive if the patient reports shoulder pain.

Jerk test

The patient is sitting comfortably on a chair. The examiner stabilizes the patient's scapula and positions the patient's arm in 90 degrees abduction and internal rotation. From this position the examiner applies longitudinal pressure on the humerus (pressure on patient's elbow) while moving the arm horizontally across the patient's body (horizontal adduction). The test is considered positive if the humeral head slides up on the glenoid rim (sudden clunk) or if pain is felt.

O'Brien's test

The patient is instructed to abduct the shoulder 90 degrees and adduct the shoulder 10 degrees. With the patient's shoulder in slight internal rotation (thumbs up), the patient is instructed to keep the position, while examiner applies downward pressure on the patient's forearm. The patient then brings the shoulder into further internal rotation (thumbs down). The patient is instructed to keep the position, while the examiner applies downward pressure on the patient's forearm. The test is considered positive if the patient reports pain in the second position (thumbs down).

Speed's test

With the shoulder resting in external rotation, the patient is instructed to elevate the arm (shoulder flexion), while the examiner applies pressure on the patient's forearm throughout the movement. The test is considered positive if the patient reports shoulder pain in the bicipital groove.

Long head biceps tendon palpation pain

The patient stands in a relaxed position with palms facing forward. The examiner palpates the long head biceps tendon in the sulcus. The test is considered positive if the patient reports pain at the site of palpation.

Cross-over test

The examiner brings the patients shoulder into 90 degrees of flexion and then maximum adduction. The test is considered positive if the patient reports pain at the acromioclavicular joint.

Acromioclavicular joint palpation pain

The examiner palpates the superior aspect of the acromioclavicular joint. The test is considered positive if the patient reports pain at the site of palpation.

DETAILED DESCRIPTION OF CONFLICTING SHOULDER-RELATED DIAGNOSES

Frozen shoulder

Frozen shoulder was defined as a progressive equal loss of active and passive shoulder ROM greater than 25 degrees in at least two planes, and a loss of external rotation greater than 50% when compared to the contralateral (unaffected) shoulder [140].

Glenohumeral osteoarthritis

Osteoarthritis of the glenohumeral joint was defined as radiological evidence of glenohumeral osteoarthritis (Kellgreen and Lawrence score of 3 or 4)[141].

Previous surgery

Includes all surgical procedures to the shoulder girdle.

Fractures

Includes fracture of the proximal humerus, clavicle and scapula (including osseous Bankart lesions). Hill Sachs lesion was not an exclusion criterion.

Radiotherapy

Includes previous radiotherapy in the shoulder girdle, neck or upper thoracic region.

Symptomatic cervical spine pathology

A positive Spurling test (foramen compression test).