Standard reference values for supraspinatus muscle and tendon

A bachelor thesis

by

Noel Tombra Abeke

Department of Physiotherapy

Fontys University of Applied Sciences, Eindhoven, The Netherlands

Email: tombra.abeke@gmail.com

Phone number: +31 17177035

Student number: 2144651

Class: ES4A

Supervisor: Marc Schmitz

Thesis Coordinator: Chris Burtin

Submitted: 31st of May 2013; Version: 1.0

Preface

Writing the bachelor thesis is the last step to be taken, on the way to be awarded a bachelor's degree. Though, the last one, it was not the only step on the road of becoming a physiotherapist.

The first one, for me personally, was the decision to leave Germany and come to the Netherlands. I started my career as physiotherapy student in Amsterdam, but I was not happy with the circumstance that I met there. So, making the decision to change the place of studying was the second step. Which brought me finally to Eindhoven and to the last step of writing the bachelor thesis.

Even though, the decision to make or steps to take were not easy, they were necessary and brought me closer to my goal, becoming a physiotherapist.

Writing the bachelor thesis itself made me aware of how dependent, practicing physiotherapists are on the evidence provided to them. Which in return puts the researching physiotherapists or scientists in general into a position of great power. I realized how delicately statistical data has to be gathered, processed and interpreted and how this may influence the outcome. Therefore, researcher should not abuse this power for their own good, since as they say, with great power comes great responsibility. Responsibility not only towards practicing physiotherapist, but also and foremost towards the patients.

Noel Tombra Abeke

Eindhoven, The Netherlands, 28th of May 2013

Abstract

Background Musculoskeletal ultrasound is frequently used to aid in the diagnosis of pathological alterations of the subabcromial space. The musculotendinous unit of the supraspinatus is most commonly affected. To scan for pathology it is important to know the normal anatomy. Therefore, the aim of this literature review was to identify exact supraspinatus muscle and tendon measurements and their possible anatomical variances, obtained by musculoskeletal ultrasound, magnetic resonance imaging and human cadaveric studies. This review was guided by the following question: What are the standard reference values for the normal supraspinatus muscle?

Method All data processing was done by one reviewer. Articles were retrieved by searching electronic databases. Articles that contained muscle or tendon measurements of the supraspinatus obtained by musculoskeletal ultrasound, magnetic resonance imaging or cadaveric dissection were included. Subject, methodological and measurement data were extracted from all articles. The methodological quality was assessed by a modified PEDro scale.

Results 18 articles were included. Five articles scored an average, two a low and three a high methodological quality. There was a trend found that fiber bundle and tendon length of the anterior part are longer than the posterior part of the supraspinatus. Greatest coherence was found on muscle thickness and width of the area of insertion and the anterior tendon.

Conclusion The description of exact standard reference values for measurements of the supraspinatus tendon and muscle remain vague. To obtain exact standard reference values it is recommended to perform experimental research incorporating study designs with a high level of clinical evidence.

Keywords Standard reference values, supraspinatus, muscle, tendon, musculoskeletal ultrasound

Introduction

Musculoskeletal disorders account for 6% of the health care cost in the Netherlands and are therefore the second most costly group of disorders for society(1). This is secondary to all psychological disorders and prior to oncological and cardiovascular disorders(1). In the Netherlands shoulder complaints are the second most common musculoskeletal disorder after lower back pain, with a 12 month period prevalence's among the general population of 5-47%(2–4). Shoulder complains are often encountered in the physiotherapy practice. In the Netherlands 53% of the patients consulting a physician with shoulder complaints are referred to a physiotherapist(5). These referrals especially involve pathologies of the shoulder tendons(5).

Amongst the tendons of the rotator cuff of the shoulder, the supraspinatus tendon is the most common to be affected by tendinopathy (6,7). Supraspinatus tendinopathy constitutes one of the most frequent tendon injuries of the body as a whole(8). The supraspinatus muscle is a structure which runs through the subacromial space of the shoulder(9). Tendinopathy might cause a combination of pain, swelling and impairment in function(8). A common cause for functional deficit and pain in the shoulder in individuals over 40 years of age, are rotator cuff tears with involvement of the supraspinatus(10). Tendon injury of the supraspinatus stands in a close cause/effect relationship with an alteration of the subacromial space or subacromial impingement, which is the most common cause for shoulder complaints(11). Van Der Windt et al. (12,13) stated that subacromial impingement accounts for 44-65% of all shoulder complaints, yet another study(14) presents numbers as high as 80%.

To distinguish between shoulder complains with involvement of the supraspinatus muscle and/or tendon, and to place the functional impairment into a contextual framework, physiotherapists need to establish a physiotherapeutic diagnosis. Common practice for physiotherapeutic diagnosing of the shoulder consists of a screening for red flags, an anamneses, a basic physical examination and a variety of orthopedic special tests, including, amongst others, tests for the integrity of supraspinatus muscle and tendon(15). However, the diagnostic accuracy and the level of evidence of the tests are low, therefore they have limited value to add information on structural level, as part of a physiotherapeutic diagnosis, based on the International Classification of Functioning, Disability, and Health (ICF) model(15–18). Nevertheless, it is important that patients are diagnosed accurately to prevent physiotherapy treatment when not indicated. Furthermore, an accurate diagnosis helps in determine treatment modalities, ensuring the best possible treatment.

Diagnostic imaging techniques can help in forming a diagnosis by providing images on structural level. They have the advantages of precisely providing information about integrity of soft tissue structures. As well as they are helpful in distinguishing between normal and pathological anatomical structures, if clinical findings are conflicting or not clear(19). Magnetic resonance imaging (MRI) is widely accepted as an excellent and reliable tool for the diagnosis of shoulder disorders, while computed tomography (CT) is a valid and reliable method to determine muscle and ligament measurements, with surgery and cadaveric studies (CS), respectively, being considered as the golden standard(20,21).

However, due to advancement in technology, musculoskeletal ultrasound (MSU) enjoys increasing popularity amongst different medical disciplines including physiotherapy(22,23). Since MSU is highly operator dependent, it needs a trained and skillful examiner. Thanks to their knowledge in examination, musculoskeletal anatomy and pathology physiotherapists, with the right training, are perfectly suited to use MSU as a diagnostic tool. MSU is a non-invasive, non-ionizing radiating, frequently available imaging technique and compared to other techniques, such as MRI, relatively inexpensive and easy to operate(6,24,25). Furthermore, MSU is able to create dynamic images, can be used to compare several joints in one session and due to its portability, it is patient friendly(25,26).

It has been shown that MSU is an excellent tool to diagnose subacromial disorders and is very useful to examine mobile structures such as tendons(24,25,27–29). Due to the close functional relationship of the musculotendinous architecture, it is advised to scan tendon and muscle(30,31). Since intratendinous oedema in tendinopathy results in an enlargement of the tendon, it is necessary to assess at least tendon thickness (TT) and width (TW), to distinguish between normal and pathological conditions(28,32). Parameters such as muscle length (ML), muscle cross sectional area (CSA), fiber bundle length (FBL) and pennation angle (PA), can be visualized with MSU and have been established to be predictors of muscle function(31,33,34). Further, to prevent false negative or positives, when diagnosing pathology of the musculotendinous supraspinatus unit with MSU, it is important to take into account variances in shoulder anatomy, which is known to be influenced by gender, race, age, profession, sports or participation in overhead activities(35–37). There are few existing articles describing non-pathological supraspinatus measurements done with the help of MSU. Measurements found by different authors contradict each other and not all spatial aspects of the tendon and muscle are considered or they lack reference of orientation on which exact site the measurements should be taken(19,22,38).

Despite the prevalence and clinical importance of supraspinatus muscle and tendon pathology, it has become evident that existing literature including existing protocols on musculoskeletal ultrasound present with a lack of standard reference values for the supraspinatus muscle and tendon(24,28,39,40). However, standard reverence values are essential to distinguish anatomical conditions from pathological ones, in particular tendinopathy. Therefore, the aim of this literature review is to compile information about the exact supraspinatus muscle and tendon measurements and their possible anatomical variances, preferably obtained by MSU. Since the literature reveals a gap on measurements obtained by MSU, also researches investigating MRI and CS are used to establish reference values. The procedure might be deemed valid, since MSU images have been found to show high concordance with MR images and CS(41,42). In this way the review tries to eventually facilitate experimental research in the field of musculoskeletal ultrasound.

This leads to the research question of this review: What are the standard reference values for the normal supraspinatus muscle? To concretize, what are the mean values of tendon thickness, width, length and muscle cross sectional area, length, fiber bundle length and pennation angle as determined by musculoskeletal ultrasound, magnetic resonance imaging and cadaveric studies? Additionally it is of interest to find out what are possible anatomical landmarks for measurements and if there are natural variances.

Method

Electronic Search

A search of the electronic databases PubMed (includes MEDLINE) and PubMed Central was conducted. If access to the full text articles was not possible via the database, articles were retrieved through access by biep.nu of the Fontys Mediatheek webpage, the Information Expertise Centre of the Technical University of Eindhoven library webpage or Google Scholar.

The database PubMed and PubMed Central were searched with a combination of MeSH (Medical Subject Headings) terms and key terms. To combine the MeSH/key terms the Boolean operators “AND”, “OR” and “NOT” were used. The index, target and avoidance set of MeSH/key terms can be found in table 1 and table 2 below.

Table 1. Key terms

"musculoskeletal imaging" OR "ultrasonography" OR "sonography" OR "ultrasound" OR "musculoskeletal ultrasound" OR "echography" OR "magnetic resonance imaging" OR "computed tomography" OR "cadaveric studies" OR "anatomic study" OR “anatomy”
AND
"shoulder" OR "rotator cuff" OR "supraspinatus "
AND
"reference values" OR "measurements"

Table 2. MeSH terms

"Ultrasonography"[Mesh] OR "Magnetic Resonance Imaging"[Mesh] OR "Tomography, X-Ray Computed"[Mesh] OR "cadaveric study"[All Fields] OR "anatomic study"[All Fields] OR “Anatomy”[All Fields]
AND
"Shoulder"[Mesh] OR "Rotator Cuff"[Mesh]OR "Supraspinatus "[All Fields]
AND
"Weights and Measures"[Mesh] Or “Anatomy”[All Fields]
NOT
"Animals"[Mesh] OR "Nerve Block"[Mesh]

Inclusion and Exclusion criteria

Due to the limited availability of the topic in literature the scope of the inclusion and exclusion criteria was chosen quite broad. Included were studies that contain architectural measurements, such as width, length, thickness, cross sectional area, fiber bundle length, pennation angle concerning supraspinatus muscle or tendon obtained by MSU, MRI, or cadaveric studies. Since articles concerning cadaveric studies are mostly of a non-randomized descriptive type all clinical study designs were accepted. There was no limitation set to the publication date. Only articles in English language were accepted. Studies that solely used measurements of pathological supraspinatus muscle or tendon were excluded, as were studies that used animal specimens for measurements. If the full text of the article could not be obtained the study could not be included neither. A list of inclusion and exclusion criteria can be found in table 3.

Table 3: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
All study designs	Measurements of pathological supraspinatus muscle/tendon
English	Animal specimens
No limit to publication date	Full text article not available
Data obtained by MSU, MRI, CS concerning: • supraspinatus muscle/tendon ○ width, length, thickness, CSA, pennation angle, fiber bundle length	

Explanation and abbriviations: MSU - musuloskeletal ultrasound; MRI - magnetic resonance imaging; cs - cadaveric studies; csa – cross sectional area

Selection procedure

Selection procedure was systematically done by one researcher applying the inclusion and exclusion criteria during the whole selection process. After entering the search string in the different databases, resulting titles of articles were scanned for relevance for the research topic. The abstracts of the selected articles were screened on whether they might meet the criteria of the review. Of the articles that were deemed to be fitting after scanning of the abstract or if uncertainties were to be clarified, the full text was obtained. The full text was thoroughly screened to make sure if the content qualified to be included in the review. Additionally, the references of the selected full text articles were checked according to the inclusion and exclusion criteria for their relevancy. The articles found by this procedure were considered fitting for the inclusion to the review and were thoroughly read and checked for content and quality.

Data extraction and presentation of findings

First data extraction was performed to give an overview of the included studies. The extracted data contained name of author and article, relevant anthropological data, such as age, sex, number of specimens/participants, part of the tendon or muscle that has been measured and details of the methodological procedure, such as exclusion criteria, self-reported limitations, handle of cadaver specimens and shoulder positioning. The data was displayed in two different tables, split according to the method used for measuring. Further tables were made displaying measurement specifics, here again tables were divided according to method of measuring. Further division was made whether muscle or tendon was measured. This resulted in four tables displaying, if applicable TW, TL, TT and FBL, ML, PA, CSA.

Quality Assessment

The assessment of reporting the methodological quality of the identified studies was done by one researcher. The assessment tool was developed by the author of the review. The PEDro scale(43) was modified according to the specific demands of the review. The assessment tool consists of ten criteria that can be answered with “yes” or “no”. The modification, rather than the usage of an existing tool was chosen, since the study design of the majority of studies identified in this review is not conform with the purpose of existing tools for assessment of methodological quality. To be able to compare the quality of the method of the different studies, the tool was applied to all identified studies. The explanatory note can be found in appendix I.

Results

Selection procedure

The electronic search of the databases PubMed and PubMed Central was conducted by a single researcher in April 2013. The search was performed according to the criteria set in the method. A total of 676 articles were found. The description of the search process is displayed in figure 1. The most common reasons for exclusion, of potentially relevant articles that were scanned on full text, was non-relevant measurement data concerning the supraspinatus. The second most common reason was that the full text was not available to the researcher. 18 articles, that were considered fitting according to inclusion and exclusion criteria, were included in this review.

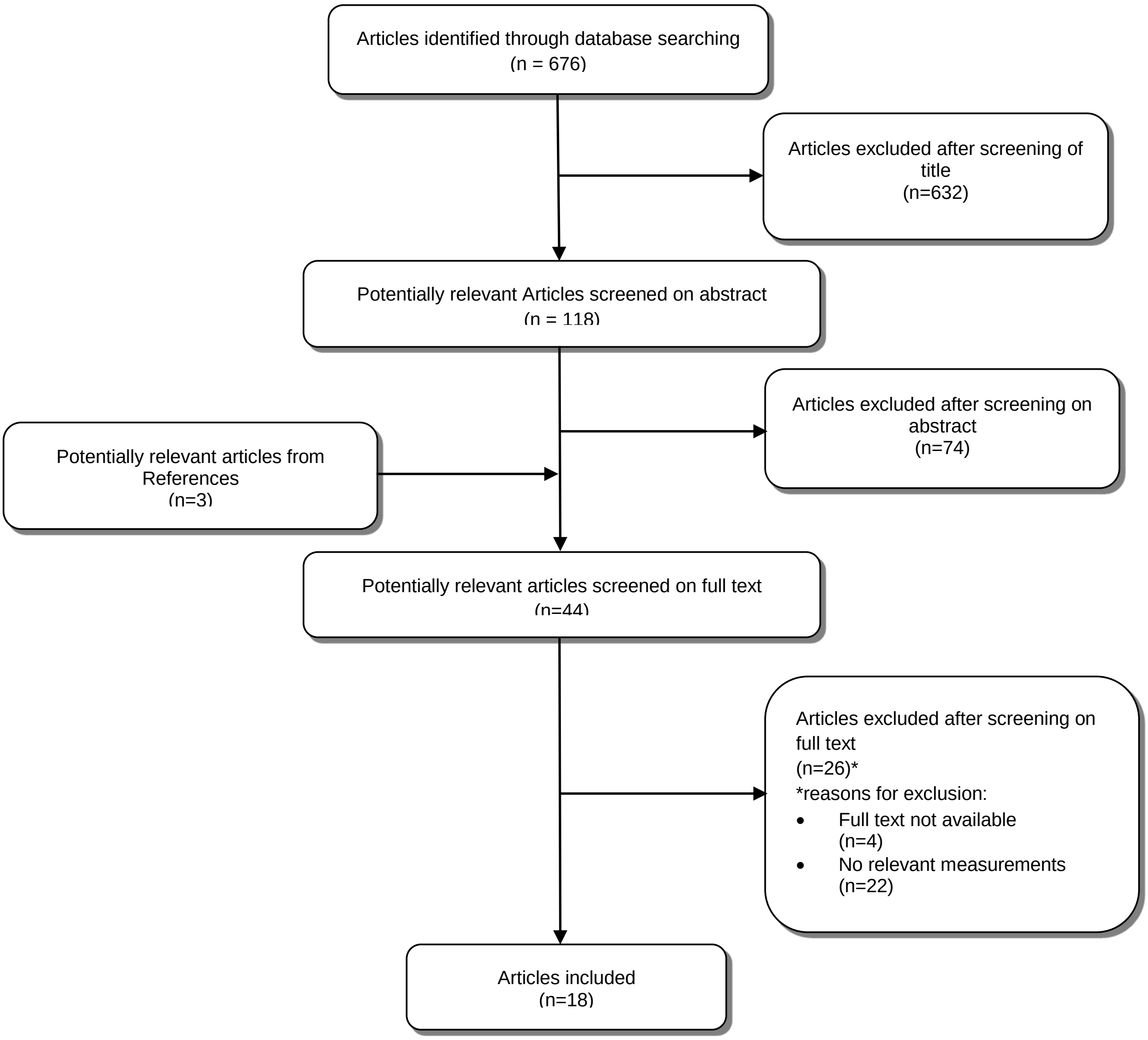

Figure 1. Flow diagram for identification and selection of studies

Reporting quality of methodology

The tool to assess the reporting of the methodology is an adaption of the PEDro scale(43) and has been modified to fit the study designs of included articles, which are mostly non-randomized observational or descriptive studies in the field of human cadaveric dissections. The adaptations were made by consulting works by Kim(44), O'Connor et al.(45) and Campbell et al.(46). The tool contains ten criteria which can be answered with "yes" or "no". The total score is represented as "score achieved/achievable score". Criteria six to eight of the tool are two fold and the sub parts apply either to cadaveric studies or to musculoskeletal ultrasound studies and magnetic resonance imaging studies. The explanatory note can be found in appendix I, and the completed form in appendix II.

Out of 18 included studies, 12 studies had a higher score than five (appendix II). Three studies even achieved a score with 10 out of 10 (7,41,47). Two studies scored with three out of 10 points below average(48,49). Criterion number nine concerned the number of investigators taking measurements and possible blinding; this was the criterion with the least positive answers. It was followed by criterion number five, asking to report definitions of anatomical parameters of the outcome measurements. Here seven studies scored with a positive mark. Criterion number two was the one with most positive scores. All studies, except for one (50), could obtain data from at least 85% of the originally recruited subjects. A summary of the scores can be found in appendix II.

Presentation of findings

The studies included in this review are displayed in appendices III (cadaveric studies) and IV (MSU and MRI studies). The tables contain study characteristics, such as details on the anthropological data of the studies concerning sample size, sex and mean age of participants. The number for "participants" represents the subjects that were involved in the study, whereas number of "supraspinatus specimens" or "shoulders scanned" represents the actual number of specimens or shoulders used for data extraction. The tables further give an overview of the muscle and tendon parts measured in each study and whether they reported exact references for the measurements taken. Also exclusion criteria and self-reported limitations are listed. Additionally, the table for MSU and MRI gives information about the shoulder position in which the different parts of the supraspinatus were measured and the resolution setting used for scanning. The table for CS displays the handling of the cadavers, meaning in which way the cadavers were preserved and prepared for the dissection. Also the instruments used to measure the supraspinatus specimens are noted.

To display the exact measurements of the supraspinatus found by cadaveric, MSU and MRI studies, data were divided into muscle and tendon measurements (tables 4 to 7). The tables give detailed information from which muscle or tendon part the measurements were taken and which exact parameters were measured. The data displayed are mean values and when available the range and standard deviations are reported.

All tables were alphabetically ordered according to the first author's name. The title of the article was also included to give the reader an idea of the objective of the studies.

Study characteristics

There were eleven studies that used cadavers (appendix III). Three studies investigated only tendon parameters (51–53), four studies only muscle (47,49,54,55) and four both tendon and muscle(36,56–58). Of all the cadaveric studies the supraspinatus sample size ranged from one to 49, with one study not being specific on number of used specimens (54). The total calculable sample size was 182. The reported mean age at death of the cadavers presented with a range of 61.9 years to 84 years. Six out of the eleven studies reported exclusion criteria (51–54,56,57) and five studies reported limitations (47,51,52,54,55). Two of the cadaveric studies did not specify the manner of preservation (49,53), whereas the others either used embalmed or fresh frozen cadavers. Five studies used calipers as measurement instruments (36,52,53,56,58), two a digitizer (52,57), the remaining studies did not report the instrument used.

Of the studies that used imaging techniques for measuring (appendix IV), three studies used MRI (47,48,50), three MSU (7,22,45) and one used MRI and MSU (41). The MRI and MSU studies presented with five investigating only muscle and two only tendon, there was no study that investigated both. The number of scanned shoulder per study ranged from 10 to 144, whereas two studies did not specify on the number of the scanned shoulders (48,50). The total calculable sample size, for both MRI and MSU studies was 213. The reported mean age ranged from 36.4 years to 49.1 years. Except for one (45), all studies reported the resolution used to scan the subjects. One study did not report exclusion criteria (48) and two studies did not report limitations (45,48). Excluding one study (48), all the other studies reported the shoulder position for scanning the supraspinatus muscle or tendon

Measurement findings

The measurement findings were split up into measurements found by cadaveric studies and measurements found by MSU and MRI. Further subdivisions were made into muscle and tendon findings.

Cadaveric studies

Muscle length

Mean muscle length has been reported by three authors, the smallest measurement was 8.6 cm, measured by Wood et al.(55) and longest was 14.5 cm by Volk et al.(58). Vahlensieck et al.(49) described measurements for the anterior and posterior part of the supraspinatus (table 4).

Fiber bundle length

Mean fiber bundle length ranged from 2.8 ± 0.5 cm measured by Itoi et al.(56), for the whole muscle to 8.3 ± 0.9 cm for the anterior part measured by Roh et al.(36). Kim et al.(57) also measured anterior and posterior part of the muscle, with measurements for the anterior region being shorter than findings by Roh et al.(36) (table 4). Exact anatomical reference points for FBL were only given by Juul-Kristensen et al.(47), it was measured from the most centrally located tendon to the deep fascia of the muscle.

Pennation angle

Three authors reported mean pennation angle. Kim et al.(57) described the PA of the anterior and posterior region of the muscle. Both regions were again subdivided into medial and lateral parts (table 4). Roh et al.(36) found PA for the anterior part and the posterior part, without dividing into lateral or medial regions (table 4). Juul-Kristensen et al.(47) described the PA for the entire muscle to be 11.4°±7.8°.

Table 4. Summary of muscle measurements by cadaveric studies

Author	Part of muscle	Fiber bundle length (cm)	Pennation angle (degrees)		Muscle length (cm)
Itoi et al.(56)	Whole muscle	2.8 ± 0.5	X		X
Juul-Kristensen et al. (47)	Whole muscle	4.7 ± 1.1	11.4 ± 7.8		
Keating et al.(54)	Whole muscle	5.6 (4.7-6.5)	X		X
Kim et al.(57)	Anterior region	6.7 ± 0.7 (5.8–7.9)	Lateral 60.0 ± 12.0 (41.8–74.5)	Medial 11.8 ± 2.7 (8.5–16.6)	X
	Posterior region	6.7 ± 0.5 (5.7–7.6)	82.2 ± 4.0 (74.7–85.9)	12.4 ± 3.6 (7.1–18.4)	X
Roh et al.(36)	Anterior	8.3 ± 0.9 (4.5-11.7)	14 ± 3 (8-20)		X
	Posterior	6.5 ± 1.2 (3.5-10.1)	10 ± 3 (2-20)		X
Vahlensieck et al.(49)	Anterior	X	X		10.6
	Posterior	X	X		8.9
Volk et al.(58)	Whole muscle	X	X		14.5 (12.2-16.8)
Wood et al.(55)	X	X	X		8.6

Explanations and abbreviations: ± - standard deviation; () – range; x – not reported

Tendon length

Six authors measured the mean tendon length. Curtis et al.(51), Dugas et al.(52) and Ruotolo et al.(53) measured the length of the tendon insertion, between muscle and humerus. Itoi et al.(56) measured the whole tendon, but intramuscular, as being 4.08 ±1.03 cm. Kim et al.(57) and Volk et al.(58) both found values for the anterior and posterior tendons. The anterior tendon was found to be 6.1 ± 0.7 cm by Kim et al.(57) and 5.4 cm by Volk et al.(58). The posterior part described as being 2.9 ± 0.6 cm long by Kim et al.(57) and 2.8 cm by Volk et al.(58). Kim et al.(57) and Vahlensieck et al.(49) reported a intramuscular tendinous slip (1.0 ± 0.2 cm) medially at the posterior tendon.

Tendon width and thickness

Mean width of the tendon was measured by six authors (table 5). Two authors (51,52) found the tendon width at insertion level to be 1.6 cm. Ruotolot et al.(53) measured TW at rotator interval, midtendon and posterior edge (table 5). Two authors(36,57) found the anterior part of the tendon to be 0.8 ± 0.2 cm and 0.84 ± 0.21 cm, the posterior parts were in both case wider. Mean thickness measurements ranged from 0.22±0.0.4 cm to 0.31 ± 0.07 cm measured by two different authors(36,56).

Tendon cross sectional area

Mean tendon CSA was measured by Roh et al.(36) for the anterior (2.64±1.13 cm^2) and posterior (3.11±1.01 cm^2) part of the tendon and by Itoi et al.(56) for the extramuscular (0.7±0.2 cm^2) part of the tendon.

Table 5. Summary of tendon measurements by cadaveric studies

Author	Part of tendon	Length (cm)	Width (cm)	Thickness (cm)	CSA (cm^2)
Curtis et al. (51)	Area of insertion	2.3 (1.8-3.3)	1.6 (1.2-2.1)	X	X
Dugas et al. (52)	Area of insertion	1.3 ± 0.6 (0.7-1.5)	1.6 ± 0.6 (1.0-2.1)	X	X
Itoi et al.(56)	Intramuscular	4.08 ±1.03	X	X	X
	extramuscular	X	1.53±0.03	0.22±0.4	0.7±0.2
Kim et al.(57)	Anterior	6.1 ± 0.7 (5.0–6.9)	0.8 ± 0.2 (0.6–1.0)	X	X
	Posterior	2.9 ± 0.6 (2.3–4.0)	1.6 ± 0.3 (1.2–2.1)	X	X
Roh et al.(36)	Anterior	X	0.84 ± 0.21 (0.49-1.34)	0.31 ± 0.07 (0.2-0.42)	2.64±1.13 (1.34-5.36)
	Posterior	X	1.28 ± 0.28 (0.66-1.57)	0.25 ± 0.07 (0.2-0.43)	3.11±1.01 (1.46-5.58)
Ruotolo et al. (53)	Anteroposterior	2.52 ± 0.24 (1.9-2.7)	X	X	X
	Rotator interval	X	1.16 ± 0.18 (0.8-1.5)	X	X
	Midtendon	X	1.21 ± 0.13 (0.9-1.5)	X	X
	Posterior edge	X	1.2 ± 0.1 (1.1-1.4)	X	X
Volk et al. (58)	Anterior	5.4 (4.1-7.7)	X	X	X
	Posterior	2.8 (2.0-3.7)	X	X	X

Explanations and abbreviations: ± - standard deviation; () – range; x – not reported

Magnetic Resonance Imaging and Musculoskeletal Ultrasound

Muscle length

Mean muscle length was measured by MRI in two different studies both conducted by Juul-Kristensen et al.(41,47), the values were found to be 12.1 cm and 12.0±0.6 cm. The measurements were described as the distance between the medial edge of the spina scapulae and the lateral edge of the acromion(41).

Fiber bundle length and pennation angle

Mean fiber bundle length and pennation angle were only reported by Kim et al.(7), measurements were done by MSU in relaxed position of the shoulder and 80° of internal and external rotation, for FBL this was done both for the anterior and posterior region, for PA only the anterior region (table 6).

Muscle thickness

Mean muscle thickness for MSU ranged from 1.74 ±0.3 cm to 2.15 ± 0.35 cm, both reported by Kim et al.(7), were first was measured in relaxed position of the shoulder and latter in 80° of external rotation. MT for MRI was only described by Juul-Kristensen at al.(41) stating 2.17 cm.

Muscle cross sectional are

Mean muscle cross sectional area was reported by Katayose et al.(22) for the right (7.07±0.94 cm^2) and left (6.91±0.90 cm^2) shoulder, measured by MSU. Whereas Juul-Kristensen et al.(41,47) highest measured value was 5.1 cm^2 and the lowest 4.0±0.6cm^2 (table 6). Juul-Kristensen et al.(41) measured at the medial fourth of the muscle length. Katayose et al.(22) measured with a tape from the posterior edge of the acromion to the medial edge of the spine of the scapula, the midpoint was chosen as point for measurement.

Table 6. Summary of muscle measurements by MRI and MSU

Author	Type of method	Part of muscle	Muscle length (cm)	Fiber bundle length (cm)	Pennation angle (degrees)	Muscle thickness (cm)	Muscle CSA (cm²)
Dupont et al.(50)	MRI	X	X	X	X	(1.32-3.39)	X
Juul-Kristensen et al. (41)	MSU	Whole muscle	X	X	X	2.0	4.98
	MRI	Whole muscle	12.1	X	X	2.17	5.1
Juul-Kristensen et al. (47)	MRI	Whole muscle	12.0±0.6	X	X	X	4.0±0.6
Katayose et al. (22)	MSU	Left shoulder	X	X	X	X	6.91±0.90
		Right shoulder	X	X	X	X	7.07±0.94
Kim et al.(7)	MSU	Anterior region Relaxed	X	5.89 ± 0.71 (4.68–7.63)	12.05 ± 3.07 (6.74–21.68)	1.74 ±0.3* (0.91–2.36)	X
		80° ER	X	4.87 ± 0.90 (2.96–6.74)	14.73 ± 3.88 (8.03–22.75)	2.15 ± 0.35 (1.6–2.96)	
		80° IR	X	5.36 ± 0.72 (3.91–7.32)	17.36 ± 3.54 (9.67–26.62)	2.01 ± 0.35 (1.47–2.88)	
		Posterior region Relaxed	X	3.57 ± 0.56 (2.45–4.61)	X	*all measurements are at the muscle belly (not anterior)	
		80° ER	X	3.44 ± 0.51 (2.56–4.64)	X		
		80° IR	X	3.74 ± 0.50 (2.70–4.90)	X		

Explanations and abbreviations: ± - standard deviation; () – range; x – not reported

Tendon length and thickness

Mean tendon length was only stated by Gagey et al.(48), reporting a range of 5.0 cm to 8.0 cm for the anterior tendon and a range of 0.5 cm to 1.0 for the posterior one, all data were acquired by MRI. Mean tendon thickness was found to be 0.87 cm measured by MSU, reported by O'Connor et al.(45). The reference for measurement was described as the first point of the tendon that can be identified beyond the acromion(45).

Table 7. Summary of tendon measurements by MRI and MSU

Authors	Type of method	Part of tendon	Tendon length (cm)	Tendon width (cm)	Tendon thickness (cm)
Gagey et al.(48)	MRI	Anterior Posterior	(5.0-8.0) (0.5-1.0)	X	X
O'Connor et al.(45)	MSU	X	X	X	0.87

Explanations and abbreviations: ± - standard deviation; () – range; x – not reported

Discussion

The main purpose of this study was to review the available literature to find standard reference values for the measurements of the normal supraspinatus muscle and tendon. Other points of interest were to find exact anatomical landmarks for the measurements and whether there are any anatomical variances described. There were elven studies included that investigated cadavers, three MSU, three MRI and one study that investigated both MRI and MSU.

It can be said that the supraspinatus has two parts. The literature search revealed that there is an anterior part and a posterior part, both with distinguishable muscular and tendon borders. However not all studies divided the supraspinatus into anterior and posterior parts. Measurements were also given for the whole muscle and tendon, or the measurement location was not specified at all. Three MSU studies(22,41,45) and one cadaveric study(47) provided exact descriptions of anatomical landmarks for measurements. Two studies, of which one MRI(49) and one CS(57), described an intramuscular tendinous slip of approximately 1 cm extending from the posterior tendon; deep in the muscle belly. There were measurement data found on ML, FBL, PA, and MT, muscle CSA, TL, TW and TT. A trend in cadaveric, MSU and MRI studies could be observed that showed that the fiber bundle and tendon length of the anterior part are longer than the posterior part of the supraspinatus. The tendon of the posterior part though, is wider than the anterior one. Greatest agreement concerning muscle parameters could be found on muscle thickness. Looking at tendon parameter, the biggest homogeneity was found with tendon width for the anterior supraspinatus tendon and the area of insertion.

First the cadaveric studies are discussed in relation to each other. Methods and measurement findings are compared. In the later section of the discussion the CS findings are compared to MSU and MRI findings.

Cadaveric studies

Muscle length

The range for mean muscle length measurements reported by cadaveric studies was big (8.6 cm- 14.5 cm). Vahlensiek et al.(49) measured anterior and posterior muscle length, but the article provides the reader with very little information on method and definition of measurements. Volk et al.(58) and Wood et al.(55) reported different lengths for the whole muscle. Wood et al.(55) dissected only one male specimen. The aim of their study was rather to establish kinematic descriptions for a prosthetic arm controller, than to determine exact supraspinatus measurements.

Fiber bundle length

Mean FBL of the posterior parts measured by Roh et al.(36), of 6.5±1.2 cm were found to be similar to measurements of 6.7±0.5 cm by Kim et al.(57), whereas the anterior parts showed no resemblance. However both studies found the posterior parts to be shorter than the anterior parts. In the study by Kim et al.(57) data were gathered from the superficial, middle and deep parts of the muscle and their means combined. The measurements were taken “in situ” by a digitizer and computerized into a three dimensional model. In comparison Roh et al.(36) took measurements manually with a caliper of the superficial fiber bundles on excised supraspinatus specimens. Three studies were identified that reported FBL data for the entire muscle, results here were significantly shorter ranging from 2.8±0.5 cm to 5.6 cm (47,54,56). Itoi et al.(56) found the shortest measurement, but the data were normalized to the scapula length, which could explain the shorter length. Keating et al.(54) who recorded 5.6 cm, had a small sample size of five specimens and reported great variation in measured FBL, which may have influenced the mean.

Pennation angle

There was a great range found amongst the recorded mean measurements of pennation angle, which might be explained by different locations and definitions of measurement sites. Therefore a comparison was difficult to make. Kim et al.(57) was the only one dividing the anterior and posterior parts of the muscle into medial and lateral sides . Medial and lateral sides had large differences in angles (table 4). This was explained by the difference in obliqueness of the muscle fibers for each side (medial and lateral). Roh et al.(36) took measurements of the anterior and posterior part (table 4) without dividing into medial or lateral sides. Juul-Kristensen et al.(47) measured the whole muscle and consequently the results were not comparable with the rest. Again, due to advanced three dimensional computer measurements Kim et al.(57) could investigate the muscle in depth.

Tendon length

Curtis et al.(51) and Ruotolo et al.(53), had concurrent measurements for mean TL at insertion level. However, the authors used different techniques to identify the insertion of the tendon. Ruotolo's et al.(53) description of the technique was not straight forward, the terms depth and width were used interchangeably. This confusion was also criticized by Curtis et al.(51). Curtis et al.(51) and Dugas et al.(52) used fresh frozen cadavers, whereas Routolo et al.(53) did not state how the cadavers were preserved. The manner of preservation influence tissue characteristics. Kim et al.(57) and Volk et al.(58) found similar results for the posterior tendon, with a measured length of 2.9±0.6 cm and 2.8 cm, respectively(57,58). As with mean FBL the tendon of the posterior part was shorter than the anterior one. Methodological and technical specifications for Kim's et al.(57) study are the same as mentioned in the paragraph before. Compared to Kim et al.(57) Volk et al.(58) excised the supraspinatus. Vahlensieck et al.(49) and Kim et al.(57) reported to have found intramuscular slips at the medial side of the posterior tendon. Kim et al. (57) suggested that this findings might be in relation to age, since the tendon slips were found on three specimens under 50 years of age. Kim et al.(57) stated that the mean age of the specimens used by Vahlensieck et al.(49) was 40.5 years. It is not clear how Kim et al. (57) found the mean age to be 40.5, since the study by Vahlensieck et al.(49) only stated range values for the age. Further, could this review identify studies(56,58), with comparable age ranges, that investigated the posterior tendon and did not report any tendon slips.

Tendon width

The results found by Curtis et al.(51), 1.6 cm for mean tendon width at insertion level are in accordance with Dugas et al.(52). However, Routolo et al.(53) used a different approach by measuring at midtendon, rotator interval and posterior edge (table 5). Kim et al.(57)and Roh et al.(36) found concurrence for anterior tendon measurements, reporting 0.8±0.2 cm and 0.84±0.21 cm.

Tendon thickness and cross sectional area

Little data were found on mean TT and CSA. Itoi et al.(56) measured the extramuscular tendon, whereas Roh et al.(36) assessed the anterior and posterior tendon. Hence, measurements are not comparable, since they were measured at different locations. Furthermore, Itoi et al.(56) normalized data. Additionally, the techniques used to obtain CSA were quite distinct. Roh et al. (36) used mean tendon width and thickness to calculate CSA, whereas Itoi et al. (56) photographed actual slices of tendons, to then measure them.

Magnetic Resonance Imaging and Musculoskeletal Ultrasound

Muscle length

Juul-Kristensen et al.(41,47) conducted two independent experiments in order to determine the mean ML using MRI. Both Trials produced congruent results with lengths of 12.1 cm and 12.0±0.6 cm, respectively. The investigators were the same, as were the setting and testing environment. The sample size was different, but both studies included female subjects only, also the mean age was approximately the same (appendix IV). This may imply good reproducibility of the method and technique used; on the other hand the authors might have been biased by the outcomes of the first study. Even though, the results found by Juul-Kristensen et al.(41,47) were within the broad range from 8.6 cm to 14.5 cm for mean muscle length by dissection, they do not show any exact agreement (table 4).

Fiber bundle length and pennation angle

Mean FBL and PA for the supraspinatus muscle by MSU has up to date only been researched by Kim et al.(59). The protocol used to obtain measurements was based on an earlier work by the same author from 2007, which has been discussed in former paragraphs of this review(57). Kim et al.(59) measured FBL and PA in relaxed state and contracted state of 60° abduction of the shoulder and either 80° of external rotation or 80° of internal rotation. MSU measurements for FBL in the relaxed state of the anterior region (5.89±0.71 cm), were still in the range of 5.8 cm to 7.9 cm, though shorter than the mean CS measurements by Kim et al.(57) (6.7±07 cm). Compared to the cadaver measurements for the anterior part by Roh et al.(36), with 8.3±09 cm, the difference was considerably bigger. This might be due to bias by Kim. Another reason could be that measurements were obtained by different techniques and methods. However, as with CS findings the posterior part was shorter than the anterior part. When contracted all the measurements taken for the anterior part were shorter compared to the relaxed state, the posterior part did not change distinguishably enough to see a trend (table 5).

Muscle thickness

Juul-Kristensen et al.(41,47) and Kim et al.(59) reported measurements of 2.17 cm (MRI), 2.0 cm (MSU) and 1.74±0.3 cm (MSU), respectively. These measurements are very homogenous. Dupont et al.(50), using MRI, only reported ranges (1.32cm-3.39 cm), but they confirm previously listed measurements. Nevertheless, results by Juul-Kristensen et al.(41,47) might be biased, due to reasons mentioned earlier in the text. Furthermore, Juul-Kristensen et al.(41) used a low frequency (5 MHz) for MSU measurements. No CS data for comparison was available.

Muscle cross sectional area

Mean muscle cross sectional area obtained by MSU and MRI, measured by Juul-Kristensen et al.(41,47) ranged from 4.0 cm to 5.1 cm. Katayose et al.(22) measured CSA of the left (6.9±10.9 cm) and right (7.07±0.94) supraspinatus muscle. Juul-Kristensen et al.(41,47) had an exclusively female study population, while Katayose et al. (22) had an all-male study population (appendix IV). This might explain the bigger CSA in the study by Katayose et al.(22).

Tendon length

Gagey et al.(48) are the only ones reporting TL with for the anterior and posterior tendon obtained by MRI. Even though the measurements were only available as ranges, they are in agreement with CS data, insofar as that the anterior tendon tends to be longer than the posterior one.

Three studies(41,47,59) scored ten out of ten achievable points. It must be noted that the study by Kim et al.(59) was by the same author as the study that was used as reference to adapt the PEDro scale utilized in this review. Therefore the outcome for this particular study might be biased. The studies that scored three points were both quite old studies from, 1990(48) and 1994(49), which leads to the assumption that the standards of reporting the methodology used to be lower. Criterion nine was the one most often scored negatively, which gives rise to concern, as this is a factor that influence internal validity of the study, hence validity of outcome measurements.

Cadaveric studies constitute most of the included studies in this review with the study design being a non-randomized descriptive or observational type. This type of study together with, for example, case reports, are consider as having a low standard of evidence, nevertheless and in despite of sufficient other articles available these studies were included. Especially in fields with little research done, studies such as cadaveric studies can help to form hypothesis and help to establish set ups for other experiments with a different study design. With the evidence based medicine scope being focused on level I research, such as randomized control trials (RCT) or meta-analysis, there are only a few tools to be found that assess the reporting of methodology of research with lower clinical evidence. No tool was found matching the criteria necessary for this review. Therefore, an existing methodological assessment tool was adapted to the specific needs of included studies. The PEDro scale (43) is a validated assessment tool for RCT's. It was used as a framework, while modifications were made by using the PhD work of Kim (44), which is an extensive work on the musculotendinous architecture of the supraspinatus, with measurements obtained by cadaveric study and MSU. In her work Kim (44) defines common methodological features of cadaveric studies investigating the supraspinatus. Further adaptations especially concerning MSU and MRI were made by taking O'Connor et al.(45) and Campbell et al.(46) into consideration. The resulting assessment tool was applied to all included studies to ensure comparability. The score was chosen to be displayed as "score achieved/achievable score", without defining margins of high or low methodological quality. This was deliberately done, to prevent rating, since the validity of the assessment tool is doubtable as it was made for the scope of this review and the first time used.

Kim (44), investigated the normal and pathological supraspinatus by means of MSU and cadaveric dissection. As part of her PhD work she conducted a literature survey on musculotendinous parameters, which is comparable to this review. Kim (44) compared measurements found in the literature with own findings. This review adds three articles (45,48,53), which were not included by Kim (44), in return two articles were presented that were not available for this review. Since not the objective of the study, no assessment of the methodological part of the studies included by Kim (44) was performed. Kim (44) suggested that the functional role of the anterior part of the supraspinatus is one of actively creating strength, while the posterior part functions more as stabilizer of the glenohumeral joint, by tensioning and distributing tension amongst structures like the joint capsule. Furthermore, Huang et al.(60) described the anterior part to be under greater axial loading in respect to the posterior part. This can be supported by the trend observed in this study, that the anterior part of the supraspinatus is longer than the posterior part, as depicted by the longer fiber bundle and tendon length, therefore suited to produce force. At the same time there was a trend recognized of the posterior tendon to be wider than the anterior one, theoretically giving more surface for tension distribution.

To recapitulate the limitations found when discussing the results, it can be said that methods, techniques, and protocols to gather measurements of the musculotendinous unit of the supraspinatus, differed significantly among the studies, this accounts for cadaveric studies as well as for MSU and MRI studies. Generally speaking definitions of measurement parameters varied and anatomical landmarks in the few cases provided were not comparable to each other. In 3 studies it was not the main purpose to find supraspinatus measurements. Sample sizes were small. In cadaveric studies this might be explained by the difficulties to obtain cadavers suitable for dissection. In all CS the mean age of subjects was quite high, which again might be a specific limitation to CS as the age of body donors is likely to be higher. Two of the CS used fresh frozen cadavers, whereas the rest used embalmed cadavers. Three studies investigated the supraspinatus “in situ”, the other studies excised muscle and tendon. Both the manner of preservation and dissection might influence tissue quality and characteristics. Most studies obtain the measurements manually with calipers, only two studies digitized data.

Even though, most MSU and MRI studies reported protocols for the assessment of their subjects they were not very detailed. This is an important factor in imaging techniques, to reduce artifacts, crosstalk and signal to noise (46). Influences like the pressure of the transducer on the skin and under lying tissue might impact quality and reproducibility of images, the same accounts for the angle of scanning (45).

Strong points found in MSU and MRI studies were that except for one (48), all described the position of the arm and shoulder when scanning the supraspinatus. This is important, since an altered arm position changes properties of muscle and tendon. The positioning was the same for all the studies, only Kim et al.(59) had two additional positions. All but one study (41), used high resolution settings for imaging. To secure the detection of small tendon and muscle abnormalities typically frequencies higher than 7 MHz for MSU and small fields of view and thin slice sections for MRI are used(46).

Concerning this review some limitations should be taken into consideration when referring to the presented results. When databases are searched by one researcher, 8% of suitable studies are missed (61). Additionally, only literature in English language and literature that was published was searched. Also the scoring for the quality of the methodology of included studies might be influenced by the scoring of only one researcher. In cases of conflicts, second and third opinions might clarify doubts. Further, the methodological assessment tool, which was modified for the scope of this review has not been validated.

Furthermore, study designs with evidence level V were accepted. Due to limited accesses to full text sources by the researcher not all articles selected for the review were retrievable.

Strong points of the review are mentioned in the following paragraph. This study, to the knowledge of the author, is the first to summarize data obtained by MSU, MRI and CS of musculotendinous parameters of the supraspinatus in the design of a systematic review. The utilized methodological assessment tool has been discussed before. Even though the validity remains doubtful this review is the first to assess the methodological quality of studies concerning supraspinatus measurements in one document.

As exact measurements were found to be conflicting clinicians when scanning the supraspinatus might take the muscle outlines discussed earlier as guidelines. The width of 0.80 cm to 0.84 cm of the anterior tendon can be used as point of orientation, since here the greatest homogeneity concerning measurements was found. Interestingly the insertional tendon width, thus the part, which has been coined by Codman (62) as the "critical zone" and is known to be prone to failure, also showed great measurement homogeneity. The width of 1.6 cm, found in this review might give clinicians an idea about the dimensions, when examining the designated area.

Besides the rather concrete clinical implications named above, the review can be seen as a further step in building a foundation for cadaveric or imaging studies. The collected data can help in the development of protocols for MSU, MRI and anatomical investigations or the computerized mapping of the musculotendinous features of the supraspinatus.

When implementing above named suggestions it is of importance to develop validated guidelines or assessment tools for methodological buildup of cadaveric studies. For MSU and MRI studies it is recommended to highly standardize the scanning protocol and to describe measures taken to reduce artifacts. For all experimental type studies, whether it is CS, MRI or MSU it is of relevance to define the anatomic structure to be measured in detail and name anatomical landmarks for orientation. To ensure internal validity of the studies it is advised to incorporate a study design that allows statistical power calculations such as inter- and intra-observer reliability and correlation coefficient.

Future reviews could adjust inclusion and exclusion criteria to filter out studies with poor methodological build up. A continuation of the present review could be to conduct a meta-analysis of the parameters that provided enough data and concurrency.

Conclusion

The description of exact standard reference values for measurements of the supraspinatus tendon and muscle remain vague. This review was able to systematically display the measurement parameters described in the literature and could find relative coherence on measurements of tendon width for the anterior tendon and the insertional part, as well as on muscle thickness. Due to average methodological quality, differences in methods of included studies and sparse data availability results should be taken with caution. Further research is recommended. To obtain exact standard reference values experimental research should be done in the form of study designs with a high level of clinical evidence.

Acknowledgement

I would like to thank my supervisor, Marc Schmitz for guiding me through the process of the bachelor thesis. The help of my fellow students and friends was truly appreciated. Special thanks go to Florian Exner, Axel Hedman and Justine Aka. Additional words of thanks go to the coordinator of the English stream physiotherapy program, Paul de Meurichy.

References

1. Meerding WJ, Bonneux L, Polder JJ, Koopmanschap MA, van der Maas PJ. Demographic and epidemiological determinants of healthcare costs in netherlands: cost of illness study. BMJ. 1998;317(7151):111–5.

2. Picavet HSJ, Gils HWV, Schouten JSAG. Klachten van het bewegingsapparaat in de nederlandse bevolking, prevalenties, consequenties en risicogroepen. 2000 [cited 2013 Feb 9]; Available from: http://rivm.openrepository.com/rivm/handle/10029/9424

3. Luime J, Koes B, Hendriksen I, Burdorf A, Verhagen A, Miedema H, et al. Prevalence and incidence of shoulder pain in the general population; a systematic review. Scand. J. Rheumatol. 2004;33(2):73–81.

4. Van der Heijden GJMG. Shoulder disorders: a state-of-the-art review. Best Pract. Res. Clin. Rheumatol. 1999;(2):287–309.

5. Van der Windt DA, Koes BW, de Jong BA, Bouter LM. Shoulder disorders in general practice: incidence, patient characteristics, and management. Ann. Rheum. Dis. 1995;54(12):959–64.

6. Gückel C, Nidecker A. Diagnosis of tears in rotator-cuff-injuries. Eur. J. Radiol. 1997;25(3):168–76.

7. Kim S, Bleakney R, Boynton E, Ravichandiran K, Rindlisbacher T, McKee N, et al. Investigation of the static and dynamic musculotendinous architecture of supraspinatus. Clin. Anat. 2010;23(1):48–55.

8. Maffulli N, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. Clin. Sports Med. 2003;22(4):675–92.

9. Neer C. Anterior acromioplasty for the chronic impingment syndrome in the shoulder: a preliminary report. J Bone Jt. Surg Am. 1972;54:41–50.

10. Matsen III FA. Repair of Rotator Cuff Tears: Surgery for shoulders with torn rotator cuff tendons can lessen shoulder pain and improve function without acromioplasty. [Internet]. 2005. Available from: http://depts.washington.edu/shoulder/Handouts/ProcedureHandouts/RotatorCuffRepair.pdf

11. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. Clin. Biomech. 2003;18(5):369–79.

12. Van der Windt DA, Koes BW, de Jong BA, Bouter LM. Shoulder disorders in general practice: incidence, patient characteristics, and management. Ann. Rheum. Dis. 1995;54(12):959–64.

13. Van der Windt DA, Koes BW, Boeke AJ, Deville W, De Jong BA, Bouter LM. Shoulder disorders in general practice: prognostic indicators of outcome. Br. J. Gen. Pract. 1996;46(410):519.

14. Winters JC, Windt D, Spinnewijn WEM, Jongh AC, Heijden G, Buis PAJ, et al. NHG-standaard schouderklachten. Nhg-Standaarden Voor Huisarts 2009. 2009;1213–29.

15. Hegedus EJ, Goode A, Campbell S, Morin A, Tamaddoni M, Moorman CT, et al. Physical examination tests of the shoulder: a systematic review with meta-analysis of individual tests. Br. J. Sports Med. 2008;42(2):80–92.

16. Hughes PC, Taylor NF, Green RA. Most clinical tests cannot accurately diagnose rotator cuff pathology: a systematic review. Aust J Physiother. 2008;54(3):159–70.

17. Jansen M, Broijmanns F, Geraets J, Lenssen A, Ottenheijm R, Penning L, et al. KNGF evidence statement subacromiale klachten. Ned. Tijdschr. Voor Fysiother. 2011;1(121).

18. Steiner WA, Ryser L, Huber E, Uebelhart D, Aeschlimann A, Stucki G. Use of the ICF model as a clinical problem-solving tool in physical therapy and rehabilitation medicine. Phys. Ther. 2002;82(11):1098–107.

19. Schmidt WA, Schmidt H, Schicke B, Gromnica-Ihle E. Standard reference values for musculoskeletal ultrasonography. Ann. Rheum. Dis. 2004;63(8):988–94.

20. Silva L, Andréu JL, Muñoz P, Pastrana M, Millán I, Sanz J, et al. Accuracy of physical examination in subacromial impingement syndrome. Rheumatology. 2008;47(5):679–83.

21. Mitsiopoulos N, Baumgartner RN, Heymsfield SB, Lyons W, Gallagher D, Ross R. Cadaver validation of skeletal muscle measurement by magnetic resonance imaging and computerized tomography. J. Appl. Physiol. 1998;85(1):115–22.

22. Katayose M, Magee DJ. The cross-sectional area of supraspinatus as measured by diagnostic ultrasound. J. Bone Joint Surg. Br. 2001;83(4):565–8.

23. Beggs I. Shoulder ultrasound. Musculoskelet. Ultrason. 2011;32(2):101–13.

24. Middleton WD, Payne WT, Teefey SA, Hildebolt CF, Rubin DA, Yamaguchi K. Sonography and MRI of the shoulder: comparison of patient satisfaction. Am. J. Roentgenol. 2004;183(5):1449–52.

25. Tan A. Imaging of the musculoskeletal system: magnetic resonance imaging, ultrasonography and computed tomography. Best Pract. Res. Clin. Rheumatol. 2003;17(3):513–28.

26. Ahmed R, Nazarian LN. Overview of musculoskeletal sonography. Ultrasound Q. 2010;26(1):27.

27. Jacobson JA, Lancaster S, Prasad A, van Holsbeeck MT, Craig JG, Kolowich P. Full-thickness and partial-thickness supraspinatus tendon tears: value of US signs in diagnosis1. Radiology. 2004;230(1):234–42.

28. Allen GM. Shoulder ultrasound imaging-integrating anatomy, biomechanics and disease processes. Should. Imaging. 2008;68(1):137–46.

29. Ottenheijm RP, Jansen MJ, Staal JB, van den Bruel A, Weijers RE, de Bie RA, et al. Accuracy of diagnostic ultrasound in patients with suspected subacromial disorders: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil. 2010;91(10):1616–25.

30. Ward SR, Hentzen ER, Smallwood LH, Eastlack RK, Burns KA, Fithian DC, et al. Rotator cuff muscle architecture. Clin. Orthop. 2006;448:157–63.

31. Kim SY, Bleakney RR, Rindlisbacher T, Ravichandiran K, Rosser BWC, Boynton E. Musculotendinous architecture of pathological supraspinatus: A pilot in vivo ultrasonography study. Clin. Anat. 2013;26(2):228–35.

32. Bianchi S, Martinoli C, de Gautard R, Gaignot C. Ultrasound of the digital flexor system: normal and pathological findings. J Ultrasound. 2007;10(2):85–92.

33. Boer M, Seynnes O, Prampero P, Pišot R, Mekjavić I, Biolo G, et al. Effect of 5 weeks horizontal bed rest on human muscle thickness and architecture of weight bearing and non-weight bearing muscles. Eur. J. Appl. Physiol. 2008;104(2):401–7.

34. Chow RS, Medri MK, Martin DC, Leekam RN, Agur AM, McKee NH. Sonographic studies of human soleus and gastrocnemius muscle architecture: gender variability. Eur. J. Appl. Physiol. 2000;82(3):236–44.

35. Edelson G. Variations in the retroversion of the humeral head. J. Shoulder Elbow Surg. 1999;8(2):142–5.

36. Roh MS, Wang VM, April EW, Pollock RG, Bigliani LU, Flatow EL. Anterior and posterior musculotendinous anatomy of the supraspinatus. J. Shoulder Elbow Surg. 2000;9(5):436–40.

37. Staniek M, Brenner E. Variations in the anatomy of the anterior-inferior rotator cuff: The “infraglenoid muscle.”Ann. Anat. - Anat. Anz. 2012;194(4):373–80.

38. Yi TI, Han IS, Kim JS, Jin JR, Han JS. Reliability of the supraspinatus muscle thickness measurement by ultrasonography. Ann. Rehabil. Med. 2012;36(4):488–95.

39. Allen G., Wilson D. Ultrasound of the shoulder. Eur. J. Ultrasound. 2001;14(1):3–9.

40. Mack LA, Matsen FA, Kilcoyne RF, Davies PK, Sickler ME. US evaluation of the rotator cuff. Radiology. 1985;157(1):205–9.

41. Juul-Kristensen B, Bojsen-Møller F, Holst E, Ekdahl C. Comparison of muscle sizes and moment arms of two rotator cuff muscles measured by ultrasonography and magnetic resonance imaging. Eur. J. Ultrasound. 2000;11(3):161–73.

42. Rutten MJCM, Maresch BJ, Jager GJ, Blickman JG, van Holsbeeck MT. Ultrasound of the rotator cuff with MRI and anatomic correlation. Eur. J. Radiol. 2007;62(3):427–36.

43. Moseley AM, Herbert RD, Sherrington C, Maher CG. Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro). Aust. J. Physiother. 2002;48(1):43–50.

44. Kim SY. Supraspinatus Musculotendinous Architecture: A cadaveric and in vivo ultrasound investigation of the normal and pathological muscle [Internet]. University of Toronto; 2009 [cited 2013 May 20]. Available from: https://tspace.library.utoronto.ca/handle/1807/17784

45. O'Connor PJ, Grainger AJ, Morgan SR, Smith KL, Waterton JC, Nash AFP. Ultrasound assessment of tendons in asymptomatic volunteers: a study of reproducibility. Eur. Radiol. 2004;14(11):1968–73.

46. Campbell RSD, Grainger AJ. Current concepts in imaging of tendinopathy. Clin. Radiol. 2001;56(4):253–67.

47. Juul-Kristensen B, Bojsen-Møller F, Finsen L, Eriksson J, Johansson G, St\aahlberg F, et al. Muscle sizes and moment arms of rotator cuff muscles determined by magnetic resonance imaging. Cells Tissues Organs. 2000;167(2-3):214–22.

48. Gagey N, Gagey O, Bastian G, Lassau JP. The fibrous frame of the supraspinatus muscle. Surg. Radiol. Anat. 1990;12(4):291–2.

49. Vahlensieck M, An Haack K, Schmidt HM. Two portions of the supraspinatus muscle: a new finding about the muscles macroscopy by dissection and magnetic resonance imaging. Surg. Radiol. Anat. 1994;16(1):101–4.

50. Dupont A-C, Sauerbrei EE, Fenton PV, Shragge PC, Loeb GE, Richmond FJ. Real-time sonography to estimate muscle thickness: comparison with MRI and CT. J. Clin. Ultrasound. 2001;29(4):230–6.

51. Curtis AS, Burbank KM, Tierney JJ, Scheller AD, Curran AR. The insertional footprint of the rotator cuff: an anatomic study. Arthrosc. J. Arthrosc. Relat. Surg. 2006;22(6):603–609.e1.

52. Dugas J. Anatomy and dimensions of rotator cuff insertions. J. Shoulder Elbow Surg. 2002;11(5):498–503.

53. Ruotolo C, Fow JE, Nottage WM. The supraspinatus footprint: an anatomic study of the supraspinatus insertion. Arthrosc. J. Arthrosc. Relat. Surg. 2004;20(3):246–9.

54. Keating J, Waterworth P, Shaw-Dunn J, Crossan J. The relative strengths of the rotator cuff muscles. A cadaver study. J. Bone Joint Surg. Br. 1993;75-B(1):137–40.

55. Wood JE, Meek SG, Jacobsen SC. Quantitation of human shoulder anatomy for prosthetic arm control—II. Anatomy matrices. J. Biomech. 1989;22(4):309–25.

56. Itoi E, Hsu H-C, Carmichael SW, Morrey BF, An KN. Morphology of the torn rotator cuff. J. Anat. 1995;186(Pt 2):429.

57. Kim SY, Boynton EL, Ravichandiran K, Fung LY, Bleakney R, Agur AM. Three-dimensional study of the musculotendinous architecture of supraspinatus and its functional correlations. Clin. Anat. 2007;20(6):648–55.

58. Volk AG, Vangsness Jr CT. An anatomic study of the supraspinatus muscle and tendon. Clin. Orthop. 2001;384:280.

59. Kim S, Bleakney R, Boynton E, Ravichandiran K, Rindlisbacher T, McKee N, et al. Investigation of the static and dynamic musculotendinous architecture of supraspinatus. Clin. Anat. 2010;23(1):48–55.

60. Huang C-Y, Wang VM, Pawluk RJ, Bucchieri JS, Levine WN, Bigliani LU, et al. Inhomogeneous mechanical behavior of the human supraspinatus tendon under uniaxial loading. J. Orthop. Res. 2005;23(4):924–30.

61. Edwards P, Clarke M, DiGuiseppi C, Pratap S, Roberts I, Wentz R. Identification of randomized controlled trials in systematic reviews: accuracy and reliability of screening records. Stat. Med. 2002 Jun 15;21(11):1635–40.

62. Codman E. The shoulder: rupture of the supraspinatus tendon and other lesions in or about the subacromial bursa. Boston: Thomas Todd; 1934.

Appendix I - Explanatory note on modified PEDro scale

To assess the reporting of the methodology the PEDro scale (43). has been modified to fit the study designs of included articles, which are mostly non-randomized observational or descriptive studies in the field of human cadaveric dissections. The adaptations were made by consulting works by Kim (44), O'Connor et al.(45) and Campbell et al.(46). The tool contains ten points which can be answered with "yes" or "no". The total score is represented as "score achieved/achievable score". Criteria six to eight of the tool are two fold and the sub parts apply either to cadaveric studies or to musculoskeletal ultrasound studies and magnetic resonance imaging studies.

1. Eligibility criteria were specified(43).

This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study(43).

2. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups(43).

This criterion is only satisfied if the report explicitly states both the number of subjects initially allocated to groups and the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time(43).

3. The study provides both point measures and measures of variability for at least one key outcome(43).

A point measure is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. Measures of variability include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group(43).

4. Anatomical location of measurements for key outcome parameters were reported(44).

Due to variability in anatomy and to ensure reproducibility it is important to report on which region of the investigated body part the measurements have been executed. For the supraspinatus muscle that could be the anterior part of the muscle.

5. Definition of anatomical parameters for key outcomes were provided(44).

Due to variability in anatomy and to ensure reproducibility it is important to report the specific definition of the anatomical parameter measured. This might include mentioning of anatomical landmarks used for orientation, such as detailed description of insertion and origin of muscle or tendon; or other criteria that help to define the exact area designated for measurement.

6. Instrumentation or properties/settings of device used to obtained measurements were reported(44,46).

This point has to be adapted to either cadaveric studies or musculoskeletal ultrasound and magnetic resonance imaging studies.

Cadaveric studies
When dissecting cadavers there are different instruments to measure dissected parts of interest. There are analogue calipers or goniometers, as well as digital versions. Further, measurements can also be obtained by digitzers or lasers which can computerize three dimensional models (44).

MSU or MRI
Using musculoskeletal ultrasound or magnetic imaging resonance technical properties and setting of the machine can influence imaging quality and subsequently influence measurement outcomes(46).

7. A Protocol for dissection method (in cadaveric studies) or subject positioning (in musculoskeletal ultrasound or magnetic resonance imaging) were reported.

This point has to be adapted to either cadaveric studies or musculoskeletal ultrasound and magnetic resonance imaging studies.

Cadaveric studies
The method of dissecting might influence outcome measurements. To be measured parts can be investigated “in situ” or excised. Also position of the cadaver might have an influence on outcome measurements.

Musculoskeletal ultrasound or magnetic resonance imaging
With imaging techniques the shoulder position might influence the part depicted and change the physiological parameters, such as contraction or stretch of muscle or tendon(45).

8. Factors that might influence- tissue quality of cadaveric specimens/image quality in musculoskeletal ultrasound or magnetic resonance imaging- were reported.

This point has to be adapted to either cadaveric studies or musculoskeletal ultrasound and magnetic resonance imaging studies.

Cadaveric studies

This may include the description of the preparation of the cadaver for dissection, as well as type of preservation used (e.g. fresh frozen, embalmed).

Musculoskeletal ultrasound or magnetic resonance imaging

This may include the description of measure taken to reduce artifacts and ensure reproducibility of image quality. For MSU that may include for example reporting of factors like the pressure of the probe on the skin, the angle between the ultrasound beam and the tendon, the use of a standoff pad(45). For both MSU and MRI this may include the placements of markers.

9. The number of investigators conducting measurements and if applicable the way of blinding was reported.

The numbers of investigators may give possibilities to calculate inter-rater reliability, which is influenced by blinding of the investigators. Due to the design of some studies blinding is not always possible.

10. Limitations of the study were reported.

This criteria is satisfied, when limitations of the study design, method or results are discussed and explicitly mentioned.

Appendix II - Modified PEDro scale

Author	1. Eligibility criteria were specified	2. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	3. The study provides both point measures and measures of variability for at least one key outcome	4. Anatomical location of measurements for key outcome parameters were reported	5. Definition of anatomical parameters for key outcomes were provided	6. Instrumentation or properties/settings of device used to obtained measurements were reported	7. A Protocol for dissection or way of obtaining images were reported.	8 Factors that might influence quality of cadavers or image	9. No. of investigators conducting measurements and if applicable the way of blinding was reported	10. Limitations of the study were reported	Total score
Curtis et al.(51)	Y	Y	N	Y	Y	N	Y	Y	N	Y	7/10
Dugas et al.(52)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9/10
Dupont et al.(50)	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	9/10
Gagey et al.(48)	N	Y	N	Y	N	Y	N	N	N	N	3/10
Itoi et al.(56)	Y	Y	Y	N	Y	Y	Y	Y	N	Y	8/10
Juul-Kristensen et al.(47)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
Juul-Kristensen et al.(41)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
Katayose et al.(22)	Y	Y	Y	Y	N	Y	Y	Y	N	Y	8/10
Keating et al.(54)	Y	Y	N	N	N	N	Y	Y	N	Y	5/10
Kim et al. (57)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	8/10
Kim et al.(7)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10
O'Connor et al.(45)	Y	Y	Y	N	N	N	Y	Y	Y	N	6/10
Roh et al.(36)	N	Y	Y	Y	N	Y	Y	Y	N	N	6/10
Ruotolo et al. (53)	Y	Y	Y	Y	Y	Y	N	N	N	N	6/10
Vahlensieck et al.(49)	N	Y	Y	Y	N	N	N	N	N	N	3/10
Volk et al.(58)	N	Y	N	Y	N	Y	Y	Y	N	N	5/10
Wood et al.(55)	N	Y	Y	N	N	N	Y	Y	N	Y	5/10

Explanations and Abbreviations: Y – Yes; N – No; no. – number

Appendix III - Summary - Study characteristics of cadaveric studies

Authors	Title of article	n (sex)	SS specimens	Age (Range)	Fiber b length	Pennation angle	Muscle length	Tendon length	Tendon width	Tendon thickness	Description of anat. ref. points	Exclusion criteria (n)	Self-reported limitations	Handle of specimens and instrument used
Curtis et al.(51)	The Insertional Footprint of the Rotator Cuff: An Anatomic Study.	X	20	X	X	X	X	*	*	X	*	Rot. cuff tear; osteophytic changes near the biceps groove or tuberosities (10)	Lack of information about age, sex and size	-Group 1: Thawed at room temp. for 24 h. Group 2: 24 h in 2.5% glutaraldehyde with cacodylic Buffer. Dehydrated with alc. -Excised SS
Dugas et al.(52)	Anatomy and dimensions of rotator cuff insertions	20	20	63 (48-88)	X	X	X	*	*	X	X	Evidence of previous shoulder surgery; visible gross shoulder abnormality	Lack of information about handedness, height, weight, medical/social/work history	-Kept frozen at -4°C till dissection; thawed to room temp. before dissection; -Excised SS -Calipers & digitizer
Itoi et al.(56)	Morphology of the torn rotator cuff	41	11	84 (64-96)	*	X	X	*	*	*	X	Previous surgery; fractures; tumors	X	-Embalmed -*"in situ"* SS -Digital caliper
Juul-Kristensen et al. (47)	Muscle sizes and moment arms of rotator cuff muscles determined by magnetic resonance imaging	9 (f)	9	78.9 (55-87)	*	*	X	X	X	X	X	X	Decay/shrinkage at dissection; only female	-Embalmed -Excised SS
Keating et al.(54)	The relative strengths of the rotator cuff muscles. A cadaver study	5	X	X	*	X	X	X	X	X	X	Rot. cuff tear; history of pathology of glenohumeral joint	Low sample size	-Embalmed -*"in situ"* SS
Kim et al. (57)	Three-dimensional study of the musculotendinous architecture of supraspinatus and its functional correlations	10 (m)	10	61.9 ± 16	*	*	X	*	*	X	*	Visible gross shoulder abnormality; previous surgery; tendon pathology (60-70%)	X	-Formalin embalmed - *"in situ"* SS -Digitizer

Explanations and Abbreviations: n – Number of subjects ; SS – supraspinatus; m – male; f – female; () – range; ± - standard deviation; alc. - alcohol; X – not reported; * - reported

Appendix III (continued) - Summary - study characteristics of cadaveric studies

Authors	Title of article	n (sex)	SS specimens	Age (Range)	Fiber length	Pennation angle	Muscle length	Tendon length	Tendon width	Tendon thickness	Description of anat. ref. points	Exclusion criteria (n)	Self-reported limitations	Handle of specimens and instrument used
Roh et al.(36)	Anterior and posterior musculotendinous anatomy of the supraspinatus	25 (10m/ 15f)	25	82	*	*	X	X	*	*	X	X	X	-Embalmed -Excised SS -Calipers
Ruotolo et al. (53)	The supraspinatus footprint: an anatomic study of the supraspinatus insertion	48	17	70.2	X	X	X	*	*	*	X	Full-/ partial-thickness cuff tear; (31)	X	-Caliper
Vahlensieck et al.(49)	Two portions of the supraspinatus muscle: a new finding about the muscles macroscopy by dissection and magnetic resonance imaging	30 (15m/ 15f)	49	(52-97)	X	X	*	X	X	X	X	X	X	X
Volk et al.(58)	An anatomic study of the supraspinatus muscle and tendon	20 (10m/ 10f)	20	(48-76)	X	X	*	*	X	X	X	X	X	-Embalmed -Excised SS -Calipers
Wood et al.(55)	Quantitation of human shoulder anatomy for prosthetic arm control—II. Anatomy matrices	1 (m)	1	X	X	X	*	X	X	X	X	X	Creep of muscle at dissection	-Embalmed -Excised SS

Explanations and Abbreviations: n – Number of subjects ; SS – supraspinatus; m – male; f – female; () – range; ± - standard deviation; alc. - alcohol; X – not reported; * - reported

Appendix IV - Summary - study characteristics of musculoskeletal ultrasound and magnetic resonance imaging studies

Author	Title of article	Type of method	Resolution	n (sex)	Shoulders scanned	Age (range)	Muscle length	Fiber length	Pennation angle	Muscle thickness	Muscle CSA	Tendon length	Tendon width	Tendon thickness	Description of anat. ref. points	Shoulder position	Exclusion criteria (n)	Self-reported limitations
Dupont et al.(50)	Real-time sonography to estimate muscle thickness: Comparison with MRI and CT	MRI	T1 weighted FOV: 24 cm ST: 5mm	6 (3m /3f)	X	(24-51)	X	X	X	*	X	X	X	X	X	*Prone with the arms held straight along the torso*	No history of shoulder injury; neuromuscular diseases (3)	Matching scan marks precisely; recognizing muscle borders
Gagey et al.(48)	The fibrous frame of the supraspinatus muscle	MRI	ST: 3mm	30	X	X	X	X	X	X	X	*	X	X	X	X	X	X
Juul-Kristensen et al.(47)	Comparison of muscle sizes and moment arms of two rotator cuff muscles measured by ultrasonography and magnetic resonance imaging	MRI	T1 weighted FOV: 24cm ST: 5mm	8 (f)	14	39.8 (27-54)	*	X	X	*	*	X	X	X	*	*Supine, upper arm lying along the side of the body*	Extreme physical activity/inactivity; accident involving dominant shoulder previous 1 year; disorder of the shoulder last 7 days; pregnancy; breast-feeding; metal parts in scanned area (1)	Superficial aponeurosis not included in US measurements; thickness might be decreased due to pressure; different positions; time difference measurement US/MRI (1year); CSA could not be measured at all points due to shadowing of the acro.
		MSU	5 MHz				X	X	X	*	*	X	X	X	*	*Seated with arm hanging along the side of the body*		
Juul-Kristensen et al.(41)	Muscle sizes and moment arms of rotator cuff muscles determined by magnetic resonance imaging	MRI	T1 weighted FOV: 24cm ST: 5mm	20 (f)	10	40.4 (22-58)	*	X	X	X	*	X	X	X	*	neutral position: *subject in supine with arm at the side of the body (elbow 155–165°) forearm mid pronated*) abducted position: *upper arm abducted 34° in the scapular plane(elbow 115–135°forearm pronate)*	previous accidents/disorder involving dominant shoulder during the last seven days; extreme physical activity; pregnancy; metal in body; claustrophobia	Training condition; only female

Explanations and Abbreviations: n – Number of subjects; CSA – cross sectional area; MRI – magnetic resonance imaging; MSU – musculoskeletal ultrasound; m – male; f – female; ab – abduction; rot. – rotation; ER – external rotation; IR – internal rotation; () – range; ± - standard deviation; FOV – field of view; ST – slice thickness; alc. – alcohol; acro. - acromion X – not reported; * - reported

Appendix IV (continued) - Summary - study characteristics of musculoskeletal ultrasound and magnetic resonance imaging studies

Author	Title of article	Type of method	Resolution	n (sex)	Shoulders scanned	Age (range)	Muscle length	Fiber length	Pennation angle	Muscle thickness	Muscle CSA	Tendon length	Tendon width	Tendon thickness	Description of anat. ref. points	Shoulder position	Exclusion criteria (n)	Self-reported limitations
Katayose et al.(22)	The cross-sectional area of supraspinatus as measured by diagnostic ultrasound	MSU	7.5 MHz	72 (m)	144	49.1 (45-53)	X	X	X	X	*	X	X	X	*	*Seated with the shoulder in neutral position, the arm by the side and the palm facing inwards*	Regular sporting activities using the upper limb; normal range of active movement; no symptoms/ surgery in neck or shoulder;	No examination for rotator cuff tear
Kim et al.(7)	Investigation of the static and dynamic musculotendinous architecture of supraspinatus	MSU	12 MHz	17 (8m /9f)	34	36.4 ±12.7 (21-60)	X	*	*	*	X	X	X	X	X	Relaxed: seated with arm resting at the subjects side, palm at the side of the chair Contracted: subject holding arm in: 60° ab neutral rot.; 60° ab with 80° ER; 60°ab with 80° IR	History of rotator cuff pathology or neuromuscular disease	Shadowing of posterior fiber bundles due to acromion
O'Connor et al.(45)	Ultrasound assessment of tendons in asymptomatic volunteers: a study of reproducibility	MSU	X	11 (m)	11	X	X	X	X	X	X	X	X	*	X	Shoulder internally rotated and extended by positioning the dorsum of the hand on the ipsilateral buttock	Consuming more than 28 units per week of alc; regular use of medication; significant musculoskeletal pathology (questionnaire)	X

Explanations and Abbreviations: n – Number of subjects; CSA – cross sectional area; MRI – magnetic resonance imaging; MSU – musculoskeletal ultrasound; m – male; f – female; ab – abduction; rot. – rotation; ER – external rotation; IR – internal rotation; () – range; ± - standard deviation; FOV – field of view; ST – slice thickness; alc. – alcohol; acro. - acromion X – not reported; * - reported

Appendix V - Assessment form project plan

Fontys Paramedische Hogeschool

B4 Assessment form project plan

Name: Tombra Abeke Student no:

Date: March 19, 2013

Title: Standard reference values for the supraspinatus muscle and tendon

---

General

- The project plan is according to format	yes
- Spelling and language are correct	yes

Problem description and problem definition (introduction)

- The problem description is sufficiently clearly formulated	yes
- The problem description reflects social and paramedical relevance	yes
- A concrete and relevant research question (or questions) can be formulated based on the problem definition, including possible sub questions	yes

Objective

The objective is:

- Sufficiently clearly and concretely formulated	yes
- Relevant for a selected target group within the (paramedical) professional practice	yes
- Practically feasible	yes
- Achievable within the set time	yes

Project product

The project product:

- Is in line with the problem definition, research question and objective	yes
- Is usable for the selected target group	yes
- Is in line with the client's wishes	yes
- The product requirements are accurately described	yes

Activities/method

Sufficient insight is given into the type of activities and types of sources for the performance of the research and the realization of the product	yes

Time schedule

- The time schedule gives a global phasing and time investment for the project as a whole and for the coming weeks an increasingly detailed schedule	yes
- Important moments are recorded in the table (typographically noticeable) (e.g. contact moments, handing-in moments)	yes

Study Guide PPP version 2012 - 2013 1

- The time schedule gives a global task division of the planned activities yes

Estimated costs

Clear insight is given in:

- The costs to be expected concerning money and hours yes
- The division of these costs (project leader, student, programme) yes

Literature

- Used and planned literature is specific and mentioned to a sufficient extent yes
- Relevant and recent literature is referred to yes
- Literature references, in the text and in the literature list, are made according to the Writer's Guide (Wouters 2012) yes

Dear Tombra. You have a GO for the projectplan. We gave you extensive feedback in your projectplan (Good points, but also feedback to improve). Please read and implement it.

All points under B3.1 up to and including B3.8 must be answered with a 'yes' in order to receive a GO for the project. The supervisor discusses with the student which points need adjustment.

GENERAL: **GO**

Name assessor:	Date + Signature
Marc Schmitz 19/3/2013	
Anke Voesenek 19/3/2013	