

REVIEW ARTICLE

Contractures with special reference in elderly: definition and risk factors – a systematic review with practical implications

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Abstract

Purpose: Contractures are common problems for the elderly with far reaching functional and medical consequences. The aim of this systematic literature review was to give an overview of contracture and to identify potential risk factors associated with contractures. **Methods:** A systematic literature search with two objectives limited to the last 10 years was performed to identify studies dealing with definition of contracture (objective 1 = O1) and with risk factors (objective 2 = O2). Predefined information including age, sample size, study design, setting, condition, joint, definition of contracture, mode of measurement, and whether inter- and/or intra-rater reliability were assessed, as well as risk factors of contracture were extracted. **Results:** One hundred and sixty one and 25 studies were retrieved. After applying exclusion criteria 47 studies (O1) and 3 studies (O2) remained. Only 9 studies (O1) provided a definition of contracture. In 3 studies (O2) several potential risk factors were identified. **Conclusions:** In most of the studies it seems that the presence of a contracture is equivalent with the presence of restriction in the range of motion (ROM) of a joint. Very little is known about risk factors for contractures. But it seems that immobility may play a pivotal role in the development of this condition.

Keywords

Contracture, definition, elderly, nursing, risk factor, systematic review

History

Received 6 December 2011
Revised 18 April 2013
Accepted 25 April 2013
Published online 17 June 2013

► Implication for Rehabilitation

- The prevalence of contractures in nursing home residents is estimated at 55% with significant functional and medical consequences.
- In most studies, which were published in the last 10 years, the presence of a contracture is equivalent with the presence of restriction in the range of motion of a joint.
- Immobility seems to play a role in the development of contractures.
- Potential avenues to prevention of contractures and subsequent functional limitations are exercise programmes for and maintenance of mobility of the elderly.

Introduction

Contractures are understood as an alteration in viscoelastic properties of the periarticular connective tissue where the muscles potentially lead to a reduction in the range of motion (ROM) in a joint, or an increased resistance to passive joint movement, which in turn reduces joint flexibility and mobility [1]. Contractures lead to impairments with far-ranging consequences on activities, social participation and consequently on quality of life, particularly for the elderly. They also represent a highly relevant problem in long-term care settings and frequently entail pain, decubital ulcers [2], discomfort, as well as compromise potential recovery [3].

For example, activities such as transfer may be severely affected by elbow or knee contractures [4]. From a caregiver's perspective, contractures increase nursing care demands, work burden and ultimately nursing home costs [5].

The current state of research has serious flaws. On the one hand, little is known about the causes and risk factors of contractures, although it seems that the condition can be mediated both by neurologic and non-neurologic factors [6]. On the other hand, currently no recommendation on effective prevention or treatment interventions can be given as summarized by a recent Cochrane review [7]. This situation is highly undesirable, and we believe that the current state of research is characterized by a number of flaws, most prominently by a lack of consensus concerning the definition of contracture [8]. As a consequence, diverging prevalence rates have been reported. As a result, the capability of caregivers to identify the risk for contractures, as well as the choice of relevant intervention strategies to limit the

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burden in their patients is compromised. In addition – especially for the setting of patient care – this lack of knowledge hampers the ability to control and plan nursing work load and to evaluate cost effectiveness of care-giving institutions, nursing care and health insurance system.

The aim of this study is to provide a systematic overview on the current state of research on contractures in older people. Specifically, we want to review common definitions of contractures and risk factors.

Methods

We conducted two different searches in MEDLINE (via Pubmed) to identify potential studies. The first search aimed to retrieve studies which are most likely to provide a definition of contractures: ((“Contracture/diagnosis”[Mesh] OR “Contracture/etiology”[Mesh] OR “Contracture/epidemiology”[Mesh]) AND (“aged”[Mesh] OR “aged, 80 and over”[Mesh])) NOT “Dupuytren Contracture”[Mesh].

The second search aimed to find studies that investigate or discuss risk factors: “Contracture”[Mesh] AND “Risk factors”[Mesh] NOT “Dupuytren Contracture”[Mesh].

Additionally, a hand search was carried out. All searches were limited to German and English articles published in the last 10 years. Eligibility criteria were the MESH terms we used in our searches. The abstracts were checked and subsequently exclusion criteria were applied. These were: paper reports on contractures as consequences of burn injuries or in relation to mastectomy, or retrieved publication type were letter to editors, cadaveric study or editorials. In the case of multiple publications of one underlying study, the paper with the highest impact factor was included.

In a next step, the following data was extracted from all eligible papers:

- information on age (mean, median and range)
- sample size
- study design
- setting
- condition
- joint
- definition of contracture
- mode of measurement
- assessment of inter- and/or intrarater reliability

- risk factors for contractures (only in articles retrieved from 2nd search)

The abstract and article checking and the retrieval of the information were performed by two trained raters. Discrepancies were solved by discussion.

Results

One hundred and sixty one studies were located by the first search strategy. Fifty one studies were preliminarily selected by abstract checking, and 47 studies remained after applying the eligibility and exclusion criteria.

A mean age of the patients of 70 years or higher was found in 6 studies and 12 studies included patients over 80. Sixteen of forty-seven studies were performed in departments of orthopedic surgery and only one study in a nursing home. Sixteen of 47 studies were retrospective cohort analysis, 11/47 studies were controlled trials and only 3/47 randomized controlled trials. The most frequent condition studied was restriction of ROM after total knee arthroplasty (10/47 studies), a condition that is also relevant in nursing home residents. 12/47 articles dealt with neurological disorders (stroke or cerebral damage). Interestingly all major joints of the upper (shoulder, elbow, wrist and fingers) and lower extremity (hip, knee and ankle) were covered in the studies. In most studies (38/47) the ROM of the joint under investigation was measured (in 11/38 studies with a goniometer), indicating that a contracture of a joint has something to do with restrictions in the ROM. Very rarely (4/47) the inter- and/or intra-rater reliability of the measurements were reported [9–12]. For further information of the retrieved data we refer to Table A1.

In 9/47 studies an explicit definition of contracture was given (see Table 1). Twenty-five studies were located by the second search strategy (two additional studies by manual search) of which 7 were selected in total. Three studies met the eligibility criteria by screening the original papers.

The mean/median age in these studies was 30, 76 and 83.7 years. One study was performed in a geriatric setting, while the other 2 were conducted in hospitals. All joints of the upper (except fingers) and lower (except toes) extremities were included. ROM measurement was performed in all of the studies.

Table 1. Descriptions of the definitions of contracture in different studies.

Author	Joint	Definition of contracture
DiGiovanni 2002 [63]	Ankle	Contracture of gastrocnemius muscle: maximal ankle dorsiflexion of $\leq 5^\circ$ or of $\leq 10^\circ$ with the knee fully extended
Singer 2004 [9]	Ankle	Contracture was considered to be present if, on a minimum of 3 measurement occasions, the maximum range of ankle motion achieved by manual stretching was less than 0° of dorsiflexion (plantigrade) with the knee extended
Bhave 2005 [66]	Knee	Knee flexion contracture: lack of extension of $> 10^\circ$
Pohl 2005 [10]	Shoulder	Moderate or clinically relevant contracture: the hand in the neck position is possible, but the manual shoulder ROM measurement determined a mean (of 6 measurements) distance between the olecranon and underlay that is higher than the age- and sex-related referent values determined for the control group
Patrick 2006 [74]	Ankle and elbow	Ankle contracture: $< 10^\circ$ ankle dorsiflexion or $< 25^\circ$ degrees ankle plantarflexion. Elbow contracture: $< 130^\circ$ elbow flexion or elbow extension was $> 5^\circ$ off a straight elbow
Arangio 2006 [81]	Ankle	Achilles tendon contracture: ankle does not dorsiflex above 90° . Gastrocnemius contracture: ankle dorsiflexed above 90° and the achilles contracture does not persist with the knee flexed, the gastrocnemius is contracted
Bellemans 2006 [82]	Knee	Flexion contracture: mild = between 5° and 15° , moderate = between 15° and 30° , severe = greater than 30°
Kolb 2008 [90]	Elbow	Mild: flexion $> 90^\circ$; moderate: flexion between 60° – 90° ; severe: 30° – 60° ; very severe: $< 30^\circ$
Sackley 2008 [13]	Not specified	Contracture was estimated as 30% or higher restriction when compared with the good side

Information on intra- and/or inter-rater reliability was not presented. One study provided a definition of contracture [13]. In this study the age range was 31 to 98 years.

Wagner et al. [3] performed a comprehensive assessment of 276 residents in order to quantify the presence of factors associated with contractures among nursing home residents. In their cross-sectional study, the authors compared the patient group with contractures with the patient group without contractures and identified several variables which were significantly associated with the presence of contractures. These included being non-White, receiving Medicaid, duration of stay longer than 3.5 years in the nursing home, having a lower functional physical status and a reduced mobility within the institution, pain during examination, poor cognitive function, physical restraints and having a comorbidity (stroke, urinary incontinence). However, in a logistic regression analysis with the above significant variables only being non-White (odds ratio 3.57) and pain during examination (odds ratio 6.78) remained significant predictors of contractures.

Bryden et al. [14] examined patients with motor complete C5 or C6 complete spinal cord injury and found that subjects with weak voluntary triceps activity had significant fewer and less severe elbow flexion contractures compared to those with paralysed triceps muscles. This result indicates that immobilization, in this case inability to actively move the joint, predisposes the patient to the development of contractures of the elbow.

In the longitudinal study by Sackley et al. [14] high rates of contractures in different joints were found in patients with Alzheimer's dementia (AD) and post stroke indicating that this disease has potential risk factors for the development of contractures. In AD the prevalence of contractures was highly correlated with the degree of functional impairment. Post-stroke patients who are more functionally dependent in self-care are likely to experience a greater number of complications, including contractures, than those who are less dependent.

Discussion

In total we included from search one 47 and from search two 3 studies in our systematic review. Only a minority of studies (2/47) were explicitly conducted in a geriatric setting and only a few studies dealt with conditions relevant to the elderly. Also the mean/median age range was lower in most studies than one would expect when performing a systematic search with a search term "age 80 and over". As we conducted two searches, results will be discussed separately.

Definition of contractures

Only 9 of the 47 studies explicitly offered a definition of contracture. The definitions were in all cases associated with a restriction of ROM in a joint. Although no explicit definition was provided in the remaining studies a ROM measurement was performed indicating that a ROM short of the normal ROM points to the presence of a contracture. In a review by Gnass et al. [8], that was based on 37 studies, the authors also found that almost all studies collected (active or passive) ROM measurements as a primary variable for assessing the presence or absence of contracture. However, they opine that only five of the included studies presented a clear definition of contractures. In three of these studies ROM at the knee in degrees was measured, in the remaining studies different clinical measures were utilized. Interestingly four studies of the review of Gnass et al. overlapped with the studies included in our systematic review. In a second systematic review regarding the epidemiology of major joint contractures Fergusson et al. [1] identified three studies [15–17] examining institutionalized elderly and one study evaluating

patients with a disease relevant to elderly [patients with Alzheimer disease [2]] that offered a definition of contracture. The authors came to the conclusions that (i) most studies focused on one joint rather than including all relevant joints, (ii) in the studies contracture was not defined and (iii) the measure for assessment of contracture was not indicated.

In summary, most studies in our review failed to provide an unambiguous definition of contractures. As a consequence, the assessment of contractures must remain unreliable as concise and clear diagnostic criteria are still lacking. However, several authors [1,7,18–20] give recommendations of how to define contractures in a clinical setting. Katalinic et al. [7], who have published a meta-analysis about the effectiveness of the treatment and prevention of contractures, included only studies which measured joint mobility in terms of bending flexibility and stretching in degrees. The authors offered in their introduction a pragmatic definition: "Contractures are characterized by a reduction in joint ROM or an increase in resistance to passive joint movement, both limiting joint mobility" (p. 5). A similar suggestion is presented by Clavet et al. [19]: "a contracture is present if the ROM of a joint is short of the full range" (p. 691). They argue that this definition reflects the fact that many activities may be limited by even small restrictions in the ROM of key joints. In some of the studies included in our review the authors also tried to classify the degree of severity by the magnitude of the restriction of the ROM [21,22]. This approach is from a clinical point of view both useful for the patient and provider perspectives in order to account for the functional consequences, although none of the studies have laid out their rationale for their classification. Overall, it seems that there is an implicit consensus that contractures are clinically characterized by a restriction of ROM in a joint and that this restriction might also have functional consequences.

However, a fundamental basis to conduct research on contractures, as in any field of research, is a sound, unambiguous definition and mode of measurement of the phenomenon under investigation. One pivotal finding of the above mentioned reviews and studies is a lack of a description on how contractures were measured, making it difficult to compare the results.

Reproducible measurements of the ROM are an important prerequisite for the interpretation of clinical assessments of contractures cross-sectionally and longitudinally. Hayes et al. [21] have pointed out that ROM reliability may vary between patient populations, the joint affected and from one joint movement to the next. In their study they found poor to good inter- and intra-rater reliability for 5 different methods assessing shoulder ROM. For the upper extremity van de Pol et al. [22] recommend that clinicians should measure passive physiological ROM using goniometers or inclinometers in order to make reliable decisions about joint restrictions in clinical practice.

In a study measuring hip ROM by Clapis et al. [23] a high correlation between a inclinometer and a goniometer of motion was obtained suggesting that these are reliable instruments for measuring hip extension flexibility. Knee joint studies have shown that goniometric measurement is more reliable than visual estimates. Watkins et al. [24] have found that goniometric passive ROM measurements of knee flexion and extension are highly reliable when taken by the same therapist. Reliability diminished when ROM is taken by different observers. The authors stressed that observers can minimize error by using a goniometer and by standardizing patient position.

For ankle plantarflexion and dorsiflexion the reliability was found to be low [25] and it is, therefore, recommended to use a goniometer in order to make objective measurements. In a recent systematic review by van Trijffel et al. [26], the authors stressed that the inter-rater reliability of the measurement of the ROM in lower extremity joints is generally lower than ROM measurement

in upper extremity joints and therefore careful consideration should be given to uniform standards of measurement procedure in order to ensure stability of participants' and raters' characteristics during the assessment. The authors also stressed that the measurement procedures should be in accordance with international standards such as described by Clarkson [27].

A lack of inter-rater reliability adversely affects the accuracy of diagnostic decisions and subsequent treatment selection [28]. This is particularly problematic when effective treatments are available and nursing home residents are at risk of not receiving them due to inappropriate decision-making due to diagnostic errors and variation in interpretation among raters/therapists. Van Trijfel et al. [26] recommend that raters/physiotherapists should incorporate a wider range of findings from their clinical assessment into their decision about patients with lower extremity disorders and not rely too strongly on results from measurements of passive movements in joints. It has been shown that a comprehensive hip and knee examination including a number of physical signs can be performed with adequate reliability if a standardized evaluation protocol is followed [29,30] allowing for reliable, and therefore, improved outcome assessments.

Since there is no acceptable consensus on the definition and measurement of contractures, we recommend the use of a goniometer to assess contractures, to standardize the measurement procedure and to maximize rater-reliability (i.e. trained rater, same rater in case of longitudinal assessments). We also would like to recommend a pragmatic definition, e.g. as brought forward by Katalinic et al. [7] and others [19], suggesting that any reduction in ROM of a joint short of the full range should be defined as a contracture.

Risk factors of contractures

Three articles matched the inclusion criteria and were included in the review for potential risk factors. All three studies are indicative that inactivity might play a major role in the development of contractures. This notion is also supported in a study by Selikson et al. [16] where a group of immobile elderly exhibited a high prevalence of contractures. In an older study Souren et al. [2] found that more than 75% of the patients who had lost the ability to walk, manifested contractures and on the other hand contractures were found in fewer than 11% of all ambulatory patients.

Interestingly, in the study by Wagner et al. [3] age was not correlated with contractures. This indicates that contracture may not be part of a normal aging process but rather reflect a pathogenetic process that insofar may be susceptible to intervention. Mounting evidence from experimental [31] and clinical studies [19,32] suggest that immobility or even inactivity may be a prime causal candidate in the course of the development of contractures. The pathophysiological effects of immobilization are complex and far reaching. With prolonged immobilisation or unweighting (e.g. due to pain caused by osteoarthritis, due to spasticity caused by stroke) connective tissue proliferates into the joint space. These changes occur within two weeks. As immobilisation continues, fibrous adhesions occur and further affect the mobility of the joint. Changes in the muscle as well as in the cartilage occur and connective tissue loses its extensibility [33,34]. There are also numerous adaptations in the electrical, mechanical and morphological properties of human muscle following prolonged unweighting, which result in loss of muscle mass and strength as well as a reduced ability of the muscle to develop force [35]. Unweighting also induces plastic changes in neural function at the level of the spinal cord and terminal branches of the motor axon and/or neuromuscular junction. When the latter findings are considered with the adaptations in the

muscles, it appears that much of the loss in strength is associated with neural deficits in central activation [36]. Furthermore there are a number of physiological changes due to disuse or immobility in different organ systems, including e.g. the cardiovascular, respiratory and metabolic systems [39,40]. Some of these changes contribute to further immobilize, resulting in a vicious cycle. Interestingly there are remarkable similarities between the physiological effects of aging and the changes found after immobilisation. Furthermore, elderly individuals are more susceptible to prolonged periods of immobility because they have only limited physiologic reserves at hand [37].

In neurological disorders in the elderly the development of contractures seems also to be at least in part initiated and negatively influenced by immobility or inactivity. In stroke an upper motor neuron syndrome including positive and negative features occurs [38]. Positive features include spasticity and abnormal postures resulting in muscle shortening and consequently muscle weakness [43,44], negative ones include loss of strength [39] and dexterity. Also adaptive features such as physiological, mechanical and functional changes in muscles and other soft tissues develop. For example, spasticity with its hypertonus and reflex hyperexcitability disrupt the remaining functional use of muscles, impede motion and may cause pain which in turn impairs motor function [40]. All the above mentioned factors are sources of impaired muscle performance and thus might contribute to the development of contractures. In Parkinson's disease Paul et al. [41] have shown that muscle power was significantly related to balance and mobility, explaining 7% to 33% of the variability in task performance. Freezing of gait, dyskinesia and executive function were not consistently related to task performance. A decline in motor performances such as walking or basic activities resulting in a more rapid decrease in mobility is frequently observed in patients suffering from dementia. In more advanced stages of this neurodegenerative disorder, motor performance is increasingly reduced by extra-pyramidal pathophysiology leading to symptoms such as tremor, rigidity, bradykinesia and postural instability [42]. These motor deficits are worsened by the reduced physical activity of demented persons eventually resulting in contractures and subsequent further functional restrictions [43].

Factors which are associated with immobility and inactivity or respective predictors are manifold. In a case control study by Selikson et al. [16] several risk factors which are associated with immobility were identified including contractures, severe dementia, poor vision and history of hip/leg fractures. It is thereby noteworthy that in this study the majority of the immobile residents' immobility was neither frequently documented as a major problem in medical records nor adequately evaluated, indicating that immobility is a neglected topic in nursing care. Miller [44] presented several case reports addressing the effects of ambulation in the elderly. In his cases he could identify poor patient motivation, depression, fear of falling and disordered family relationships as major determinants of immobility. In addition he emphasized the iatrogenic component of immobility such as overuse of restraints or medication for sedation. Immobility may also be the long-term disability resulting from disease such as e.g. stroke or AD, or due to inactivity because residents are not enabled to achieve or maintain their maximum level of functioning [45].

To our knowledge there is no clear cut concept or definition of immobility/inactivity and no clear criteria exist to guide clinicians in assessing and quantifying inactivity in elderly. Emed et al. [46] conducted a systematic review to determine how immobility is defined and operationalized in randomized-controlled trials (RCTs) of thromboprophylaxis in medical inpatients. In 17 out of 18 studies reviewed a definition, to varying degrees, of immobility was provided. Studies used several definition criteria.

including the patient's degree of activity (14 studies), time spent immobile or mobile (13 studies), distance walked (4 studies) and underlying reason for immobility (4 studies). The authors concluded that there is a marked lack of consistency in how the concept of immobility is defined and utilized. One could argue that this lack of conceptualisation of immobility in long-term care might also contribute to underutilization of mobilisation of elderly in the nursing home setting. Although practical considerations can also be tentative, owing to the still poorly understood state of research regarding risk factors of contractures. It seems worthwhile to recommend reduction of immobility in the aged and to foster training for mobility, including training the multidisciplinary team to practice or encourage team participation as an avenue to reduce contractures. Clearly, more research is needed to better understand the risk factors and causal relations involved in pathogenetic and clinically relevant etiology of contractures in the elderly.

To conclude, contractures and reduced ROM of joints are a common end result of different processes and diseases in an elderly population including immobilisation, unweighting, osteoarthritis as well as stroke and other neurological diseases. Some authors argue that any condition preventing a joint going through its full ROM may result in changes in the cartilage, shortening of periarticular tissue and muscles, eventually leading to degeneration and/or a contracture [47,48].

Contractures, either of the upper or lower extremity significantly predict functional performance [17]. Mollinger et al. [15] e.g. showed that there is a relationship of increasing knee flexion contracture (KFC) and ambulation score meaning that most individuals in their study with a KFC of 20° or greater were in the nonambulatory category and all KFCs greater than 33° were found in individuals who were nonambulatory. The authors stressed that even small magnitude losses of knee extension could have ramifications for postural alignment, gait efficiency and gait speed [49], energy expenditure [50], muscle force around the joints, forces within the joint and stress on adjacent joints. Impaired lower extremity function increases the likelihood of becoming disabled [51,52] especially in the presence of pain [53,54]. In the upper extremity an association of ROM and functional restriction could also be found, i.e. a higher shoulder or elbow flexion range is associated with a lower likelihood of having a short functional reach [55]. In AD motor performance of the upper and lower extremity is an independent predictor of a broad range of functional abilities indicating that, regardless of the cognitive decline, it is important to preserve motor performance in individuals with AD because it might influence physical function throughout the course of the disease [56].

There are three limitations which need to be mentioned: (1) we decided only to search in PUBMED and neglected other databases such as EMBASE, CINAHL, AMED or PEDro. Including these would have produced more studies and subsequently a clearer picture of the definition and risk factors of contractures. (2) Due to the lack of well designed studies with clear definitions of contractures is difficult to make firm conclusions about potential risk factors. (3) Only a minority of studies were performed in a geriatric setting. This is an additional drawback for interpretation of our result in respect to an elderly population.

However, there is a great body of evidence that physical inactivity or lack of motor performance is a modifiable risk factor for a wide variety of chronic diseases and functional limitations in the upper and lower extremity. Especially in the elderly this issue is highly relevant, because in this group the ageing process has resulted in limited physiologic reserve which make the person more susceptible to periods of inactivity or immobilisation eventually leading to a reduction in ROM of joints as well as functional limitations notably when comorbidities are present [57].

Mobility is more than the ability to move from one point to another [58] or to prevent contractures and disability. Mobility has a great impact for quality of life and the feeling of independence and freedom. Therefore, effective interventions should be integrated in long-term care settings of the elderly. Beyond doubt from a clinical point of view mobilizing residents is an important preventive and therapeutic strategy in order to tackle the development of restriction in ROM and functional abilities. It has been shown that elderly benefit from exercise [59] and that provision of physical rehabilitation interventions to long-term care residents is worthwhile and safe, reducing disability with few adverse events [60]. In our point of view, if a programme of exercise and maintenance of mobility can reduce the incidence of contractures, the presence of contractures could be a marker of the quality of care within continuous residential care for the elderly [45].

Acknowledgements

Niko Kohls work is made possible through the generous long-standing support of the Samuelli Institute, USA.

Declaration of interest

The authors declare that they have no conflict of interest.

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Appendix

Table A1. Data extracted from the studies retrieved from search 1. TKA = total knee arthroplasty.

Author	Age (mean and range)	Sample size	Design	Setting	Condition	Joint	Definition of contracture	Mode of measurement
Li-Tsang 2002 [61]	35	30	Controlled trial	Department of rehabilitation	Rheumatoid arthritis	Finger	No	ROM with goniometer
Shah 2002 [62]	52 (34–79)	15	Controlled trial	Department of orthopedic surgery	Contracture after distal radius fracture	Wrist	No	ROM with goniometer
DiGiovanni 2002 [63]	47 (28–76)	68	Cross sectional	Foot and ankle clinic	Forefoot and midfoot pain	Ankle	Yes	ROM with equinometer
Pandyan 2003 [64]	64.9 (40–93)	22	Longitudinal observational study	No information	Stroke	Wrist	Partly specified	Custom built system
Singer 2004 [9]	Median age 37 (13–87)	105	Longitudinal observational study	Neurosurgical rehabilitation unit	Acquired brain injury	Ankle	Yes	ROM with goniometer
Moriya 2004 [65]	71.6 (47–84)	52	Case series	University hospital	Osteoarthritis of knee	Knee	No	ROM
Bhave 2005 [66]	65.3 (47–72)	118	Case series	Rehabilitation center	TKA or hip arthroplasty	Knee, hip	Yes	ROM
Schurman 2005 [67]	69	358	Retrospective cohort analysis	University hospital	TKA	Knee	No	ROM with goniometer
Pohl 2005 [10]	58.2	50	Longitudinal observational study	Rehabilitation center	Severe cerebral damage	Shoulder	Yes	Standardized measurement protocol
Moriya 2005 [68]	62.3 (32–85)	105	Retrospective cohort analysis	Department for hand surgery	Trigger finger	Fingers	No	No
Takamoto 2005 [69]	88	18	Case series	No information	Spontaneous fracture in bedridden patients	Shoulder, knee, hip	No	No
Hutchinson 2005 [70]	65	13	Case series	University hospital	TKA	Knee	No	ROM
Keeney 2005 [71]	63.3	23	Retrospective cohort analysis	Department of orthopedic surgery	Revision TKA	Knee	No	ROM
Schurr 2006 [72]	73	21	Observational study	Local community	Healthy older people	Shoulder	No	ROM
Huang 2006 [73]	53.5 (25–73)	44	Retrospective cohort analysis	Department of orthopedic surgery	Deltoid contracture and rotator cuff tear	Shoulder	No	No
Patrick 2006 [74]	63 (51–77)	16	Cross sectional	Local community	Stroke	Elbow, ankle	Yes	ROM

Martin 2006 [75]	36 (21–77)	59	Retrospective cohort analysis	Department of orthopedic surgery	Flexion contracture of knee, hip and ankle secondary to neurological disease	Hip, knee, ankle	No	ROM
Mont 2006 [76]	56 (35–74)	17	Retrospective cohort analysis	Department of orthopedic surgery	TKA	Knee	Partly specified	ROM
Sammarco 2006 [77]	53.4 (18–74)	40	Retrospective cohort analysis	Department of orthopedic surgery	Major foot and ankle deformity	Ankle	No	ROM
Radic 2006 [78]	49 (32–73)	28	Cross sectional	Department of internal medicine	Systemic sclerosis	Finger joints	No	ROM
Ada 2006 [79]	63 (36–82)	27	Longitudinal observational study	No information	Stroke	Elbow	No	ROM
Hattori 2006 [80]	40 (16–65)	11	Retrospective cohort analysis	Department of orthopedic surgery	Post traumatic wrist contracture	Wrist	No	ROM
Arangio 2006 [81]	57 (21–81)	21	Cross sectional	Local hospital	Achilles tendon contracture	Ankle	Yes	ROM
Bellemans 2006 [82]	Three groups: 67.9; 64.4; 61.5	2593	Retrospective cohort analysis	University hospital	TKA	Knee	Yes	ROM
Lannin 2007 [11]	75.4; 70.3; 68.7	63	RCT	University hospital	Stroke	wrist	No	ROM
Horsley 2007 [83]	61; 62	40	RCT	Rehabilitation center	Stroke or stroke like brain injury	Wrist	No	ROM
Lindenhovius et al 2007 [84]	43 (17–73)	16	Retrospective cohort analysis	University hospital	Prior injury to elbow	Elbow	No	ROM
Meneghini 2007 [85]	69.4 (35–92)	720	Retrospective cohort analysis	Department of orthopedic surgery	TKA	Knee	No	ROM
Cipriano 2007 [86]	45–75	14	Retrospective cohort analysis	No information	Bed bound patients with contractures	Hip, knee	No	ROM
Ritter 2007 [87]	69.3 (21–91)	3672	Retrospective cohort analysis	Department of orthopedic surgery	TKA	Knee	No	ROM with goniometer
Seyler 2007 [88]	62 (43–80)	10	Controlled trial	Department of orthopedic surgery	TKA with post-operative flexion contracture	Knee	No	ROM
Robinson 2008 [12]	Two groups 74; 72	30	RCT	Metropolitan Hospital	Stroke	Ankle	No	Joint angle measured on photographed ankle in degrees
Gundlach 2008 [89]	40 (10–76)	21	Controlled trial	Department of orthopedic surgery	Posttraumatic stiffness of elbow	Elbow	No	ROM

(continued)

Table A1. Continued

Author	Age (mean and range)	Sample size	Design	Setting	Condition	Joint	Definition of contracture	Mode of measurement
Clavet 2008 [19]	59.6	155	Retrospective cohort analysis	University hospital	Patients who stayed 14 days or longer on intensive care unit	Elbow, knee, hip, ankle	Yes	ROM
Kolb 2008 [90]	45 (17–75)	35	Retrospective cohort analysis	Department of orthopedic surgery	Prior injury to elbow	Elbow	Yes	ROM
Wagner 2008 [3]	83.7	273	Cross sectional	Nursing homes	Nursing home residents	Shoulder, elbow, wrist, hand, hip, knee, ankle	No	ROM
Sackley 2008 [13]	76	122	Longitudinal observational study	Different settings	Stroke	Not specified	Yes	ROM
McGrath 2009 [91]	47–71	47	Controlled trial	Department of orthopedic surgery	TKA	Knee	No	ROM
Bonutti 2010 [92]	56 (23–78)	41	Controlled trial	Department of orthopedic surgery	Knee stiffness due to different causes	Knee	No	ROM with goniometer
Hahn 2010 [93]	35.4 (17–66)	42	Retrospective cohort analysis	University hospital	Fracture related stiff knee	Knee	No	ROM with goniometer
Ulrich 2010 [94]	45 (22–78)	37	Controlled trial	Department of orthopedic surgery	Posttraumatic elbow contracture	Elbow	No	ROM with goniometer
Suksathien 2010 [95]	35 (4–66)	13	Controlled trial	Department of rehabilitation medicine	Flexion contracture of knee or elbow due to different causes	Knee, elbow	No	ROM with goniometer
Mulroy 2010 [96]	58.3 (36–75)	30	Controlled trial	Outpatient rehab center	Stroke	Ankle	Partly specified	ROM with goniometer
Park 2010 [97]	37 (15–69)	42	Controlled trial	Department of orthopedic surgery	Contracture following trauma	Elbow	No	ROM with goniometer
Malhotra 2011 [98]	Median age 79 (52–90)	30	Longitudinal observational study	University hospital	Stroke	Wrist	No	ROM with custom built system