The relationship between functional upper limb kinematics, pain and perceived disability in individuals with rheumatoid arthritis

by

Jacqueline Dawn Ripat

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University of Manitoba
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THE RELATIONSHIP BETWEEN FUNCTIONAL UPPER LIMB KINEMATICS, PAIN AND PERCEIVED DISABILITY IN INDIVIDUALS WITH RHEUMATOID ARTHRITIS

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JACQUELINE DAWN RIPAT

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

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ABSTRACT

Shoulder motion is needed to perform essential independent living tasks such as feeding and bathing. Rheumatoid arthritis (RA) of the shoulder joint can result in pain and stiffness that may interfere with performance of such activities.

This study compared the upper limb kinematics of a control group and a group of subjects with RA primarily affecting the glenohumeral joint, and examined the relationship between upper limb kinematics, pain and perceived disability in the RA group. Motion about four upper limb joints while performing various tasks (lifting two items to shoulder height, combing hair, touching back of opposite scapula and touching sacrum) was filmed using a three-dimensional motion analysis system. Data was collected from the RA subjects on their perception of the magnitude of upper limb pain (visual analog scale) and on their self stated ability to perform tasks of daily living (Health Assessment Questionnaire - HAQ and the Canadian Occupational Performance Measure - COPM).

Results showed few differences in range of motion (ROM), maximum angular velocity and maximum angular acceleration between the groups during performance of the five functional tasks. The magnitude of upper limb pain was not associated with the functional ROM used by the RA group, however the magnitude of upper limb pain was positively correlated to the HAQ. Upper limb pain was negatively associated with maximum angular acceleration. Functional ROM used was not related to the HAQ. A comparison between the HAQ and the COPM revealed some conceptual differences.

Although a direct relationship between functional upper limb kinematics, pain and perceived disability in individuals with rheumatoid arthritis was not found, various significant associations were discovered which warrant further study and definition of the factors which influence the study variables.

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DEFINITIONS

disability - inability or limitation in performing socially defined activities and roles expected of individuals within a social and physical environment (Pope & Tarlov, 1991)

functional limitation - restriction or lack of ability to perform an activity in the manner or within the range considered normal that results from impairment (Pope & Tarlov, 1991)

impairment - a loss or abnormality of mental, emotional, physiological or anatomical structure or function and includes pain (Pope & Tarlov, 1991)

maximum angular velocity - the maximum of the absolute values of angular velocity

maximum angular acceleration - the maximum of the absolute values of angular acceleration

movement unit - a positive acceleration, followed by acceleration in the negative direction; examination of an acceleration trace shows one crossing of the zero line (Brooks, 1974; Kluzik et al., 1990)

pathology - interruption or interference of normal bodily processes or structures; includes cellular and tissue changes caused by disease, infection, trauma, congenital conditions or other agents (Pope & Tarlov, 1991)

post-task pain score (PTP) - the magnitude of pain experienced following completion of a task associated with a specific joint region as measured by a visual analog scale

pain change score (PCS) - the difference between the initial pain score (P_1) and *PTP*

total upper limb pain (*$\sum$PTP*) - the sum of the *PTP* for all three upper limb joint regions

UM²AS - The University of Manitoba Motion Analysis System

1. INTRODUCTION

1.1 Statement Of The Problem

Rheumatoid arthritis (RA) has an approximate worldwide prevalence of 1.0% (Harris, 1990; Spector, 1990). It is two to three times more common in women than men (Melvin, 1989; Spector, 1990; Verbrugge, Gates & Ike, 1991); the incidence is greatest between the third and fourth decades of life and increases with age (Melvin, 1989; The Arthritis Society, 1995). Approximately 293,000 Canadians are afflicted with this disease, with an annual Manitoba incidence of 560-750 individuals per year (The Arthritis Society, 1995).

The glenohumeral joint is affected in an estimated 70-90% of the individuals with RA and involvement of this joint can have profound effects on adjacent upper limb joints and function (Melvin, 1989; Kelly, 1994). RA of the shoulder can limit individuals' performance of self-care activities such as dressing, hair and perineal care (Melvin, 1989).

Decreased range of motion (ROM) about one upper limb joint in normal individuals has been shown, through three-dimensional motion analysis, to have an impact on the range of motion of adjacent joints during feeding activities (Cooper, Shwedyk, Quanbury, Miller & Hildebrand, 1993), and altered upper limb movement patterns have been observed about the elbow joint in individuals with RA (Packer, Wyss & Costigan, 1994). However, upper limb movement patterns during functional activities and the influence of pain on upper limb kinematics have not been studied in the RA population with shoulder involvement. In addition, the relationship between upper limb kinematics, pain and perceived disability in individuals with RA has not been clarified.

1.2 Significance of the Study

Normal kinematic patterns required for the completion of a movement must be determined before identification of kinematics of individuals with pathology can be achieved (Nuzik, Lamb, VanSant & Hirt, 1986; Cooper et al., 1993). Documentation of the normal kinematics of upper limb motion during functional tasks will provide a standard for determining limitations and setting goals for those individuals limited by a pathological condition such as RA. In a disease that affects the joints (such as RA), movement patterns are inevitably altered from the normal and individuals with shoulder involvement often use altered patterns of motion of adjacent (elbow, radioulnar and/or wrist) joint regions to compensate for the diminished range of motion (ROM) (Askew, Chao, An, Cooney & Morrey, 1980; Vasen, Lacey, Keith & Shaffer, 1995). Although compensation can result in increased function (Gerber, 1993) it is possible that this compensation may result in further damage and joint destruction in the adjacent joint region due to overuse, and may be particularly destructive in a joint that is already showing some signs of degeneration or inflammation.

Determining the relationship between upper limb kinematics, pain and perceived disability is also important in the overall rehabilitation of the individual with RA. Defining the correlation between these variables is important before a causative relationship can be identified. Identifying the relationship between the variables will provide valuable information to therapists and physicians that can be used with an individual with RA to set and prioritize rehabilitation goals. This, in turn, will have important consequences for the method in which physical, psychosocial and functional retraining programs are delivered and for selection of therapeutic and preventative methods. The results of this investigation will clarify how RA of the shoulder affects upper limb function, and will provide direction for the management and rehabilitation of the upper limb in this population.

2.0 REVIEW OF THE LITERATURE

2.1 Summary

2.1.1 Rheumatoid Arthritis

Rheumatoid arthritis (RA) is a systemic disease characterized by inflammation and destruction of the joint structures, with commonly associated symptoms of fatigue and malaise (Melvin, 1989). The pattern of involvement is generally a chronic, symmetrical and erosive destruction of peripheral joints and loss of structural support resulting in an unstable joint (Wilder, 1993). The initial destructive events may involve t-cells and the microvascular endothelial cells of the joint synovium. An exudate accumulates within the joint cavity. As the disease progresses to the chronic stages, inflammation and proliferation of the synovial membrane and connective tissue generate an invasive pannus which destroys the periarticular bone and cartilage (Wilder, 1993). The joint capsule and ligaments are subjected to prolonged mechanical stress and the resultant overstretching may eventually lead to joint subluxation or dislocation (Salter, 1983). In addition, subchondral bone is progressively destroyed partly as a result of increased osteoclastic activity (Wilder, 1993). The later stages of the disease are eventually characterized by joint fusion and deformity due to chronic synovitis (Wilder, 1993). Although the signs and symptoms of RA can differ between individuals, and even within the same individual over time (Anderson, 1993), joint pain is a consistent sign of the disease in its acute stages (Kelly, 1994, MacKinnon, Avison & McCain, 1994).

The shoulder joint region is commonly affected bilaterally in individuals with RA

(Kelly, 1994). The process of involvement of the RA shoulder begins with the individual immobilizing the arm during the acute phases of the disease by positioning the joint in the least painful position (Anderson, 1993). This pattern of mobilization and immobilization is repeated throughout the cyclical disease process of exacerbations and remissions, resulting in progressive limitation of motion (Kelly, 1994). Rotator cuff and extra articular soft tissue involvement (nodules, tenosynovitis) are common (Bröstrom, Wallenstein, Olsson & Anderson, 1992), as is muscle wasting due to disuse (Öberg, Karsznia, Andersson & Lagerstrand, 1994).

The primary cause of RA is unknown (Spector, 1990; Wilder, 1993; Alarcon, 1995). Genetic, environmental and other hormonal or infectious agents have been implicated as possible interacting factors that predispose an individual to the disease (Hochberg & Spector, 1990; Wilder, 1993; Alarcon, 1995). Diagnosis is based on the presence of specific signs and symptoms as no laboratory test can diagnose RA with certainty (Wilder, 1993).

2.1.2 Measurement of Disability

Pope & Tarlov (1991) presented a framework of the disabling process that distinguished between pathology, impairment, functional limitations and disability (*Figure 1*). This type of framework is such that intervention at one level has the potential of modifying the consequences at another level (Badley, Lee & Wood, 1979). Within this model, *"impairment"* is "a loss or abnormality of mental, emotional, physiological or anatomical structure or function" (p.79) and includes pain (Pope & Tarlov, 1991). In a disease such as rheumatoid arthritis, impairment is demonstrated by pain and decreased joint range of motion (Badley, Wagstaff & Wood, 1984; Frymoyer & Mooney, 1986; Neer, 1990; Eberhardt & Fex,

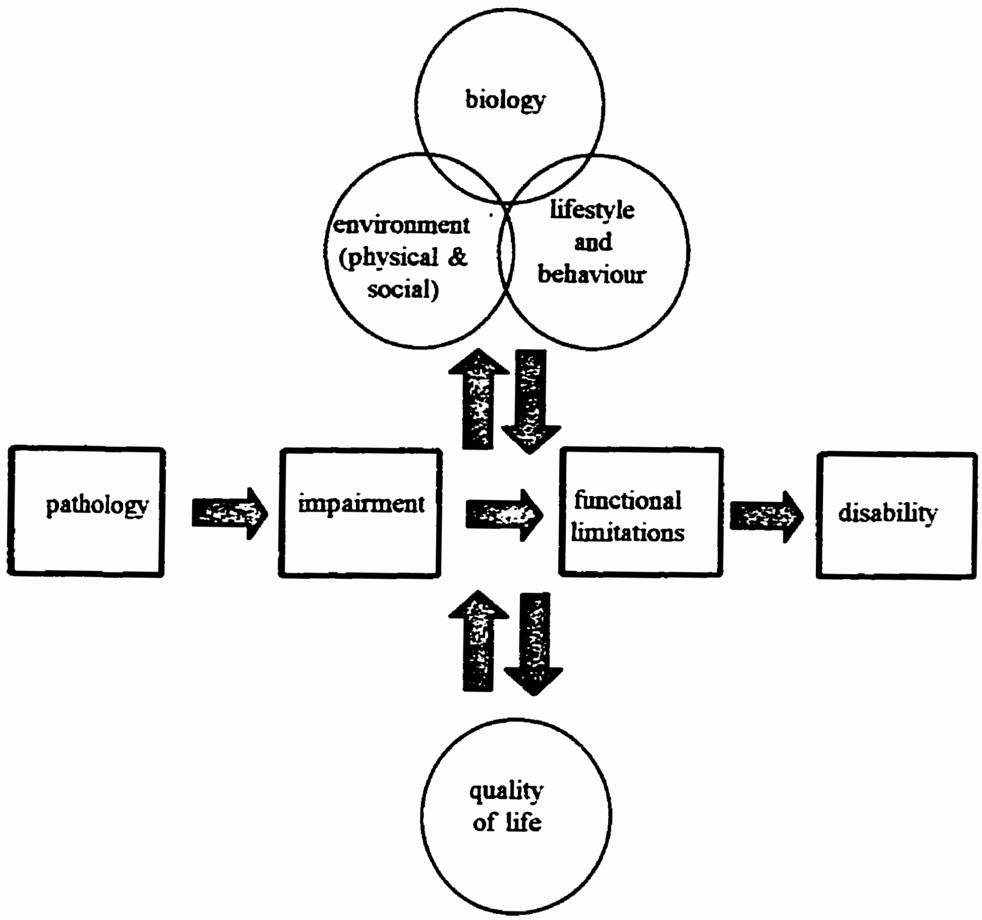

Figure 1. The Disabling Process. Pope & Tarlov, 1991.

1995). The term "functional limitation" is used to describe a "restriction or lack of ability to perform an action or activity in the manner or within the range considered normal that results from impairment" (p.79, Pope & Tarlov, 1991). Therefore, functional limitations in individuals with RA are demonstrated as an inability to perform certain tasks important for everyday living (Badley et al., 1984; Cofield, 1987; Kelly, Foster & Fisher, 1987; Hawkins & Neer, 1987; Welsh & Constant, 1987; Frich, Moller & Sneppen, 1988; Jonsson, Brattstrom & Lidgren, 1988; Eberhardt & Fex, 1995). For example, shoulder impairment due to RA may lead to a functional limitation when there is an inability to perform basic self-care tasks such as having a bath, dressing, combing hair and feeding oneself (Boström, Harms-Ringdahl & Nordemar, 1991). "Disability" refers to "inability or limitation in performing socially defined activities and roles expected of individuals within a social and physical environment" (p.79) or the difference between an individual's abilities and the demands of the environment (Pope & Tarlov, 1991). An individual with RA who requires a wheelchair for mobility might be considered disabled if unable to enter his or her office due to physical or environmental barriers preventing wheelchair access. Although this model appears to describe a step-wise progression from pathology to eventual disability, this is not always a consistent finding (Pope & Tarlov, 1991). Risk factors (biological, environmental and lifestyle/behavioral) and perceptions of quality of life interact reciprocally with the disabling process to determine the final manifestation of the disease. With this interaction, the disabling process can be accelerated or halted. Factors such as socioeconomic status, educational attainment and secondary diagnoses may facilitate or hinder the process. Individuals' perceptions of their quality of life may also influence the process; satisfaction with their life and situation may preclude disability or conversely, disability may diminish their quality of life.

Measurement of functional limitations and/or disability of individuals with rheumatoid arthritis has been attempted using several different scales. The Health Assessment Questionnaire (HAQ[1]) is a widely used, self-administered questionnaire that takes approximately three minutes to complete (Wolfe et al., 1988). The "disability" dimension covers eight component areas with twenty questions regarding dressing and grooming, hygiene, eating, walking, arising, reaching, gripping and other household and community activities. This is a self-report questionnaire which asks the subject to indicate the level of difficulty that he or she has in completing each of the identified tasks. In addition, the subject indicates if he or she requires any aids, devices or help from another individual to complete the tasks. The discomfort dimension requires the subject to record the level of pain experienced in the last week on a 15 centimetre visual analog pain scale. One week test-retest reliability (r=+0.93) was determined for this instrument with a group of 60 individuals with RA and osteoarthritis (Goeppinger, Doyle, Murdock, Wilcox & Brunk, 1985). Construct validity of this instrument has also been examined. When the self-scored disability index was compared with actual performance in 25 subjects, a Spearman correlation of +0.88 was determined (Fries, Spitz, Kraines & Holman, 1980). Convergent validity was examined by comparing the HAQ and the Arthritis Impact Measurement Scale (AIMS[2]). In one study the correlation was +0.89 (n=91) (Hakala, Nieminen & Manelius, 1994) and in a second study it was +0.84 (n=50) (Liang et al., 1995). The HAQ has also been compared with the

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[1]Fries, Spitz, Kraines et al., 1980

[2]Meenan, Gertman & Mason, 1980

Sickness Impact Profile (r=+0.78), the Functional Status Index (r=+0.75) and the Quality of Well-Being Scale (r=+0.60) (Liang et al., 1995).

The Arthritis Impact Measurement Scale (AIMS2) is another widely used instrument for assessing the health status of individuals with rheumatic disease. It consists of 39 items grouped into 9 scales covering areas such as mobility, self-care, support from family and friends and pain due to arthritis. A study of 299 RA subjects determined the internal consistency of this instrument to be greater than 0.72 (Cronbach's coefficient alpha) for all subscales (Meenan, Mason, Anderson, Guccione & Kazi, 1992). The same investigators determined the two to three week test-retest reliability to be greater than 0.74 (intraclass correlation coefficient) in a sub-sample of 45 RA and OA subjects from the former study. Construct validity of the AIMS2 was examined by comparing subject's scale scores to their other responses in the questionnaire; it was found that subjects who identified an area as a health status problem had consistently lower scale scores ($p<0.001$). Subjects (n=24) took an average of 23 minutes to complete this survey.

The Canadian Occupational Performance Measure (COPM[3]) is a generic assessment, (not specific for a particular age, disease or impairment) developed to take into account variations in individuals' perception of the influence of a disease. This measure considers the importance of a task to the individual and the satisfaction with present performance of the task (Pollock, 1993). It ensures that the unique characteristics, needs and situations of the individual are taken into account and it has the potential to define disability (a subjective

[3] Canadian Association of Occupational Therapists, Suite 3400, 1125 Colonel By Drive, Ottawa, Ontario

experience) in objective terms. The COPM is a standardized instrument that uses a semi-structured interview to measure an individual's perception of his or her performance of tasks of daily living. Subjects rate the importance of the task, perception of their performance and satisfaction with their performance on a 10-point scale (Law et al., 1994). As this is a new measure, reliability, validity and responsiveness of the test are in the process of being established (Pollock, 1993). The COPM manual cites intra-class correlation coefficients of 0.63 for the performance and 0.84 for the satisfaction components when measuring test-retest reliability (n=27). It has been shown to be responsive to change ($p<0.001$) in both performance and satisfaction components (Law et al., 1994).

2.1.3 The Consequences of RA

Eberhardt & Fex (1995) examined the relationship between the impairment components of pain and ROM by following sixty-seven individuals with RA for five years. Pain intensity was measured by a visual analog scale (VAS[4]) and was significantly correlated ($r=-0.39$, $p<0.01$) to the ROM scores after five years. This correlation indicated that as the level of pain intensity increased, the ROM attained by the subjects decreased. Using the Health Assessment Questionnaire these investigators also examined the relationship between pain and the limitations in activities of daily living (ADL) experienced by the individuals and found significant correlations both at the beginning of the study ($r=+0.44$, $p<0.01$) and after five years ($r=+0.59$, $p<0.001$). As the HAQ scores remained relatively constant throughout the five-year study, the authors speculated that the full effect of the disease on ADL may not be evident until ten years post diagnosis.

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4 Huskisson, 1983

Another group of investigators examined the relationship between impairment and functional limitations in individuals with RA. They found significant positive correlations between the site and nature of joint involvement and an inability in these individuals to perform groups of activities composed of similar types of actions or tasks (Badley et al., 1979; Badley et al., 1984; Badley & Lee, 1987). For example, increased pain and involvement of the shoulder joint were consistently shown to affect the perceived difficulty experienced by the subjects in their ability to accomplish activities such as pouring liquids, getting in and out of the bath and cleaning windows (Badley et al., 1979).

Affleck, Tennen, Urrows & Higgins (1991) used daily pain logs to report joint pain intensity for each of 20 joints/joint groups and the AIMS to investigate the relationship between pain and limitations in ADL in individuals with RA over a period of 75 consecutive days. They found that "mean" pain was significantly correlated to limitations identified by the AIMS (+0.48, $p<0.01$). That is, the greater the joint pain intensity, the greater the limitations in ADL.

In a study of 1522 subjects, Hawley & Wolfe (1991) showed that, although individuals with RA had the least pain intensity (measured by a VAS) compared with individuals with low back pain, osteoarthritis of the hands or knees, fibromyalgia, cervical pain or a mixed group consisting of more than one of the above diagnoses, the RA group had the greatest amount of difficulty performing activities of daily living (measured by the HAQ) of the six groups studied. They concluded that individual differences in pain level and functional limitations were more important than overall differences observed between the diagnostic groups.

Badley et al. (1984) further examined the relationship between impairment (a decrease in ROM about specific joints) and functional limitations. This group of investigators determined significant correlations between joint rotations and inability to perform specific groups of tasks, with shoulder abduction the correlations ranged between $r=-0.42$ for dexterity tasks (e.g., opening jars, cutting meat) and $r=-0.78$ for reaching tasks (e.g., combing hair, placing items on a shoulder height shelf). That is, those subjects with greater ROM were better able to perform specific groups of tasks. These authors chose to measure the movement on the most limited side, disregarding the fact that individuals are able to compensate for lack of motion with the opposite limb. They suggested that other factors such as pain, motivation and fatigue contribute to the presentation of a functional limitation or disability. Others have concurred, stating that assuming that decreased ROM at individual upper limb joints results in decreased functional ability is incorrect as the latter is the result of a complex interaction of physiologic, psychosocial and environmental variables (Liang & Jette, 1981; Frymoyer & Mooney, 1986). This is also consistent with the suggestion presented by Boström et al. (1991) that high positive correlations between impairment and disability (functional limitations) are not necessarily expected due to the influence of a variety of other factors and variables.

Pincus, Summey, Soraci, Wallaston & Hummon (1983) attempted to characterize functional capacity by including the measurement of satisfaction with task performance when determining level of disability. In this study of individuals with RA, a strong negative correlation (-0.69, $p<0.001$) was found between perceived difficulty in doing a task and satisfaction with performance (i.e., increased difficulty resulted in decreased satisfaction with performance) as measured by a modified version of the HAQ. However, these investigators found that although only 42% of the activities were reported to be performed without any difficulty, 60% of the activities were reported to have been performed satisfactorily by the individuals surveyed. Approximately two-fifths of those who said that they had "*some difficulty with the task*" and one-fifth of those who said they had "*much difficulty with the task*" still stated that they were satisfied with their performance. This study limited the rating of satisfaction to "*satisfied*" or "*not satisfied*," losing some potential sensitivity of the question dealing with the degree of satisfaction. The authors concluded that although general patterns of disability may be observed in populations with particular diagnoses, these patterns are not necessarily applicable to individuals.

Meenan et al. (1992) modified the AIMS scale to include three new areas: a satisfaction rating, documentation of attribution of problems to arthritis, and a prioritization for improvement. The results of this study (n=408) concurred with those described by Pincus et al. (1983); a direct causal relationship between satisfaction and functional ability cannot be inferred due to the influence of other interacting variables.

MacKinnon et al. (1994) had 143 subjects with RA complete logs of the time they spent in each of 12 categories of daily activities. Pain (variety of measures), functional limitations (HAQ), and satisfaction with life (Satisfaction with Life Scale[5]) were also measured in this study. A significant (although low) negative correlation ($r=-0.26$, $p<0.05$) between functional limitations and satisfaction with life was found. Thus, as functional limitations increased, satisfaction with life decreased. However, the correlation between the

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[5]Diener, Emmons, Larsen & Griffin, 1985

pain measures and Satisfaction with Life Scale was not significant. Although pain can be considered a major consequence of RA, one could conclude that for this group of subjects, inability to perform daily living tasks had a greater influence on satisfaction with life than did pain.

Pain, perceived limitations, and dependence were the three most important life stressors listed by 66 individuals with RA in a study by van Lankveld, Naring, van der Staak, van't Pad Bosch & van de Putte (1993). In an extension of their study with a larger sample of subjects (n=415), it was found that individuals that had difficulty with their self-care and mobility (as measured by a sub-scale of the AIMS) did not necessarily feel limited or dependent.

Pain and functional impairment are considered two of the most important consequences of RA (Hagglund, Haley, Reveille & Alarcon, 1989; Affleck et al., 1991; Hawley & Wolfe, 1991; van Lankveld et al., 1993). However, generalizations about pain and its influence on impairment of function are impossible due to individual differences in the experience of pain (Affleck et al., 1991). Similarly, although patterns of impairment may be alike between groups of individuals with the rheumatoid arthritis (Badley et al., 1979; Badley et al., 1984), the perception of disability is subjective and takes into consideration multiple factors, including psychosocial characteristics, satisfaction with ability to perform tasks, and environmental influences (Pope & Tarlov, 1991).

Standardized functional scales based on an arbitrary selection of activities thought to represent the common tasks of daily living are commonly used to obtain information on an individual's ability to accomplish a set task. Studies using these scales to measure functional limitation generally resulted in a degree of positive association with impairment (as measured by pain and/or ROM) (Badley et al., 1979; Badley et al., 1984; Affleck et al., 1991; Eberhardt & Fex, 1995). Although these methods are valuable in obtaining information regarding function, they fail to take into account individual differences in perceptions of limitations or recognize the need to determine those functional tasks most important to the individual (Pollock, 1993; Badley et al., 1987). Neer (1990) stated that the definition of adequate upper limb function was dependent upon the demands of the activities normally carried out by an individual. Pincus et al. (1983) stated that a simple scale that determines whether an individual is able or unable to perform an activity is not comprehensive enough to determine where the areas of disability lie. A scale must also include some measure of the degree of satisfaction with task performance. When satisfaction is included in the examination of the relationship between impairment, functional limitation and disability, the relationship between variables is not clear. Individuals' perceptions of their functional limitations influence their perception of disability. The individual's subjective evaluation of his or her function may be a more important consideration than the disease activity or physical ability in determining disability (van Lankveld et al., 1993). Therefore, a generic measure of disability is impractical and any measure chosen must be flexible enough to incorporate individual differences and perceptions.

2.1.4 Normal Shoulder Function

The shoulder complex consists of four joints (the sternoclavicular, acromioclavicular, glenohumeral and scapulothoracic joints) that allow the upper limb to rotate fully and freely to participate in its reaching and grasping functions (Zuckerman & Matsen, 1989; Neer, 1990). Impaired motion about any one of these joints results in loss of the simultaneous and smooth movement of the shoulder complex observed to occur during shoulder abduction that is referred to by Lucas (1973) as the normal "scapulohumeral rhythm" of the shoulder (p.429). The glenohumeral joint is a multi axial ball-and socket joint; the articular surfaces include the large spherical head of the humerus and the relatively shallow glenoid fossa of the scapula. This size discrepancy allows for great joint mobility but in doing so sacrifices stability (Zuckerman & Matsen, 1989). Stability is increased passively by the presence of the glenoid labrum, a fibrocartilaginous ring that deepens the glenoid fossa, and both dynamically and passively by the presence of the rotator cuff muscles (supraspinatus, infraspinatus, teres minor and subscapularis) which counteract the internal and external forces that tend to pull the head of the humerus away from the glenoid fossa during movement (Saha, 1971; Basmajian & Slonecker, 1989; Bradley & Tibone, 1991).

It has been found that the relatively small glenohumeral joint is exposed to loads and joint reaction forces comparable to those experienced by the much larger hip joint (Bergmann, 1987; Inglis, 1989; Zuckerman & Matsen, 1989). Joint compression forces equal to almost 90% of body mass have been calculated when the arm is abducted to 90° (Inman, Saunders & Abbott, 1944, Poppen & Walker, 1978); placing a 50 Newton (approximately 5 kilogram) mass in the hand of an outstretched upper limb increases the compression force across the joint to almost 250% of body mass (Bergmann, 1987).

2.1.5 ROM of the Shoulder Complex

The overall active ROM that occurs at the shoulder complex is the greatest of all joints in the body (An, Browne, Korinek, Tanaka & Morrey, 1991; McCann, Wootten, Kadaba & Bigliani, 1993), allowing the upper limb to place the hand in a wide variety of positions in order to contact and connect with objects during activities of daily living (Dempster, 1965; Brumfield & Champoux, 1984; Johnson & Gill, 1987). There are three rotations possible at the glenohumeral joint: flexion and extension (about the frontal axis), abduction and adduction (about the sagittal axis) and medial and lateral rotation (about the vertical axis). The mean range of active flexion has been determined using manual goniometry to be 179° (n=159, age range <1-103 years) (Germain and Blair, 1983), while active extension is approximately 58° (n=80) (Murray, Gore, Gardner & Mollinger, 1985). Active abduction in the frontal plane is considered to be 180° (Murray et al., 1985) and adduction in front of the body was measured as 75° (Zuckerman & Matsen, 1989). Mean medial rotation has been measured to be 54° while the mean range of available lateral rotation ranges from 82° (older men, n=20, mean age=62) to 101° (younger women, n=20, mean age=29) (Murray et al., 1985). Poppen & Walker (1976) advocated that "true" abduction of the arm be measured in the scapular plane (30° to 40° anterior to the frontal plane); this has been recorded as a maximum range between 90°-120° (An et al., 1991). A roentgenographic study has shown that during abduction in the scapular plane in the normal glenohumeral joint, motion between the two contacting surfaces is mainly rotational, with minimal translation of the humeral head (Poppen & Walker, 1976).

2.1.6 Motion Analysis

Methods such as photography (Hall, 1991) and manual goniometry (Doody, Freedman, & Waterland, 1970; Boone & Azen, 1979) have been used to measure the angle of a joint in a static position. Systems such as 35 mm cameras (Engen & Spencer, 1968), eight and 16 mm video cameras (Armstrong, Chaffin & Foulke, 1979; Gilad, 1986; Hall, 1991), biplanar video recording (Langrana, 1981), sonic digitizing (Engin, Peindl, Berme & Kaleps, 1984; Fleischer & Becker, 1986), and electromagnetic movement sensors (Johnson, Fyfe & Heward, 1991) have been used to monitor the position and angular displacement of limb segments. Each of these systems permits determination of the joint kinematics during motion. Measurement of range of motion while performing functional activities has been studied using methods such as visual observation (Davis, 1977) and uniaxial electrogoniometry (Brumfield & Champoux, 1984; Packer, Peat, Wyss & Sorbie, 1990). Three-dimensional motion analysis was developed with the recognition that human motion occurs in more than one plane; this motion has been measured by equipment such as a 35 mm movie camera, with mirrors positioned to capture the functional movement of an individual from three perspectives (Engen & Spencer, 1968) and a triaxial electrogoniometer (Chao, An, Askew & Morrey, 1980; Morrey, Askew, An & Chao, 1981; Palmer, Werner, Murphy & Glisson, 1985; An & Bejani, 1990). Video based (e.g., Safaee-Rad, Shwedyk & Quanbury, 1990; Safaee-Rad, Shwedyk, Quanbury & Cooper, 1990; Cooper et al., 1993; Bennett, Marchetti, Iovine & Castiello, 1995) and optoelectric (e.g., Scholz, 1989; Kluzik, Fetters & Coryell, 1990; Trombly, 1992; Jevsevar, Riley, Hodge & Krebs, 1993; Wu, Trombly & Lin, 1994) systems have been used to obtain measurements of the kinematics of human motion in a relatively unobtrusive manner in experimental settings. These systems require the use of two or more cameras that monitor the position of markers placed on the body, and software that can process the image to determine the x, y and z coordinates of the markers.

2.1.7 Functional Range of Motion of the Upper Limb

Although large ranges of motion are possible at the shoulder complex, only a limited amount of the available range is generally used during activities of daily living (Chao et al., 1980, Brumfield & Champoux, 1984, Cooper et al., 1993). Relatively few studies have examined the range of motion required to accomplish daily living tasks. Two studies have used 3-D motion analysis to examine the range of motion required by the upper limb joints during three feeding tasks: eating with a fork, eating with a spoon and drinking from a cup (Safaee-Rad et al., 1990, Cooper et al., 1993) (*Table 1*). In 10 male subjects with no reported upper limb pathology, shoulder flexion range was determined to be approximately 8°- 43°, abduction range was approximately 6° - 31° and medial rotation was 5°- 23°. The subjects in the study by Cooper et al. (1993) used slightly smaller arcs of flexion and abduction motion to accomplish the same tasks and slightly greater ranges of medial rotation. When the elbow was splinted in a 110° flexion splint to restrict natural flexion, the range of motion used in shoulder flexion and medial rotation increased substantially to compensate for the restriction.

author & year	flexion	abduction	medial rotation
Safaee-Rad et al. 1990	8° - 43°	6° - 31°	5° - 23°
Cooper et al. 1993	♂9°- 36° ♀4°- 31°	6° - 23° 13°- 28°	-1°- 22° 2° - 28°

*range of values indicates minimum and maximum range of motion required to accomplish the tasks examined in each study.

Table 1. Functional Shoulder Range of Motion.

The functional ROM of the elbow and forearm has been examined by several investigators (*Table 2*). Chao et al. (1980) used a triaxial electrogoniometer to measure functional ROM about the elbow region in 15 men and 18 women during four activities of daily living. It was determined that the activities could be accomplished with a range of 30° - 130° elbow flexion and 25° pronation to 40° supination. In another study using triaxial electrogoniometry, seven static positions of the upper limb and eight tasks requiring an arc of motion were examined in 33 subjects; these activities required the range of forearm rotation to increase to 100° consisting of 50° pronation and 50° supination (Morrey et al., 1981). Uniaxial goniometry was used to determine that a minimum elbow flexion angle of 15° and a maximum angle of 140° were used by five subjects during three activities of daily living chosen to represent the extremes of elbow motion required in functional tasks (Packer et al., 1990). Elbow flexion and forearm rotation were measured by 3-D motion analysis during three feeding tasks in two studies; it was determined that an elbow flexion range of 72° - 130° and a forearm rotation range of 38° pronation to 59° supination was used by 10 male subjects (Safaee-Rad et al., 1990). In the second study, Cooper et al. (1993) determined that a slightly smaller elbow flexion and forearm supination range was required and that males used an average of 47° and females required 38° of pronation to complete the same feeding tasks. In another study, fifty subjects were serially limited in an adjustable bilateral elbow orthoses to determine the ranges of elbow flexion required to perform 12 functional tasks; it was determined that most tasks could be accomplished when the elbow was limited to a range of 75° - 120° flexion (Vasen et al., 1995). In this study, compensatory and accessory movements at all other joints were permitted.

author & year	flexion	pronation	supination
Chao et al. 1980	30° - 130°	25°	40°
Morrey et al. 1981	30° - 130°	50°	50°
Safaee-Rad et al. 1990	72° - 130°	38°	59°
Packer et al. 1990	15° - 140°	n/a	n/a
Cooper et al. 1993	♂77° - 126° ♀86° - 136°	47° 38°	53° 51°
Vasen et al. 1995	75° - 120°	n/a	n/a

*range of values indicates minimum and maximum range of motion required to accomplish the tasks examined in each study. A single value indicates the maximum range of motion required for the tasks.

Table 2. Functional Elbow And Forearm Range Of Motion.

Functional wrist motion has similarly been studied by using uniaxial and triaxial goniometry and 3-D motion analysis (*Table 3*). Twenty degrees of flexion and 15° of extension was the range measured by uniaxial goniometry to accomplish fourteen activities of daily living by 10 subjects (Brumfield & Champoux, 1984). Palmer et al. (1985) examined 52 tasks with triaxial electrogoniometry and determined that the functional range of wrist motion was 5° flexion, 30° extension, 10° radial deviation and 15° ulnar deviation. Safaee-Rad et al. (1990) in their examination of the three feeding activities reported that 8° flexion, 20° extension, 16° ulnar deviation and 5° radial deviation were required at the wrist. In the same three feeding tasks, 10 males and nine females used an average wrist range between 7° flexion and 22° extension (Cooper et al., 1993). Wrist ulnar deviation for males was reported as 19°, while females only used 3°. Conversely, males used only 2° radial deviation for these tasks, while females used 18°.

author & year	flexion	extension	radial deviation	ulnar deviation
Brumfield et al. 1984	20°	15°	n/a	n/a
Palmer et al. 1985	5°	30°	10°	15°
Safaee-Rad et al. 1990	8°	20°	5°	16°
Cooper et al. 1993	♂7° ♀8°	21° 22°	2° 18°	19° 3°

Table 3. Functional Wrist Range of Motion.

2.1.8 Kinematic Variables

Scholz and Kelso (1989) have identified a need to determine the essential variables of the motor system that underlie the movement processes. If the appropriate variables can be identified and measured, studies that examine the effectiveness of a treatment procedure can be undertaken. Kinematic variables such as overall movement time (Kluzik et al., 1990; Wu et al., 1994), maximum and minimum joint rotation angles reached (Safaee-Rad et al., 1990; Cooper et al., 1993; Packer et al., 1994) and arc of motion (Packer et al., 1990; Safaee-Rad et al., 1990; Cooper et al., 1993; Packer et al., 1994) have been defined and used to quantify movement in previous studies.

Velocity is the first order derivative of displacement and is another variable used to describe movement (Kluzik et al., 1990). Peak angular velocity was calculated and used as a kinematic variable representative of upper limb movement patterns in one study (Packer et al., 1994). Lower than normal angular velocity may be related to increased joint impairment (Packer et al., 1994).

The second order derivative of displacement is acceleration. A "movement unit" has been described as a variable representing acceleration, and has been defined as an acceleration pattern where a positive acceleration is followed by acceleration in the negative direction; examination of an acceleration trace shows one crossing of the zero line (Brooks, 1974; Kluzik et al., 1990). A smooth, or "well-programmed" motion (calculated from the trajectory recorded from a wrist marker) is observed as a continuous (or open loop) movement that exhibits two peak velocity values and contains one movement unit (Brooks, 1974; Brooks & Watts, 1988; Trombly, 1992). This type of movement is generally seen during reaching with an unimpaired limb.

2.1.9 Kinematic Analysis of Pathological Conditions

Review of the literature was limited to those studies that included kinematic analysis of upper limb motion to examine the effects of pathology. In a study that compared the shoulder ROM in a normal group to that of a heterogeneous group with soft tissue lesions of the shoulder, it was demonstrated that the ROM used by the soft tissue lesion group was less than that of the normal group and that a longer time was used to complete the motion (Peat & Grahame, 1977). The authors hypothesized that the decreased ROM used and the slower movement time may have been an attempt to decrease pain.

Packer et al. (1990) measured elbow ROM in 5 RA subjects using uniaxial electrogoniometry during three activities of daily living and found that the RA group used a significantly smaller arc of elbow flexion to complete the tasks than did a control group. The same investigators compared the elbow joint kinematics of a normal group with that of a group of subjects with RA of the elbow during a sit-to-stand-to-sit activity (Packer et al., 1994). Results demonstrated that although both groups used consistent patterns of motion, maximum and minimum angles used and the maximum angular velocity were different. The authors concluded that with increasing impairment of the elbow, more deviation from the normal pattern of movement was seen.

Several studies have focused on measuring the kinematics of motion in individuals with neurological impairments. Kluzik et al. (1990) examined the effect of neurodevelopmental treatment on five children with spastic quadriplegia using 3-D data to determine the number of movement units, movement time, and distance (trajectory of the path) used by each subject during a reaching task. Fewer movement units and decreased distance of the path of the hand were taken as indicative of an improved or more mature reaching pattern. This study had a small number of subjects, no control group and the results varied on a case-by-case situation. However, it was useful in attempting to define some kinematic variables able to measure a change in motor behavior (Scholz, 1989; Kluzik et al., 1990).

McPherson et al. (1991) examined the quality of movement (as defined by the number of movement units used) of 12 subjects (six unaffected control subjects and six subjects with spastic cerebral palsy) during reaching while positioned in four different seat angles. They discovered a significant difference in the number of movement units used by the two groups and hypothesized that the movements used by the cerebral palsy groups were less programmed and more reliant on visual feedback than those of the control group.

Trombly (1992) used 3-D motion analysis to assess the reaching patterns of five left hemiplegic subjects and found that significantly more movement units were used in the impaired upper limb than in the unimpaired upper limb, indicating the use of a discontinuous strategy. As well, movement time was longer for the impaired upper limb and peak velocity occurred earlier in the reach (although not significantly). The amplitude of peak velocity was less in the impaired upper limbs of four subjects, with the velocity profile showing a much more variable pattern than that of the unimpaired upper limb.

Nine subjects with Parkinson's disease and nine control subjects were studied by 3-D motion analysis during a drinking action (Bennett et al., 1995). Compared with the control group, the Parkinson group performed the drinking task in a slower manner, and the task was distinctly broken down into two components by the Parkinson group while the control group performed the task in a smooth and continuous manner.

Preliminary examination of data obtained in the Biomedical Engineering Laboratory at the University of Manitoba from an individual with osteoarthritis of the glenohumeral joint before and after shoulder arthroplasty indicated that glenohumeral pain (as measured by a VAS) decreased markedly post arthroplasty. The acceleration traces also illustrated a difference in the maximum angular acceleration used to complete the same task. With a painful shoulder, the maximum angular accelerations used were very low; in the "pain-free" (post-arthroplasty) state, the angular accelerations increased markedly. Angular acceleration data can be used to determine the kinetics of the upper limb. The high accelerations post-arthroplasty may result in increased compressive forces across the glenohumeral joint (Enoka, 1994).

There is a direct relationship between angular acceleration and sum of the moments of the system under study as defined by Newton's second law of motion applied to angular motion:

$$\sum M = I\alpha \qquad \textit{(equation 1)}$$

where $\sum M$ =sum of the moments applied to the segment, I = the moment of rotational inertia (resistance of the body to angular acceleration) and α = the angular acceleration of the segment. Therefore, assuming that the rotational inertia of the limb remains constant, an increase in angular acceleration will result in an increase in the sum of the muscle moments. The muscle forces acting about the joint can be resolved into their normal (perpendicular or rotational) and tangential (stabilization or compression force) components (Enoka, 1994). As angular acceleration increases, the compression, or bone-on-bone (Winter, 1990), forces may increase with the increased possibility of joint damage and destruction (Nordin & Frankel, 1989). Thus, it is anticipated that individuals with existing joint damage will reduce the maximum acceleration attained in an attempt to decrease the bone-on-bone forces developed in the joint.

In summary, the relationship between kinematics and function in a multiple degrees of freedom system such as the upper limb is not obvious due to the multitude of potential interactions. Relationships can be determined by studying normal upper limb motion in 3-D space during performance of functional tasks; the resulting normal kinematic data can be used as a standard against which patient performance can be measured (Johnson & Gill, 1987). Data are required on the clinical conditions or impairments that lead to functional limitations and disability, and the impact the resultant disability has on the individual (Pope & Tarlov, 1991). Boström et al. (1991) have identified a need for further study between impairment in the shoulder and the resultant disability in the RA population. As pain is considered a major symptom of arthritis, the relationship between pain and perceived disability requires further investigation. Baseline kinematic data for the normal glenohumeral joint are required before speculations on the movement patterns employed by those with glenohumeral pathology can be made. Data obtained on movement patterns in normal subjects enhance the understanding of pathological movement patterns and assist therapists in setting treatment goals, measuring treatment progress and determining the success of a treatment procedure (Nuzik et al., 1986).

In a disease (such as RA) that affects the joints, movement patterns are inevitably altered from the normal. What is not known is which movement patterns are affected and to what extent. The relationship between the kinematics of movement, pain and the resultant perceived disability has not been examined in detail. Subtle differences in movement strategies employed by individuals with RA may be identified through the examination of kinematic data that may not be identified by a functional assessment.

2.2 Purpose of the Study

Therefore, the overall purpose of this study is to investigate the relationship between upper limb kinematics, pain and perceived disability in individuals with rheumatoid arthritis of the glenohumeral joint. The kinematic data obtained from a control group will be compared with that obtained from an RA group.

2.3 Hypotheses

1. There will be a difference in the arc of motion in each of seven upper limb rotations during performance of functional tasks between the control and the RA groups.
2. There will be a difference in maximum angular velocity in each of seven upper limb rotations during performance of functional tasks between control and RA groups.

3. There will be a difference in the maximum angular acceleration of each of seven upper limb rotations during performance of functional tasks between the control and the RA groups.

4. There will be a correlation between the maximum angular acceleration at each of the seven upper limb rotations and pain (at each of the three upper limb regions).

5. There will be a correlation between upper limb arc of motion (at each of the seven joint rotations), pain (at each of three regions of the upper limb) and disability in the individuals with RA for each of the five tasks.

6. There will be a correlation between the Health Assessment Questionnaire score (disability index) and the score obtained from the Canadian Occupational Performance Measure.

2.4 Limitations

The University of Manitoba Motion Analysis System (UM²AS) has some limitations inherent in the system. It has been designed to measure upper limb motion during performance of functional tasks. Markers are not placed on the neck, trunk, or scapula therefore motion that occurs at these regions is not recorded. Any compensatory motion of the trunk that occurs may be viewed on the videotape, but is not quantified or considered when the upper limb calculations are completed. Markers are placed on the upper limb at defined anatomical landmarks which are assumed to represent joint centres and inaccurate placement of the markers may affect the resultant data. In addition, as with any motion analysis system requiring operator input, accuracy of the data is limited by the accuracy of digitization - missing markers and error in determining the centroid of a marker due to reflections may result in inaccurate determination of the placement of a marker.

Euler angles are used to represent anatomical angles in this system; they have been commonly used to model human motion by describing the displacement of a marker in space. Euler angles describe motion as occurring in three consecutive rotations about fixed axes. Using Euler's equations of motion, rotation occurs in a pre-determined order. The final marker position is determined following these three sequential rotations. No evidence was found that indicated the human nervous system initiates the production of motion from one point to the next as three distinct sequential rotations, but rather that simultaneous motion occurs about the three orthogonal axes. However, use of this method of calculating angles to represent complex three-dimensional joint motion has been used by other investigators (Safaee-Rad, 1987; An et al., 1991; Barker, Nicol, Kelly & Paul, 1996).

The process of digitizing markers in the UM^2AS is labor intensive. The operator time required to digitize three repititions of a task at 6 Hz from one camera view was from 1.5-3 hours depending on the task. Three camera views were required for each task and five tasks were recorded per subject. If the data had been digitized at a rate of 30Hz, the time required to digitize the repititions from one task would have increased five-fold. Thus, the choice of a 6Hz digitizing rate was partially for convenience. Digitizing at a higher rate might have resulted in a more accurate set of data as each position captured on tape would have been used.

The choice to use the velocity formula recommended by Winter (1990) may have underestimated the slope of the displacement curve due to the fact that the calculation uses the data points immediately before and immediately after the point of interest and not the actual point itself. This method may result in slopes that are different from those calculated by a formula that uses the point of interest and the adjacent point. A comparison was made between the two methods of velocity calculation using a random sample of the data for different tasks from six subjects. The results showed that the mean difference of the results between the two methods of calculation was -2 degrees/s; i.e. the formula advocated by Winter (1990) underestimated by 2 degrees/s the value of the velocity as calculated by the use of continuous points. This represents appoximately a 3% underestimation of the velocity values calculated using continuous points. Because the formula used to calculate velocity was the same for the two groups, and the difference in values between the two methods was small, the use of Winter's formula (1990) was considered to be acceptable. It is acknowledged that use of the Winter (1990) method will also reduce the sampling frequency for the velocity calculation to half of what it would have been with the use of continuous samples.

Unpaired t-tests were used to compare the kinematics of the two groups in this study. When multiple comparisons are made, it is recommended that a Bonferroni correction be made to reduce the risk of commiting a Type I error (Hassard, 1991). In the current study, use of a Bonferroni correction would have resulted in a critical value of $p<0.001$ (for 35 comparisons); in a small study such as this, this would substantially increase the chance of commiting a Type II error (failing to pick up genuine differences) (Hassard, 1991). Thus, the critical value of $p<0.05$ was chosen to ensure that clinically relevant differences were considered.

In this study, it was assumed that control subjects represent the normal population with respect to upper limb motion during functional tasks. The control subjects were selected from a sample of convenience and are not a random sample. Exclusion criteria had been set regarding involvement of this group in upper limb activities and the presence of any upper limb pathology. The age of the subjects in this study was limited to between 18 and 65 years old. Therefore, the results cannot be generalized to any other age groups. The RA group was also limited to individuals with stage II or III involvement of the glenohumeral joint (Steinbrocker, Traeger & Batterman, 1949) therefore the results cannot be considered valid for individuals with different levels of joint involvement. The number of subjects for this study was determined using a power calculation based on the results of an individual with osteoarthritis of the shoulder joint because of the lack of published data on shoulder ROM in individuals with rheumatoid arthritis of the glenohumeral joint.

As each of the RA subjects was tested on only one occasion, the results obtained may or may not be representative of daily function. Several subjects postponed their testing appointment due to the severity of pain they were experiencing. Therefore, this study may have obtained the "best" results from these subjects, and not their typical results.

Only five functional activities were chosen in this study to represent the motion utilized by the upper limb. Although countless activities are performed using the upper limb each day, these specific tasks were chosen as the requirements of the tasks included components of upper limb rotations in various directions. The number of tasks chosen to examine was limited to keep the data obtained at a manageable level. However, the five tasks cannot be considered representative of all tasks that can conceivably be performed with the upper limb and the results are limited to the ones studied in the manner in which they are described in the protocol (*Appendix G*).

2.5 Delimitations

In this study, movement units were not analyzed as a kinematic parameter. The UM^{2}AS determines rotational motion at joints; translational motion of a hand marker has been used in determining movement units in the past. Although time was considered as a factor in determining velocity and acceleration, overall time to complete each functional motion was not analyzed. This data was collected and is available for future analysis. Additionally, although the relationship between angular acceleration about a joint and joint reaction forces is briefly discussed, further kinetic analysis was beyond the scope of this project. Technical specifications about the UM^{2}AS can be obtained by referring to Safaee-Rad et al. (1990).

3.0 METHODOLOGY

3.1 Subjects

Sample size was determined using data from an individual with osteoarthritis of the glenohumeral joint and data from control subjects (n=10). A comparison was made between the individual and the group of each joint rotation during the five representative tasks used in the current study. Only results in which there was a ROM difference greater than 10° were included in the analysis (subjectively determined to indicate a clinical difference.) A power analysis (Portney & Watkins, 1993) showed that a sample size of 10 subjects per group was sufficient (β=0.80, $p<0.05$).

Twenty subjects (ten control and ten RA) met all inclusion criteria and participated in the study. Control subjects consisted of five males and five females recruited from a sample of convenience. Inclusion criteria for the control group were: in good general health, no pathology of the dominant upper limb, between the ages of 18 and 65, and of normal height and mass as determined by anthropometric tables (Pheasant, 1988). Experimental subjects consisted of 10 subjects diagnosed with RA of the glenohumeral joint and recruited from the caseload of one physician (Dr. H. El-Gabalawy). Inclusion criteria for the RA experimental group were: referral from the physician, diagnosis of rheumatoid arthritis, roentgenographic evidence of stage II (moderate) or stage III (severe) involvement of the dominant glenohumeral joint (Steinbrocker, Traeger & Batterman, 1949), pain in the glenohumeral joint not primarily due to inflammation of the periarticular structures, uninvolved elbow joint, between the ages of 18 and 65, and of normal height and mass as determined by anthropometric tables (Pheasant, 1988). Subjects were excluded from entering the study if they had a history of previous surgery to the dominant upper limb, if they were pregnant or lactating or if they had insufficient comprehension and expression of English to complete the pain and disability measures. Participation in the study was voluntary and non-remunerated; however direct costs required to attend the experimental session (taxi fare, parking) were covered. Subjects gave informed consent prior to commencement of the study (*Appendix A*). Approval of the study was obtained from the Faculty of Medicine Committee on the Use of Human Subjects in Research (*Appendix B*).

3.2 Research Design

Normative studies are essential for determining normal patterns or expected standards of performance (Portney & Watkins, 1993). This study design was used to document the kinematics of the upper limb during performance of five representative functional tasks from a sample of convenience. A comparative study was used to compare the kinematics of the control group with those of the RA group. Correlational research investigates the possibility of relationships between variables (Portney & Watkins, 1993), therefore a correlational design was used to investigate a possible relationship between pain, perceived disability and upper limb kinematics (ROM and maximum angular acceleration) at each of the upper limb regions examined (shoulder, elbow and wrist) in the RA group.

3.3 Instrumentation

3.3.1 Motion Analysis

The system used to capture functional motion was the University of Manitoba Motion Analysis System (UM^{2}AS) (*Figure 2).* This system produces a visual record of the movement that can be kept permanently for later referral (Safaee-Rad et al., 1990). The UM^{2}AS system is based on a kinematic model that calculates seven rotations about four upper limb joints (shoulder, elbow, radioulnar, wrist); Euler angles are used to define the rotation at each joint. Reflective markers are placed on upper limb landmarks and then performance of functional upper limb activities can be recorded with no disruption of the normal pattern of movement. The UM^{2}AS is a video-based system that consists of three parts: an image acquisition and recording component, an image digitizing component and the UM^{2}AS software.

Image Acquisition and Recording Component

Three orthogonally placed charge coupled device (CCD) video cameras recorded human motion *(Figure 3*). Details of system specfications can be found in the work of Safaee-Rad (1990). The imaging space is approximately 1 cubic metre in volume, illuminated by three pot lights and the walls are draped in non-reflective material. Two views of the same motion are required to calculate the three-dimensional coordinates. Using three cameras prevented the problem of disappearing markers when motions were not in the field of view of one camera.

A calibration frame (45.7 cm x 68.1 cm x 96.5 cm steel frame) with reflective markers was used to provide a fixed frame of reference. The frame was placed in centre of the

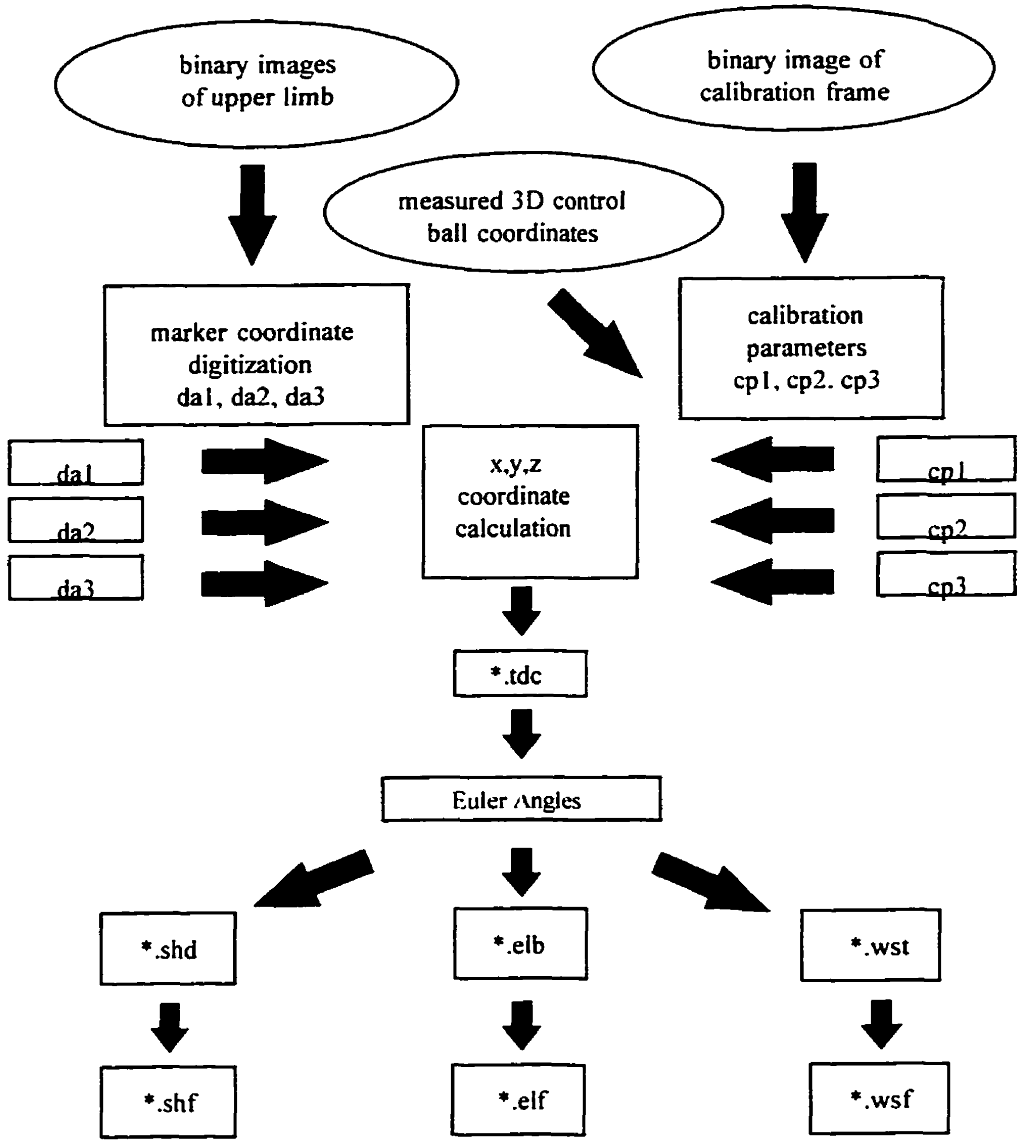

Figure 2. University of Manitoba Motion Analysis System Flow Chart. Adapted from Giles, 1994

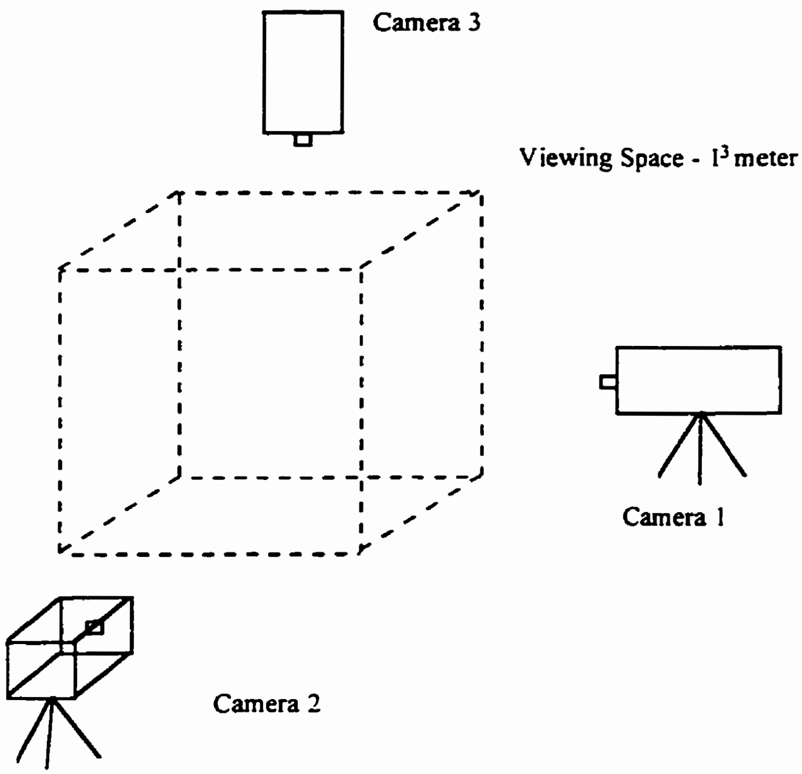

Figure 3. UM²AS - laboratory set-up

viewing area and videotaped by all three cameras before each subject performed the tasks. The purpose of calibrating the cameras before each subject session was to prevent any error that might occur in digitizing due to inadvertent movement of the cameras between sessions.

A camera flash was used to synchronize the videotape; this was done at the beginning of each trial recording. The upper limb motion was recorded at a rate of 30 frames/second (30 Hertz) by three Beta recorders set up in the digitizing area. The recommended recording rate given for gait studies is 24 Hz (Winter, 1990); therefore 30 Hz is considered adequate for the functional upper limb tasks studied.

Image Digitization

The videotaped sequences of the task trials were played back by a Beta recorder with manual frame-by-frame advance capability and a frame counter. The image was displayed on a black and white monitor. The synchronizing flash was located; this signalled the beginning of the segment to be digitized. The image of each frame selected for analysis was captured by an image acquisition board which is capable of displaying a black and white binary image of the markers. The threshold to obtain this binary image was set by the software, but allowed user intervention to adjust the setting depending on the reflection captured by the video camera. The operator was directed by the software to identify each marker by clicking a crosshair on its centre for the first two frames digitized; after the first two frames, linear extrapolation was used by the software to predict the centroid of the markers. If the markers were correctly identified by the system, the operator accepted them and advanced to the next frame. If they were incorrectly identified, the operator could manually enter the correct location of the marker by clicking on it. This process continued until all desired frames were digitized. The process of digitizing identifies the x and y coordinates of each marker and must be done for all three views of the same task trials. The x and y coordinates from the three views were fed into the system and the three-dimensional (x,y,z) coordinates were generated by the software.

Euler Angle Calculation

The three-dimensional coordinate file was imported into a software program for calculating the Euler angles of the motion. Euler angles are a mathematical means to define 3 rotational motions with respect to 3 orthogonal axes (Beer & Johnston, 1972). Euler angles assume the final position of a segment to be described by three sequential rotations; the order of these rotations is held constant for all motion. The sequence used by the UM²AS program is: first, rotation about the z axis (flexion/extension), then the x axis (abduction/adduction, or ulnar/radial deviation at the wrist) and finally the y axis (internal/external rotation or pronation/supination) (Safaee-Rad, 1987).

Error in UM²AS

Error exists in the system and the resultant calculations due to camera distortion; reflections from light, skin or clothing; marker placement error and human error in digitizing. Error in the UM²AS was studied by measuring the distance between two markers (11cm), and then using the system to measure the distance between the markers on ten subjects. The maximum static error was reported as 1.5% (0.17 cm) and a maximum dynamic error of 2.6% (0.29 cm), based on a field of view of 800mm x 800mm (Giles, 1994).

3.3.2 Pain Measurement

A visual analogue scale (VAS) (*Appendix C*) was used to measure the subjective experience of pain intensity at each of the three upper limb regions (shoulder, elbow and wrist) before and after performing each of the functional tasks. This method of measuring pain is considered to be sensitive and reproducible (Huskisson, 1974; Huskisson, 1983), is easily understood by subjects, is completed quickly, has been widely used in clinical studies and is considered to be valid and stable over repeated measurements (Huskisson, 1974; Huskisson, 1983; Streiner & Norman, 1992).

3.3.3 Disability Measurement

The disability and discomfort dimensions of the HAQ (*Appendix D*) were used to measure and quantify disability. This instrument was chosen over the AIMS2 as it takes approximately 20 minutes less to complete and is more concise, while retaining excellent psychometric properties (having undergone extensive reliability and validity testing). The HAQ has been recommended by McDowell and Newell (1996) as a good descriptive instrument for use with the population afflicted with arthritis. The scores obtained from the disability index of the HAQ were then compared to the performance score obtained from Canadian Occupational Performance Measure (COPM). The COPM was used to quantify the subjective experience of disability (*Appendix E*) as it was the only instrument available that allowed a subject to determine the importance of, and satisfaction with the activities that they identified as difficult to perform. This assessment was chosen as a second measure of disability due to the individualized format of the instrument.

3.4 Procedure

A detailed description of the protocol used for this study is located in *Appendix G*. Subjects were tested once. Approval of the physician was given prior to the test session for the RA subjects. RA subjects were tested in the afternoon whenever possible to minimize any effects of morning stiffness. It was requested (and confirmed at the testing session) that these subjects refrained from taking any pain medication for four hours immediately prior to the test session. Prior to the testing, demographic data and anthropometric measurements of the upper limb segments, height and body mass were recorded for each RA subject (see data collection sheet in *Appendix F*). The test session for the RA group consisted of four components - administration of the COPM, the HAQ and the VAS, followed by performance of the representative functional tasks. These tasks were: reaching backwards to touch the sacrum, combing hair, lifting and placing two objects of different mass (maximum 1 kilogram) on a shelf at shoulder level, and reaching across the body to touch the back of the opposite shoulder. Each task was assigned in random order. The same person administered all components according to detailed protocols for each (*Appendix G*). The COPM and HAQ were administered at the beginning of the test session; the VAS was administered immediately before and again after performance of each of the functional tasks with joint region order randomized. The test session for the control group consisted of recording of demographic data, measurement of anthropometric data, measurement of height and body mass and a videotaped performance of the five representative functional tasks.

Each subject was dressed in a black turtleneck sweater and draped with a black cloth to prevent reflection from lighter coloured clothing or material that might have interfered with marker identification. Subjects that had substantial hair loss from their head were asked to wear a cap, as reflection from the skin interfered with marker identification in the combing task. Holes were cut into the sweater to allow attachment of markers directly to the skin over defined anatomical landmarks. The markers consisted of seven 2.5 cm Styrofoam balls; these were securely attached to the skin of the subject's upper limb with double sided adhesive tape (Safaee-Rad et al., 1990). The anatomical landmarks used in this study were: 2 cm inferior to the lateral border of the acromion process of the scapula (two markers attached by a 7.6 cm rod), the lateral epicondyle of the elbow (one marker), the distal ends of the radius and ulna as identified by a line between the ulnar and radial styloid processes (two markers attached by a 12.7 cm rod and placed perpendicular to the long axis of the forearm), and the head of the third metacarpal. The subject was seated in the viewing area on a height-adjustable stool. The seat was adjusted to ensure that the subject was positioned with hip, knee and ankle angles at approximately 90°. The upper limb was positioned such that the shoulder, forearm and wrist joints were in at 0° (neutral), the elbow joint at 90° flexion and the fingers extended. Careful placement of the upper limb in this initial position was required as it was used by the software as the reference for all subsequent motion.

Upper limb motion was recorded simultaneously by the three videocassette recorders and then extracted and processed by the UM^2AS software as previously described. The sequence of tasks was randomized. Each task was performed five times with a three minute rest period between tasks to reduce the possibility of muscle fatigue. The middle three recordings of five were used for analysis as it has been suggested that the most variation in motion occurs between the first and subsequent repetitions when performing five repetitions of a task (Barker et al., 1996).

3.5 Data Analysis

3.5.1 Motion Data

The middle three repetitions of each functional task were identified on the videotapes, digitized and the resultant x, y, z coordinate data were stored in a computer file. The beginning of each repetition was identified in a standardized manner for each of the task trials. The displacement values of shoulder flexion/extension were visually analyzed to determine when the minimum angle of shoulder flexion occurred between each of the repetitions; this point was taken as the beginning of the repetition.

Rate of Digitization

Motion was recorded at a rate of 30 Hz; every fifth frame was then digitized. To determine the appropriate digitization rate, representative motion was digitized at three rates: every frame (30 Hz), every second frame (15 Hz) and every fifth frame (6Hz). The resultant displacement curves were then compared visually. For the reaching motions of the upper limb, it was found that a rate of every five frames was adequate to capture the pattern of motion and the maximum and minimum rotation angles (Safaee-Rad, 1987).

The displacement values were differentiated over time to obtain velocity and acceleration values. Differences in maximum angular velocity among the digitizing rates were present; however, the values showed similar trends. The velocity values were consistently lower for motion digitized at every five frames than at every one or two frames. The largest difference occurred in the calculation of the maximum angular acceleration values. Although the formula used to calculate acceleration used the displacement values directly (instead of velocity values), the lower rate of digitizing resulted in lower maximum acceleration values than when the motion was digitized at every frame. Digitizing at every five frames would not capture movement that might have occurred between frame 5 and frame 10; for example in frame seven, a large positive or negative acceleration might have occurred which would not be captured by the slower digitizing rate. The choice to digitize the motion at every five frames ensured that the values obtained were conservative and did not overestimate the actual value obtained. In addition, due to the large time commitment required to digitize (refer to 2.4 Limitations), the choice to digitize the motion at 6 Hz was felt to be an acceptable compromise.

Filter Method

Raw (or unprocessed) data may contain additive noise from a variety of sources which results in error. Raw data must therefore be smoothed using a method that removes or minimizes the additive noise (Winter, 1990) prior to differentiation.

Seven joint angle values were calculated by the UM^2AS software (Safaee-Rad et al., 1990) and represented in both numerical and graphic form. To determine the appropriate data filtering method to use, a comparison was done on a set of data which had been digitized at the three different rates (30 Hz, 15 Hz and 6Hz) and then smoothed using a digital filter (second order Butterworth filter with cutoff frequency of 6Hz) (Winter, 1990). The same set of data was then smoothed using a cubic spline technique (Woltring, 1985), with the parameter set at 50. Cubic spline smoothing is a method of smoothing raw data that uses a type of polynomial curve fitting (Winter, 1979). With the cubic spline method, the curve is broken into sections and approximated with different third order polynomials. The parameter of 50 was chosen, as this was the best balance between smoothing the data while maintaining the integrity of the angle curve. An example of data smoothed with both the Butterworth and cubic spline techniques is shown in *Figure 4*. A visual comparison of these filtering methods showed that the Butterworth filter reduced or smoothed the angle of the slope and therefore did not reflect the actual pauses that had occurred in the motion. This observation was confirmed by a frame-by-frame advancement inspection of the video tape of the motion.

Visual inspection of the data showed that when the angle data was differentiated to acceleration, the acceleration values derived with the cubic spline smoothing were similar at all three digitizing rates for the upper limb joints. Thus, the cubic spline method was chosen as the more accurate of the filter methods when the displacement data were differentiated to acceleration for the upper limb joints. This method filtered the data to an acceptable level (maintained the integrity of the curve while removing noise).

The filtered angular displacement data were imported into QuattroPro for Windows 6.0[6]. The maximum and minimum joint position values for each repetition were extracted and the resultant joint ROM (maximum minus minimum joint position), the absolute value of the maximum angular velocity and the absolute value of the maximum angular acceleration were calculated by the software. Angular velocity was calculated from the displacement data using the formula recommended by Winter (1990):

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[6]Novell Inc, 1994

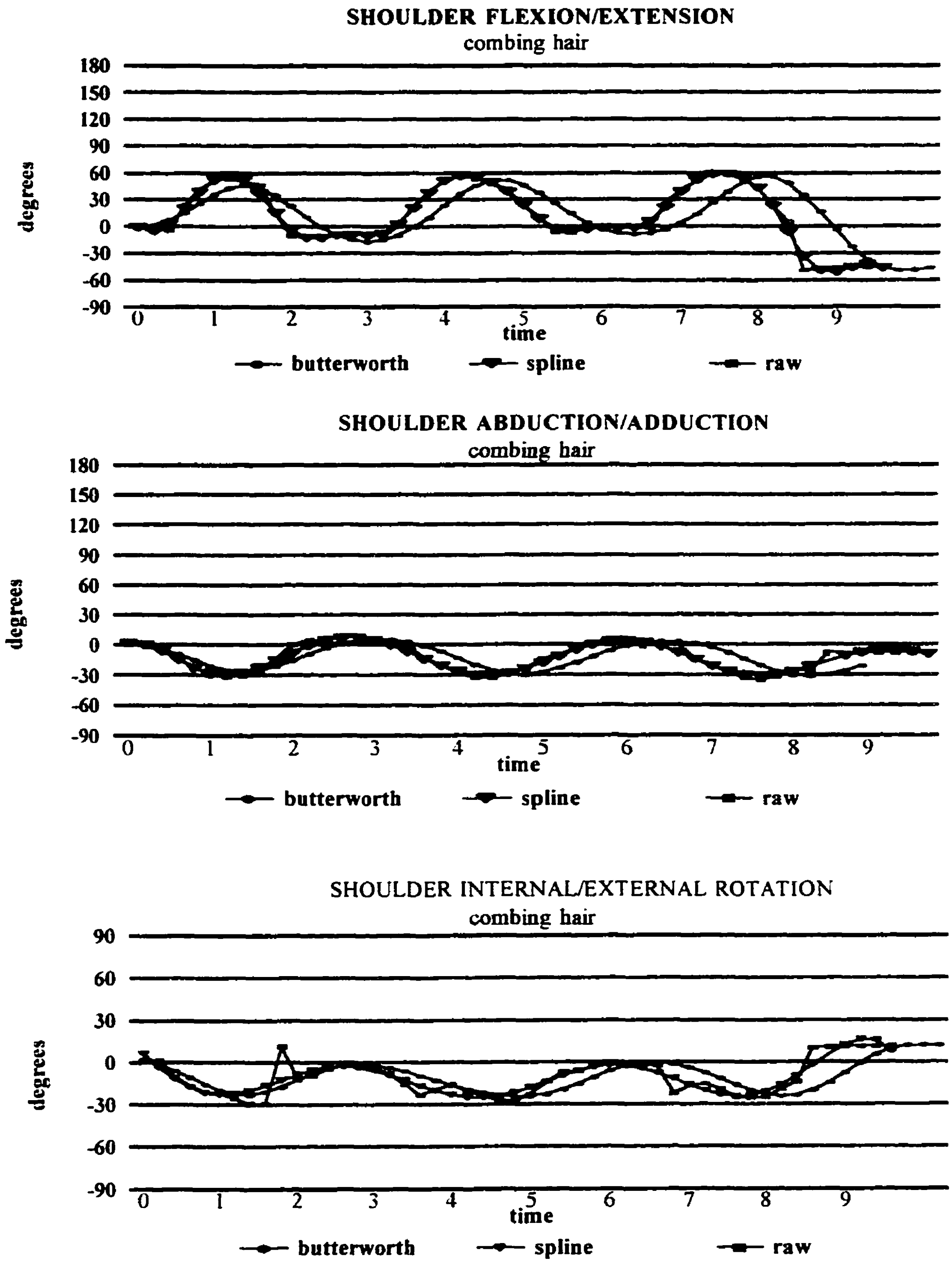


Figure 4. Comparison of filtering methods.

$$Vx_i = \frac{x_{i+1} - x_{i-1}}{2\Delta t} \qquad \textit{(Equation 2)}$$

where Vx_i = the velocity of the sample x_i, x_{i+1} = the sample immediately following x_i, x_{i-1} is the sample immediately prior to x_i, and Δt is the time between adjacent samples. Use of this formula allows calculation of the velocity that occurs at a point halfway between the adjacent samples. It assumes that the slope of the line connecting the point directly before (x_{i-1}) and directly after (x_{i+1}) the sample will be the same as the tangent to the curve at the point of interest (x_i) (Winter, 1990); this eliminates the problem that would occur if displacement data were compared to velocity data which represented the velocity at the point halfway between two consecutive samples. Angular acceleration was calculated directly from the displacement data using Winter's (1990) formula:

$$Ax_i = \frac{x_{i+1} - 2x_i + x_{i-1}}{\Delta t^2} \qquad \textit{(Equation 3)}$$

where Ax_i = the acceleration of the sample x_i, x_{i+1} = the sample immediately following x_i, x_{i-1} is the sample immediately prior to x_i, and Δt is the time between adjacent samples.

Filtered data were graphed using the software. Range of motion, angular velocity and angular acceleration were plotted with respect to time for each joint rotation during each functional task *(see Figures 5 & 6 for sample plots)*.

3.5.2 VAS Data

The VAS was administered according to the protocol of Huskisson (1974). The subject's mark was measured (in millimetres) from the lower (no pain) end of the scale

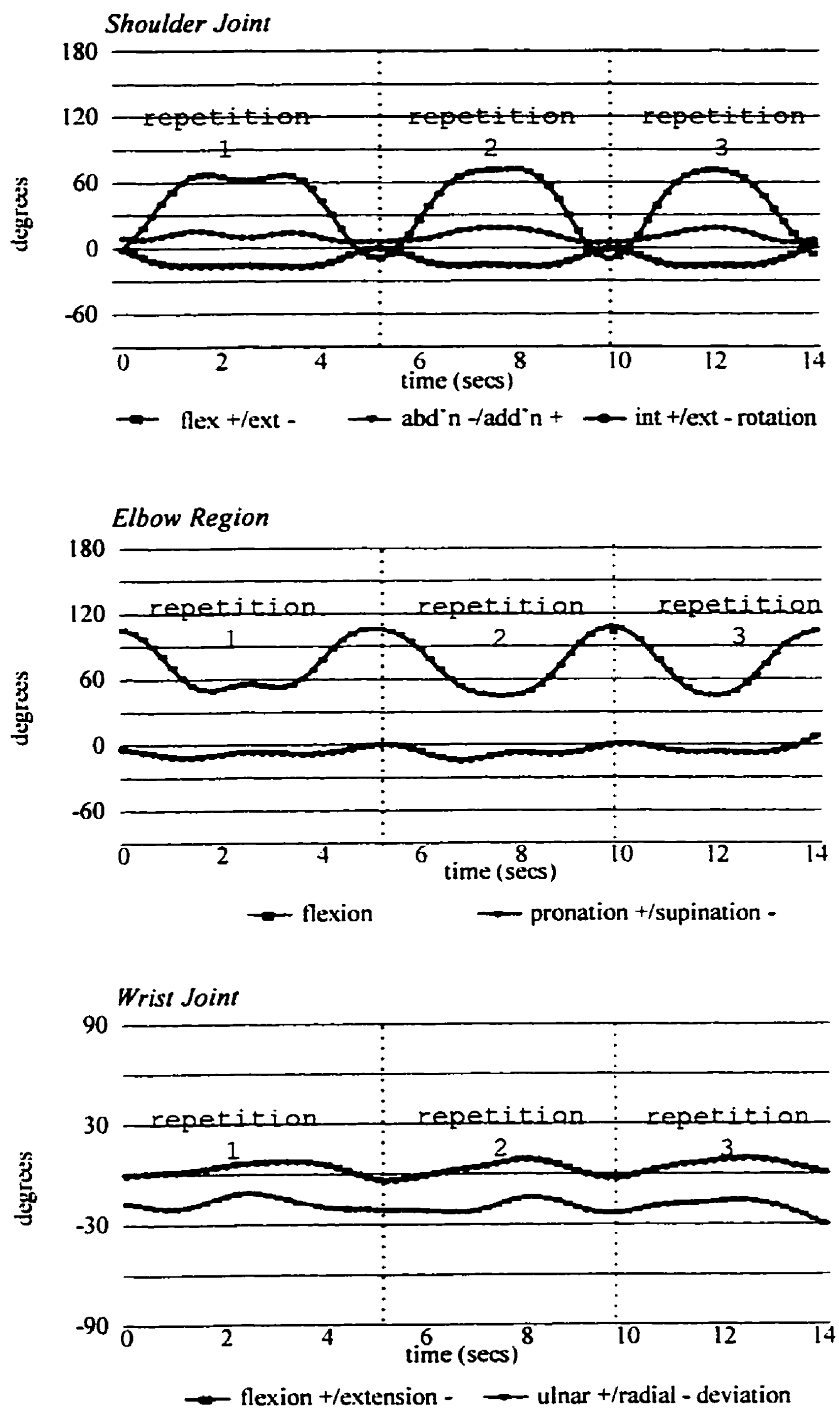


Figure 5. Sample range of motion plots - Subject 5 (control) Lifting Bottle

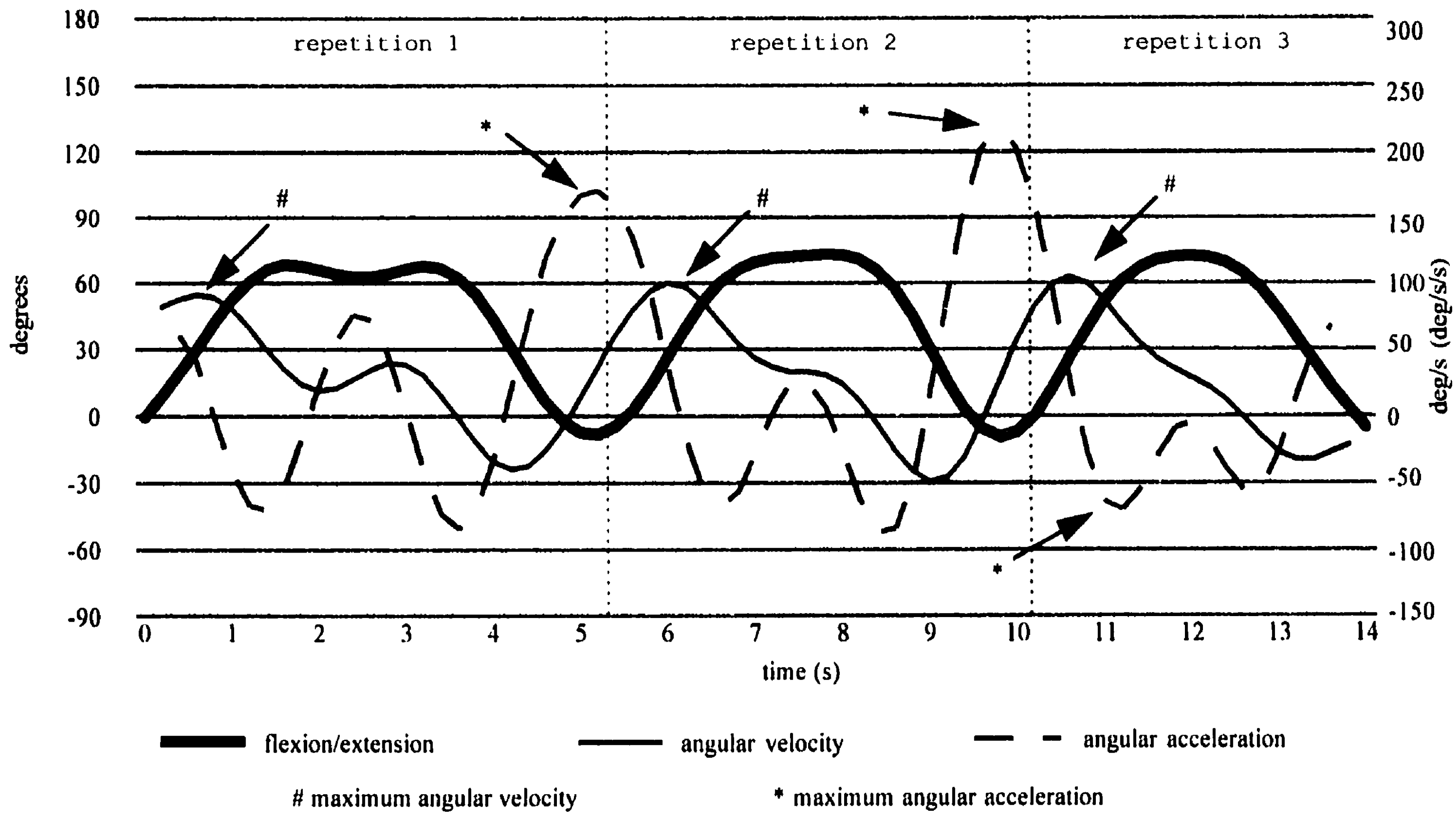


Figure 6 . Sample angular velocity and acceleration plots
Subject 5 (control) Lifting Bottle - Shoulder Flexion and Extension

(McDowell & Newell, 1996). Pain scores for each of three upper limb regions were generated - pain level before performance of all functional tasks (P_1), pain level after performance of each of the functional tasks (PTPn, n = can, bottle, comb, scapula, sacrum) and the difference between P_1 and PTPn (PTPn - P_1= PCS_n). A total of fifteen post-task pain scores (PTPn) were calculated for each subject. These scores were the absolute level of pain in each joint region following completion of each task. Fifteen pain change scores (PCS_n) were also calculated for each subject. Finally, five total upper limb pain scores were calculated (one score for each of the tasks). This score was the sum of the post-task (Σ PTPn) pain scores of each of the joints. *Table 4* illustrates the different pain calculations made. The same calculations were made for each of the five representative functional tasks for each of the 10 RA subjects.

Subject 1_ra - Lifting Bottle				
	shoulder	**elbow**	**wrist**	
$\mathbf{P_1}$	P_{1_shd}	P_{1_elb}	P_{1_wst}	
PTP bottle	PTP bottle_shd	PTP bottle_elb	PTP bottle_wst	ΣPTP bottle
PCS bottle	PCS bottle_shd	PCS bottle_elb	PCS bottle_wst	

Table 4. Example of pain calculations for one functional task.

3.5.3 HAQ Data

The HAQ was scored as described by McDowell & Newell (1996). To calculate the disability index of the HAQ, the task which the subject had indicated was the most difficult to perform was used as the representative score within each component. The eight component scores are then averaged to obtain a disability index score ranging from 0 (indicated no difficulty in performing tasks) to3 (indicating unable to do tasks). The Discomfort dimension was scored by measuring the length of the line from *no pain* and multiplying the length by 0.2.

3.5.4 COPM Data

Two scores (Performance and Satisfaction) were generated by this instrument. The performance (PF) score was obtained by having the subjects rate their ability to perform the activities they had identified as important, adding the resultant values and dividing by the number of rated activities. The range of possible scores for PF are from 1 (not able to do it) to 10 (able to do it extremely well). The Satisfaction score (S) was obtained by having subjects rate their satisfaction with their ability to perform the activity, adding the resultant values and dividing by the number of rated activities (Law et al., 1994). The range of possible scores for satisfaction was from 1 (not satisfied at all) to 10 (extremely satisfied).

3.6 Statistical Analysis

For each of the groups (control and experimental), maximum and minimum joint position, arc of motion, maximum angular velocity and maximum angular acceleration were documented as the mean value, ± the sample standard deviation (sd) (Portney & Watkins, 1993) A two-tailed, unpaired t-test was used to determine if a significant difference existed between the upper limb displacement values of the male and the female subjects in the control group. As the t-tests showed no significant difference between the ranges used by males and females at the $p<0.05$ level (except for one joint rotation during one task: shoulder abduction/adduction where females used more abduction than males, $p=0.032$), the data from the two groups were combined for further analysis.

Unpaired t-tests were performed on the RA and control group subject demographic data. No significant differences were found in age, mass or height between the two groups.

ROM, minimum and maximum angles used were compared between tasks using a one way repeated measures ANOVA with a post-hoc Student-Newman-Keuls test for multiple comparisons if a significant difference was found.

Values of upper limb kinematics were determined for the control group during functional tasks. These values were then compared to the data obtained from the RA group by way of two-tailed unpaired t-tests. A Pearson product moment test was used to detect if a relationship existed between the arc of motion, pain and disability variables in the RA group. The Pearson product moment test was also used to determine if a relationship existed between angular acceleration and pain in the RA group; regression analysis was performed to determine if the level of pain could be predicted from the angular acceleration. The disability index of the HAQ was correlated to the performance data from the COPM using the Pearson product moment test (Portney & Watkins, 1993). A significance value of $p<0.05$ was used for all tests.

Comparison	Type of Test
control males vs. females -ROM	unpaired t-test for data with equal variance Mann-Whitney U test for data with unequal variance
control vs. RA -age, mass, height	unpaired t-test
between task comparisons -ROM,minimum & maximum angle	one way repeated measures ANOVA; Student-Newman-Keuls test for multiple comparisons
control vs. RA -ROM, angular velocity, angular acceleration	unpaired t-test for data with equal variance Mann-Whitney U test for data with unequal variance
RA group -ROM, pain and functional limitations (HAQ)	Pearson product moment
RA group -pain and angular acceleration	Pearson product moment regression analysis
disability index HAQ & performance score COPM	Pearson product moment

Table 5. Summary of Comparisons and Statistical Tests.

4.0 RESULTS

4.1 Subject Demographics

The average age of the control group was 43 years, 8 months (±14 years, 2 months). There were 5 females and 5 males; all of the subjects were right dominant. The average height of the control subjects was 172.0 cm (±10.1 cm), while the average mass was 73.5 kg (±10.4 kg) (*Table 6*).

subject	age yrs/mos	sex	dominance	height (cm)	mass (kg)	occupation
1_n	53/6	F	R	160	64	professor
2_n	34/11	M	R	180	78	research assistant
3_n	54/10	F	R	165	60	social worker
4_n	24/2	F	R	170	62	occupational therapist
5_n	59/2	M	R	177	82	professor
6_n	29/6	M	R	188	88	social worker
7_n	48/8	M	R	178	85	social worker
8_n	24/6	M	R	181	81	primary school physical education teacher
9_n	46/7	F	R	159	70	professor
10_n	61/2	F	R	162	65	social worker

Table 6. Control Subject Data.

The average age of the RA group was 52 years, 2 months (±8 years, 0 months); the average duration of RA was 16 years, 2 months (±7 years, 0 months). There were 8 females and 2 males; all but two were right dominant. Average height of the RA subjects was shorter than the control group at 167. 9 cm (±11.2 cm). Average mass was also lower at 68 kg (±16.5 kg) (*Table 7*).

subject	age yrs/mos	sex	dominance	height (cm)	mass (kg)	occupation	years diagnosed
1_ra	64/1	F	R	155	61	homemaker	30
2_ra	61/9	F	R	160	43	homemaker	13
3_ra	46/6	F	R	160	67	teacher	7
4_ra	56/6	F	R	161	50	homemaker	22
5_ra	38/11	F	R	168	86	retail sales	13
6_ra	42/0	F	R	182	82	homemaker	11
7_ra	52/5	M	L	170	65	electrician	18
8_ra	54/4	F	R	167	63	homemaker	25
9_ra	55/7	F	L	164	65	child care worker	10
10_ra	50/2	M	R	192	98	office worker	13

Table 7. RA Subject Data.

4.2 Description of Data

4.2.1Task Comparison-Range of Motion, Minimum & Maximum Angles

Control Group

The mean values for range of motion (ROM), maximum and minimum angles for this group are presented in *Table 8* and in *Figure 7*. Each of these parameters were compared between tasks using a one way, repeated measures analysis of variance (ANOVA) (Portney & Watkins, 1993) to determine differences. If a significant difference was found between the five tasks, a post-hoc multiple comparison was done using a Student-Newman-Keuls test (Portney & Watkins, 1993).

JOINT	lift bottle			lift can			comb hair			touch scapula			touch sacrum		
	min	max	rom	min	max	rom	min	max	rom	min	max	rom	min	max	rom
shoulder flexion		73 (11)	77 (14)		72 (8)	75 (13)		59 (17)	60 (17)	6 (7)	86 (12)	80 (15)		18 (8)	62 (8)
extension	3 (5)			3 (6)			2 (10)							44 (6)	
abduction	2 (4)	20(8)	18 (9)	2 (5)	21 (4)	19 (5)	3 (6)	51 (16)	48 (12)		10 (5)	24 (5)		21 (7)	23 (10)
adduction											14 (8)			2 (12)	
*int rot	2 (9)	26 (12)	23 (18)	3 (3)	24 (11)	21 (13)		17 (11)	48 (25)	11 (11)	63 (6)	52 (14)	3 (20)	59 (18)	56 (22)
*ext rot								30 (19)							
elbow flexion	45 (10)	101 (16)	56 (19)	44 (9)	98 (15)	54 (18)	69 (15)	148 (5)	79 (16)	69 (10)	122 (5)	53 (12)	70 (17)	98 (15)	28 (16)
forearm pronation		10 (15)	21 (8)		2 (11)	20 (12)		10 (18)	45 (19)		27 (13)	55 (16)		35 (16)	121 (17)
supination		11 (16)			17 (13)			35 (13)			28 (10)			87 (6)	
wrist flexion									16 (9)		20 (13)	24 (16)		18 (7)	30 (15)
extension	19 (14)	33 (9)	14 (8)	9 (5)	20 (11)	11 (10)	0 (9)	16 (6)			3 (8)			12 (14)	
*ulnar dev		10 (12)	16 (9)		9 (9)	16 (5)		14 (7)	27 (13)		12 (9)	29 (12)		20 (14)	29 (21)
*radial dev		6 (11)			7 (7)			10 (11)			18 (10)			8 (16)	

Table 8. Range of Motion, Minimum & Maximum Angles - Control group - degrees (± standard deviation)

*int rot = internal rotation; ext rot = external rotation; ulnar dev = ulnar deviation; rad dev = radial deviation

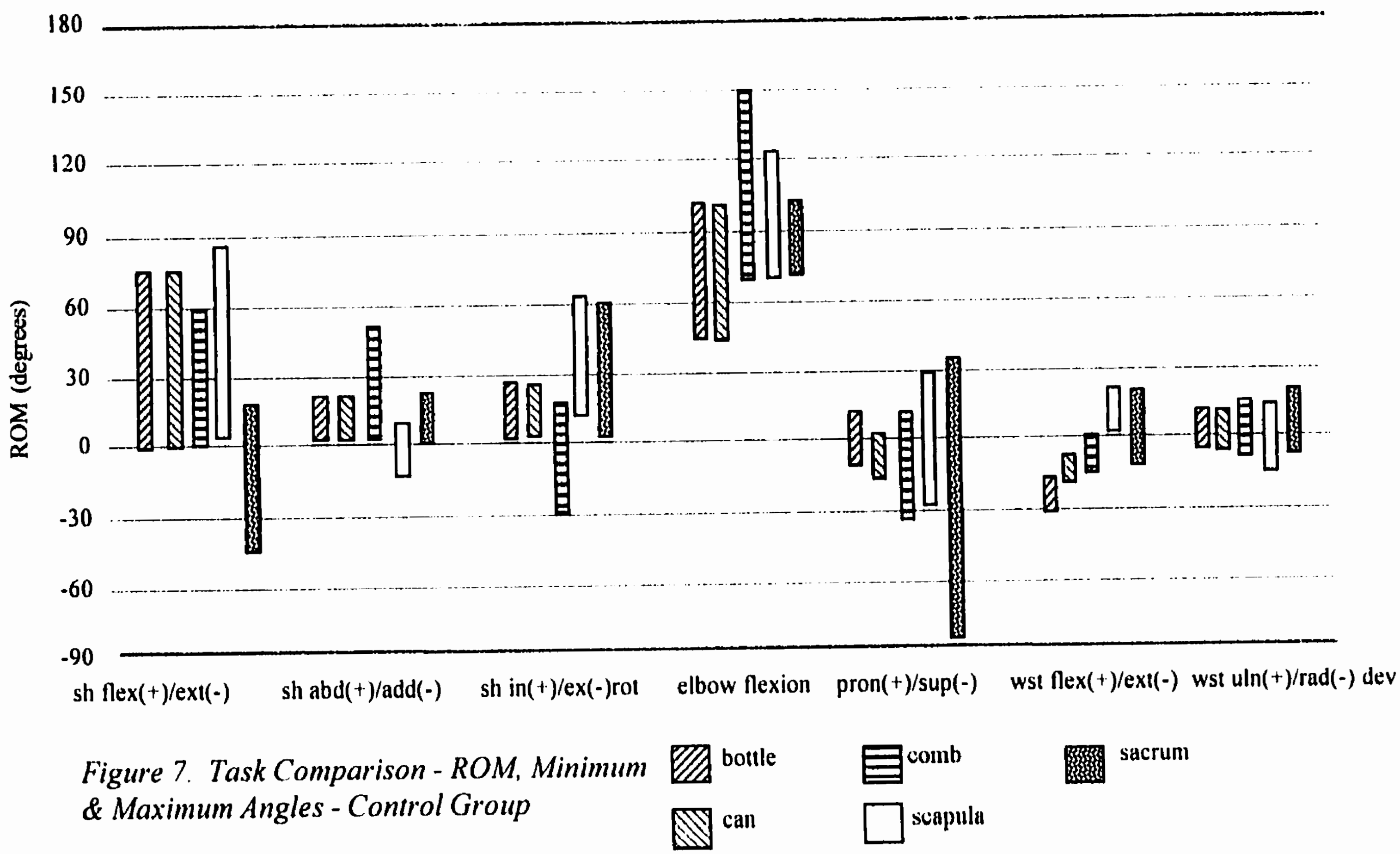


Figure 7. Task Comparison - ROM, Minimum & Maximum Angles - Control Group

sh flex(+)/ext(-) = shoulder flexion/extension   sh abd(+)/add(-) = shoulder abduction/adduction   sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination   wst flex(+)/ext(-) = wrist flexion/extension   wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

A summary of these comparisons is presented in *Table 9*. Tasks which are not significantly different are underlined as per the method described in Hassard (1991). The tasks are arranged in each cell from smallest to largest value.

	Range of Motion	Minimum Angle	Maximum Angle
shd flex(+)/ext (-)	com sac can bot opp	sac bot can com opp	sac com can bot opp
shd abd(+)/add(-)	bot can sac opp com	can bot com sac opp	opp bot can sac com
shd in(+)/ex(-)rot	can bot com opp sac	com bot can sac opp	can bot com opp sac
elbow flexion	sac opp can bot com	can bot opp com sac	sac can bot opp com
pro(+)/sup(-)	can bot com opp sac	can bot com opp sac	can com bot opp sac
wst flex(+)/ext(-)	can bot com opp sac	bot can com sac opp	bot can com sac opp
wst uln(+)/rad(-dev	bot can com sac opp	can bot opp com sac	opp com sac can bot

Table 9. One Way Repeated Measures Analysis of Variance of ROM, Minimum & Maximum Angles (Between Task Comparison) Control Group.

key
can = lifting can
com = combing hair
sac = touch sacrum
shd flex (+)/ext(-) = shoulder flexion/extension
shd in(+)/ex(-)rot = shoulder internal/external rotation
wst flex (+)/ext (-) = wrist flexion/extension
bot = lifting bottle
opp = touch opposite scapula
underlined = no significant difference between tasks.
shd abd(+)/add(-) = shoulder abduction/adduction
pro(+)/sup(-) = forearm pronation/supination
wst uln (+)/rad (-) dev = wrist ulnar/radial deviation

It can be seen that the ROM used in the lifting bottle and lifting can tasks was not significantly different for any joint rotation. ROM used during combing hair differed from that used in touching the opposite scapula only in shoulder flexion and abduction, and in elbow flexion. Touching the sacrum used a different ROM at the elbow region than the other tasks (the least amount of elbow flexion and the greatest amount of supination); however shoulder and wrist joint ROM during this task was similar to that of the other tasks. The minimum angle used may refer to either rotation in the complementary direction to the stated one (i.e. into shoulder extension, adduction, external rotation, forearm supination, wrist extension or wrist radial deviation) or to the smallest angle in the rotation specified if motion did not occur in the complementary direction. A significant difference was found in the minimum angle of wrist flexion used for lifting the can and lifting the bottle tasks. Differences for the other tasks showed unique differences depending on the principal rotations used. For example, touching the sacrum was the only task requiring a component of shoulder extension, while combing the hair was the only task that used a significant component of external rotation.

When maximum angles were compared, the bottle and can tasks differed only in the amount of wrist flexion used. Touching the opposite scapula and touching the sacrum were significantly different from each other in only three of the joint rotations (shoulder flexion, abduction and elbow flexion). The same three maximum angle rotations were different for the lifting the can and combing hair tasks.

RA Group

The RA group ROM, minimum and maximum angle data are presented in *Table 10* and *Figure 8*. The data were subjected to the same statistical analysis described above; this is summarized in *Table 11*.

	lift bottle			lift can			comb hair			touch scapula			touch sacrum		
JOINT	min	max	rom	min	max	rom	min	max	rom	min	max	rom	min	max	rom
shoulder flexion		56 (28)	61 (29)		59 (19)	66 (22)	2 (6)	61 (25)	59 (26)	7 (7)	65 (21)	59 (20)		13 (10)	61 (12)
extension	6 (6)			7 (8)										48 (8)	
abduction	2 (6)	23 (11)	20 (10)		21 (12)	22 (12)	0 (3)	37 (22)	38 (21)		12 (9)	19 (9)	0 (6)	19 (9)	19 (13)
adduction				1 (7)							8 (10)				
int rot	3 (7)	20 (12)	17 (10)	2 (9)	17 (9)	16 (7)		13 (4)	37 (13)	16 (13)	52 (12)	38 (13)	13 (19)	57 (20)	44 (21)
ext rot								24 (12)							
elbow flexion	52 (24)	99 (8)	46 (22)	45(21)	100(15)	54 (19)	67 (13)	142 (5)	75 (16)	57 (13)	127(10)	70 (17)	60 (9)	89 (13)	30 (14)
forearm pronation								3 (10)	43 (11)		28 (28)	54 (27)		22 (13)	103 (22)
supination	10 (15)	24 (15)	14 (6)	5 (16)	26 (15)	20 (10)		39 (11)			27 (11)			81 (15)	
wrist flexion					10 (15)	9 (3)		1 (15)	20 (7)		19 (24)	27 (30)		4 (17)	29 (17)
extension	9 (16)	18 (17)	8 (3)		19 (14)			19 (15)			8 (11)			24 (24)	
ulnar dev	1 (12)	11 (10)	11 (5)		13 (13)	15 (6)		21 (18)	23 (14)		17 (17)	18 (12)	2 (8)	15 (16)	13 (5)
radial dev					2 (12)			2 (15)			1 (16)				

Table 10. Range Of Motion, Minimum & Maximum Angles - RA group - degrees (± standard deviation)

*int rot = internal rotation; ext rot = external rotation; ulnar dev = ulnar deviation; rad dev = radial deviation

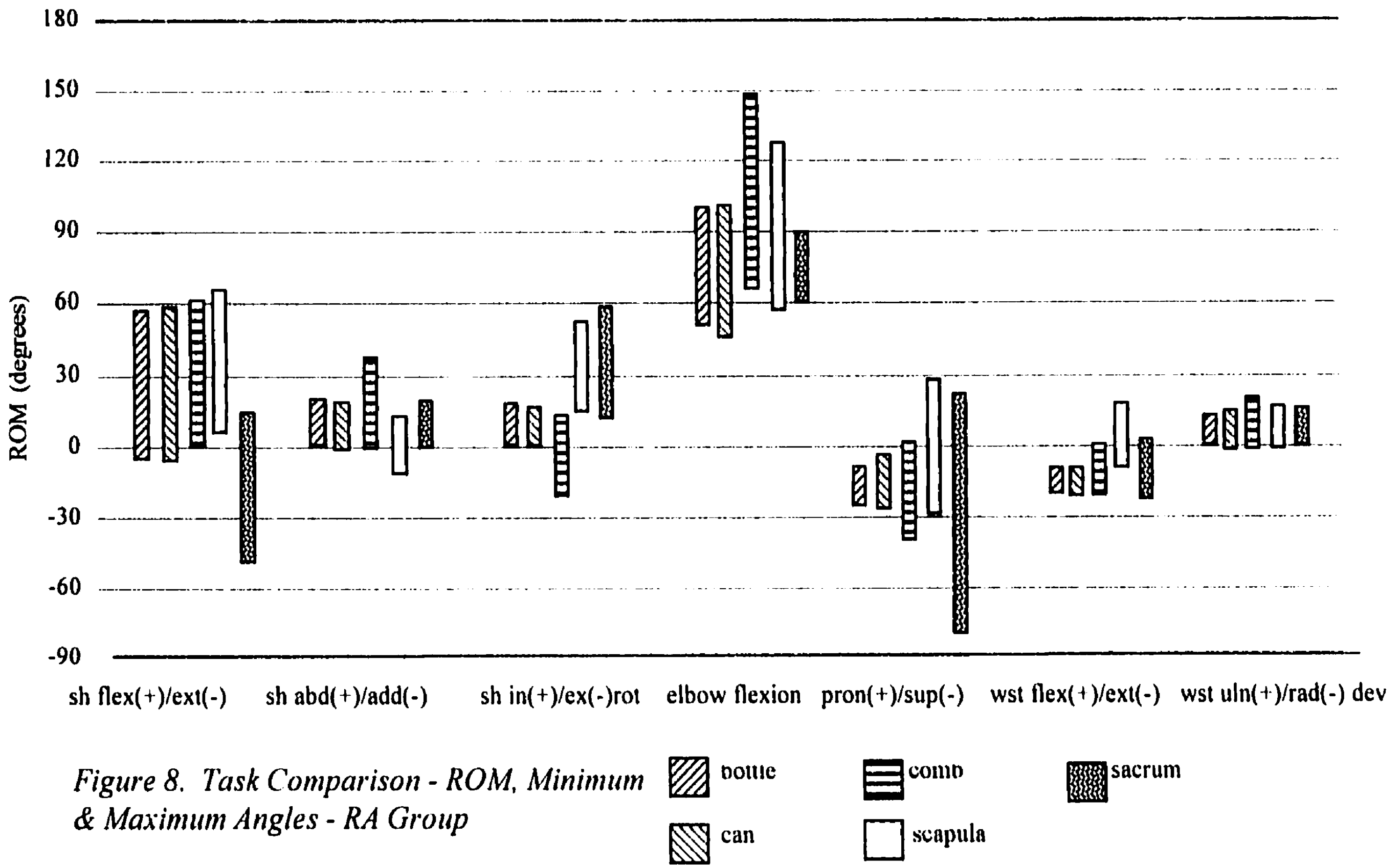


Figure 8. Task Comparison - ROM, Minimum & Maximum Angles - RA Group

sh flex(+)/ext(-) = shoulder flexion/extension   sh abd(+)/add(-) = shoulder abduction/adduction   sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination   wst flex(+)/ext(-) = wrist flexion/extension   wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

	Range of Motion	Minimum Angle	Maximum Angle
shd flex(+)/ext (-)	com opp sac bot can	sac can bot com opp	sac bot can com opp
shd abd(+)/add(-)	com can bot opp sac	bot com sac can opp	com bot can sac opp
shd in(+)/ex(-)rot	can bot com opp sac	com can bot sac opp	com can bot opp sac
elbow flexion	sac bot can opp com	can bot opp sac com	sac bot can opp com
pro(+)/sup(-)	bot can com opp sac	sac com opp can bot	bot can com sac opp
wst flex(+)/ext(-)	bot can com opp sac	sac com can bot opp	bot can com sac opp
uln(+)/rad(-)dev	bot sac can opp com	com can opp bot sac	bot can sac opp com

Table 11. One Way Repeated Measures Analysis of Variance of ROM, Minimum & Maximum Angles (Between Task Comparison) RA Group.

key
can = lifting can
com = combing hair
sac = touch sacrum
shd flex (+)/ext(-) = shoulder flexion/extension
shd in(+)/ex(-)rot = shoulder internal/external rotation
wst flex (+)/ext (-) = wrist flexion/extension
bot = lifting bottle
opp = touch opposite scapula
underlined = no significant difference between tasks.
shd abd(+)/add(-) = shoulder abduction/adduction
pro(+)/sup(-) = forearm pronation/supination
uln (+)/rad (-) dev = wrist ulnar/radial deviation

Shoulder flexion and wrist deviation ROM showed no differences between tasks. The can and bottle tasks resulted in lower ranges of motion of wrist flexion than the other three tasks. Except for the greater ROM of shoulder abduction used when combing the hair, this task and touching the opposite scapula were very similar as no other significant differences were seen.

Three of the rotations (shoulder abduction, wrist flexion and wrist ulnar deviation) showed no significant difference in the minimum angle used between tasks.

The bottle and can were again very similar in the maximum angle used; the only difference occurred in the amount of wrist deviation. Although the other tasks used some similar rotations patterns to others, each other task was unique in the overall patterns of joint rotations used.

4.2.2Group Comparison - Range of Motion & Minimum/Maximum Angles

The comparisons of kinematic data between the control and RA groups are presented graphically in *Figures 9a-9g.*

With respect to the shoulder joint, the RA group used lower ranges of shoulder rotations to complete the tasks. However, only two significant differences were found; significantly lower ranges of shoulder flexion and internal rotation were used by the RA group when touching the opposite scapula (*Figures 9a & 9c)*. No significant differences were seen in the range of shoulder abduction/adduction used for any of the tasks.

Similar arcs of motion were also seen at the elbow region between the two groups; there were only three instances where a significant difference occurred. The RA group used a significantly higher range of elbow flexion than the control group when touching the opposite scapula (*Figure 9d)* and a lower range of pronation/supination when lifting the bottle

Figure 9a. Shoulder Flexion/Extension - Range of Motion

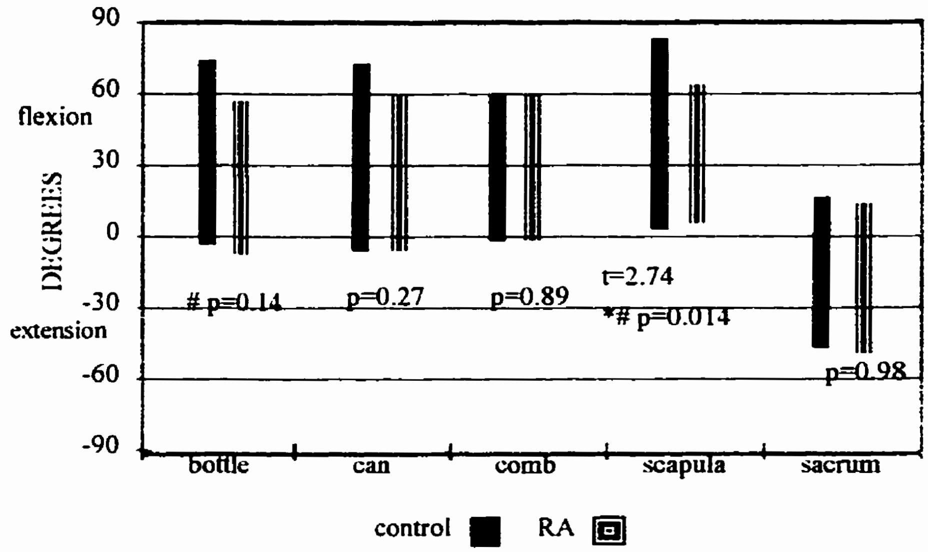
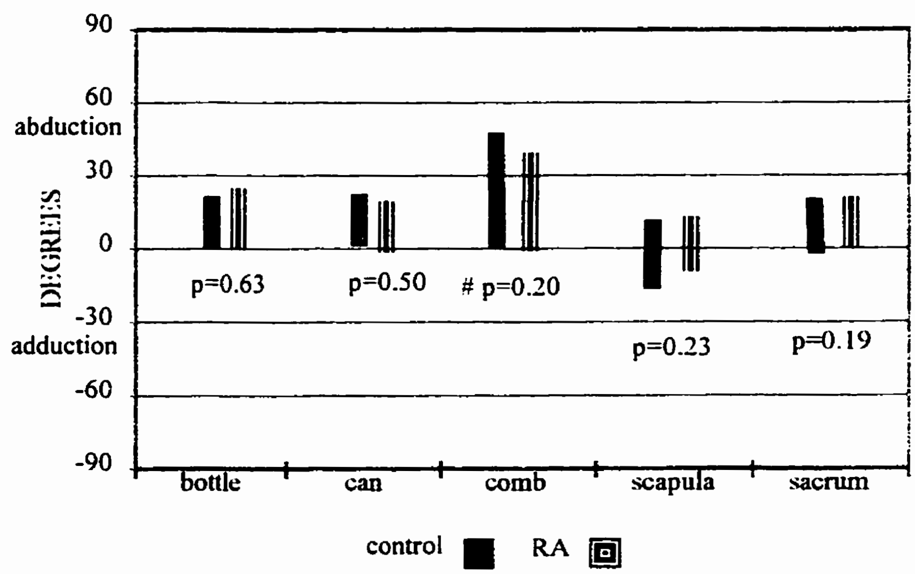


Figure 9b. Shoulder Abduction/Adduction - Range of Motion



* significant at p<0.05, unpaired t-test

**significant at p < 0.05, Mann-Whitney rank sum test

difference in ROM > 10 degrees

Figure 9c. Shoulder Internal/External Rotation - Range of Motion

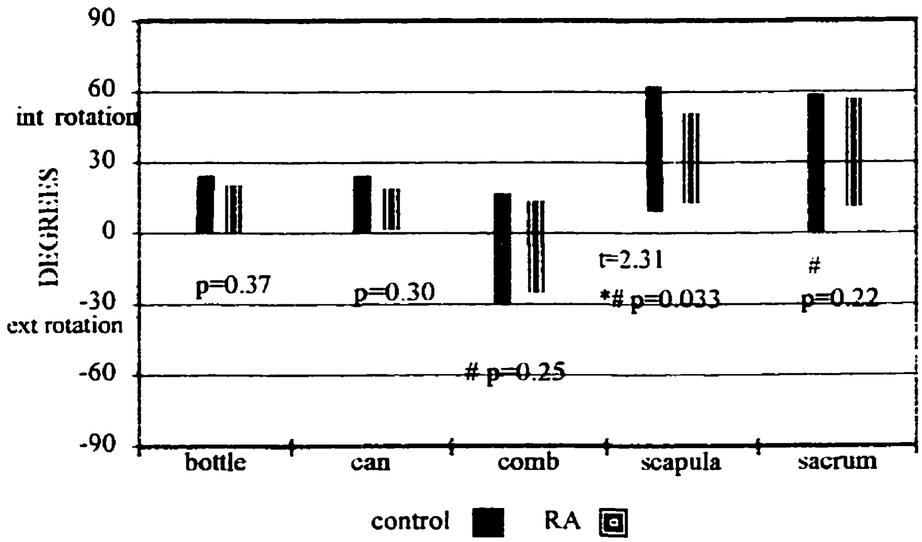
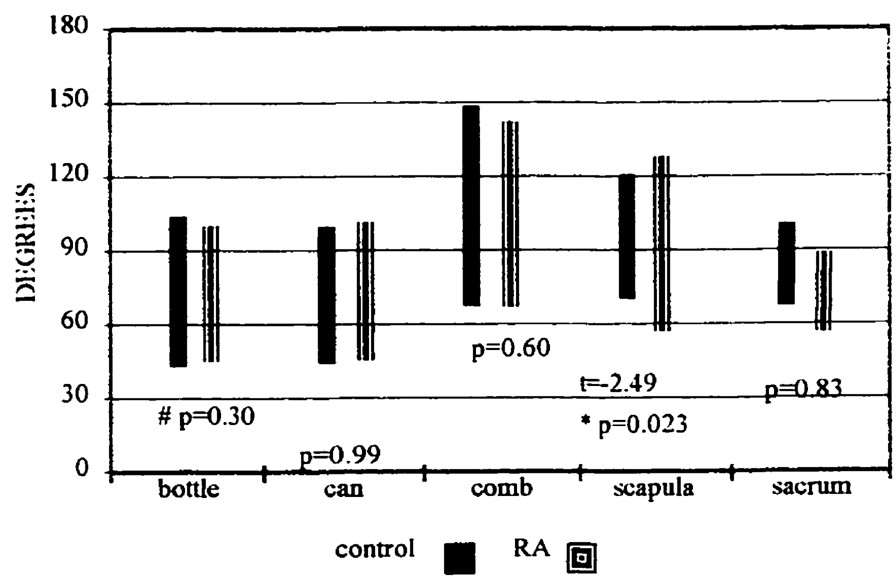


Figure 9d. Elbow Flexion - Range of Motion



* significant at p<0.05, unpaired t-test

**significant at p < 0.05, Mann-Whitney rank sum test

difference in ROM > 10 degrees

Figure 9e. Forearm Pronation/Supination - Range of Motion

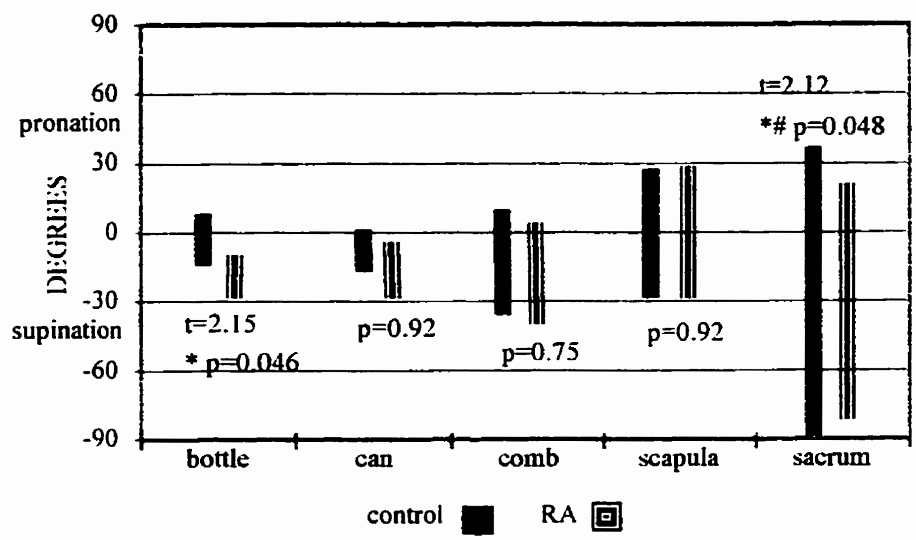
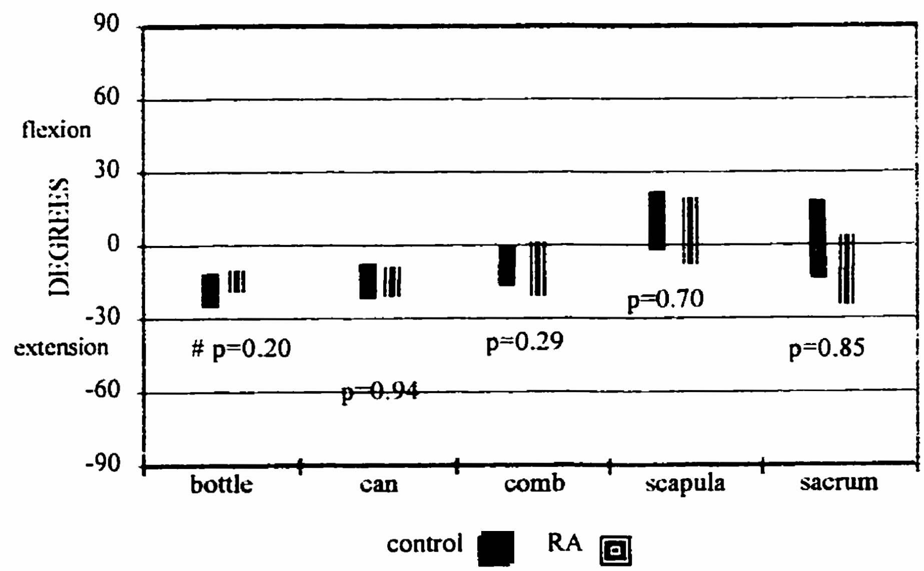


Figure 9f. Wrist Flexion/Extension - Range of Motion

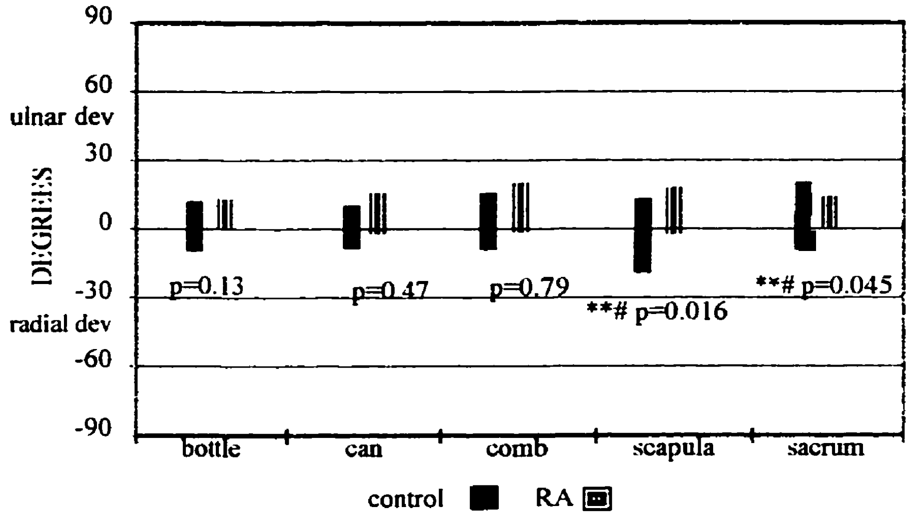


* significant at p<0.05, unpaired t-test

**significant at p < 0.05, Mann-Whitney rank sum test

\# difference in ROM > 10 degrees

Figure 9g. Wrist Ulnar/Radial Deviation - Range of Motion



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test
difference in ROM > 10 degrees

and when touching the sacrum (*Figure 9e)*.

No significant differences were seen between the two groups in the range of wrist flexion/extension used (*Figure 9f)*. The amount of wrist radial deviation used by the RA group was also significantly less when touching the opposite scapula and sacrum (*Figure 9g)*.

The results were also examined for clinical differences (subjectively chosen to be a difference in ROM greater than 10° through clinical experience). Clinical differences are marked by the # symbol on *Figures 9a-9g*.

The coefficient of variation was lower for the control group for shoulder flexion/extension and abduction/adduction; it was higher for the control group in shoulder internal/external rotation. This coefficient was similar between the two groups for elbow region rotations. Wrist flexion/extension coefficient of variation was higher for the control group; this calculation was similar between the two groups in wrist ulnar/radial deviation.

Although differences in ROM were seen between the two groups, hypothesis 1, *there will be a difference in the arc of motion in each of seven upper limb rotations during performance of functional tasks between the control and the RA groups,* cannot be supported as only seven of the 35 comparisons were found to be significant. If the number of clinical differences and significant differences were combined, ten of the 35 of the rotations were observed to be different. Refer to *Appendix L* for specific hypotheses results.

4.2.3 Task Comparison - Maximum Angular Velocity

The maximum angular velocity attained during performance of each task is presented in *Table 12* and *Figure 10* for the control group and in *Table 13* and *Figure 11* for the RA group. Maximum angular velocity was compared between tasks to determine if there were

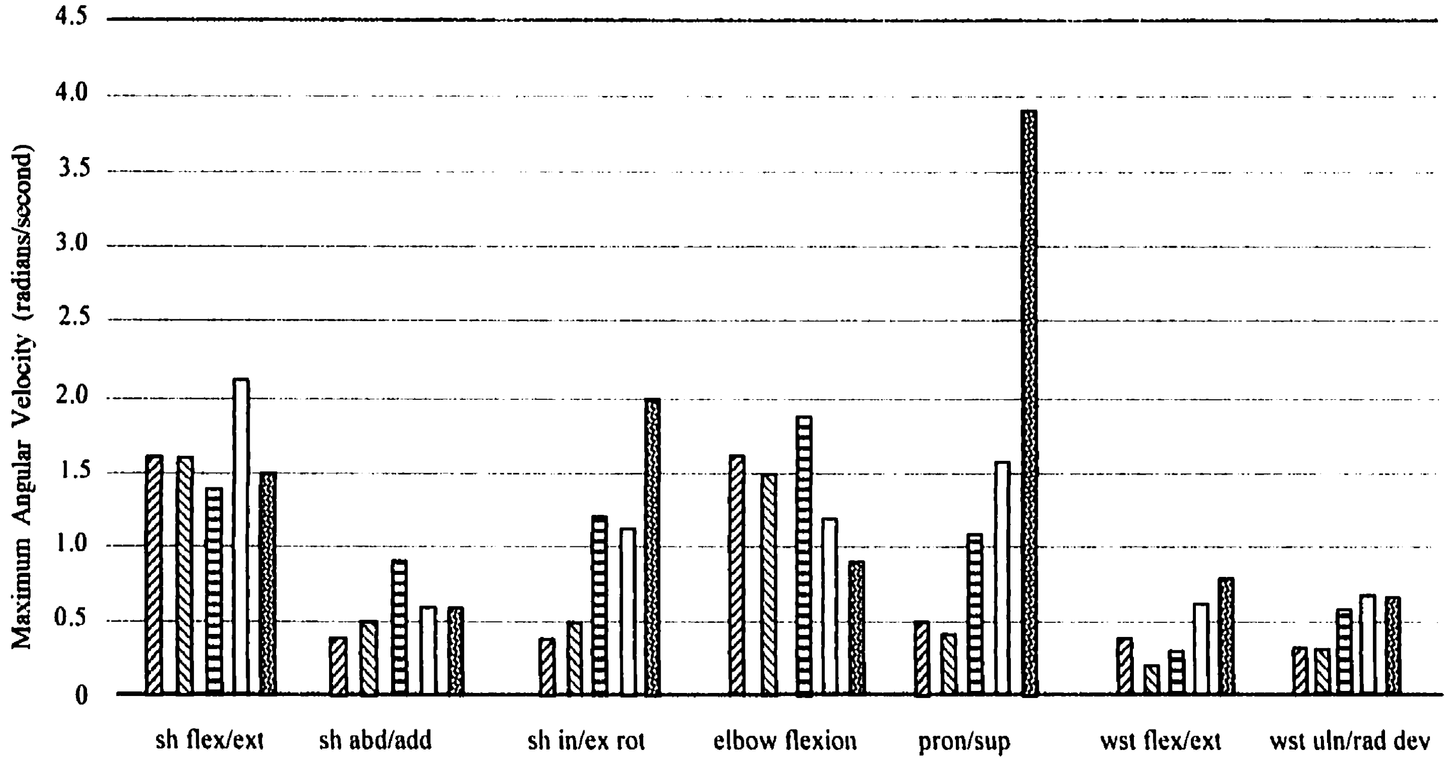


Figure 10. Task Comparison
Maximum Angular Velocity - Control Group

bottle
comb
sacrum
can
scapula

sh flex(+)/ext(-) = shoulder flexion/extension   sh abd(+)/add(-) = shoulder abduction/adduction   sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination   wst flex(+)/ext(-) = wrist flexion/extension   wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

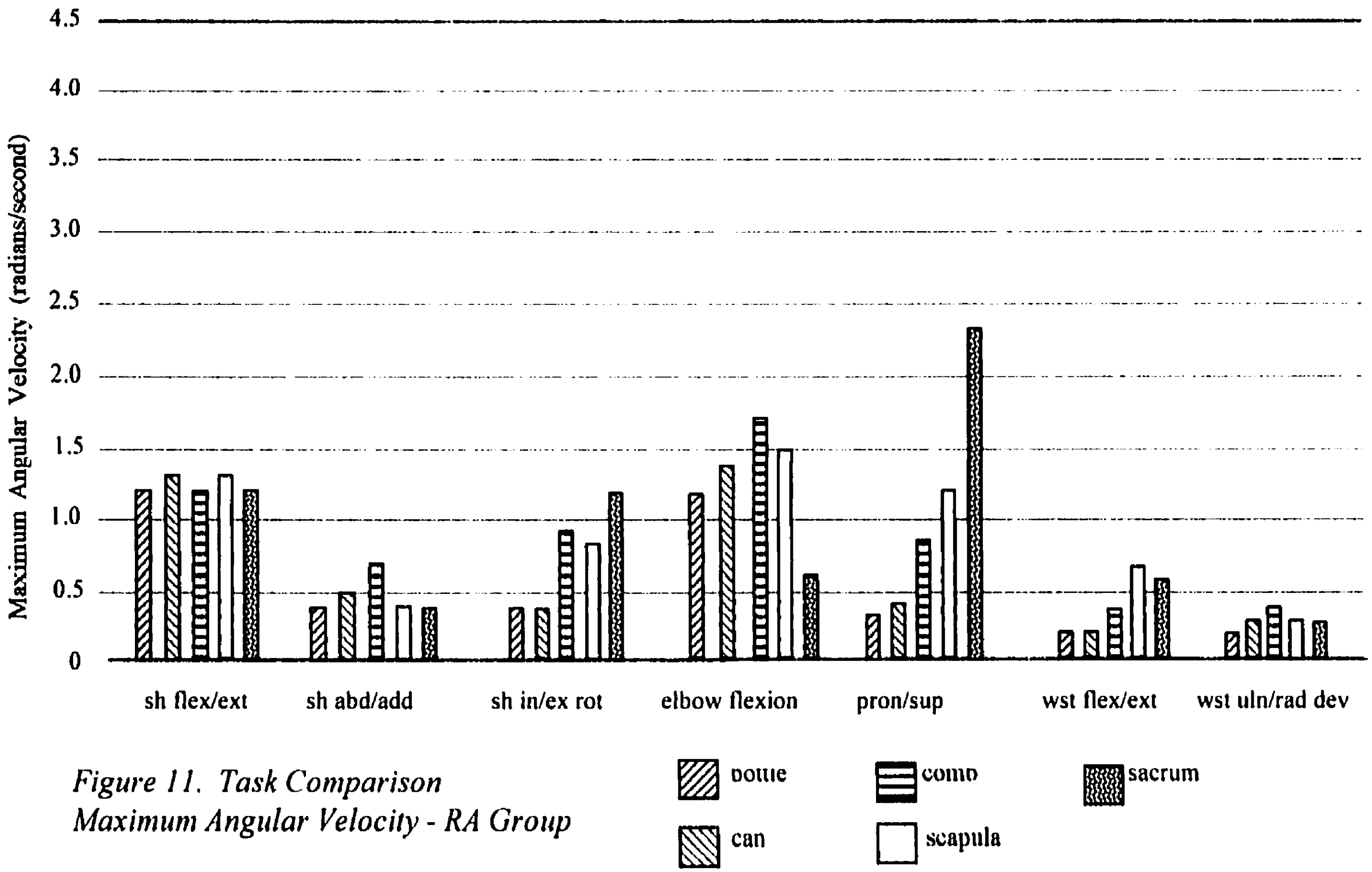


Figure 11. Task Comparison
Maximum Angular Velocity - RA Group

sh flex(+)/ext(-) = shoulder flexion/extension sh abd(+)/add(-) = shoulder abduction/adduction sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination wst flex(+)/ext(-) = wrist flexion/extension wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

differences for each joint rotation. The comparison was performed using an ANOVA and a post-hoc Student-Newman-Keuls test for multiple comparisons (Portney & Watkins, 1993). A summary of these comparisons is presented in *Table 14*.

	shoulder region			elbow region		wrist region	
	flex/ext	**abd/add**	**int/ext rotation**	**flexion**	**pro/sup**	**flex/ext**	**uln/rad deviation**
lift bottle	1.6 (0.2)	0.4 (0.2)	0.4 (0.3)	1.6 (0.7)	0.5 (0.4)	0.4 (0.5)	0.3 (0.3)
lift can	1.6 (0.3)	0.5 (0.2)	0.5 (0.4)	1.5 (0.5)	0.4 (0.2)	0.2 (0.2)	0.3 (0.1)
comb hair	1.4 (0.5)	0.9 (0.3)	1.2 (0.6)	1.9 (0.7)	1.1 (0.5)	0.3 (0.2)	0.6 (0.4)
touch scapula	2.1 (0.5)	0.6 (0.1)	1.1 (0.4)	1.2 (0.2)	1.6 (0.8)	0.6 (0.5)	0.7 (0.3)
touch sacrum	1.5 (0.2)	0.6 (0.3)	2.0 (0.9)	0.9 (0.6)	3.9 (1.1)	0.8 (0.7)	0.7 (0.5)

Table 12. Maximum Angular Velocity - Control Group - radians/sec (±standard deviation)

	shoulder region			elbow region		wrist region	
	flex/ext	**abd/add**	**int/ext rotation**	**flexion**	**pro/sup**	**flex/ext**	**uln/rad deviation**
lift bottle	1.2 (0.6)	0.4 (0.2)	0.4 (0.3)	1.2 (0.6)	0.3 (0.1)	0.2 (0.1)	0.2 (0.1)
lift can	1.3 (0.6)	0.5 (0.2)	0.4 (0.2)	1.4 (0.6)	0.4 (0.2)	0.2 (0.1)	0.3 (0.1)
comb hair	1.2 (0.6)	0.7 (0.5)	0.9 (0.5)	1.7 (0.7)	0.8 (0.3)	0.4 (0.2)	0.4 (0.4)
touch scapula	1.3 (0.6)	0.4 (0.2)	0.8 (0.4)	1.5 (0.5)	1.2 (0.6)	0.7 (1.1)	0.3 (0.3)
touch sacrum	1.2 (0.4)	0.4 (0.3)	1.2 (0.7)	0.6 (0.4)	2.3 (1.1)	0.6 (0.5)	0.3 (0.2)

Table 13. Maximum Angular Velocity - RA Group - radians/sec (±standard deviation)

	Maximum Angular Velocity control group	Maximum Angular Velocity RA group
shoulder flex/extension	com sac bot can opp	bot sac com can opp
shoulder ab/adduction	can bot opp sac com	opp sac bot can com
shoulder int/ext rotation	bot can opp com sac	bot can opp com sac
elbow flexion	sac opp can bot com	sac bot can opp com
forearm pron/supination	can bot com opp sac	bot can com opp sac
wrist flexion/extension	can com bot opp sac	can bot com sac opp
wrist uln/rad deviation	can bot com sac opp	bot can sac opp com

Table 14. One Way Repeated Measures Analysis of Variance of Maximum Angular Velocity (Between Task Comparison) Control and RA Groups

key
can = lifting can
com = combing hair
sac = touch sacrum
shd flex (+)/ext(-) = shoulder flexion/extension
shd in(+)/ex(-)rot = shoulder internal/external rotation
wst flex (+)/ext (-) = wrist flexion/extension
bot = lifting bottle
opp = touch opposite scapula
underlined = no significant difference between tasks.
shd abd(+)/add(-) = shoulder abduction/adduction
pro(+)/sup(-) = forearm pronation/supination
wst uln (+)/rad (-) dev = wrist ulnar/radial deviation

For the control group, the maximum angular velocity attained at the distal (wrist) joints was not found to be significantly different. More differences between tasks was observed at the proximal joints. Shoulder flexion when touching the opposite scapula, shoulder abduction when combing the hair and shoulder internal rotation and forearm supination when touching the sacrum were rotations in which the maximum angular velocity attained was significantly different than that attained in performance of the other tasks. The lifting can and bottle tasks were not calculated to be significantly different from one another for either group. The maximum angular velocity attained during shoulder flexion/extension and abduction/adduction was not significantly different between tasks for the RA group. In the RA group, more differences were observed at the distal joints than at the proximal joints.

Differences were observed in maximum angular velocity of shoulder internal rotation, elbow flexion and forearm supination when touching the sacrum. Pronation/supination maximum angular velocity was different across tasks (with the exception of bottle and can tasks).

4.2.4 Group Comparison - Maximum Angular Velocity

A comparison of the mean maximum angular velocity and standard deviation attained at each joint rotation by the control and RA subjects is presented in *Figures 12a-12g.*

It can be seen from the relatively high standard deviations that there was high inter-subject variability. However, in general a lower mean maximum angular velocity was used by the RA group at each of the joint rotations during performance of all tasks. Calculation of the coefficient of variation showed lower values for the control group in the shoulder flexion/extension, abduction/adduction, elbow flexion and wrist ulnar/radial deviation maximum angular velocites. The coefficient of variation was generally lower for the RA group in forearm pronation/supination and wrist flexion/extension maximum angular velocities. For shoulder internal/external maximum angular velocity, the coefficients of variation were similar.

Although the maximum angular velocity attained during elbow flexion and wrist flexion/extension while reaching to touch the opposite scapula, and the maximum angular velocity of wrist flexion/extension while combing the hair and touching the opposite scapula were greater in the RA group than the control group, none of these differences was significant.

The mean maximum angular velocity of shoulder flexion/extension was significantly greater in the control group compared to the RA group when touching the opposite scapula

Figure 12a. Maximum Angular Velocity - radians/sec
Shoulder Flexion/Extension

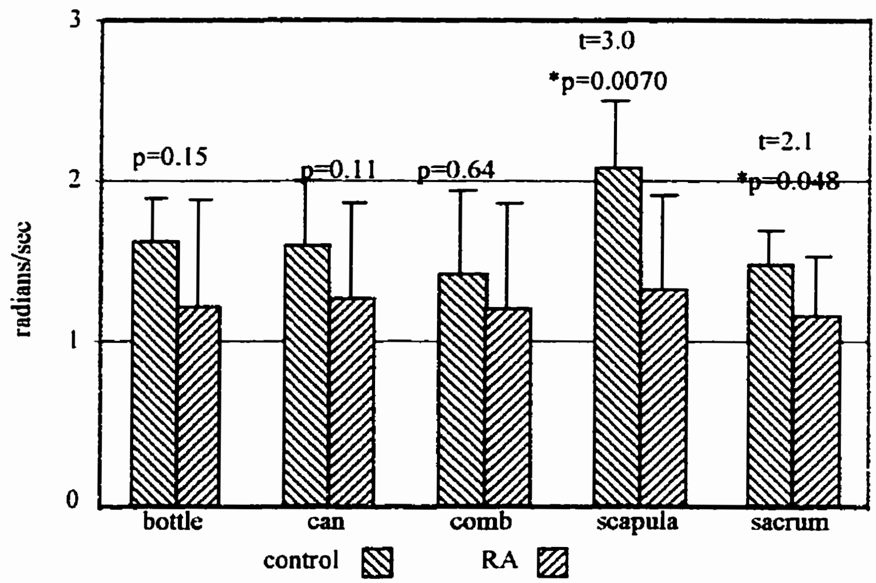
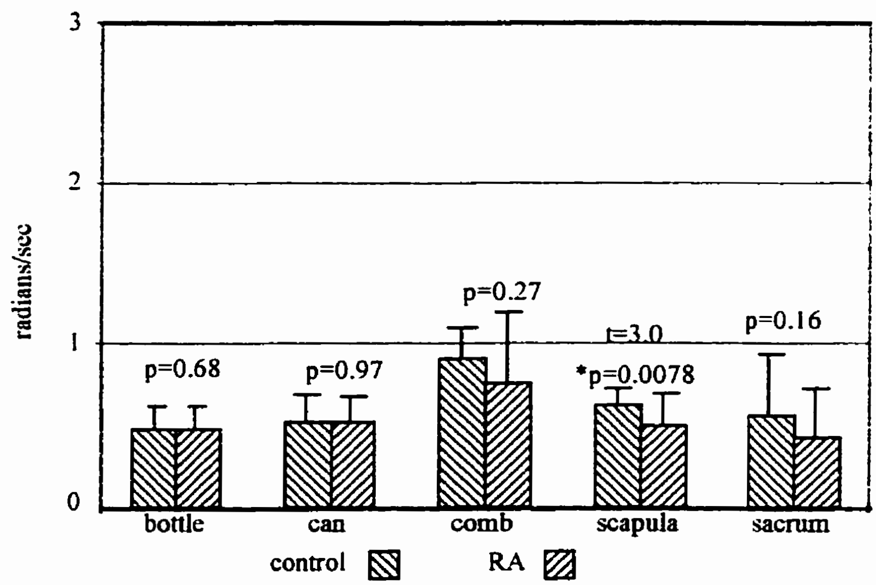


Figure 12b. Maximum Angular Velocity - radians/sec
Shoulder Abduction/Adduction



* significant at p<0.05, unpaired t-test

**significant at p < 0.05, Mann-Whitney rank sum test

Figure 12c. Maximum Angular Velocity - radians/sec
Shoulder Internal/External Rotation

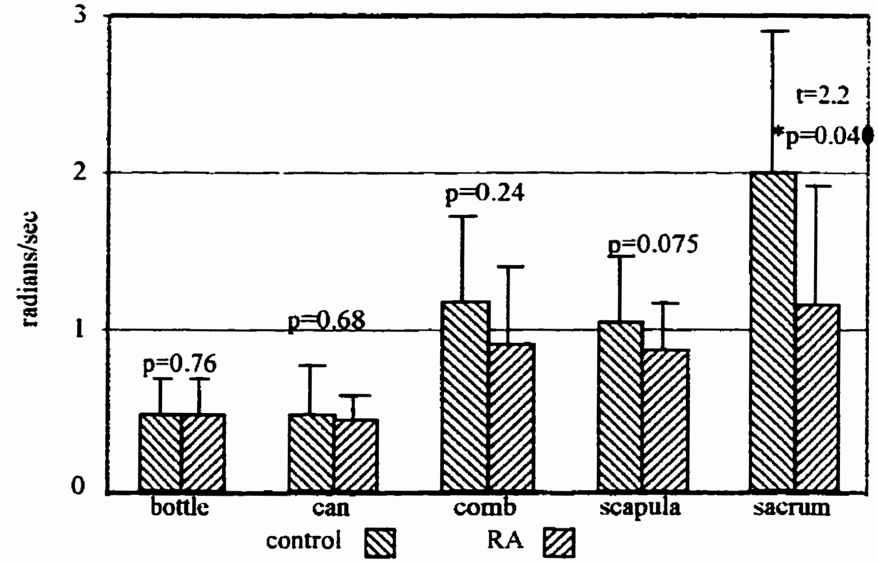
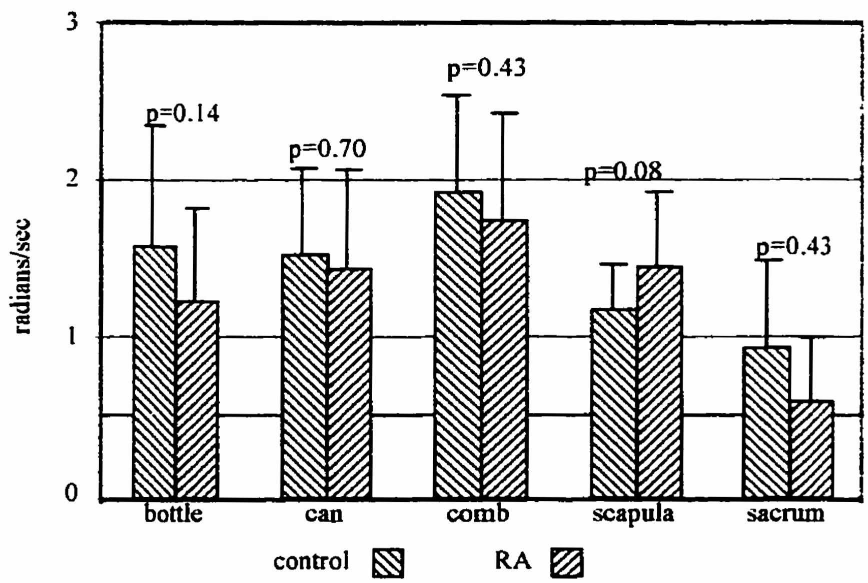


Figure 12d. Maximum Angular Velocity - radians/sec
Elbow Flexion



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

Figure 12e. Maximum Angular Velocity - radians/sec
Forearm Pronation/Supination

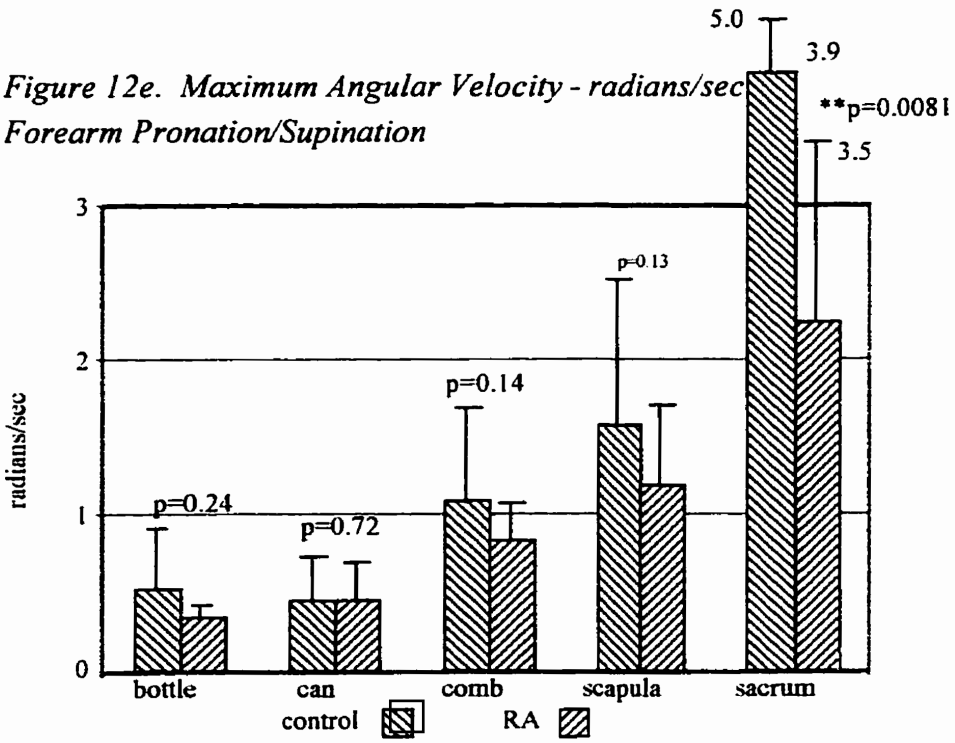
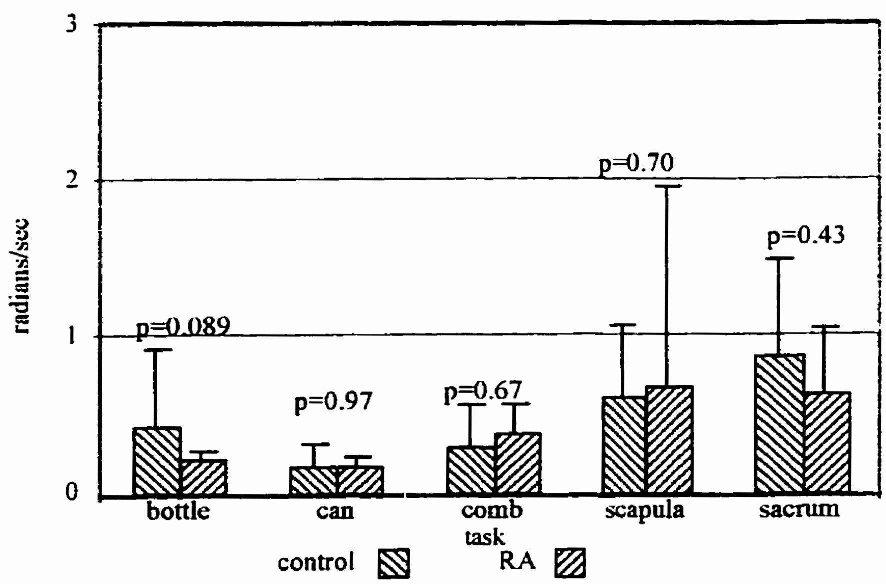
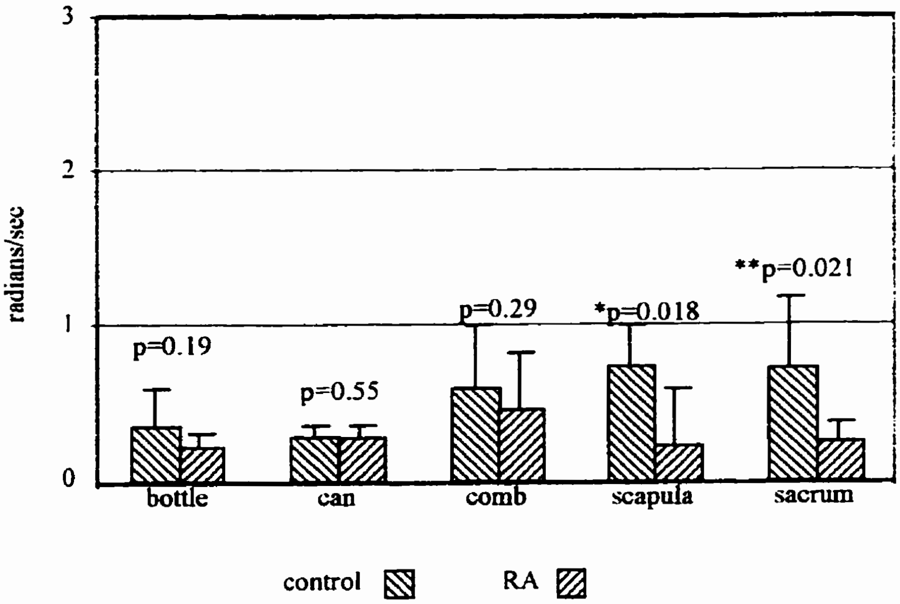


Figure 12f. Maximum Angular Velocity - radians/sec
Wrist Flexion/Extension



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

Figure 12g. Maximum Angular Velocity - radians/sec
Wrist Ulnar/Radial Deviation



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

and sacrum (*Figure 12a*). Shoulder abduction/adduction velocity of the control group was also significantly greater than that of the RA group when touching the scapula, as was shoulder internal/external rotation when touching the sacrum (*Figures 12b & 12c)*. No significant differences were found between the two groups during elbow flexion (*Figure 12 d)*, however the difference seen between the groups during forearm pronation/supination when touching the sacrum was significant *(Figure 12e)*. At the wrist joint, there were no significant differences during flexion/extension (*Figure 12 f);* however the maximum angular velocity during wrist ulnar/radial deviation was significantly greater in the control group than in the RA group when touching the scapula and sacrum *(Figure 12g)*. The second hypothesis stated that *there will be a difference in the maximum angular velocity in each of seven upper limb rotations during performance of functional tasks between the control and the RA groups*. Although differences were observed between the groups, this difference was significant in only seven out of the 35 comparisons and thus the hypothesis cannot be supported for all comparisons. Refer to *Appendix L* for specific hypotheses results.

4.2.5 Task Comparison - Maximum Angular Acceleration

The maximum angular acceleration attained during performance of each task is presented in *Table 15* and *Figure 13* for the control group and in *Table 16* and *Figure 14* for the RA group. Maximum angular acceleration was compared between tasks to determine if there were differences within each joint rotation. Again, a One Way Repeated Measures ANOVA with a post-hoc Student-Newman-Keuls test for multiple comparison was used (Portney & Watkins, 1993). A summary of significant comparisons is presented in *Table 17.*

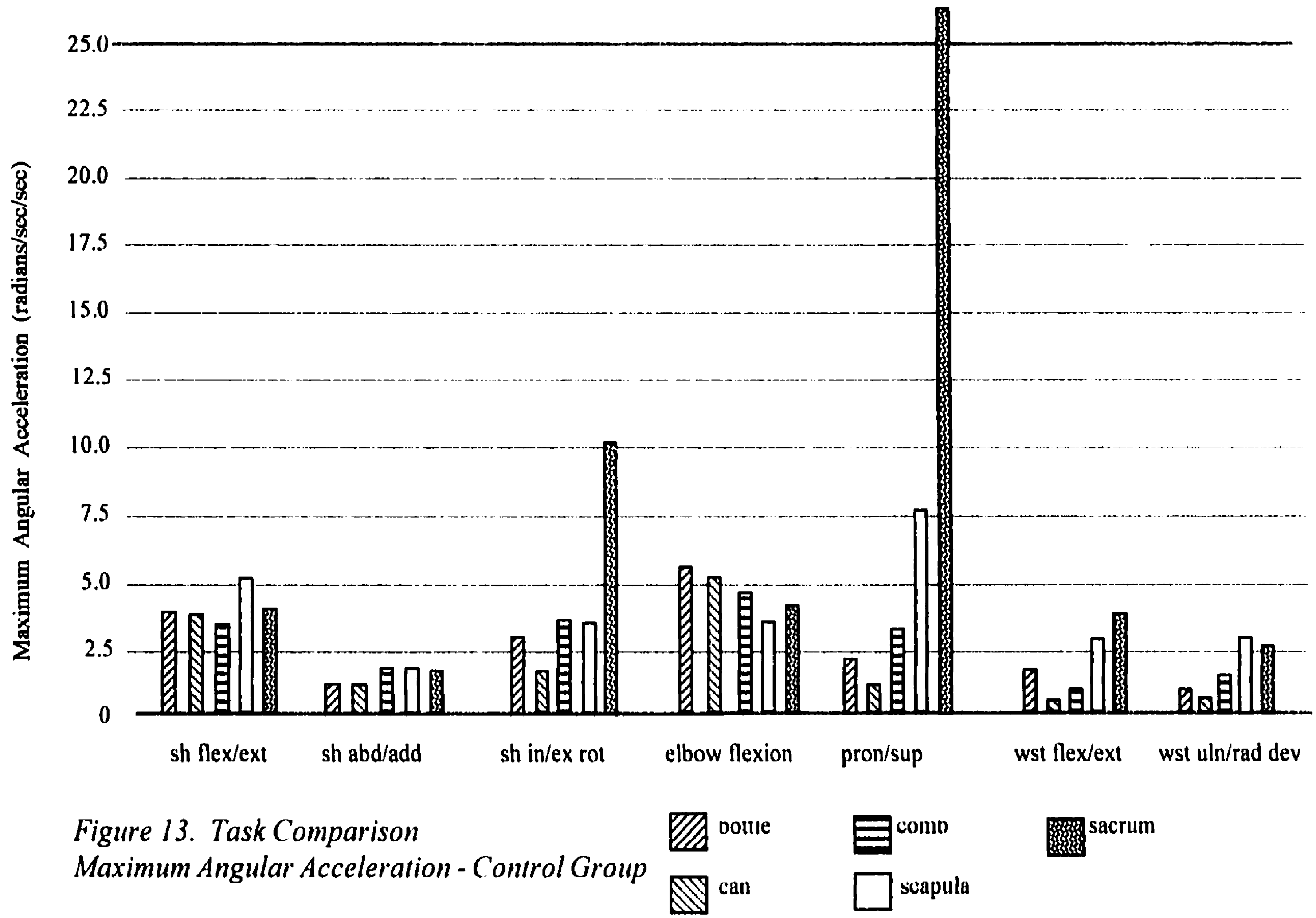


Figure 13. Task Comparison
Maximum Angular Acceleration - Control Group

sh flex(+)/ext(-) = shoulder flexion/extension   sh abd(+)/add(-) = shoulder abduction/adduction   sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination   wst flex(+)/ext(-) = wrist flexion/extension   wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

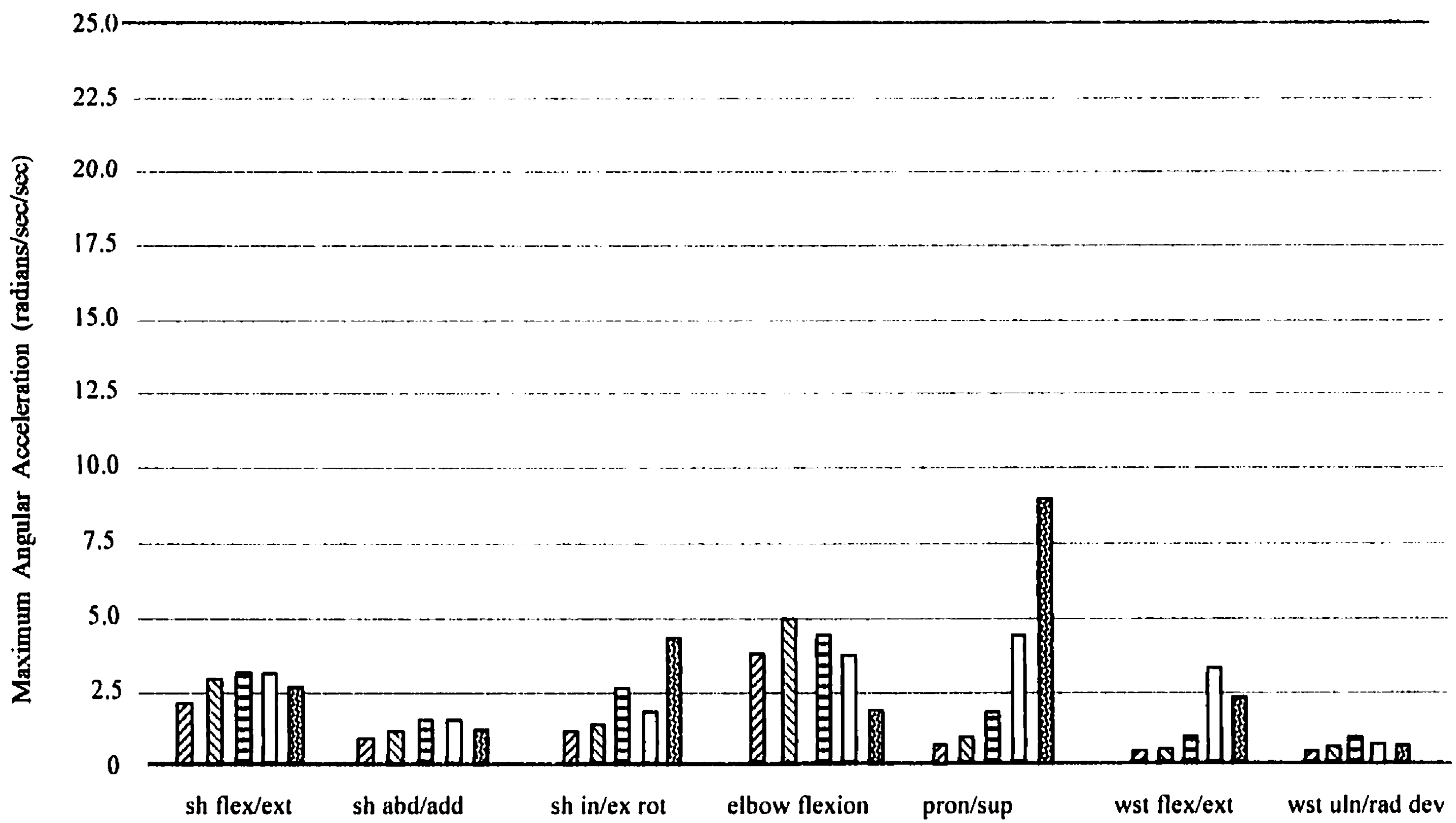


Figure 14. Task Comparison
Maximum Angular Acceleration - RA Group

sh flex(+)/ext(-) = shoulder flexion/extension sh abd(+)/add(-) = shoulder abduction/adduction sh in(+)/ex(-) rot = shoulder internal/external rotation

pron(+)/sup(-) = forearm pronation/supination wst flex(+)/ext(-) = wrist flexion/extension wst uln(+)/rad(-) dev = wrist ulnar/radial deviation

	shoulder region			elbow region		wrist region	
	flex/ext	abd/add	int/ext rotation	flexion	pro/sup	flex/ext	uln/rad deviation
lift bottle	3.8 (0.8)	1.2 (0.8)	2.9 (5.9)	5.7 (3.6)	2.3 (4.0)	1.9 (3.8)	0.9 (1.0)
lift can	3.7 (1.1)	1.2 (0.6)	1.4 (1.7)	5.2 (1.9)	1.2 (0.9)	0.5 (0.4)	0.5 (0.2)
comb hair	3.5 (1.7)	2.0 (0.7)	3.5 (2.1)	4.8 (2.3)	3.6 (2.5)	0.9 (0.8)	1.5 (1.4)
touch scapula	5.2 (1.6)	2.0 (0.5)	3.3 (2.1)	3.4 (2.4)	7.7 (6.7)	3.0 (3.5)	3.0 (3.0)
touch sacrum	4.0 (1.7)	1.9 (1.1)	10.2 (5.8)	4.0 (3.9)	26.4(18.9)	3.9 (5.9)	2.7 (2.0)

Table 15. Maximum Angular Acceleration - Control Group - radians/sec/sec (±std deviation)

	shoulder region			elbow region		wrist region	
	flex/ext	abd/add	int/ext rotation	flexion	pro/sup	flex/ext	uln/rad deviatio n
lift bottle	2.2 (1.3)	0.9 (0.6)	1.1 (0.9)	3.7 (2.9)	0.6 (0.3)	0.3 (0.1)	0.3 (0.2)
lift can	2.8 (1.5)	1.1 (0.6)	1.4 (1.1)	5.0 (3.3)	0.8 (0.7)	0.4 (0.2)	0.5 (0.3)
comb hair	3.0 (2.0)	1.6 (1.2)	2.6 (2.5)	4.5 (2.9)	1.9 (1.4)	1.0 (0.7)	1.1 (1.6)
touch scapula	3.0 (1.9)	1.0 (0.5)	1.9 (1.6)	3.7 (2.5)	4.5 (5.7)	3.4 (7.7)	0.8 (0.9)
touch sacrum	2.6 (1.4)	1.1 (0.7)	4.2 (3.1)	2.0 (2.0)	8.3 (7.8)	2.3 (2.5)	0.7 (0.8)

Table 16. Maximum Angular Acceleration - RA Group - radians/sec/sec (±standard deviation)

	Maximum Angular Acceleration control group	Maximum Angular Acceleration RA group
shoulder flex/extension	com sac can bot opp	can sac bot opp com
shoulder ab/adduction	can bot sac com opp	bot sac opp can com
shoulder int/ext rotation	can bot opp com sac	bot can opp com sac
elbow flexion	opp sac bot can com	sac bot opp com can
forearm pron/supination	can bot com opp sac	can bot com opp sac
wrist flexion	can bot com opp sac	bot can opp com sac
wrist uln/rad deviation	bot can com opp sac	bot sac can opp com

Table 17. One Way Repeated Measures Analysis of Variance (Between Task Comparison) Control and RA Groups.

key

can = lifting can	bot = lifting bottle
com = combing hair	opp = touch opposite scapula
sac = touch sacrum	underlined = no significant difference between tasks.
shd flex (+)/ext(-) = shoulder flexion/extension	shd abd(+)/add(-) = shoulder abduction/adduction
shd in(+)/ex(-)rot = shoulder internal/external rotation	pro(+)/sup(-) = forearm pronation/supination
wst flex (+)/ext (-) = wrist flexion/extension	wst uln (+)/rad (-) dev = wrist ulnar/radial deviation

Touching the sacrum elicited the highest maximum angular acceleration in the control group and this occurred during forearm supination. This value was almost twice as large as the next highest maximum angular acceleration which occurred during shoulder internal rotation, also while touching the sacrum. The maximum angular acceleration attained during the lifting can and lifting bottle tasks was not significantly different for the control group. Shoulder abduction/adduction was not significantly different for any of the tasks for either group. Elbow flexion and wrist ulnar/radial deviation also were not significantly different between the tasks for the control group.

The RA group also used similar maximum angular acceleration for the can and bottle tasks in the proximal joints, however differences between the tasks were apparent in the distal joint rotations. As with the other tasks, touching the sacrum elicited different values at several joints (shoulder internal rotation, forearm supination and wrist flexion).

4.2.6 Group Comparison - Maximum Angular Acceleration

A comparison of the mean maximum angular acceleration and standard deviation attained at each joint rotation by the control and RA groups is presented in *Figures 15a-15g.*

Again, relatively high standard deviations were calculated for maximum angular acceleration, a further reflection of inter-subject variability within each group. Examination of the coefficients of variation revealed that the control group had lower values for shoulder flexion/extension, abduction/adduction, internal/external rotation, forearm pronation/supination and wrist ulnar/radial deviation maximum angular acceleration values. Elbow flexion and wrist flexion/extension coefficients of variation for maximum angular acceleration were generally lower for the RA group.

The greatest number of significant differences between the two groups was observed when examining the kinematic parameter of maximum angular acceleration (significantly different in nine out of a total of 35 rotations). As with velocity, the control group attained a consistently higher mean maximum angular acceleration to complete the tasks in all cases except for two: elbow flexion and wrist flexion/extension when touching the opposite scapula were greater in the RA group although not significantly so. Maximum angular acceleration during shoulder flexion/extension was significantly greater in the control group than in the RA group when lifting the bottle, when touching the opposite scapula, and when touching the sacrum *(Figure 15a)*. Shoulder joint abduction/adduction acceleration was significantly

Figure 15a. Maximum Angular Acceleration - radians/sec/sec Shoulder Flexion/Extension

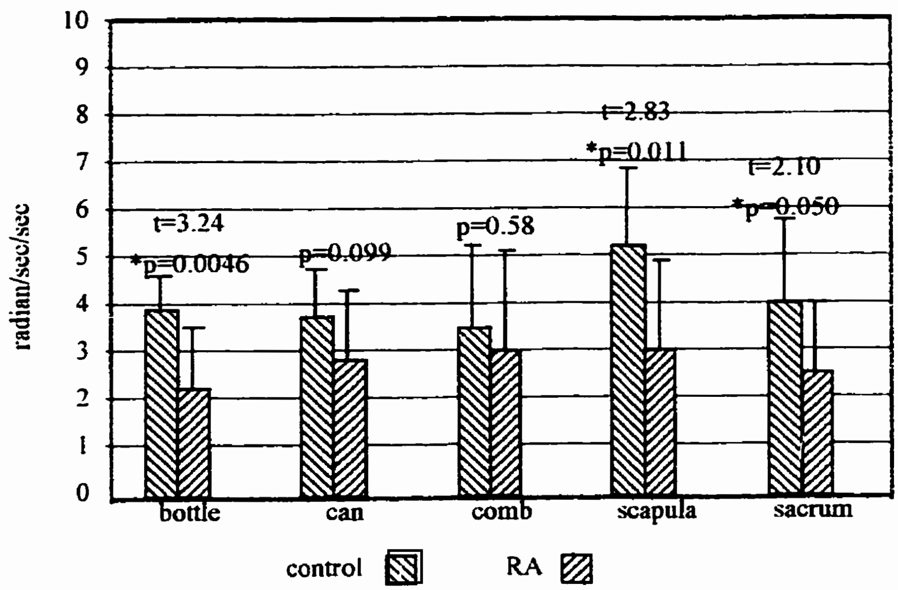
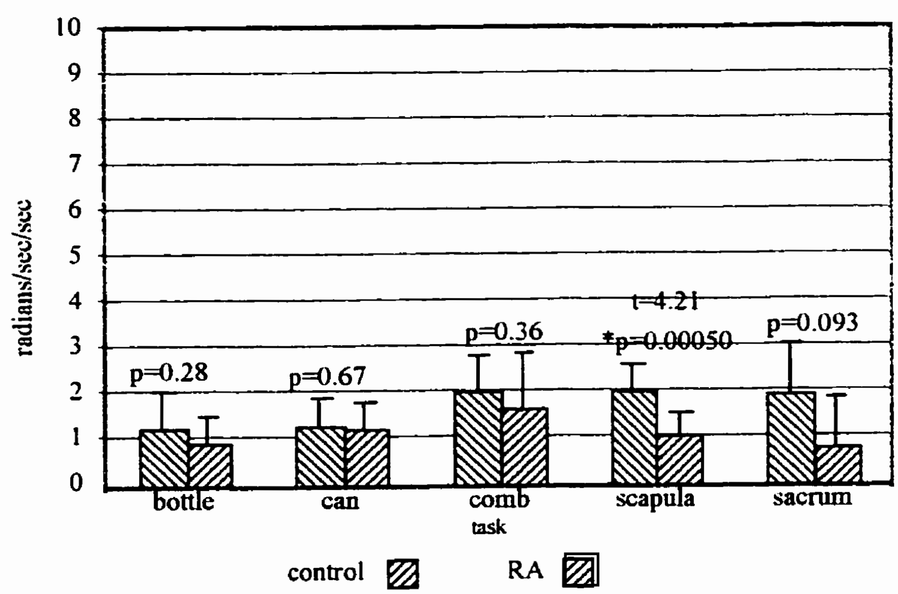


Figure 15b. Maximum Angular Acceleration - radians/sec/sec Shoulder Abduction/Adduction



* significant at p<0.05, unpaired t-test

**significant at p < 0.05, Mann-Whitney rank sum test

Figure 15c. Maximum Angular Acceleration - radians/sec/sec
Shoulder Internal/External Rotation

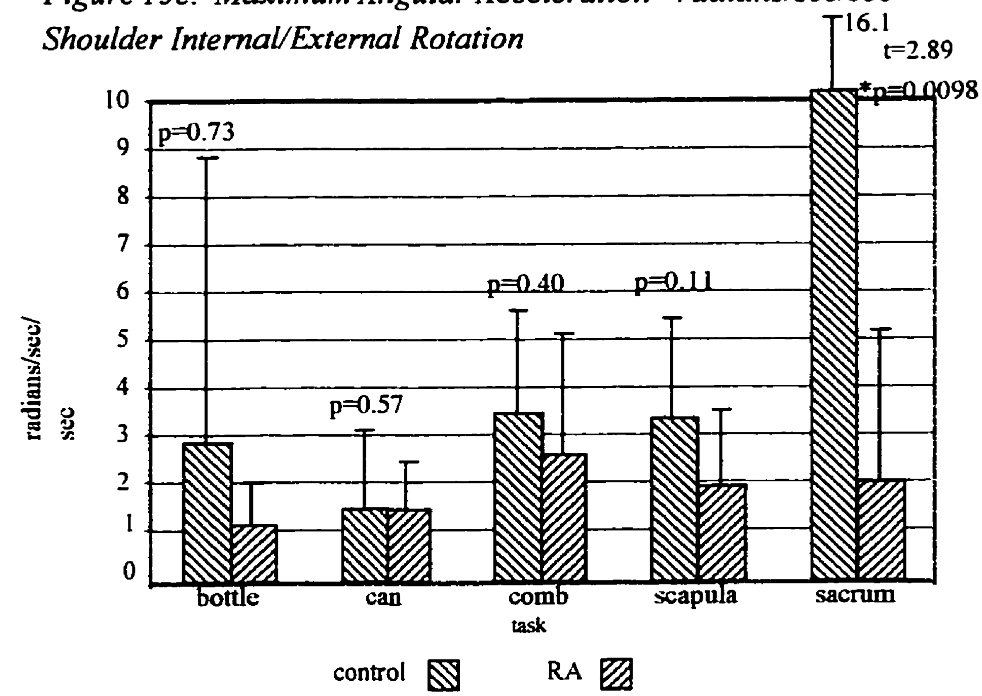
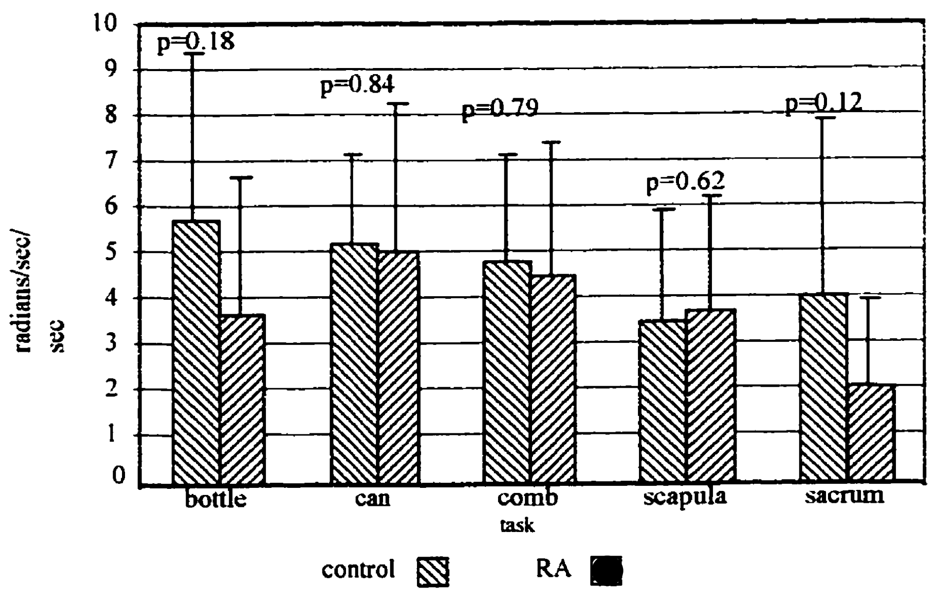


Figure 15d. Maximum Angular Acceleration - radians/sec/sec
Elbow Flexion



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

Figure 15e. Maximum Angular Acceleration - radians/sec/sec
Forearm Pronation/Supination

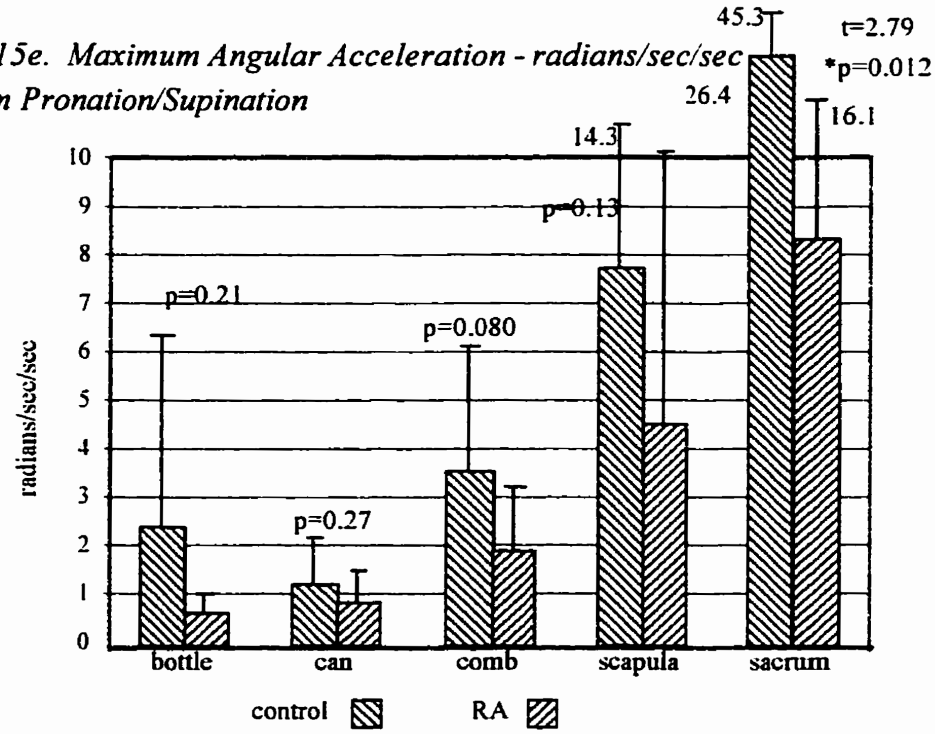
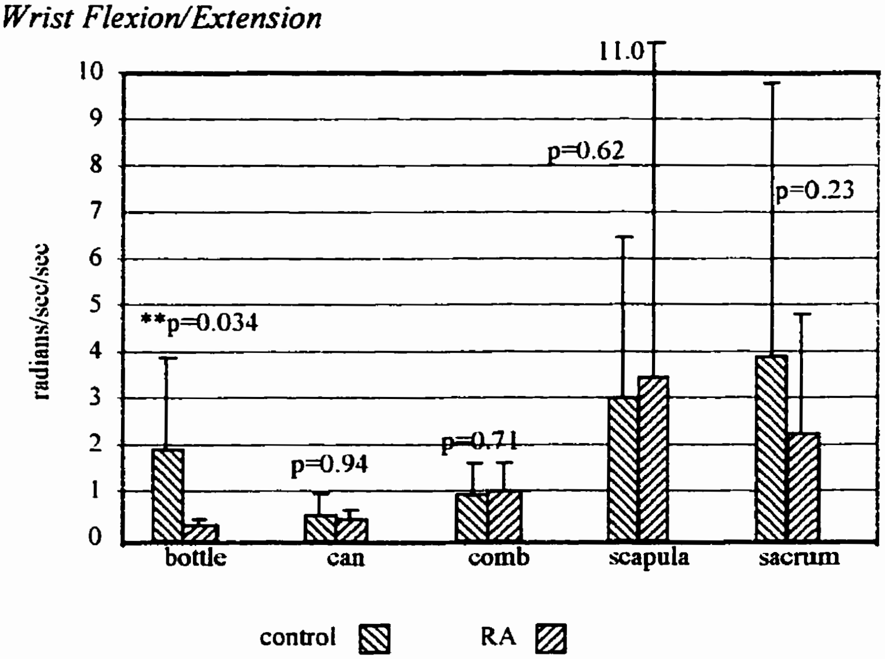
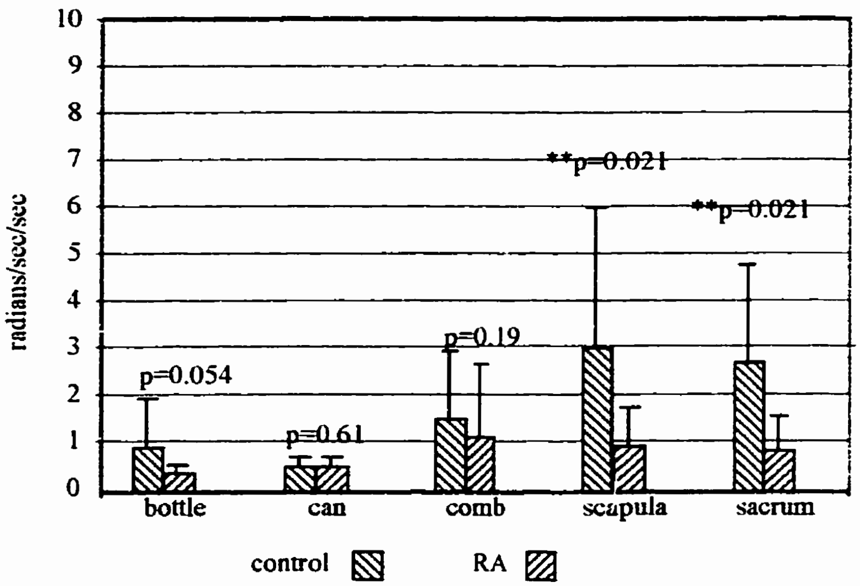


Figure 15f. Maximum Angular Acceleration - radians/sec/sec
Wrist Flexion/Extension



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

Figure 15g. Maximum Angular Acceleration - radians/sec/sec
Wrist Ulnar/Radial Deviation



* significant at p<0.05, unpaired t-test
**significant at p < 0.05, Mann-Whitney rank sum test

greater in the control group than the RA group when touching the scapula (*Figure 15b)* as was shoulder internal/external rotation and forearm pronation/supination when touching the sacrum (*Figure 15c & 15e)*. Maximum angular acceleration during wrist flexion/extension when lifting the bottle and ulnar/radial deviation when touching the scapula and sacrum again emerged as significantly greater in the control group than in the RA group (*Figures 15f & 15g)*.

The third hypothesis which stated *there will be a difference in the maximum angular acceleration of each of seven upper limb rotations during performance of functional tasks between the control and the RA groups* reached a level of significance in nine out of 35 comparisons and thus cannot be supported for all instances. Refer to *Appendix L* for specific hypotheses results.

4.2.7 Maximum Angular Acceleration and VAS Results

The pain change scores (PCS) obtained from the 10 RA subjects during performance of each functional task were compared to determine if differences existed between the tasks. This comparison was done using a Friedman Repeated Measures Analysis of Variance on Ranks (Portney & Watkins, 1993). No significant differences were found between the tasks at any of the three joint regions. *Figure 16* shows the mean pain change scores (PCS) obtained from the 10 RA subjects and the median PCS are shown in *Figure 17*. All PCS were less than 20 mm. As the median value discounts the extreme values, it may be a more accurate reflection of this data.

Figures 18 & 19 show the mean and median VAS score for each joint that the individual had marked after completing each task as well as the total post-task pain score

Figure 16. Mean Pain Change Score.

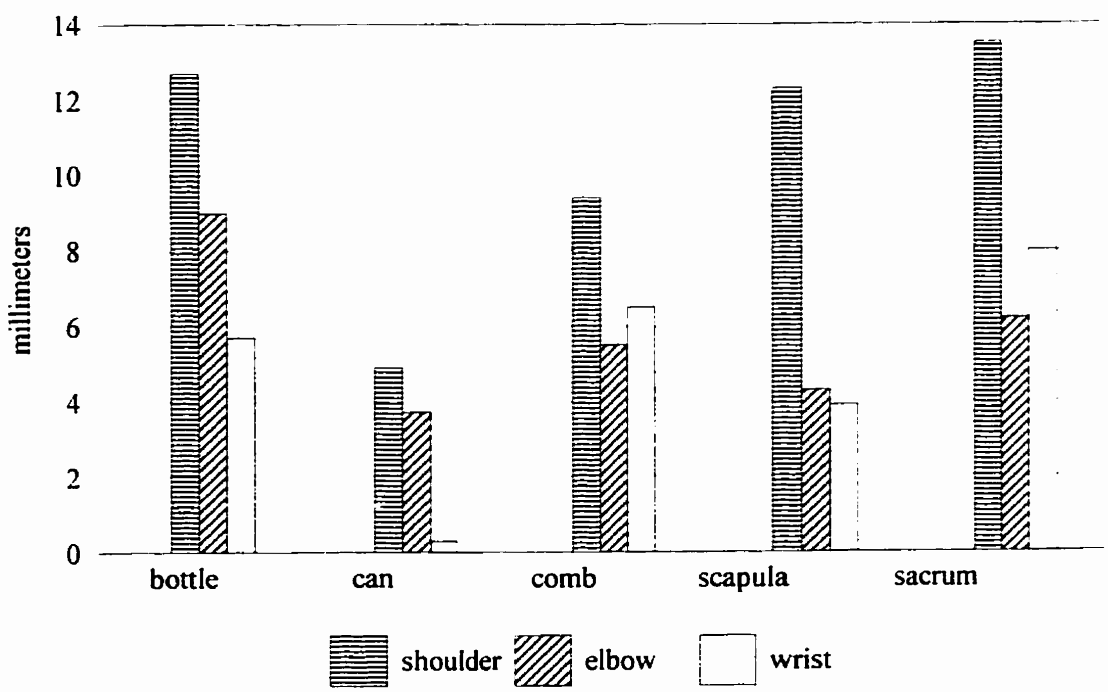


Figure 17. Median Pain Change Score.

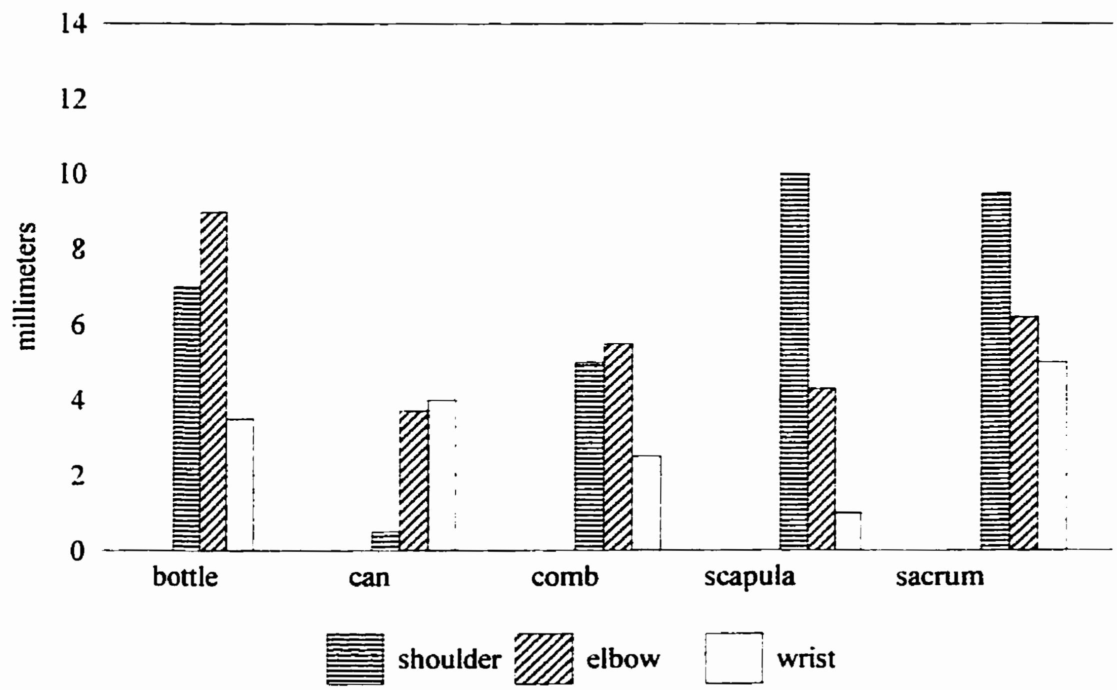


Figure 18. Mean Post-Task Pain Score.

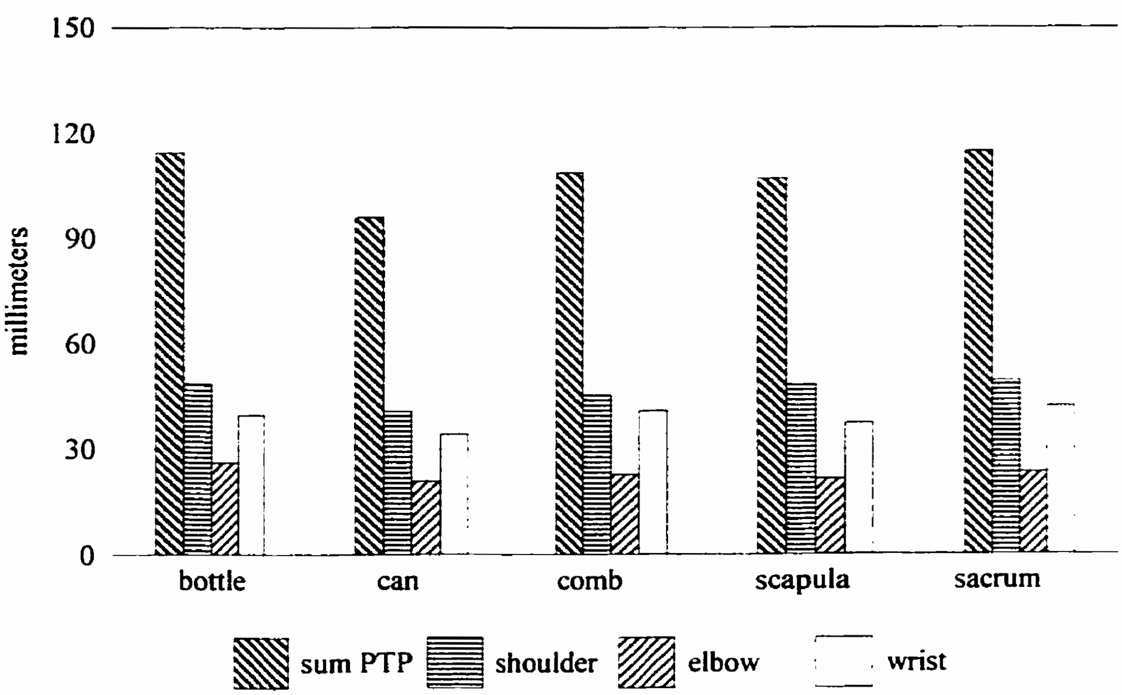
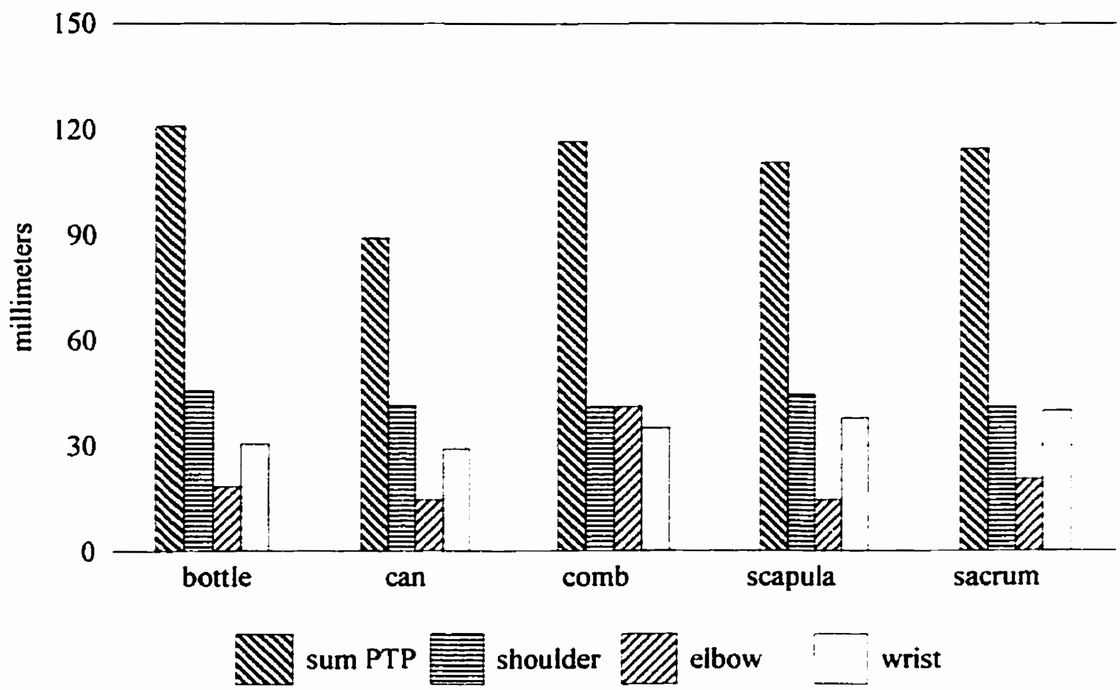


Figure 19. Median Post-Task Pain Score



($\sum$PTP). The latter is a sum of the three joint post-task pain scores and represents the total pain experienced in the upper limb after completing the task. As with the PCS, the $\sum$PTP and the PTP scores were not significantly different between tasks when compared with One Way Repeated Measures Analysis of Variance tests.

Correlations between maximum angular acceleration and the PCS were calculated for each joint rotation (*Appendix J*); a summary of the significant correlations is shown in *Table 18*. This result indicates that the greater the maximum angular acceleration of shoulder flexion/extension, the greater the change in pain score when lifting the can.

	Lift Bottle	**Lift Can**	**Comb**	**Scapula**	**Sacrum**
shoulder flexion/extension	n.s.	p=0.033	n.s.	n.s.	n.s.
shoulder abd/adduction	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder int/ext rotation	n.s.	n.s.	n.s.	n.s.	n.s.
elbow flexion	n.s.	n.s.	n.s.	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	n.s.	n.s.	n.s.
wrist flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
wrist ulnar/radial deviation	n.s.	n.s.	n.s.	n.s.	n.s.

Table 18. Summary of Correlation between Pain Change Score (PCS) and Maximum Angular Acceleration. (n.s. = not significant)

The correlations between maximum angular acceleration and PTP scores for each of the joint regions were also calculated (*Appendix J*) and are summarized in *Table 19*.

	Lift Bottle	Lift Can	Comb	Scapula	Sacrum
shoulder flexion/extension	n.s.	p=0.013	n.s.	n.s.	p=0.042
shoulder abd/adduction	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder int/ext rotation	n.s.	n.s.	p=0.032	n.s.	n.s.
elbow flexion	p=0.0032	p=0.022	p=0.023	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	n.s.	n.s.	n.s.
wrist flexion/extension	p=0.023	n.s.	n.s.	n.s.	p=0.049
wrist ulnar/radial deviation	n.s.	n.s.	n.s.	n.s.	n.s.

Table 19. Summary of Correlation between Post-Task Pain Score (PTP) and Maximum Angular Acceleration. (n.s. = not significant)

The use of the PTP score as the variable to compare the relationship of pain with acceleration yielded different results from those derived using the PCS. Eight of the 35 comparisons were significantly related at the $p<0.05$ level. Except for touching the opposite scapula, all shoulder and elbow joint maximum angular accelerations were calculated to be negatively correlated to post-task pain at a level greater than $r=-0.40$ (*Appendix J*). That is, as post-task pain decreased, shoulder and elbow joint maximum angular acceleration increased.

Because many of the correlations were found to reach or be near significance, regression equations were calculated for all of the joint rotations (*Table J1, Appendix J*). This was done to examine if a predictive relationship existed between the independent variable (angular acceleration) and the dependent variable (PTP) (Portney & Watkins, 1993). Seven regression equations were found to be significant, two for each of the lifting bottle, can and combing hair tasks and one for touching the sacrum. Six out of seven of the regression equations calculated for both lifting the bottle and combing hair had a p value <0.10.

Maximum angular acceleration was also correlated to total upper limb pain scores

$\sum$PTP at each of the seven upper limb joint rotations (*Appendix J*) and summarized in *Table 20*. Eleven of these correlations were significant at the $p<0.05$ level. All correlations were negative: as total upper limb pain increased, maximum angular acceleration decreased.

	lift bottle	**lift can**	**comb**	**touch scapula**	**touch sacrum**
shoulder flex/extension	p=0.0091	p=0.0023	p=0.017	n.s.	p=0.039
shoulder abd/adduction	p=0.05	n.s.	p=0.028	n.s.	n.s.
shoulder int/ext rotation	p=0.047	n.s.	n.s.	n.s.	n.s.
elbow flexion	p=0.015	p=0.024	p=0.018	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	p=0.030	n.s.	n.s.
wrist flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
wrist rad/ulnar deviation	n.s.	n.s.	n.s.	n.s.	n.s.

Table 20. Correlation between $\sum$PTP scores and task joint maximum angular acceleration. (n.s. = not significant)

The greatest number of significant correlations was found for the lifting bottle and combing hair tasks.

The hypothesis *there will be a correlation between the maximum angular acceleration at each of the seven upper limb rotations and pain (at each of the three upper limb regions)* was generally not supported for the correlation with CPS and PTP, however, more support for the hypothesis could be found when correlating maximum angular acceleration with $\sum$PTP. Refer to *Appendix L* for specific hypotheses results.

4.2.8 Pain, Range of Motion and Perceived Disability

The Health Assessment Questionnaire disability scores for each of the RA subjects are shown in *Figure 20*. Correlations of range of motion, pain and disability were calculated (*Appendix K*).

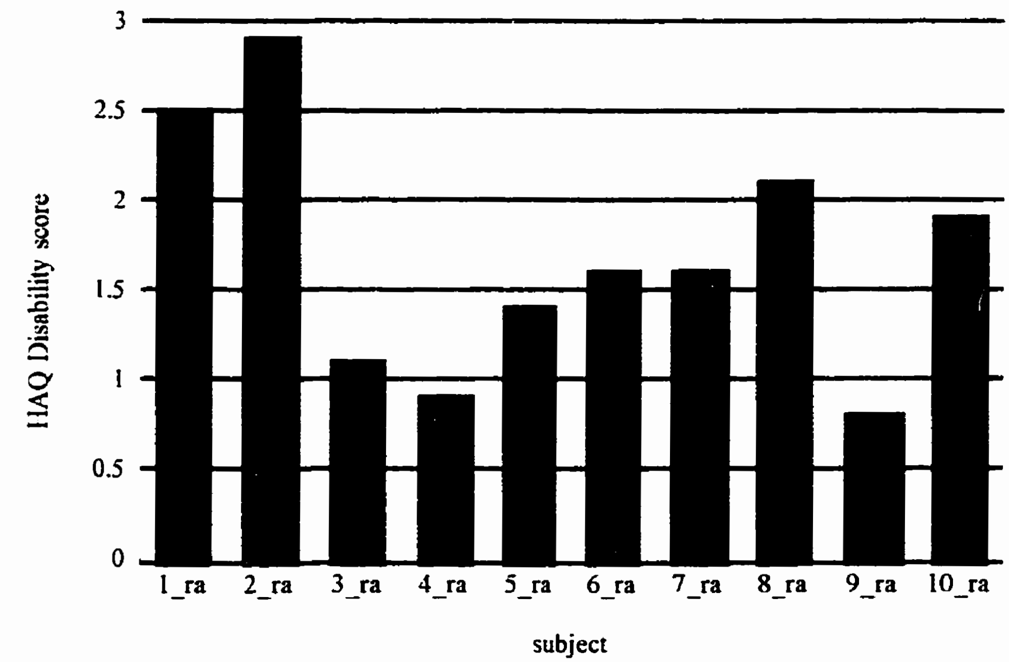


Figure 20. HAQ Disability Scores.

Pain & ROM Correlation

A summary of the results of the correlation between change in pain score (PCS) and ROM is presented in *Table 21.*

	Lift Bottle	**Lift Can**	**Comb**	**Scapula**	**Sacrum**
shoulder flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder abd/adduction	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder int/ext rotation	n.s.	n.s.	n.s.	n.s.	p=0.045
elbow flexion	n.s.	n.s.	n.s.	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	n.s.	n.s.	n.s.
wrist flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
wrist ulnar/radial deviation	n.s.	p=0.020	n.s.	n.s.	n.s.

Table 21. Summary of Correlation between Pain Change Score (PCS) and ROM. (n.s. = not significant)

The PCS score at any one joint region was significantly negatively correlated to the ROM used by the RA subjects on only two occasions. In addition, 14 out of the 35 comparisons were calculated to have a positive although not significant correlation. This would indicate that as ROM increased, pain increased in these rotations.

A second comparison was made of pain and functional ROM; this time PTP was used as one of the variables. The significant results are summarized in *Table 22.* The PTP score was representative of the overall pain in the joint region, and was assumed to indicate a more global (as opposed to an instantaneous) level of pain.

	Lift Bottle	Lift Can	Comb	Scapula	Sacrum
shoulder flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder abd/adduction	n.s.	n.s.	n.s.	n.s.	n.s.
shoulder int/ext rotation	n.s.	n.s.	n.s.	n.s.	n.s.
elbow flexion	p=0.017	n.s.	n.s.	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	n.s.	n.s.	n.s.
wrist flexion/extension	n.s.	n.s.	n.s.	n.s.	n.s.
wrist ulnar/radial deviation	n.s.	n.s.	n.s.	n.s.	n.s.

Table 22. Summary of Correlation between Post-Task Pain Score (PTP) and ROM. (n.s.= not significant)

Calculation of this comparison resulted in only one rotation being significantly correlated to post-task pain. Thus, as post-task elbow pain decreased, elbow flexion ROM increased when lifting the bottle. As with the previous comparison, there was a combination of both positive and negative correlations.

A final calculation was done that correlated $\sum$PTP with ROM at each joint region. No significant correlations were found between these two variables. This pain score (representative of the total amount of pain experienced in the upper limb) was also not significantly correlated to the functional ROM for any joint region during any task.

Pain & Disability Correlation

When the relationship of the pain scores with disability (as measured by the Health Assessment Questionnaire) was explored, it was found that the PCS was not significantly related to disability. However, the PTP was significantly related to disability at both the shoulder and elbow regions for selected tasks *(Table 23)*.

	Lift Bottle	Lift Can	Comb	Scapula	Sacrum
shoulder joint region	n.s.	p=0.016	p=0.048	n.s.	n.s.
elbow joint region	p=0.0034	p=0.0026	p=0.048	p=0.0034	p=0.018
wrist joint region	n.s.	n.s.	n.s.	n.s.	n.s.

Table 23. Summary of Correlation between Post-Task Pain Score (PTP) and HAQ Disability.

The PTP at the shoulder region after performance of two of the tasks and the PTP at the elbow region after each of the tasks were significantly positively related to perceived disability. That is, in the shoulder region the greater the PTP following the lift can task and comb hair task, the greater the perceived disability score. In addition, as PTP increased in the elbow region for all tasks, the perceived disability score was also shown to increase. At the wrist joint region, no significant relationships were found between PTP and perceived disability. Further, the ∑PTP scores were significantly related to perceived disability for four of the five representative functional tasks; the fifth task, touching the opposite scapula was positively correlated with an r value of +0.62 (p=0.053). *Figures 21a-21e* show the scatter plots of each of these correlations and the results are summarized in *Table 24*.

lift bottle	r=0.72, p=0.018*
lift can	r=0.82, p=0.0033*
comb hair	r=0.68, p=0.029*
touch opposite scapula	r=0.62, p=0.053
touch sacrum	r=0.65, p=0.042*

Table 24. Correlation between Sum of Post-Task Pain Score (ΣPTP) and HAQ Disability.
*significant at p<0.05

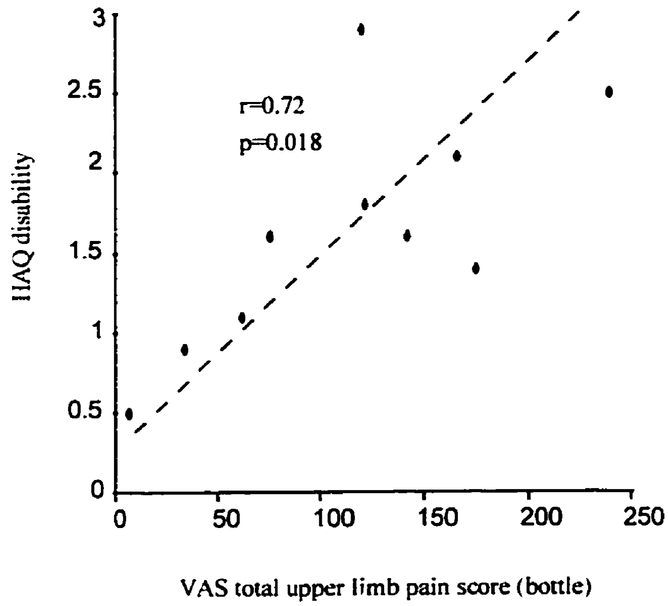


Figure 21a. Scatter Plot - sum of PTP (bottle) and HAQ disability

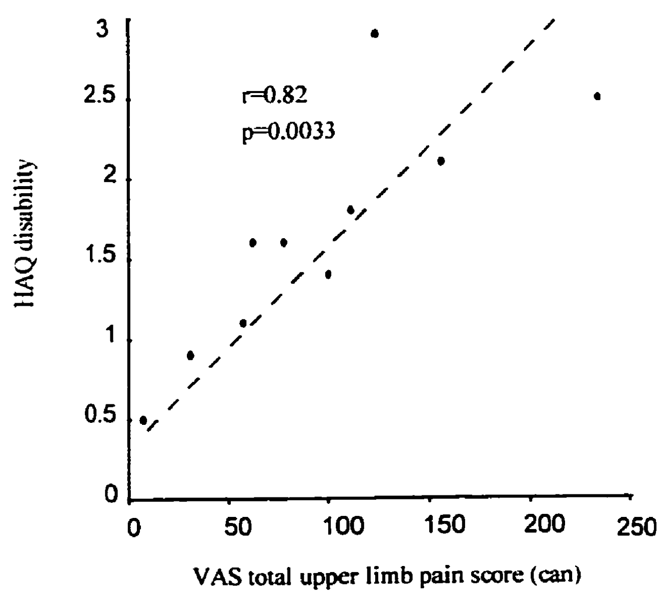


Figure 21b. Scatter Plot - sum of PTP (can) and HAQ disability

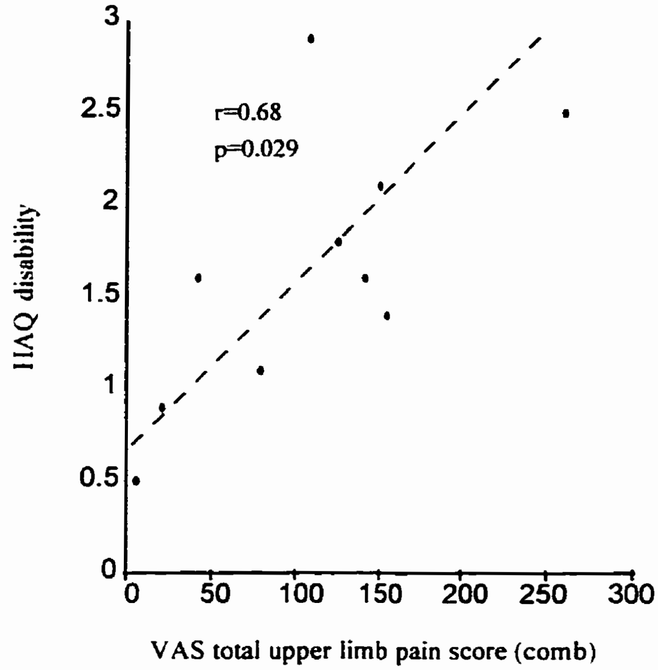


Figure 21c. Scatter Plot - sum of PTP(comb) and HAQ disability

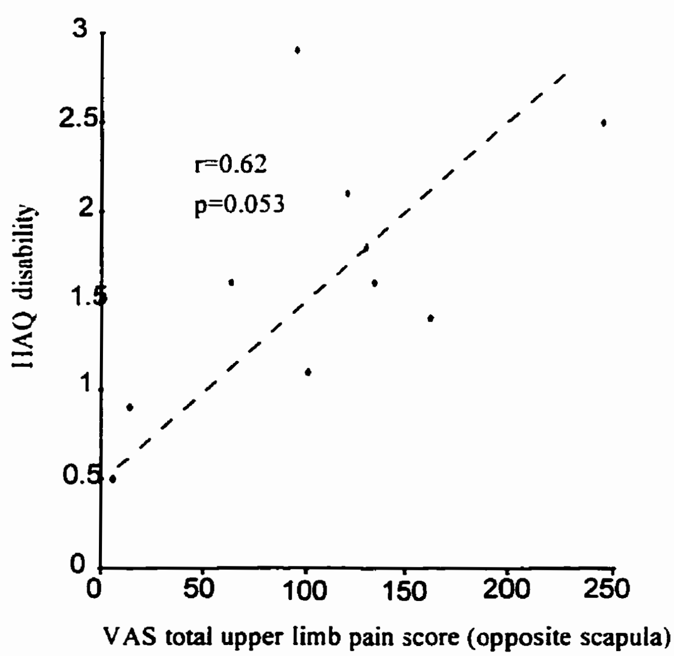


Figure 21d. Scatter Plot - sum of PTP(opposite scapula) and HAQ disability

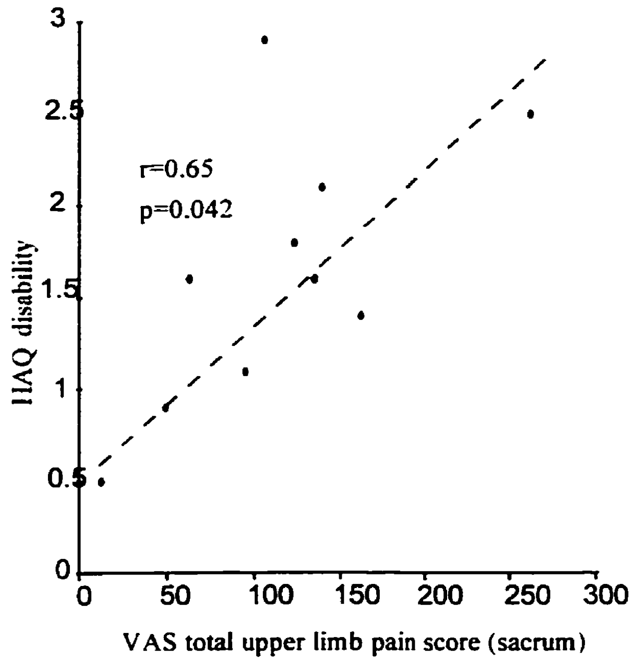


Figure 21e. Scatter Plot - sumof PTP(sacrum) and HAQ disability

ROM and Perceived Disability Correlation

Functional ROM was only significantly correlated to perceived disability in five of the thirty five comparisons (*Table 25)*. Furthermore, in 31 of 35 of the rotations, there was a negative correlation calculated. This indicated that as functional ROM increased, perceived disability tended to decrease.

	Lift Bottle	Lift Can	Comb	Scapula	Sacrum
shoulder fl/extension	p=0.016	n.s.	n.s.	n.s.	n.s.
shoulder ab/adduction	p=0.032	n.s.	n.s.	n.s.	n.s.
shoulder int/ext rotation	n.s.	n.s.	n.s.	n.s.	n.s.
elbow flexion	n.s.	n.s.	n.s.	n.s.	n.s.
forearm pron/supination	n.s.	n.s.	n.s.	n.s.	n.s.
wrist flex/extension	n.s.	p=0.012	n.s.	n.s.	n.s.
wrist uln/rad deviation	n.s.	n.s.	p=0.025	n.s.	n.s.

Table 25. Summary of Correlation between ROM and HAQ Disability. (n.s.= not significant)

The fifth hypothesis stated that *there will be a correlation between upper limb arc of motion (at each of the seven joint rotations), pain (at each of three regions of the upper limb) and perceived disability in the individuals with RA for each of the five tasks.* This hypothesis cannot be supported with the data obtained from correlating pain and ROM as none of the three pain scores derived were correlated to the functional ROM of a joint. Pain change score (PCS) was not significantly correlated to perceived disability, however post-task pain (PTP) in several regions was significantly correlated to perceived disability, as was the ∑PTP score. Thus the hypothesis that a correlation exists between pain and perceived disability was supported by the above results. However the hypothesis that there would be a correlation between upper limb arc of motion and perceived disability was not supported by the results of this study, although some significant correlations did exist in the lifting bottle task. Refer to *Appendix L* for specific hypotheses results.

4.2.9 HAQ and COPM Comparison

Results from the COPM (performance component) and the HAQ (disability component) are listed in *Table 26*. The Pearson product moment was calculated to be r=-0.34, showing no significant correlation (p=0.34) between the data obtained from the two tests. A scatter diagram of the data shows the relationship between the two measures (*Figure 22a)*. The negative correlation was expected, as lower scores on the COPM indicate difficulty in performing the task, while the higher scores on the HAQ indicate greater difficulty.

subject	COPM(P)	HAQ (disability)
1_ra	1.2	2.5
2_ra	1.4	2.9
3_ra	3.2	1.1
4_ra	5.6	0.9
5_ra	4.2	1.4
6_ra	4.8	1.6
7_ra	2.0	1.6
8_ra	6.4	2.1
9_ra	7.6	1.8
10_ra	4.4	1.9

Table 26. COPM Performance and HAQ Disability scores.

To examine the data further, the individual item scores on the COPM and of the HAQ

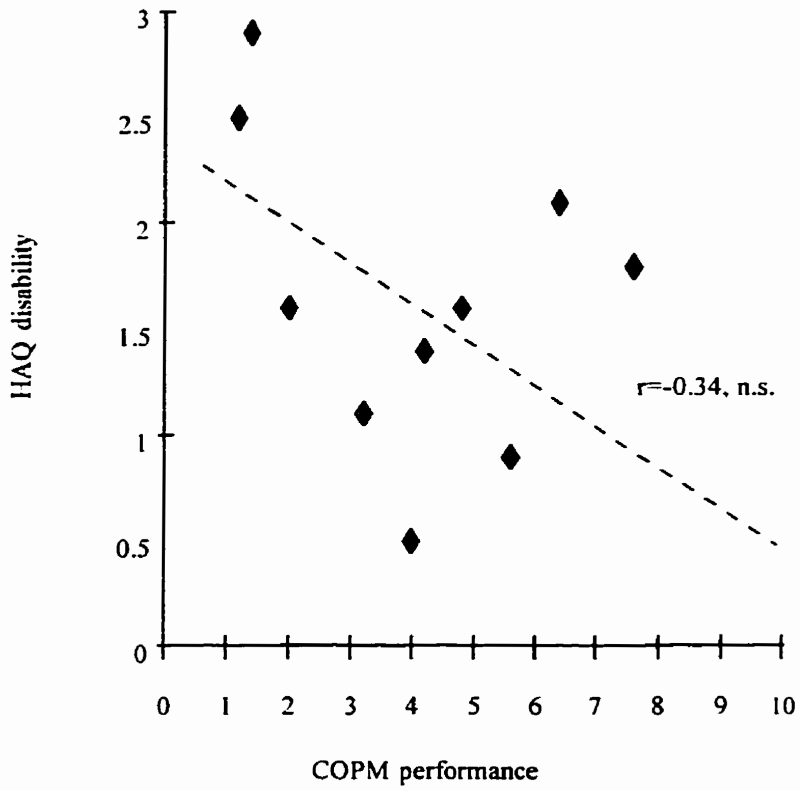


Figure 22a. Scatter Plot - COPM performance and HAQ disability

were compared. To make this comparison, the items identified as difficult by the subject on the COPM which had a corresponding component category on the HAQ were listed. Then the individual scores for the COPM items were compared to the component score on the HAQ. For example, if the subject had identified the task of *putting on socks* as important on the COPM and had rated her performance a 2, this score was compared to the score she had assigned the *dressing/grooming* component on the HAQ which was also a 2. Using this method of comparison, the Pearson product moment was determined as $r=-0.61$, $p=0.000063$ (*Figure 22b*) indicating that the lower the subject rated herself in specific areas on the COPM the higher was the disability rating in comparable performance categories on the HAQ.

Thus hypothesis six - *there will be a correlation between the Health Assessment Questionnaire score (disability index) and the (performance) score obtained from the Canadian Occupational Performance Measure* - was not supported by this study. However, when the analysis of COPM and HAQ data was modified to include comparison of individual performance scores on the COPM with the corresponding component scores on the HAQ, significant negative correlations were found.

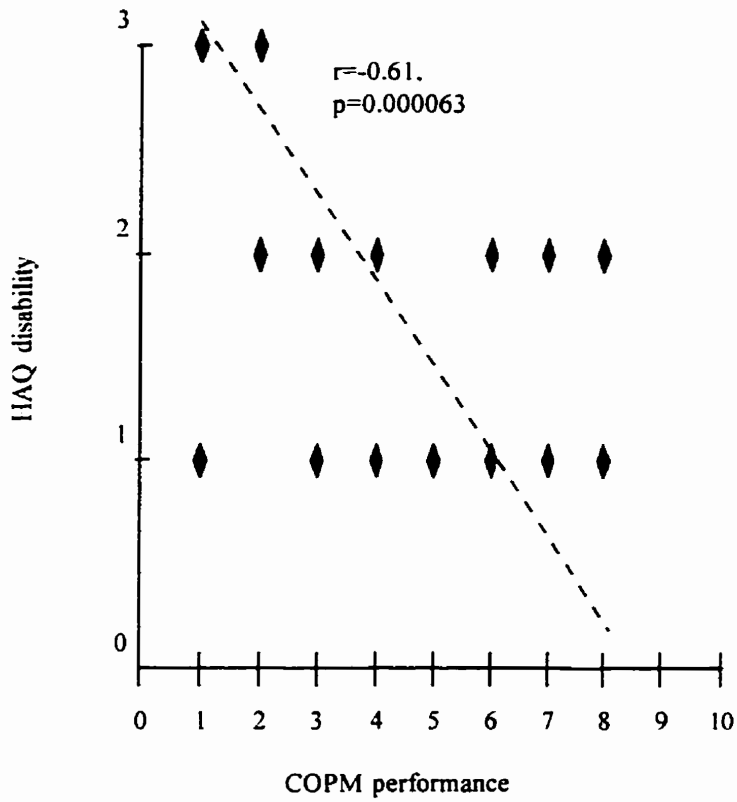


Figure 22b. Scatter Plot - Individual Items from COPM performance and HAQ disability scales

5.0 DISCUSSION

5.1 Subject Demographic Differences

Although not significant, differences between the control and RA groups were observed. Any difference in mean height and mass between the two groups may be explained in part by the overall group composition. The control group consisted of an equal number of males and females, while the RA group had eight female and only two male subjects. The average lower height and mass of females are represented in the lower mean values of the RA group. The higher number of females in the RA group was also representative of the prevalence of RA which is higher for females than males (Wilder, 1993). The overall upper limb activity level between the two groups varied. Eight out of ten of the control group subjects mentioned participating in some type of activity that involved the dominant upper limb; only one of the ten RA subjects stated that they actively used their dominant upper limb for any activity other than everyday living tasks. Some examples of the activities that the control group participated in were golf, gardening and squash; all subjects participated at a recreational level only. This may have led to less dominant upper limb muscle mass in the RA group than in the control group. However, all RA group members were participating in their own self care routines at home. The tasks analysed in this study were ones required for everyday living and did not represent any activity that would be out of the realm of requirements for everyday occupation. Therefore, the control group could not be presumed to have any advantage regarding specificity of training for the tasks performed in this study.

Another notable difference between the two groups related to their educational attainment and vocation. In the control group, all of the subjects were university educated professionals, while in the RA group only three of the subjects were trained in an area requiring post-secondary education; two of these three subjects were on, or applying for, disability benefits.

5.2 Discussion of Results

5.2.1 Task Comparison - Range of Motion, Minimum & Maximum Angles

Lifting Bottle and Can

These two tasks were strikingly similar in the ROM, minimum and maximum values used to complete them. The essential rotations required to accomplish these two tasks can be considered to be shoulder and elbow flexion - the rotations with the greatest ROM used to accomplish the task. This observation makes sense as the item to be lifted was placed on a shelf directly in front of the subject at shoulder height. The similarities observed in the ROM of the joints used to accomplish the tasks of lifting the bottle and can are understandable due to the similar requirements of the tasks; the subjects were required to lift an item from their thigh to a shelf at shoulder height for both tasks. Any differences noted between performance of the two tasks can be attributed to the differing mass and shape of the objects.

The primary difference in joint ROM required to complete these two tasks was in the amount of wrist extension used by the control subjects. As the mass of the bottle was approximately twice that of the can, the need to position the wrist in extension is expected.

Placing the wrist into extension while the fingers are in flexion allows the long flexor tendons of the hand to work to their mechanical advantage in producing a tenodesis grasp (Kapandji, 1982). The maximum grip strength obtained in wrist extension is greater than that obtained in wrist flexion (Pryce, 1980) and thus allows secure grasping of the heavier bottle.

Another possible explanation for the similarity between the ROM used to accomplish the tasks is that the two tasks were performed consecutively (although order was determined randomly). This was done to reduce the set up requirements while the subject was being videotaped. This may have resulted in the use of similar joint patterns as the subject was not required to re-position his or her body between performance of the two tasks.

Combing Hair

This task was one of two tasks that required full ROM in any one joint rotation; full elbow flexion was consistently used by the subjects and thus can be considered the principal rotation required to accomplish this task. More shoulder abduction was used to complete this task than any of the other tasks studied.

The standard deviations of shoulder abduction and elbow flexion angles were relatively low as a percentage of the overall ROM used. This is consistent with the need to move the hand up to some relatively similar point where it can initiate and complete combing. The variability seen in the shoulder internal rotation, forearm and wrist rotations may be attributed to learned differences in combing one's hair related to individual hair styles and lengths.

Touch Opposite Scapula

Although shoulder flexion was again the principal rotation required to accomplish this task, shoulder adduction also made a substantial contribution. The ROM of shoulder internal/external rotation and the distal rotations (forearm pronation/supination, wrist flexion/extension and wrist ulnar/radial deviation) were not significantly different than when combing the hair. However, the position (minimum and maximum angles used) within this total arc of motion was different for shoulder internal/external rotation and wrist flexion/extension. This was surprising as, on observation of these tasks, they appear quite different and it was expected that touching the opposite scapula would require significantly lower ROM than combing the hair. Thus the ROM requirements for this task were greater than was expected; this result is further discussed in section 5.2.2 with reference to differences between the control and RA groups.

Touch Sacrum

This task showed the least stereotyped pattern of movement of the five tasks studied. Touching the sacrum showed similarities to other tasks in specific individual joint rotations, but as it was the only task that required motion to occur posterior to the body (using substantial shoulder extension), thus the overall pattern was unique. This task was the second of the two tasks that required full range in any one rotation. To accomplish this task, full supination was required at the forearm, and thus could be considered the principal rotation.

5.2.2Group Comparison - Range of Motion, Minimum & Maximum Angles

High inter-subject variability (as evidenced by the standard deviations calculated) was observed in this study. This result is consistent with that of Packer et al. (1993) in their study of sit-to-stand motion. Although individual subjects may perform a task in a consistent manner (low intra-subject variability), differences exist between the way different individuals complete the task (high inter-subject variability). Generally, there was more inter-subject variability in distal joint rotations than in proximal rotations. For each task in this study, the rotations which occurred at the wrist were calculated to have a higher standard deviation as a percentage of the overall range used than those of the shoulder or elbow region. This intuitively makes sense, as the total degrees of freedom increase when progressing from proximal to distal joints in the upper limb. This increase in degrees of freedom results in a greater variety of possible forearm and wrist positions that could be used to position the hand in order to complete each task. Individually learned patterns of motion were more evident at the distal joints.

The principal rotations (rotations with the greatest ROM and thus accounting for the majority of the total motion) used to perform a task showed less inter-subject variability than the other rotations. This suggests that the principal rotations are more stereotyped in their performance. Motor patterns are perhaps more rigidly "set" for the principal rotations, and the majority of difference in performance of tasks between individuals occurs in the rotations that do not contribute as much to the overall movement. This allows the tasks to be completed in a similar manner between individuals, while still allowing for anthropometric differences and different patterns of movement to occur.

Of the three rotations examined at the shoulder, internal/external rotation was calculated to be the most variable (except for touching the sacrum, where internal rotation was one of the principal rotations used to complete the task). Shoulder flexion and abduction may have been used in order to move the upper limb toward the target or intended goal, while internal/external rotation was primarily used to position the hand.

The results obtained from the control group can be compared to previous studies of functional upper limb ROM. The only prior studies on functional shoulder motion that were found examined rotations during three feeding tasks (Safaee-Rad et al., 1990; Cooper et al., 1993). Feeding oneself takes place predominantly in front of the body, therefore the finding that shoulder flexion had a greater range than abduction or internal rotation during feeding is consistent with the results obtained from the three tasks performed in front of the body in this study (lifting bottle, lifting can and touching the opposite scapula). The 20° range of shoulder abduction reported by Safaee-Rad et al. (1990) and Cooper et al. (1993) was also consistent with the range used for these three tasks. Lifting the bottle or can and the feeding tasks used similar ranges of shoulder internal rotation.

The maximum elbow flexion of 148° used by the control group when combing hair was comparable to the maximum elbow flexion reported in previous studies of functional upper limb ROM (Chao et al, 1980; Morrey et al, 1981; Safaee-Rad et al., 1990; Packer et al., 1990, Cooper et al, 1993; Packer et al, 1993; Vasen et al., 1995). However, the minimum angle required to complete the tasks (44° when lifting the can) was greater than that reported in the studies by Chao et al. (1980), Morrey et al. (1981) or Packer et al. (1990). Both pronation and supination rotations were used by the majority of subjects to perform the tasks in this study. This finding is consistent with the results from the previous studies on elbow region motion. However, except for the pronation/supination required to touch the sacrum, the overall range was within previously reported limits.

The amount of wrist flexion/extension range was task dependent and therefore difficult to compare to previous studies. However, the range of flexion/extension used by the control group for any of the five tasks in this study approached the ranges in previous studies of a maximum reported 20° of wrist flexion by Brumfield et al. (1984) and 30° of wrist extension by Palmer et al. (1985). Four of the five tasks studied had a bimodal pattern of wrist flexion/extension. In these tasks, about half the subjects used a small range of wrist flexion/extension (10°), while the other half used a larger range (25°-35°). Examination of individual results did not show any consistent pattern in whether a smaller or larger range of motion was used by an individual subject. That is, a subject who used a larger ROM for one task may or may not have used a larger ROM for subsequent tasks. This observation has not been reported in any previous study. The lower ROM may have been an attempt to stabilize the hand by some subjects when performing a particular task.

Ulnar and radial deviation ranges used by the control group were also observed to be task dependent, and are comparable to the results of previous studies (Brumfield et al., 1984; Palmer et al., 1985; Safaee-Rad et al., 1990; Cooper et al., 1993). The one exception was the maximum ulnar deviation used to touch the sacrum; this range was higher than previously reported although was similar to the amount of ulnar deviation used by males in feeding tasks. The difference observed by Cooper et al. (1993) between males and females in the use of a predominantly radial or ulnar deviation pattern was not observed in this study.

There were few significant differences between the groups in ROM, minimum and maximum angles. Thus the results of this study contrast with the findings of Peat & Grahame (1977) who found that pathology reduced the ROM at the joint. These investigators had measured full ROM and not functional ROM (as was measured in the current study); this may partially account for this finding. In addition, Peat & Grahame (1977) used a heterogeneous sample of subjects, whereas the subjects in this study were similar with respect to their shoulder pathology.

Although seven (20%) of the rotations were significantly different, the majority showed no significant difference in each of the five tasks. Touching the scapula was the one task which was performed quite differently by the two groups. This task had required some of the highest joint rotation ROM by the control group. The inability to obtain these ROM values by the RA group was evidenced by the significant differences between the groups. Touching the opposite scapula was the only task in which shoulder adduction was required. The lower ranges of shoulder flexion and internal rotation may have been attempts by the RA group to stabilize the shoulder while reaching across the chest. If greater shoulder flexion and internal rotation were used, the rotator cuff muscles would have been required to play a greater role in mobilization; limiting the ability to produce stabilization.

Ten out of the 35 rotations (28%) could be considered clinically different (greater than a 10° difference between the two groups). Any differences noted in the lifting bottle task between the two groups can most likely be attributed to the fact that two of the RA subjects were unable to complete the task (i.e., unable to place the bottle on the shelf at shoulder height). Their results would reduce the RA group mean compared to the control group (who were all able to complete this task). The range of shoulder abduction and internal/external rotation used by the RA group when combing hair was considered clinically different from that of the control group. Again, the lower ranges of this group may be an attempt to maintain the shoulder joint in a range of stability. As the rotator cuff muscles play a substantial role in producing shoulder abduction and internal/external rotation, they are less able to participate in a stabilizing role and thus the overall stability of the shoulder joint is reduced during these tasks if the full rotation is used.

Touching the sacrum also resulted in several clinical differences. The RA group used less shoulder internal rotation, less forearm supination and less wrist deviation. Again, as the task required the shoulder to rotate into a significant amount of internal rotation, the RA subjects may have limited this motion due to pain and/or instability in the shoulder joint region. The difference observed in forearm supination is difficult to explain, as one of the exclusion criteria had been rheumatoid arthritis involvement in the elbow region. However, as most of the subjects reported at least minor elbow region pain after completing each of the tasks, there may have been some elbow involvement which had previously gone undetected or undiagnosed. The systemic nature of rheumatoid arthritis may have caused some disease activity in the elbow region of these subjects. Differences seen in the wrist region were ascribed to the lack of radial deviation range available for four of the RA subjects. The notable ulnar drift of the metacarpal joints of these subjects skewed the data towards movement in the ulnar deviation range.

Thus, these results showed that apart from some isolated instances, functional range of motion used by a group with RA of the shoulder was not significantly different from that of a control group. Nevertheless, the shoulder rotation ROM measured for the RA group was consistently less than that used by the control group. Full or available active ROM was not measured or compared in this study and it is suspected that more differences may have been observed between the two groups if this parameter had been measured. However, it can be argued that it is the functional and not the full active range of motion that is important for performance of daily living tasks. The ROM requirements of the tasks chosen for this study were found to be attainable by the RA subjects in most cases (exception was two subjects lifting the bottle). If this argument is correct, then rehabilitation programs designed to maintain full upper limb ROM may be unnecessary. As few significant differences were observed in the representative tasks of this study, it is the functional, and not the full active ROM that individuals with RA should strive to preserve. Although only five representative functional tasks were measured in this study, the rotations that comprise these tasks included components of most functional activities. The tasks performed required shoulder flexion, extension, abduction and adduction and both internal and external rotation. Substantial ROM of the elbow, forearm and wrist were also required for successful completion of these tasks. Increased focus on maintenance of functional ROM (specific to the tasks important and meaningful to the client) should be made in the therapeutic settings.

Compensation for loss of range by other upper limb joints appeared to occur in only one instance. This occurred when reaching to touch the opposite scapula; although lower shoulder rotations were used by the RA group than the control group, the RA group compensated by increasing the amount of elbow flexion used. This result (lack of compensation) was unexpected as it was thought that the other upper limb joints would act to compensate for any decrease in ROM at the shoulder (Cooper et al., 1993). However, few significant differences were actually observed in the functional shoulder ROM used between the two groups. Compensation by other joint regions was not required to make up for a lack of ROM at the shoulder in order to successfully complete these tasks. It must be noted that any other compensatory techniques used by the RA group were not measured in this study.

Compensation may have occurred by rotation or translation of the scapula, clavicle or vertebral column. The UM^2AS is not configured to measure these rotations or translations; thus actual determination of proximal joint compensation was not possible in this study.

5.2.3 Maximum Angular Velocity

Maximum angular velocity attained at each joint rotation was task related. The joint rotation that had the largest range while completing the task was also the one with the highest calculated maximum angular velocity (the time derivative of the change in displacement) for all five representative functional tasks. From this finding, it can be further hypothesized that the principal rotation of any task performed would also have the greatest maximum angular velocity.

The maximum elbow region angular velocities attained by the control group can be compared to those reported by Packer et al. (1994). The latter study examined elbow region (flexion/extension and pronation/supination) kinematics during the task of standing up from and sitting down in an armchair. The maximum elbow flexion velocity used by this control group was similar to those of Packer's control group for the tasks of lifting the bottle, lifting the can and combing hair. Lower maximum angular velocities of elbow flexion were used by this control group to touch the opposite scapula and to touch the sacrum. Only during combing the hair was the maximum angular velocity of forearm pronation/supination of this control group similar to the results obtained by Packer et al.(1994). The ROM used to complete the combing task (mean of 45°) was also similar to that required for going from sitting to standing and returning to sitting (approximately 50°). When lifting the bottle and can, lower maximum angular velocities for pronation/supination were attained than in the

Packer et al. study; however the functional ROM was also lower. Values exceeding those calculated by Packer et al. for forearm rotation were attained when touching the opposite scapula and sacrum; however the ROM used to complete the latter tasks was also greater than that used to stand and sit from an armchair.

Only seven of the 35 measured rotations (seven joint rotations for each of five tasks) were significantly different between the control and RA groups. If a similar length of time was used by each of the groups to complete the functional tasks, then a lower ROM would result in lower overall velocity. However, the maximum angular velocity obtained represented the maximum instantaneous velocity, and not the average velocity, used to complete this task. Except for one rotation (maximum angular velocity of elbow flexion when touching the opposite scapula), the maximum angular (or peak) velocities of the RA group were lower than those of the control group. This indicated that the RA group in general did not reach peak velocities equal to that of the control group, and in fact were significantly lower in specific rotations when touching the opposite scapula and touching the sacrum. This is consistent with the observation made by Packer et al. (1994) that subjects with RA of the elbow attained a lower maximum angular velocity of elbow flexion than a control group.

5.2.4 Maximum Angular Acceleration

Studies that report maximum angular acceleration during functional activities have been limited to ambulation and to sports related activities. In the lower limb, Winter (1990) calculated relative joint accelerations of nearly 100 radians/sec/sec in the ankle and knee during locomotion. At the hip, maximum reported accelerations were 38 radians/sec/sec. The values obtained in this study were of a much smaller magnitude, although a maximum mean value for the control group of 26.4 radians/sec/sec was calculated for forearm pronation/supination while touching the sacrum. Most of the maximum angular acceleration values attained by the control group were less than 10 radians/sec/sec for functional upper limb activities.

Except for the touching the opposite scapula task, the highest maximum angular acceleration values in each of the tasks were observed in the elbow region. These high acceleration values in the elbow region may be attributed to the anatomical or structural stability in the elbow region which may permit high acceleration with minimal joint damage. The bony stability of the humeroulnar joint (created by the interlocking of the trochlea of the humerus and trochlear notch of the ulna) and the ligamentous stability provided by the collateral ligaments of the elbow (Zuckerman & Matsen, 1989) allows significant force to be transmitted through this region without resultant dislocation or damage to the joint.

Maximum angular acceleration was the kinematic variable that showed the greatest number of differences between the two groups of the three variables examined in this study. Still, only nine of the 35 comparisons were calculated to be significantly different. As with maximum angular velocity, touching the opposite scapula and reaching for the sacrum were the tasks where the majority of the differences occurred. Specifically, the mean of the control group's maximum angular acceleration of shoulder internal rotation when touching the sacrum was eight times greater than that attained by the RA group, and forearm supination rotation acceleration was three times greater during the same task. Thus this parameter (maximum angular acceleration) was found to be more sensitive to differences between the two groups than ROM or maximum angular velocity. Although more differences existed in this parameter than the others, the hypotheses cannot be fully supported. The one exception to this statement may be the maximum angular acceleration during shoulder flexion/extension, as three of the five tasks showed significant differences ($p<0.05$). This finding will be further discussed in section 5.2.5, the relationship between maximum angular acceleration and pain.

5.2.5 Maximum Angular Acceleration and VAS Results

Pain in a joint region may result from a variety of sources including an increase in pressure in the joint capsule or tension in the ligaments (Salter, 1983). In this study, pain was specific to the individual and interpretation of pain was variable between subjects. This is not surprising considering the subjective experience of pain (Huskisson, 1982) and the variation in pain tolerance between persons with similar conditions. In the current study, the pain experienced in a joint region was compared to the initial pain that the individual had reported prior to performing the functional task. Several subjects had PTP scores that were less than the initial score even though they were allowed to see the score that they had initially marked. For example, subject 3 had negative wrist scores for four out of the five tasks. This may have been due to an actual decrease in the experience of pain (e.g. as the joint loosened up with activity), or due to interpretation of the pain compared with the other joints at that point in time instead of to the initial score.

No significant differences were calculated in the PCS, the PTP or the ΣPTP between tasks. This was unexpected as it was anticipated that movement which required the rotator cuff muscles to act as prime movers (touching sacrum and combing hair) would cause more pain than those movements requiring them to act in a stabilizing role.

It was also expected that lifting the bottle would cause significantly more pain than the other tasks, considering the added mass of the bottle and the compression forces that would be developed across the shoulder joint to confer sufficient stability in order to lift this object. This was not found to be the case in this study although two subjects were unable to complete the task.

Touching the sacrum required a significant portion of the overall range of shoulder internal rotation and caused more shoulder pain than the other tasks (although not significant). The rotator cuff muscles primarily responsible for the internal/external rotation most likely had undergone some pathological damage due to RA, limiting their ability to generate the forces required to perform this rotation. The additional ligamentous and bone-on-bone forces that are developed at the end of joint range may have also contributed to an increase in compression force across the joint and resultant pain.

The lack of significant difference in the PCS, PTP or ΣPTP between the tasks may have indicated a baseline level of pain experienced by the subjects. Although the pain may have increased after performing the tasks, it was not necessarily task related. Thus, overall pain in this group was more closely related to involvement in any upper limb activity rather than to participation in specific tasks. The RA subjects were unable to distinguish pain related to performance of a particular task as much greater or less than pain from another task. The initiation of movement and requirement to continue moving an already painful upper limb was relevant, not the actual tasks that were required of these subjects.

Both the mean and the median PCS scores were calculated for the RA group. It was found that the median PCS were up to 10 millimeters lower than the mean PCS. This may be attributed to the contribution of subject 7 to the mean scores. This subject had high PCS and PTP scores on four out of five of the tasks studied. Individual joint region PCS for this subject generally increased more than 30 millimeters at each joint region after performing the tasks. Very few of the other subjects had PCS greater than 30 millimeters at any one joint region during any of the tasks studied. Thus, the median scores may be a more accurate representation of the RA group's pain level after completing the tasks.

The hypothesis which guided this portion of the study was not supported when correlating maximum angular acceleration with PCS. A closer relationship was seen between maximum angular acceleration and the PTP score. Although only eight of the 35 rotations showed a significant negative correlation, 10 more rotations were calculated to have an r value greater than -0.50 (moderate agreement, Portney & Watkins, 1993). Further calculation showed that 11 of the 35 maximum angular acceleration values were negatively related to $\sum$PTP with 10 more calculated to be greater than r= -0.50. Again, this result shows that the more specific measurements (such as the PCS) do not have as strong a relationship to the variable of maximum angular acceleration as do the more global and pervasive PTP or $\sum$PTP scores. This result indicates that as overall upper limb pain (PTP or $\sum$PTP) increases, the maximum angular accelerations used decrease, particularly in the proximal upper limb joints.

This pain/acceleration relationship in the upper limb of individuals with RA has not been previously reported. In this study it was the maximum angular acceleration used, rather than functional ROM used, that was found to be the kinematic parameter most sensitive to the experience of pain. By lowering the maximum angular acceleration used, the muscle moment required is reduced. The muscle force can be calculated from the moment, and therefore would also be reduced. It can be speculated that reducing the bone-on-bone (compression) force will limit the experience of pain within a damaged joint. As discussed by Nordin & Frankel (1989), one of the two main factors that influence the magnitude of forces on a joint is the acceleration of a body part. High forces produced by a joint may result in increased damage to the joint. A protective mechanism may be used by individuals with RA in which they reduce acceleration in an attempt to reduce the bone-on-bone compression force, protecting the joint from further damage and destruction. The results obtained from this study warrant further investigation into this relationship and the meaning that it may have for rehabilitation.

5.2.6 Range of Motion, Pain and Perceived Disability

The results of this hypothesis are best discussed by recalling the framework of the disabling process (refer to *Figure 1)*. This framework implies that pathology leads to impairment, impairment to functional limitations and functional limitations to disability. The model does not predict that the process will necessarily be linear or unidirectional, and it also acknowledges that many other factors may intervene to accelerate or halt the process. In the current study the measurement of pain was considered to be at the impairment level, the measurement of functional ROM was viewed at the functional limitation level and the completion of the Health Assessment Questionnaire was considered a measurement of disability.

In this study, the lack of significant correlations coupled with the observation that nearly half the correlations were positive lead to the conclusion that functional ROM was not correlated to pain. This result is in contrast to the results obtained by Eberhardt & Fex (1995) who reported that pain was related to ROM. However, these investigators had measured an overall level of pain (not joint specific pain) and correlated the results with full active ROM (and not functional ROM) which had been classified into an ordinal rating scale. Thus, their study was less sensitive as it was not specific to each joint region and did not use the ratio measurement of ROM as was done in this study. The results also conflict with those of Lund, Donga, Widmer & Stohler (1991) who demonstrated that experimentally induced pain in the jaw closing muscles reduced the amplitude of the jaw opening. Again, this study measured total active ROM as opposed to functional ROM. For example, these investigators might have measured the ability to open the mouth wide enough to insert a soup spoon and related this measurement to the pain. Although previous results indicated that individuals would limit their ROM in the presence of pain, this was not the finding in this study, and it is speculated that perhaps pain has an influence only on the total active ROM which an individual can achieve.

Returning to the model of disablement, it predicts that a relationship should exist between pain and functional ROM (representing ability to perform specific daily living tasks). Therefore the results from the current study were unexpected and the conclusion can be made that pain experienced in the upper limb did not result in functional limitations as measured in this study by five representative functional tasks.

The present study results also contrast with those from a study by Jette, Mango, Medved, Nickerson, Waryzycha & Bourgeois (1997) which compared pulmonary impairments with a 6 minute walk distance test (functional limitation) in individuals with pulmonary disease. This group found that four pulmonary impairment measures were related to the functional limitation measure. The results also conflict with that of Badley and colleagues (1979, 1984, 1987) who found a relationship between pain and ability to perform specific tasks of daily living. The latter investigators did not use objective or standardized testing to document their findings.

When the results of *hypothesis 1* are recalled (no significant difference in functional ROM between the control and RA group in the majority of joint rotations) it can be stated that the RA group did not experience functional limitations as measured by functional ROM during the tasks studied. However, this result must be considered with caution as only five of an infinite number of possible tasks were studied, and the results were measured in a controlled, experimental setting. Internal factors (e.g., motivation to perform well and knowledge that the tasks were limited in the number of repetitions performed) and external factors (e.g., resting the upper limb in anticipation of testing) may have influenced and improved the results for the RA group. Thus, although there may be some relationship between the impairment and functional limitation factors chosen for this study, it appears that other intervening factors may have played a greater influence on the relationship.

These findings have interesting implications for rehabilitation. The results obtained in this study indicate that interventions with an individual can be performed within functional limits without an undue increase in pain. This suggests that if a marked increase in pain occurs while working with an individual within a functional range (not to the extremes of ROM) the individual is either in an acute stage of the disease and motion should be limited, or that the functional range of the client has been exceeded and an alternate method of accomplishing the task should be sought (e.g. providing the individual with assistive devices to allow completion of the task). Conversely, if the individual is limited in ability to perform specific functional tasks, pain is only one of many other possible internal or external factors which might be explored as contributing factors. These results must be used with caution as it is noted that in this study only 10 RA subjects were used, and the results of this study should not be generalized to a larger population.

A relationship between "functional limitation" (functional ROM used) and "disability" (HAQ) was not determined by this study. Although a negative correlation was calculated for 31/35 of the comparisons, only three of the 35 comparisons reached significance. In addition, four of the 35 correlations were found to have a positive relationship (i.e., as functional ROM decreased, functional limitations decreased). This finding does not support the hypothesis of a relationship between these two parameters and conflicts with the results of Jette et al. (1997) who found a significant relationship between their measurement of functional limitation and disability (the Functional Status Questionnaire).

The finding of the current study can be interpreted as the following: the amount of functional ROM used to perform a task had little or no effect on the individual's level of "disability". That is, the requirements for the functional tasks studied were within a range that small decreases in upper limb ROM used did not prevent the individual from performing these representative functional tasks. The subjects in this study (except for two subjects who were unable to complete the lifting bottle task) were able to complete the tasks asked of them. As the RA group did not experience any "functional limitation" in performing the representative functional tasks compared to the control group, again other intervening internal or external factors must influence the experience of disability. Liang & Jette's (1981) statement that decreased functional ability is related to more than decreased ROM at a particular joint is supported by this study.

This result also has implications for rehabilitation of individuals with RA of the glenohumeral joint. It would suggest that less time and effort be spent by therapists in ensuring that complete ROM can be produced and that more time be invested in determining the factors contributing to the individual's perception of disability. Other intervening factors should be addressed including adaptation of the environment to ensure the individual can participate in daily living tasks in a meaningful way.

The final comparison was between the impairment variable (pain) and the disability variable (HAQ). PCS was not related to the HAQ at any of the joint regions. This result indicated that instantaneous pain, or pain caused by performing an activity, did not affect the individual's overall (or day-to-day) ability to perform daily living tasks. The results of the present study support the findings of Jette et al. (1997) as these investigators failed to find a relationship between their measurements of impairment and the disability in individuals with pulmonary disease.

The absence of a relationship between instantaneous pain and overall disability can be explained in two ways. First, the level of disability (HAQ score) was taken prior to the initiation of any of the tasks used in this study. Therefore, the subjects had not yet experienced a change in their level of pain at any specific joint region when they completed the HAQ. Second, the increase in pain resulting from performance of one of the representative tasks was short-lived in comparison to the general, or overall, pain the subject may have experienced in his or her upper limb joints and most subjects would be aware that the short-lived pain from participating in the tasks would subside and that the usual level of pain experienced would continue. This baseline or overall level of pain might be expected to have a greater influence on perception of disability than the instantaneous change in level of pain, as was found in this study.

In fact, PTP (overall joint region pain) was found to be significantly correlated to the HAQ score at seven of the 15 joint regions (three joint regions times five tasks). The post-task pain experienced at the elbow region for all five tasks studied was found to be positively correlated to the HAQ with r values ranging from +0.64 to +0.84. The importance of the elbow in performing functional tasks has been emphasized by several authors (Figgie, Inglis, Mow & Figgie, 1989; Safaee-Rad et al., 1990) and has been reemphasised by the results of this study. As pain in the elbow increased, individuals were less likely to be able to perform their activities of daily living without difficulty. Other studies of the relationship between specific joint region pain and ability to perform activities of daily living could not be found, therefore this result cannot be compared to other findings. The observation that elbow region pain was so strongly related to disability was surprising. Overall, the subjects in this study experienced more pain in their shoulder region than in the other two regions studied, with elbow region pain being the least. However, it was the experience of elbow region pain after completing the tasks that was more closely related to disability for these subjects than the more involved shoulder or wrist joints. The relationship between PTP experienced in the shoulder region and HAQ score was significant for two of the five tasks, however four of the five tasks had calculated r values equal to or greater than +0.56, considered to be a moderate degree of correlation by Portney & Watkins (1993). Thus the PTP experienced at the shoulder cannot be discounted as a factor contributing to an individual's perception of disability.

The final pain-disability comparison was made using the $\sum$PTP (or the total of the three joint regions post-task pain scores). This pain score was found to be positively correlated to the HAQ scores with r values ranging from +0.62 to +0.82. These high correlations indicate that there is a strong relationship between the overall pain experienced in the upper limb and the ability to perform activities of daily living. The findings regarding the relationship between overall level of upper limb pain and disability concur with the results obtained by Eberhardt & Fex (1995) and by Affleck et al. (1991) that showed overall pain to be positively correlated with HAQ scores. Obviously then, the overall experience of upper limb pain had a stronger relationship with ability to perform activities of daily living than did either instantaneous changes in pain or pain in a specific joint region (except for the elbow region).

This result points to the need for overall management of pain in the individual with upper limb RA. Individuals who reported higher levels of overall pain in the upper limb also reported increasing levels of disability or difficulty in performing daily tasks. If the day-to-day experience of upper limb pain can be managed in these individuals, it would be expected that their ability to perform tasks without difficulty would also improve. The management of pain can be considered an important, but not exclusive, factor to attend to in the medical and rehabilitative treatment of these individuals.

5.2.7 HAQ and COPM Comparison

As stated previously, no correlation was found between the COPM performance scores and the HAQ disability dimension scores. This unexpected result may be due to differences in the items that the individual had identified as important. In the COPM, the individual subjectively chooses the five most important activities of daily living to rate. Conversely, in the HAQ, there is a list of predetermined tasks on which the subject must rate his or her performance. The list provided in the HAQ may or may not be tasks that the individual deems important. This list includes tasks mainly related to the ADL or instrumental ADL of an individual with little reference to performance of tasks related to productivity or leisure. The list of tasks that the individual identifies as important in the COPM is also value-laden in that the subject has spent some time analysing and discussing the importance of, performance of and satisfaction with a particular activity.

The adjusted comparison (HAQ with selected similar items identified on the COPM) was more fitting with the expected result of a strong correlation between the two tests. By using this method of analysis, items identified on the COPM that related to tasks other than those identified on the HAQ were disregarded. However, it is important to note that 37 out of 49 (75%) of the items identified by subjects spontaneously on the COPM fit into the established categories of the HAQ. This indicates that the majority of difficulties experienced by individuals are covered by the HAQ. However, the correlation between the two tests is still not as high as might be expected. One possible reason for this discrepancy may be due to the method of scoring the component items on the HAQ. For example, if the subject indicates that she can put on her socks with *no difficulty* (score 0) but indicates that she uses a sock aid to assist her to complete this task, the score is automatically dropped down to *with some difficulty* (score 2). When completing the COPM, the subject may have indicated that putting on her socks was performed with *no difficulty* (score 10), in this instance the fact that she is using a sock aid does not affect performance score. Thus, it appears that she is having some difficulty on the task according to the HAQ and no difficulty with the same task as indicated by the COPM. A conceptual difference may exist in the scales used to measure performance between these two instruments. While the HAQ requires the subjects to rate his or her level of difficulty in performing a given task, performance on the COPM is rated on a scale ranging from "unable to do" to "able to do". The level of difficulty may or may not be considered by the individual when rating performance on the COPM. If the task is completed (by any means, including external assistance), then the subject may indicate that he or she is "able to do".

5.3 Future Recommendations & Study

Several areas of future investigation are suggested by this study. The functional ROM, velocity and angular acceleration data of normal individuals during performance of functional tasks have been collected and can be utilized as a standard for comparison with individuals with pathology other than RA of the glenohumeral joint. The length of time that individuals with joint impairment took to complete the representative functional tasks could also be investigated and compared to the time taken by the control group. Further description of each of the tasks could be made, with definition of the specific phases and of the simultaneous joint rotations. For both the control and the RA groups, only the maximum angular velocity and acceleration data were used in analysis, however the continuous data are available for both parameters and the averages of these parameters could be used in a descriptive analysis of the movement.

The relationship between impairment, functional limitation and disability, although explored, requires further definition using variables other than the ones used in this study. Pain and its relationship with perception of disability might be further explored in a qualitative study. In addition, identification of other factors which influence the experience of disability in this population would improve the treatment and rehabilitation of others with rheumatoid arthritis.

Data was collected on the overall level of pain that an individual had experienced over the past week by the HAQ. This data could be compared to a variety of other measures examined in the current study such as $\sum$PTP or COPM Performance.

Data was also collected on the relationship between a widely used and standardized measure of disability (HAQ) and a relatively new measure which is still undergoing testing (COPM). Further work should be done comparing the two measures for use with this population.

6.0 SUMMARY

Typical patterns of motion used to accomplish each of five functional tasks have been described; individual exceptions from the patterns have also been indicated. Rotations at the shoulder and elbow joints were generally seen to be more consistent between subjects than those occurring at the more distal joints. Forearm rotation, wrist flexion/extension and wrist radial/ulnar deviation showed that more individualized patterns of motion were used to accomplish the same task. The tasks performed in front of the body (lifting bottle, lifting can, touch to the opposite scapula) used shoulder flexion as the principal rotation. The task performed lateral to the body (combing hair) used elbow flexion as its principal contributor to total motion. The task completed behind the body used forearm supination as the principal rotation.

Comparisons were made between the two groups on three kinematic parameters (functional ROM used, maximum angular velocity and maximum angular acceleration). Although individual differences were observed, in general it was concluded that overall differences did not exist between the two groups on these three kinematic parameters. The pattern of movement as described by the range of motion, angular velocity and angular acceleration was similar, although not identical between the two groups. Overall, the ROM, velocity and acceleration values attained by the RA group were lower than those of the control group. This difference reached statistical and/or clinical significance in only a minority of the comparisons.

The sum of post-task pain in the upper limb has been found to be positively correlated to disability, emphasizing the importance of ensuring adequate pain control in the RA population. A non-significant relationship between upper limb pain and functional ROM, and between functional ROM and disability indicated that other internal and external intervening factors must be considered in this population. Thus, from the results of this study, the view proposed by several groups of investigators (Hagglund et al., 1989; Affleck et al., 1991; Hawley & Wolfe, 1991; van Lankveld et al., 1993) that pain and inability to perform daily living tasks are two of the most important consequences of RA can be supported.

The relationship between the two disability measures, the Health Assessment Questionnaire and the Canadian Occupational Performance Measure, showed that the tasks included in the HAQ were, for the most part, similar to the tasks identified as important by the same subjects on the COPM.

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APPENDIX A

APPENDIX A

UNIVERSITY OF MANITOBA
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

AND

FACULTY OF MEDICINE
DIVISION OF OCCUPATIONAL THERAPY
DEPARTMENT OF INTERNAL MEDICINE

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF THE STUDY: **The relationship between functional upper limb kinematics, pain and perceived disability in individuals with rheumatoid arthritis.**

Motion at the shoulder joint required to perform certain independent living tasks may be affected by rheumatoid arthritis. However, the relationship between upper limb range of motion, pain and satisfaction with task performance is unclear. Therefore, the purpose of this study is to measure functional motion of the upper limb in individuals with rheumatoid arthritis of the shoulder and to determine if a relationship to joint region pain and satisfaction with task performance exists.

Your physician has given written permission for you to participate in this study. There will be one testing session conducted in the Biomedical Engineering Laboratory in the Faculty of Engineering at the Fort Garry Campus of the University of Manitoba, lasting up to an hour and a half. The University of Manitoba Motion Analysis System (UM^2AS) will be used to record the motion of your upper limb on videotape while you perform the following tasks: reaching to touch the small of the back, combing hair, lifting and placing two objects of different weights (up to a maximum of 1 kg) on a shelf at shoulder level, and touching the back of the opposite shoulder. You will be required to perform each task five times; there will be a three minute rest period between tasks to minimize the possibility of muscle fatigue. For recording purposes you will be required to wear a dark turtleneck pullover or shirt provided by the researchers and reflective markers will be attached with double sided adhesive tape to specific points on your upper limb. Data from the videotape will be extracted and stored in a microcomputer for analysis. Height, weight and upper limb segment lengths will be recorded for the biomechanical analysis. Your pain level in the upper limb will be measured before and after the testing session; your perceived level of disability will be surveyed with the Canadian Occupational Performance Measure and the Health Assessment Questionnaire. Photographs may also be taken for use in research papers, lectures and presentations; all identifying features will be removed from any photograph used. All data produced by this study will be identified by a code to protect anonymity. The key to connect the code to the name will be kept in a separate location from the data files. Videotapes will be secured in the Biomedical Engineering Laboratory and accessed only by individuals directly involved in this study. They will be erased within three years of completion of the study.

The procedures have been fully explained to me and I understand that I might experience minimal soreness of shoulder muscles for up to two to three days after the testing session. My participation in this research project is voluntary and I have the right to withdraw from the testing procedure whenever I wish, without prejudice. I understand that I will receive no payment for participating in this project and that there are no benefits to me for taking part in the study. I have the right to ask and have answers to any questions about my participation in this project by calling Jacquie Ripat at 269-0478, Dr. J. Cooper at 789-3413, Dr. E. Shwedyk at 474-9651 or Dr. H. El-Gabalawy at 787-2209 during Monday to Friday, 8:00 AM to 5:00 PM.

I authorize Drs. J. Cooper, E. Shwedyk, H. El-Gabalawy or Ms. J. Ripat to use the results of this research provided that my name or any identifying features are not associated with the findings in any way.

I have read and understood the contents of this form and have been given a copy of it. I hereby consent to act as a subject in a research project to be conducted in the Biomedical Engineering Laboratory of the Faculty of Engineering by Jacquie Ripat (graduate student) under the direction of Drs. J. Cooper, E. Shwedyk and H. El-Gabalawy.

Participant	Date	Witness	Date
Investigator	Date		

31/5/95/consent.frm

APPENDIX B

UNIVERSITY OF MANITOBA

FACULTY COMMITTEE ON THE USE OF HUMAN SUBJECTS IN RESEARCH

NAME: Ms. J. Ripat, BMR (OT)

REFERENCE: E96:281
DATE: 10 April 1997

YOUR PROJECT ENTITLED:

Protocol Title: **The Relationship of Functional Upper Limb Kinematics, Pain and Perceived Disability in Individuals with Rheumatoid Arthritis**

HAS BEEN APPROVED BY THE COMMITTEE AT THEIR MEETING OF:

Approved by Dr. Grahame on behalf of the Committee on March 11, 1997.

COMMITTEE PROVISOS OR LIMITATIONS:

Approved as per your letters dated October 21, 1996 and February 4 and February 21, 1997.

You may be asked at intervals for a status report. Any significant changes of the protocol should be reported to the Chairman for the Committee's consideration, in advance of implementation of such changes.

****THIS IS FOR THE ETHICS OF HUMAN USE ONLY. FOR THE LOGISTICS OF PERFORMING THE STUDY, APPROVAL SHOULD BE SOUGHT FROM THE RELEVANT INSTITUTION, IF REQUIRED.**

Sincerely yours,

Gordon R. Grahame, M.D.,
Chairman,
Faculty Committee on the Use of
Human Subjects in Research

GRG/tk

Telephone Inquiries should be directed to Theresa Kennedy
Telephone: 789-3255 or
E-mail: kennedy@bldghsc.lan1.umanitoba.ca

APPENDIX C

VISUAL ANALOG PAIN SCALE

subject____________
date____________

APPENDIX C

SHOULDER

PRE-TEST

***Joint sequence*_______**

pain as bad as it could be |--| no pain

POST-TEST

***Task*_______________**
***Joint sequence*_______**

pain as bad as it could be |--| no pain

***Task*_______________**
***Joint sequence*_______**

pain as bad as it could be |--| no pain

***Task*_______________**
***Joint sequence*_______**

pain as bad as it could be |--| no pain

***Task*_______________**
***Joint sequence*_______**

pain as bad as it could be |--| no pain

***Task*_______________**
***Joint sequence*_______**

pain as bad as it could be |--| no pain

VISUAL ANALOG PAIN SCALE

subject____________
date____________

ELBOW

PRE-TEST

Joint sequence________

pain as bad as it could be |————————————————| no pain

POST-TEST

Task________________
Joint sequence________

pain as bad as it could be |————————————————| no pain

Task________________
Joint sequence________

pain as bad as it could be |————————————————| no pain

Task________________
Joint sequence________

pain as bad as it could be |————————————————| no pain

Task________________
Joint sequence________

pain as bad as it could be |————————————————| no pain

Task________________
Joint sequence________

pain as bad as it could be |————————————————| no pain

VISUAL ANALOG PAIN SCALE

subject______________
date______________

WRIST

PRE-TEST

*Joint sequence*________

pain as bad as it could be |--| no pain

POST-TEST

*Task*________________
*Joint sequence*________

pain as bad as it could be |--| no pain

*Task*________________
*Joint sequence*________

pain as bad as it could be |--| no pain

*Task*________________
*Joint sequence*________

pain as bad as it could be |--| no pain

*Task*________________
*Joint sequence*________

pain as bad as it could be |--| no pain

*Task*________________
*Joint sequence*________

pain as bad as it Could be |--| no pain

APPENDIX D

Appendix D

The Health Assessment Questionnaire

In this section we are interested in learning how your illness affects your function in daily life.

•Please check the one response which best describes your usual abilities OVER THE PAST WEEK

	without any difficulty	with some difficulty	with much difficulty	unable to do
DRESSING AND GROOMING *are you able to:*				
dress yourself, including tying shoelaces and doing up buttons?	------------	------------	------------	------------
shampoo your hair?	------------	------------	------------	------------
ARISING *are you able to:*				
stand up from an armless straight chair?	------------	------------	------------	------------
get in and out of bed?	------------	------------	------------	------------
EATING *are you able to:*				
cut your meat?	------------	------------	------------	------------
lift a full cup of water to your mouth?	------------	------------	------------	------------
WALKING *are you able to:*				
walk outdoors on flat ground?	------------	------------	------------	------------
climb up five steps?	------------	------------	------------	------------

• Please check any AIDS or DEVICES that you usually use for any of these activities:

_______cane
_______walker
_______crutches
_______wheelchair
_______devices used for dressing (button hook, zipper pull, long handled shoe horn, etc.)
_______built up or special utensils
_______special or built up chair
_______other (specify:_________________________)

• Please check any categories for which you usually need HELP FROM ANOTHER PERSON:

_______dressing and grooming
_______arising
_______eating
_______walking

	without any difficulty	with some difficulty	with much difficulty	unable to do
HYGIENE *are you able to:*				
wash and dry your entire body?	-----------	-----------	-----------	-----------
take a tub bath?	-----------	-----------	-----------	-----------
get on and off the toilet?	-----------	-----------	-----------	-----------
REACH *are you able to:*				
reach and get down a five pound object (such as a bag of sugar) from just above your head?	-----------	-----------	-----------	-----------
bend down and pick up clothing from the floor?	-----------	-----------	-----------	-----------
GRIP *are you able to:*				
open car doors?	-----------	-----------	-----------	-----------
open jars which have been previously opened?	-----------	-----------	-----------	-----------
turn faucets on and off?	-----------	-----------	-----------	-----------
ACTIVITIES *are you able to:*				
run errands and shop?	-----------	-----------	-----------	-----------
get in an out of a car?	-----------	-----------	-----------	-----------
do chores such as vacuuming or yard work?	-----------	-----------	-----------	-----------

• Please check any AIDS or DEVICES that you usually use for any of these activities:

______raised toilet seat
______bathtub seat
______jar opener (for jars previously opened)
______bathtub bar
______long handled appliances for reach
______long handled appliances in bathroom
______other (specify:________________________)

• Please check any categories for which you usually need HELP FROM ANOTHER PERSON:

______hygiene
______reach
______gripping and opening things
______errands and chores

We are also interested in learning whether or not you are affected by pain because of your illness.

• How much pain have you had because of your illness IN THE PAST WEEK?

NO PAIN — PLACE A MARK ON THE LINE TO INDICATE THE SEVERITY OF THE PAIN — VERY SEVERE PAIN

|____|

0 — 100

Subject Comments:

name: ____________________

date: ____________________

subject number: ____________________

APPENDIX E

Appendix E

CANADIAN OCCUPATIONAL PERFORMANCE MEASURE

SECOND EDITION

Authors:
Mary Law, Sue Baptiste, Anne Carswell,
Mary Ann McColl, Helene Polatajko, Nancy Pollock

The Canadian Occupational Performance Measure (COPM) is an individualized measure designed for use by occupational therapists to detect self-perceived change in occupational performance problems over time.

Client Name:		
Age:	Gender:	ID#:
Respondent (if not client:)		
Date of Assessment:	Planned Date of Reassessment:	Date of Reassessment:

Therapist:
Facility/Agency:
Program:

Published by CAOT Publications ACE

STEP 1: IDENTIFICATION OF OCCUPATIONAL PERFORMANCE ISSUES	STEP 2: RATING IMPORTANCE
To identify occupational performance problems, concerns and issues, interview the client, asking about daily activities in self-care, productivity and leisure. Ask clients to identify daily activities which they want to do, need to do or are expected to do by encouraging them to think about a typical day. Then ask the client to identify which of these activities are difficult for them to do now to their satisfaction. Record these activity problems in Steps 1A, 1B, or 1C.	Using the scoring card provided, ask the client to rate, on a scale of 1 to 10, the importance of each activity. Place the ratings in the corresponding boxes in Steps 1A, 1B, or 1C.

STEP 1A: Self-Care

		IMPORTANCE
Personal Care (e.g., dressing, bathing, feeding, hygiene)		
Functional Mobility (e.g., transfers, indoor, outdoor)		
Community Management (e.g., transportation, shopping, finances)		

1B: Productivity

		IMPORTANCE
Paid/Unpaid Work (e.g., finding/keeping a job, volunteering)		
Household Management (e.g., cleaning, laundry, cooking)		
Play/School (e.g., play skills, homework)		

1C: Leisure

		IMPORTANCE
Quiet Recreation (e.g., hobbies, crafts, reading)	______	[ ]
	______	[ ]
	______	[ ]
Active Recreation (e.g., sports, outings, travel)	______	[ ]
	______	[ ]
	______	[ ]
Socialization (e.g., visiting, phone calls, parties, correspondence)	______	[ ]
	______	[ ]
	______	[ ]

STEPS 3 & 4: SCORING - INITIAL ASSESSMENT and REASSESSMENT

Confirm with the client the 5 most important problems and record them below. Using the scoring cards, ask the client to rate each problem on performance and satisfaction, then calculate the total scores. Total scores are calculated by adding together the performance or satisfaction scores for all problems and dividing by the number of problems. At reassessment, the client scores each problem again for performance and satisfaction. Calculate the new scores and the change score.

Initial Assessment:			**Reassessment:**	
OCCUPATIONAL PERFORMANCE PROBLEMS:	PERFORMANCE 1	SATISFACTION 1	PERFORMANCE 2	SATISFACTION 2
1. ______	[ ]	[ ]	[ ]	[ ]
2. ______	[ ]	[ ]	[ ]	[ ]
3. ______	[ ]	[ ]	[ ]	[ ]
4. ______	[ ]	[ ]	[ ]	[ ]
5. ______	[ ]	[ ]	[ ]	[ ]
SCORING:	PERFORMANCE SCORE 1	SATISFACTION SCORE 1	PERFORMANCE SCORE 2	SATISFACTION SCORE 2
Total Score = Total performance or satisfaction scores / # of problems	/ = [ ]	/ = [ ]	/ = [ ]	/ = [ ]

CHANGE IN PERFORMANCE = Performance Score 2 [ ] - Performance Score 1 [ ] = [ ]

CHANGE IN SATISFACTION = Satisfaction Score 2 [ ] - Satisfaction Score 1 [ ] = [ ]

ADDITIONAL NOTES AND BACKGROUND INFORMATION:

Initial Assessment:

Reassessment:

APPENDIX F

APPENDIX F

subject #________

DATA COLLECTION SHEET
RHEUMATOID ARTHRITIS OF THE SHOULDER
UPPER LIMB KINEMATICS/PAIN/PERCEIVED DISABILITY STUDY

Date:______________________________

SUBJECT DATA

Group:
- normal______
- RA________ years since diagnosis___________

Name:______________________________

Phone Number:________________________

Date of Birth:_________________________

Medications:____

____

____

ANTHROPOMETRIC DATA

Mass (kg):__________________________

Height (cm):__________________________

Limb Segments (cm):
- lateral border of acromion to lateral epicondyle:___________________
- lateral epicondyle to radial styloid process:______________________
- midway between radial and ulnar styloids to head of 3rd MCP:_________
- posterior axillary fold to the floor:______________________________

Hand Dominance:____________

Other Upper Limb Activities:____

____

____

____

____

____

____

APPENDIX F

subject #________

DATA COLLECTION

Order of Presentation of Tasks:

1)____________________________ digitize every ___ frames

2)____________________________ digitize every ___ frames

3)____________________________ digitize every ___ frames

4)____________________________ digitize every ___ frames

5)____________________________ digitize every ___ frames

COPM Score:

*performance*________________ *satisfaction*___________________

HAQ Score:

disability index ________________

APPENDIX F

subject #________

VAS Pain Scale Score:

JOINT:	***task***				
pre-test					
post-test					
Δpain					

JOINT:	**task**				
pre-test					
post-test					
Δpain					

JOINT:	***task***				
pre-test					
post-test					
Δpain					

Comments:____

____

____

____

____

File name______________

Disk______________

subjects\data.wpd-dec96

APPENDIX G

Experimental Protocol

1. Greet subject and familiarize them with the experimental set up and procedure as outlined in the protocol provided.

2. Provide subject with an informed consent form to read and answer any questions pertaining to it. Ask the subject to sign the form. (The experiment cannot proceed further without a signed consent form.)

3. Confirm the subject number and record on the subject data collection sheet. Complete other pertinent information on the data sheet.

4. Measure the subjects weight and record on the data collection sheet. Before weighing the subject, the scale should be realigned to zero. Ask the subject to remove their shoes and tell them to:

   "Stand still with your feet inside the footprints on the scale"

   The subject should be allowed to stand for 5 seconds, after which the experiment administer should make a reading. The scale needle must maintain a stationary position for a minimum of 3 seconds for an accurate reading. This measurement should be recorded in kg on the data collection sheet.

5. Measure the subjects height and record on the data collection sheet. Have them stand against the wall and mark their height. Use the measuring tape to measure the height of the mark from the ground. Record the measurement in cm on the data collection sheet. The subject can now put their shoes back on.

6. Measure the length of their limb segments on their dominant arm. Use the measuring tape and measure from the lateral border of the acromion process to the lateral epicondyle. Record this measurement in cm. Measure from the lateral epicondyle to the radial styloid process. Record this measurement in cm. Measure from midway between the radial and the ulnar styloid processes to the head of the 3rd MCP. Record this measurement in cm. Measure from the posterior axillary fold to the floor. Record this measurement in cm.

7. Seat the subject comfortably at a table with a large working space. Administer the COPM as outlined in the protocol. Ensure that the subject information on the COPM is completed.

8. Administer the HAQ as outlined in the protocol. Ensure that the subject information on the HAQ is completed.

9. Have the subject mark the VAS pre-test as outlined in the VAS protocol. Ensure that the subject information on the VAS is completed.

10. Choose an appropriate sized turtleneck sweater (sizes small, medium and large available). Ask the subject to remove the shirt they are wearing and put on the turtleneck sweater.

11. Attach double sided adhesive tape to the back of the cloth section of each marker Attach the markers as described below.
    i. Markers 1 & 2: Attach the pair of markers attached by a straw segment 2.5 cm distal to the midline of the lateral border of the acromion process, through the opening in the sweater.
    ii. Marker 3: Attach the elbow marker directly over the later epicondyle through the sweater opening.
    iii. Markers 4 & 5: Secure wrist band around wrist, fastening with Velcro, so that the marker rod lies parallel and in midline immediately above the radiocarpal joint. The marker on the shorter rod is directed to the radial side (marker 4) and the marker on the longer rod is directed towards the ulnar side of the wrist (marker 5).
    iv. Marker 6: Attach the metacarpal marker to the dorsal surface of the dominant hand, longitudinally along the third metacarpal directly over the metacarpal head and proximally.

    Use long strips of black hockey tape to tape down the cloth on the markers, to close any open holes in the sweater and around the markers and to secure the sweater so that it is not bunching around the markers.

12. Position the subject on the stool and adjust height for maximum visibility from all three cameras. The markers should be centred on the monitor for each camera and all markers should be visible when the subject places their hand on their head, sacrum or reaches out to the stand. Place a support under the subject's feet, if necessary, to fix hip, knee and ankle joints at 90 degrees, as outlined in the task completion protocol.

13. Consult the task sequence table and the task completion protocol o confirm order for each specific subject. The "Instructions to Subject" should be read verbatim (exactly as printed) with demonstration as indicated.

14. Read the "Instructions to Subject" for the first task and confirm that they understand what they should do (i.e. ask "Do you understand what you are to do?") If they are unsure, ask them to demonstrate and confirm whether they are performing the task appropriately.

15. Position the subject in the neutral position , confirming the following joint positions:
    glenohumeral joint in neutral
    elbow joint flexed to 90 degrees
    radioulnar joint in neutral
    radiocarpal joint in neutral

16. Place the subject numbers on the identification block, and have the subject hold it on their lap, or elsewhere, so it is fully visible to all camera. Ensure that the cameras, lights, monitors and VCRs are operational and turned "on", and commence recording with all three VCRs. Remove the subject identification block and immediately activate the synchronization flash in full view of all cameras and continue recording for ten (10) seconds, using stopwatch/timer as a guide.

17. Have the subject assume the starting position as outline in the Task Completion Protocol, confirming visibility of all markers. Begin VCR recording and reactivate the synchronization flash. Instruct the subject to begin task. Count out loud at the end of each trial and ask subject to stop only after the fifth trial is complete.

18. Stop the VCR recording and present the VAS posttest score sheets in the order outlined in the VAS sequence. Have the subject mark the VAS score for each region. Ensure that the subject's identification, correct task and joint region is recorded on each VAS collection sheet. Instruct the subject to rest for three (3) minutes. Set the timer/stopwatch for three minutes.

19. During the three minute rest break, review the next task with the subject and confirm that they understand what they should do, as described in step 14, using the Task Completion Protocol.

20. After three minutes has elapsed, reposition the subject for the next task, and commence recording with the VCRs. Repeat steps 17 through 19 (including the synchronization flash) until all five tasks are completed.

21. Have the subject assume the starting position as outline in the Task Completion Protocol, confirming visibility of all markers. Begin VCR recording and reactivate the synchronization flash. Have the subject perform their full range of upper limb motion as described in the Range of Motion Protocol.

22. Stop recording. Remove all tape and markers from the subject.

23. Have the subject remove the turtleneck sweater.

24. Thank the subject for their time and participation in the project.

SUBJECT ORIENTATION PROTOCOL

1. Greet subject and thank them for coming.

2. Alert subject to the sensitivity of the environment and equipment used in the experiment, and caution them to be careful not to bump or move anything.

3. Show the subject the experimental setup and explain that they will be asked to perform five very simple tasks. They will be videotaped using the three cameras. Light reflective markers will be attached to their upper body, and a computer will analyze their body movements by tracking these markers on the videotape. Because the markers are light reflective, it is necessary to cover up other potentially reflective surfaces, such as the walls and the subjects skin. This is why everything is covered with black fabric.

4. Show the subject the video monitors and computer, and explain that this is the equipment used to record and analyze the videotape.

5. Inform the subject that you will need to measure their weight for statistical purposes, and have them sign a consent form. They will also be required to complete several assessments. The entire experiment should take approximately one hour.

6. Ask the subject if they have any questions. If not, proceed to step 2 (informed consent form) in the experimental protocol.

COPM ADMINISTRATION PROTOCOL

BEFORE YOU START

Select a Canadian Occupational Performance Measure assessment form and complete the subject information on the first page as outlined below.

Under "ID#" write the subject number (eg S01), and write their name beside "Client Name". For presurgery subjects, put today's date beside "Date of Assessment". For 3 and 6 months postsurgery subjects, write in beside "Date of Reassessment" either "3 month postsurgery" or "6 month postsurgery" and the date, as appropriate. Put your name in the space provided for "Therapist", to the left of "Date of Assessment/Reassessment". All three lines should have a name opposite the date. Everything else on the front page can be left blank.

Introduce the Client to the assessment as follows:

> **"This is the Canadian Occupational Performance Measure. It is a simple assessment used to identify those activities in your life that you find most difficult or frustrating to perform. I will suggest some tasks with which some people experience difficulty and I would like you to identify any of these activities, or any others you can think of, which have been a problem for you. I will also be asking you to think about how important these problems are to you. I may be writing down your ideas as we talk, so I don't forget them. All of this information will remain confidential, as with all aspects of this study. Do you have any questions? If not, we will begin."**

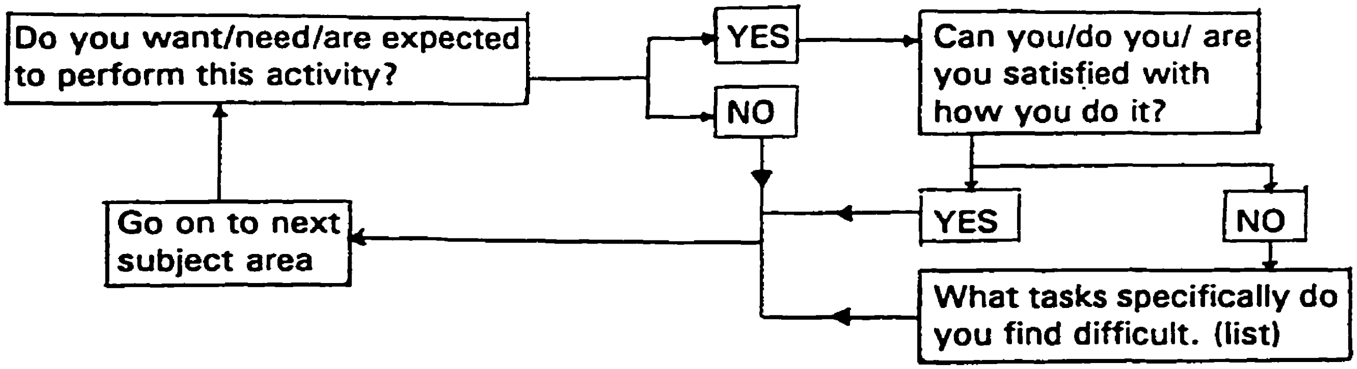
INITIAL ASSESSMENT

1. Open the assessment form to STEP 1: PROBLEM DEFINITION.

Your task is to interview the subject and determine whether they are experiencing difficulty in the performance of tasks in their daily life as a consequence of their Osteoarthritis in their right shoulder. The following are guidelines for questions, but the experimenter should feel free to create their own questions if it will elicit more information.

Begin by asking whether the subject needs, wants, or is expected to perform tasks in the particular area of daily life outlined (ie TOPICS), giving several EXAMPLES. If the subject responds "no", go on to the next topic. If the subject responds "yes", ask whether they can/do/are satisfied with the way they perform these types of tasks. If they are able and satisfied, go on to the next topic. If they are not both able and satisfied, proceed to the subsections below (STEPS 1A/1B/1C on the assessment) and inquire about which SPECIFIC TASKS are difficult, using the examples provided (these examples are not exhaustive; encourage the subject to be as specific as possible). List these tasks on the lines next to the appropriate performance area. When this is complete, go back to the next topic area. Continue through the TOPIC list until you have covered all the areas listed.

Question Protocol:



2. When you have completed all the subject topics, go to STEP 2: PROBLEM WEIGHTING. Take out the Importance Scale included in the kit and have the subject individually rank the importance of each task you have written down in sections 1A, 1B and 1C. Instruct the subject that:

> **"A rank of 1 means that being able to do the task is not important at all to you, and a rank of 10 means doing the task is extremely important to you. A rank of 2-9 means the importance is somewhere in between these extremes."**

You may choose to ask the subject:

> **"How important is it for you to be able to do this activity?"**

or you may choose a similar question which you find more comfortable. Mark down this score individually in the boxes under the heading IMPORTANCE, next to each task identified.

3. When you have completed rating the importance of each task, move to STEP 3: SCORING. Ask the subject to choose up to five (5) of the problems identified (1A/B/C) which they feel are the most important or pressing. These will likely be the five with the highest IMPORTANCE rating. Write these tasks on the lines provided under the heading "PROBLEMS." Transfer the IMPORTANCE ratings from STEP 2 to the boxes in STEP 3, under the IMPORTANCE heading, next to the appropriate PROBLEM.

4. Take out the Performance Scale included in the kit and have the subject individually rate their performance in each of the tasks written down under "PROBLEMS". Instruct the subject that:

> **"A rank of 1 means you are not able to do the task at all; a rank of 10 means you are able to do the task extremely well; and a rank of 2-9 means your performance is somewhere in between these extremes."**

You may choose to ask the subject:

"How would you rate the way you do this activity now?"

or you may choose a similar question which you find more comfortable. Mark down the subjects performance rating for each task in the corresponding box under the heading PERFORMANCE1.

5. Take out the Satisfaction Scale included in the kit and have the subject individually rate their satisfaction with each of the tasks identified under PROBLEMS. Instruct the subject that:

"A rank of 1 means you are not satisfied at all with the way you do this activity; a rank of 10 means you are extremely satisfied; and a rank of 2-9 means your satisfaction level is somewhere in between these extremes."

You may choose to ask the subject:

"How satisfied are you with the way you do this activity?"

or you may choose a similar question which you find more comfortable. Mark down the subjects satisfaction rating for each task in the corresponding box under the heading SATISFACTION1.

6. Instruct the subject that:

"This assessment is now complete, and we will move on to the next part of the study."

The following section should be completed after the experiment is complete, so that the subject does not need to wait while you perform the calculations outlined below. Move to the next part of the experimental protocol and complete sections 7 and 8 after the subject has left.

7. For each of the activities under PROBLEMS, multiply the IMPORTANCE score by the PERFORMANCE1 score and write the product in the corresponding box under the heading IMP x PERF1. Add all the scores in the boxes under IMP x PERF1, and divide this total by the number of problems listed. Write the result next to "Performance Score 1" in the TOTALS section of STEP 3: SCORING.

8. For each of the activities under PROBLEMS, multiply the IMPORTANCE score by the SATISFACTION1 score and write the product in the corresponding box under the heading IMP x SAT1. Add all the scores in the boxes under IMP x SAT1, and divide this total by the number of problems listed. Write the result next to "Satisfaction Score 1" in the TOTALS section of STEP 3: SCORING.

NOTE: Any subjective comments can be entered on the back page of the assessment, if you feel they are relevant.

LIST OF TOPICS AND EXAMPLES FOR QUESTIONS

TOPICS		EXAMPLES	SPECIFIC TASKS
1A	Self-Care:		
	i)Personal Care	Dressing	managing fasteners
			removing clothing
			putting on clothing
		Bathing	washing self
			washing hair
			towelling dry
		Feeding	holding utensils
			bringing food/drink to mouth
		Hygiene	shaving
			applying makeup
			toileting
			brushing teeth
			opening containers
			pouring liquids
	ii)Functional Mobility	Transfers	getting in/out of tub
			getting in/out chairs
			turning in bed
	iii)Community Management	Transportation	driving a car
			using public transit
			using a telephone
		Shopping	pushing a grocery cart
			picking up groceries
			carrying shopping bags
1B	Productivity:		
	i)Paid/Unpaid Work	Keeping a job	working expected hours
			fatigue
			performing tasks at workplace
	ii)Household Management	Cooking	preparing food
			setting table
			getting/putting away or washing dishes
		Cleaning	vacuuming
			ironing
			laundry
	iii)Play/School	Play	playing sports
			playing games
			drawing/painting
		School	note-taking/writing
1C	Leisure:		
	i)Quiet Recreation	Hobbies and Crafts	knitting/sewing
			woodworking
	ii)Active Recreation	Travel and Outings	going to park/beach
			caring for pet
		Sports	participation
	iii)Socialization	Visiting	talking on phone
			hosting parties
			writing letters

Health Assessment Questionnaire Protocol

1. Ensure that the subject identification number is recorded on the HAQ questionnaire. Present the questionnaire to the subject and ask them to complete it to the best of their ability. Refer to step 2 if the subject asks questions regarding how to respond.

2. Disability Index - The subject is required to record the amount of difficulty they may have in each of the twenty areas within the eight categories. Do not define the terms some, much or usual for the subjects. They must be allowed to use their own frame of reference. For example, if they ask what "some" means, say "whatever you think of as some".

   The time frame is over the past week. If the subject questions whether you are interested in a particularly good time or bad time that is out of this time frame, indicate that you are not.

   If they do not do some of the activities out of preference, then they should leave that question blank. If they have modified or adapted items, they should answer the questions based on their usual equipment. If they have no difficulty when using the adapted equipment, they should mark the "no difficulty" column. If they can open their own car doors, but not others, they should respond considering the usual equipment and their usual encounters. Subjects must make their own decision concerning distance in the question referring to walking.

3. Discomfort Index - The subject is required to provide information about the presence or absence of arthritis related pain and its severity over the past week. If they say that their varies from day to day and during the day, remind them that they must consider how the pain has usually been over the past week.

VAS Protocol

1. Take a Visual Analog Pain Scale recording sheet and complete the subject information section in the upper portion. Record the task sequence that was randomly selected on each of the three forms. All three forms should have the same sequence listed. After each task, record the order that the joint recording forms will be presented to the subject as has been randomly selected from the Joint Sequence List. Each task on each of the three forms should have the same sequence written after it. For example, if the random task sequence selected is bottle, can, comb, scapula, sacrum, record with the random joint sequence as follows:

   pretest - wst, shd, elb
   bottle - shd, wst, elb
   can - wst, elb, shd
   comb - elb, wst, shd
   scapula - elb, shd, wst
   sacrum - shd, elb, wst

2. All six VAS measurements for each joint region should be recorded on the same respective joint form.

3. Show the subject the VAS and then direct them to the sample VAS form saying:

   "This is an example of a Visual Analog Scale for Hunger. The right end means you are absolutely famished, or starving. The left end means that you are so full, you couldn't eat another bite. In this example, the person was quite hungry as it was just before lunch time, but not excessively so because they ate a large breakfast."

   Direct the subject to the Pain Scale for them to complete and say:

   "This is an example of a Visual Analog Scale on which you rate your pain. The left end means 'no pain at all', and the right end means 'Pain as bad as it can be'; and the line represents degrees of pain in between. Do you have any questions about how the scale works?"

   If the subject has any questions, attempt to clarify using the suggestions in step 4. The instructions must be given verbatim.

4. If the subject demonstrates difficulty with the scale, or has questions, repeat the above instructions once. If the subject has more questions, or still does not understand, explain what each extreme in the scale represents, and that the level of pain they experience falls somewhere between these (and including them). Do not suggest where an 'x' should be place, or where on the line a specific degree of pain might be, only that as you get closer to each end, you come closer to that extreme in pain experience.

The subject must complete the scale independently. Direct the subject to the appropriate VAS line for the appropriate joint and instruct them to:

> **"Mark an 'x' right on the line where you would rate the pain you are feeling in your (right/left) (shoulder/elbow/wrist) at this moment"**

After the subject has completed the pretest VAS for each joint region, put it aside and complete steps 10 to 18 of the experimental protocol.

5. After completion of each task, present the VAS in the sequence designated for each task and direct the subject to the appropriate VAS line. Instruct them:

> **"This is your rating of the pain in your shoulder/elbow/wrist when we first measured it. Remember what you felt like then, and think about how your pain right now compares, and mark the scale accordingly. Mark an 'x' right on the line where you would rate the pain you are feeling in your (right/left) (shoulder/elbow/wrist) at this moment."**

Repeat this step for the remaining two joints in the order designated for the task.

Diagram 1.

APULA

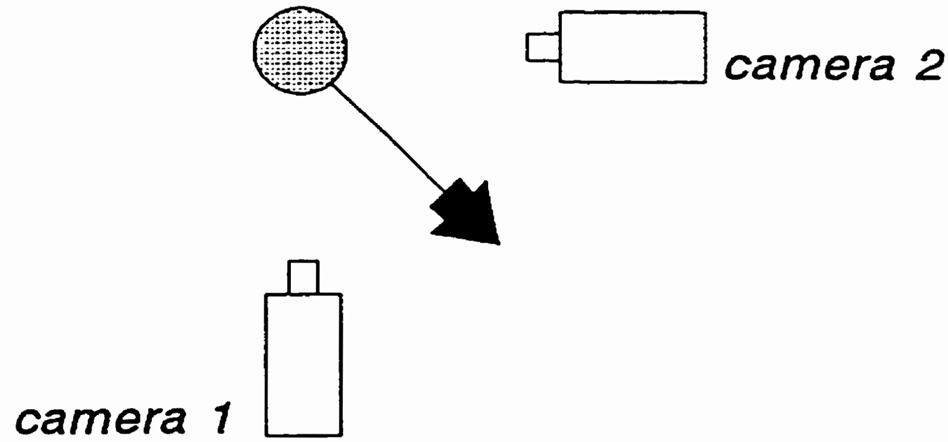


Diagram 2.

COMB
SACRUM

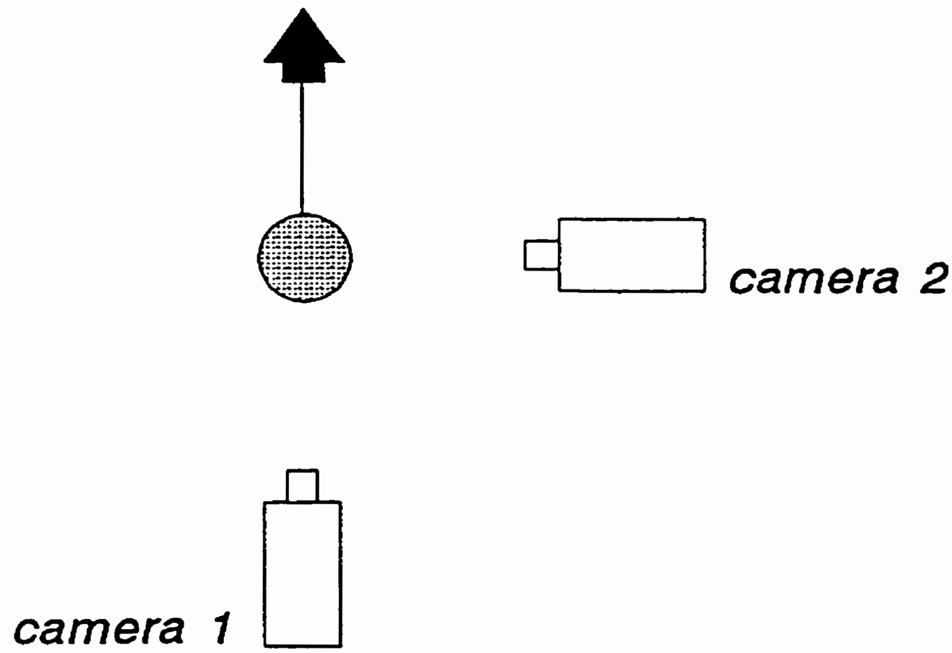
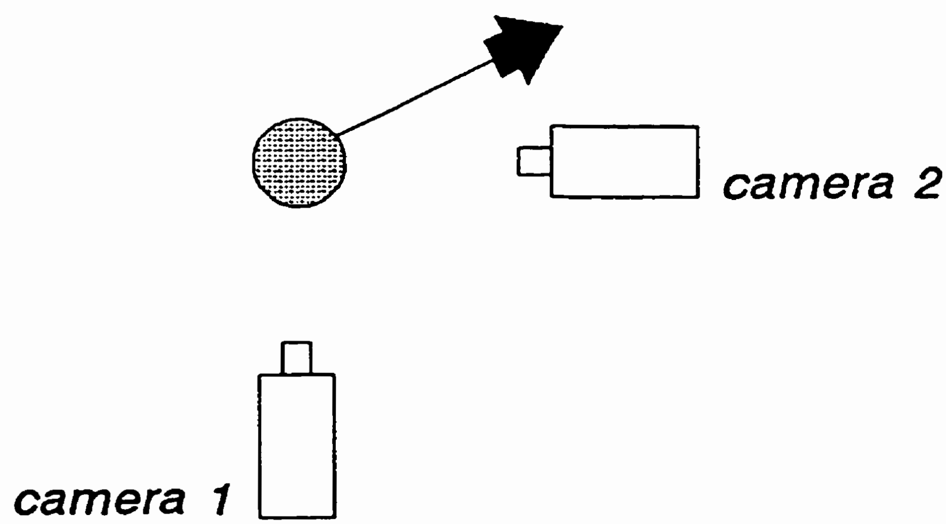


Diagram 3.

WEIGHTS



WEIGHT1 (TIN CAN)

Set up: The two tasks involving lifting must be done consecutively, in either order as outlined in the task sequence table. With the subject seated on the stool, and the right arm in neutral position, measure the distance from the floor to the anterior fold of the axilla. Adjust the shelf to this same height and situate it in front and slightly to the left of the subject. Place the shelf at a distance from the stool which will be comfortable for the subject to reach. Situate the stand such that it does not impinge on the position or visibility of the wrist markers.

Orientation: Have the subject seated on a stool at a comfortable height such that their feet are supported and their hips, knees and ankles are all fixed at 90 degrees. All markers are clearly visible from the three camera views. The subject should be facing approximately 15 degrees away from camera 2 (towards the wall with the black fabric) as illustrated in diagram 3, or similarly as allows maximal visibility of markers.

Task Completion Criteria: Have the subject rest their hand on their lap or right thigh, as is most comfortable for them. The tin should be held in a gross palmer grasp (power grasp) with the right hand in neutral. The hand and tin should be resting on the right thigh. The subject should flex the shoulder, extending the elbow, and set the tin momentarily on top of the shelf, without releasing it. The hand (and tin) should then return to the starting position, resting on the thigh. Subject must complete the task five (5) times, including return to the starting position. Count out loud after each return to the starting position, and after the fifth complete cycle, tell the subject to "stop".

Instructions to Subject:

> "Hold your right arm loosely at your side grasping the tin can in your right hand between your fingers and your thumb between the black lines, like this (demonstrate), and rest your hand and tin can on your right thigh. Lift the tin up to the shelf and place it on top of the shelf for one moment, but don't let go of it. Then bring the tin back down and rest it on your thigh again. Repeat this movement until I tell you to stop. I will count out loud and tell you to stop after the fifth time."

WEIGHT2 (BOTTLE)

Set up: The two tasks involving lifting must be done consecutively, in either order as outlined in the task sequence table. With the subject seated on the stool, and the right arm in neutral position, measure the distance from the floor to the anterior fold of the axilla. Adjust the shelf to this same height and situate it in front and slightly to the left of the subject. Place the shelf at a distance from the stool which will be comfortable for the subject to reach. Situate the stand such that it does not impinge on the position or visibility of the wrist markers.

Orientation: Have the subject seated on a stool at a comfortable height such that their feet are supported and their hips, knees and ankles are all fixed at 90 degrees. All markers are clearly visible from the three camera views. The subject should be facing approximately 15 degrees away from camera 2 (towards the wall with the black fabric) as illustrated in diagram 3, or similarly as allows maximal visibility of markers.

Task Completion Criteria: Have the subject rest their hand on their lap or right thigh, as is most comfortable for them. The bottle should be held in a gross palmer grasp (power grasp) with the right hand in neutral and the thumb web space around the narrower edge. The hand and bottle should be resting on the right thigh. The subject should flex the shoulder, extending the elbow, and set the bottle momentarily on top of the shelf, without releasing it. The hand (and bottle) should then return to the starting position, resting on the thigh. Subject must complete the task five (5) times, including return to the starting position. Count out loud after each return to the starting position, and after the fifth complete cycle, tell the subject to "stop".

Instructions to Subject:

> "Hold your right arm loosely at your side and place your hand on your lap or thigh, whatever is most comfortable. Hold the bottle in your right hand between your fingers and your thumb between the black lines, on the flat sides like this (demonstrate), and rest your hand and bottle on your right thigh. Lift the bottle up to the shelf and place it on top of the shelf for a moment, but don't let go of it. Then bring the bottle back down and rest it on your thigh again. Repeat this movement until I tell you to stop. I will count out loud and tell you to stop after the fifth time."

COMB

Orientation: Have the subject seated on a stool at a comfortable height such that their feet are supported and their hips, knees and ankles are all fixed at 90 degrees. All markers should be clearly visible from the three camera views. The subject should be facing directly away from camera 1 (towards black fabric on the brick wall) and roughly perpendicular to camera 2 as illustrated in diagram 2, or similarly as provides maximal visibility of markers.

Task Completion Criteria: Have the subject rest their hand on their lap or right thigh, as is most comfortable for them. The subject will hold a comb in their right hand using a modified key grip. The comb will be situated between the thumb and the second and third phalanges. Subjects will bring their right hand medially and superiorly across ventral aspect of trunk to the head. They will draw the comb through their hair with forearm in pronation, beginning at the ventral hairline and following along the sagittal plane bisecting the skull and adhering to the contour of the head and neck. The motion will be complete when the comb is free from the hair. The hand should return to the ventral aspect of the trunk as is comfortable for the subject, but need not return to the starting position. Subject must complete the task five (5) times. Count out loud after each return to the ventral position, and after the fifth complete cycle, tell the subject to "stop".

Instructions to Subject:

> "Hold your right arm loosely at your side and place your hand on your lap or thigh, whatever is most comfortable. Hold the comb in your right hand between your thumb and your next two fingers (demonstrate). Bring the comb up to your hair and comb straight back along the centre of your head, all the way back down your neck, until the comb is out of your hair (demonstrate). Then bring the comb in front of you, where it is comfortable. You don't have to go back to the starting position. Repeat this movement until I tell you to stop. I will count out loud and tell you to stop after the fifth time."

SACRUM

Orientation: Have the subject seated on a stool at a comfortable height such that their feet are supported and their hips, knees and ankles are all fixed at 90 degrees. All markers should be clearly visible from the three camera views. The subject should be facing directly away from camera 1 (towards black fabric on the brick wall) and roughly perpendicular to camera 2 as illustrated in diagram 2, or similarly as provides maximal visibility of markers. Place a 3 cm square piece of velcro (rough surface) on the subject's right buttock approximately 5 cm laterally to the right of the sacral marker rod, using two sided adhesive tape or J & J Clear Adhesive tape.

Task Completion Criteria: Have the subject rest their hand on their lap or right thigh, as is most comfortable for them. Have subject bring hand medially (backwards) across dorsal aspect of trunk and place palmer surface of third distal phalange on the velcro patch secured to their right buttock; and return to starting position, all in one continuous motion. Subject must complete the task five (5) times, including return to the starting position. Count out loud after each return to the starting position, and after the fifth complete cycle, tell the subject to "stop".

Instructions to Subject:

> "Hold your right arm loosely at your side and place your hand on your lap or thigh, whatever is most comfortable. From this position, bring your right hand behind your back and put palm side of your fingertips on the velcro patch on your right buttock, and then return your hand to your lap. Try to do this in a natural, continuous motion. Repeat this movement until I tell you to stop. I will count out loud and tell you to stop after the fifth time."

TASK COMPLETION PROTOCOL

SCAPULA

Orientation: Have the subject seated on a stool at a comfortable height such that their feet are supported and their hips, knees and ankles are all fixed at 90 degrees. All markers shoulde be clearly visible from the three camera views. The subject should be facing between cameras 1 and 2, at roughly 45 degrees to each as illustrated in diagram 1, or similarly as allows maximal visibility of markers.

Task Completion Criteria: Have the subject rest their hand on their lap or right thigh, as is most comfortable for them. Subject will bring hand medially across the front of the ventral aspect of trunk; over contralateral shoulder, and place palmer aspect of distal phalanges directly on the superior border of the scapular spine, roughly midway laterally along the spine; and return to the starting position all in one continuous motion. Subject must complete the task five (5) times, including return to the starting position. Count out loud after each return to the starting position, and after the fifth complete cycle, tell the subject to "stop".

Instructions to Subject:

> "Hold your right arm loosely at your side and place your hand on your lap or thigh, whatever is most comfortable. From this position, bring your right hand in front of your body and over your left shoulder. Touch your fingertips to the bony ridge on your shoulder blade, halfway between your neck and your shoulder (demonstrate) and then return your hand to your lap. Try to do this in a natural, continuous motion, as if you were reaching to wash your back. Repeat this movement until I tell you to stop. I will count out loud and tell you to stop after the fifth time."

TASK SEQUENCE RANDOMIZED LIST

Subject		Task1	Task2	Task3	Task4	Task5
S01	A	WEIGHT1	WEIGHT2	COMB	SACRUM	SCAPULA
	B	SACRUM	COMB	SCAPULA	WEIGHT2	WEIGHT1
	C	WEIGHT1	WEIGHT2	SCAPULA	COMB	SACRUM
S02	A	WEIGHT2	WEIGHT1	SCAPULA	SACRUM	COMB
	B	WEIGHT2	WEIGHT1	COMB	SCAPULA	SACRUM
	C	SCAPULA	SACRUM	COMB	WEIGHT2	WEIGHT1
S03	A	WEIGHT1	WEIGHT2	COMB	SACRUM	SCAPULA
	B	WEIGHT2	WEIGHT1	COMB	SACRUM	SCAPULA
	C	SACRUM	SCAPULA	COMB	WEIGHT2	WEIGHT1
S04	A	COMB	SCAPULA	SACRUM	WEIGHT2	WEIGHT1
	B	COMB	SACRUM	SCAPULA	WEIGHT1	WEIGHT2
	C	SCAPULA	COMB	SACRUM	WEIGHT1	WEIGHT2
S05	A	COMB	SACRUM	SCAPULA	WEIGHT2	WEIGHT1
	B	SACRUM	COMB	SCAPULA	WEIGHT2	WEIGHT1
	C	COMB	SACRUM	SCAPULA	WEIGHT2	WEIGHT1
S06	A	WEIGHT1	WEIGHT2	SACRUM	SCAPULA	COMB
	B	WEIGHT1	WEIGHT2	COMB	SCAPULA	SACRUM
	C	WEIGHT2	WEIGHT1	SACRUM	SCAPULA	COMB
S07	A	SCAPULA	COMB	SACRUM	WEIGHT1	WEIGHT2
	B	SCAPULA	SACRUM	COMB	WEIGHT2	WEIGHT1
	C	WEIGHT1	WEIGHT2	COMB	SACRUM	SCAPULA
S08	A	WEIGHT2	WEIGHT1	SCAPULA	COMB	SACRUM
	B	WEIGHT1	WEIGHT2	COMB	SCAPULA	SACRUM
	C	SCAPULA	SACRUM	COMB	WEIGHT1	WEIGHT2
S09	A	WEIGHT1	WEIGHT2	COMB	SCAPULA	SACRUM
	B	SCAPULA	SACRUM	COMB	WEIGHT2	WEIGHT1
	C	WEIGHT1	WEIGHT2	SACRUM	COMB	SCAPULA
S10	A	COMB	SACRUM	SCAPULA	WEIGHT1	WEIGHT2
	B	SCAPULA	COMB	SACRUM	WEIGHT1	WEIGHT2
	C	WEIGHT2	WEIGHT1	COMB	SCAPULA	SACRUM

S** subject number
ABC A = presurgery
B = 3 months postsurgery
C = 6 months postsurgery
Weight1 = lift soup tin onto shelf
Weight2 = lift bottle onto shelf
Sacrum = touch right palm to sacrum
Scapula = touch right palm to left scapula (across chest)
Comb = comb hair with right hand

Joint Sequence Randomized List

subject	pretest	task 1	task 2	task 3	task 4	task 5
S01	SWE	ESW	WES	SEW	EWS	WSE
S02	WSE	EWS	SWE	WES	ESW	SEW
S03	EWS	WSE	SWE	ESW	WES	SEW
S04	SEW	WES	ESW	SWE	WSE	EWS
S05	WSE	SEW	EWS	WES	SWE	ESW
S06	ESW	SEW	WSE	EWS	SWE	WES
S07	SEW	WES	ESW	SWE	WSE	EWS
S08	WES	EWS	SEW	WSE	ESW	SWE
S09	ESW	WSE	SEW	EWS	WES	SWE
S10	EWS	SWE	WSE	ESW	SEW	WES

key
S = shoulder joint
E = elbow region
W = wrist joint

APPENDIX H

APPENDIX H - Control Group

Table H1							
	bottle		RANGE OF MOTION				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	63	8	12	41	18	30	31
2_n	81	30	23	77	15	28	9
3_n	69	9	9	59	24	26	18
4_n	98	27	36	70	32	19	15
5_n	81	18	12	62	12	10	9
6_n	93	32	64	88	36	46	32
7_n	63	17	15	33	12	10	11
8_n	68	11	35	31	16	6	10
9_n	81	14	22	51	28	6	14
10_n	68	17	4	50	17	5	10
MEAN	77	18	23	56	21	19	16
SD	12	9	18	19	8	14	9
plus sd	89	27	41	75	29	32	25
minus sd	64	10	5	37	13	5	7
	LIFTING BOTTLE		MINIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	0	8	0	64	1	-42	2
2_n	-9	2	-6	46	18	-45	11
3_n	5	2	13	43	9	-42	-2
4_n	-4	4	-1	37	-23	-35	-5
5_n	-11	-1	5	47	-11	-24	-2
6_n	-2	-2	-16	27	-27	-39	-20
7_n	-1	-2	12	47	-9	-32	-4
8_n	-4	7	6	39	-31	-25	-22
9_n	-7	0	2	52	-22	-29	-18
10_n	-1	1	9	45	-13	-18	3
MEAN	-3	2	2	45	-11	-33	-6
SD	5	4	9	10	16	9	11
plus sd	1	5	11	54	5	-24	5
minus sd	-8	-2	-6	35	-27	-42	-17
	LIFTING BOTTLE		MAXIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	63	16	12	105	19	-12	33
2_n	72	32	17	123	33	-17	20
3_n	74	11	22	102	33	-16	16
4_n	94	31	35	107	9	-16	10
5_n	70	17	17	109	1	-14	7
6_n	91	30	48	115	9	7	12
7_n	62	15	27	80	3	-22	7
8_n	64	18	41	70	-15	-19	-12
9_n	74	14	24	103	6	-23	-4
10_n	67	18	13	95	4	-13	13
MEAN	73	20	26	101	10	-14	10
SD	11	8	12	16	15	8	12
plus sd	84	28	38	117	25	-6	23
minus sd	62	12	13	85	-4	-23	-2

APPENDIX H - Control Group

Table H2							
	LIFTING BOTTLE		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1 _n	82	7	14	80	23	45	49
2_n	82	32	22	108	15	25	12
3_n	82	6	8	94	16	25	9
4_n	110	39	48	99	33	16	20
5_n	98	24	12	83	18	12	10
6_n	80	24	20	185	86	97	46
7_n	92	34	38	57	12	10	10
8_n	92	22	55	43	15	7	12
9_n	105	24	24	77	40	7	14
10_n	94	34	6	88	34	6	14
MEAN	92	25	25	91	29	25	20
SD	10	11	17	38	22	28	15
radians	1.6	0.4	0.4	1.6	0.5	0.4	0.3
sd	0.2	0.2	0.3	0.7	0.4	0.5	0.3
plus sd	1.8	0.6	0.7	2.3	0.9	0.9	0.6
minus sd	1.4	0.2	0.1	0.9	0.1	-0.1	0.1
	LIFTING BOTTLE		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1 _n	242	15	36	363	47	135	120
2_n	147	81	52	304	41	50	23
3_n	187	9	18	271	34	64	16
4_n	279	107	125	294	91	31	46
5_n	216	41	21	227	36	20	16
6_n	167	139	1124	882	764	712	187
7_n	185	51	59	227	18	18	16
8_n	245	58	150	127	29	13	25
9_n	272	68	73	240	97	15	25
10_n	230	138	23	358	161	15	31
MEAN	217	71	168	329	132	107	51
SD	44	46	339	206	226	216	57
radians	3.8	1.2	2.9	5.7	2.3	1.9	0.9
sd	0.8	0.8	5.9	3.6	4.0	3.8	1.0
plus sd	4.6	2.0	8.8	9.3	6.3	5.6	1.9
minus sd	3.0	0.4	-3.0	2.1	-1.7	-1.9	-0.1

APPENDIX H - Control Group

Table H3							
	can		RANGE OF MOTION				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	64	11	7	36	27	26	25
2_n	83	19	16	81	14	33	19
3_n	72	12	4	53	15	4	14
4_n	93	19	32	63	3	5	15
5_n	79	21	16	63	8	4	10
6_n	97	31	43	81	43	10	21
7_n	63	21	19	28	14	7	15
8_n	64	17	35	34	27	10	12
9_n	75	20	26	50	28	8	16
10_n	59	19	7	54	19	8	12
MEAN	75	19	21	54	20	11	16
SD	13	5	13	18	12	10	5
	88	24	34	73	31	21	21
	62	14	7	36	8	2	11
	LIFTING CAN		MINIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	-1	6	3	64	2	-39	6
2_n	-5	9	5	36	-2	-40	-4
3_n	-2	5	9	48	-11	-17	-9
4_n	-9	6	2	44	-13	-18	-14
5_n	-8	-3	0	42	-13	-11	-3
6_n	-10	-4	-1	31	-37	-18	-15
7_n	2	-2	4	45	-18	-18	-3
8_n	-2	0	4	39	-32	-20	-12
9_n	-3	-1	-1	47	-30	-16	-15
10_n	10	0	8	40	-19	-5	2
MEAN	-3	2	3	44	-17	-20	-7
SD	6	5	3	9	13	11	7
	3	6	7	52	-5	-9	1
	-9	-3	-0	35	-30	-31	-14
	LIFTING CAN		MAXIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	63	17	10	100	29	-13	31
2_n	78	28	21	117	12	-7	15
3_n	70	17	13	101	4	-13	5
4_n	84	25	34	107	-10	-13	1
5_n	71	18	16	105	-5	-7	7
6_n	87	27	42	112	6	-8	6
7_n	65	19	23	73	-4	-11	12
8_n	62	17	39	73	-5	-10	0
9_n	72	19	25	97	-2	-9	1
10_n	69	19	15	94	0	3	14
MEAN	72	21	24	98	2	-9	9
SD	8	4	11	15	11	5	9
	81	25	35	113	14	-4	19
	64	16	13	83	-9	-14	-0

APPENDIX H - Control Group

Table H4							
	LIFTING CAN		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	82	8	7	64	31	36	24
2_n	77	20	16	114	13	20	21
3_n	94	12	4	90	10	5	11
4_n	123	23	43	119	20	6	12
5_n	95	23	15	83	7	5	9
6_n	125	47	73	138	43	10	24
7_n	76	31	34	45	13	8	15
8_n	74	23	32	48	22	9	9
9_n	105	42	28	85	44	11	18
10_n	77	34	10	98	41	10	16
MEAN	93	26	26	88	24	12	16
SD	19	12	21	30	14	9	6
radians	1.6	0.5	0.5	1.5	0.4	0.2	0.3
sd	0.3	0.2	0.4	0.5	0.2	0.2	0.1
plus sd	2.0	0.7	0.8	2.1	0.7	0.4	0.4
minus sd	1.3	0.2	0.1	1.0	0.2	0.0	0.2
	LIFTING CAN		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	223	15	11	240	116	83	46
2_n	126	48	53	280	28	57	37
3_n	241	22	17	331	32	19	26
4_n	282	56	132	433	45	14	23
5_n	229	66	30	212	21	8	13
6_n	297	125	340	479	90	13	52
7_n	161	74	82	193	21	13	28
8_n	154	69	65	143	41	24	14
9_n	222	103	56	302	124	19	24
10_n	201	109	15	386	167	19	35
MEAN	214	69	80	300	69	27	30
SD	55	36	98	108	52	24	13
radians	3.7	1.2	1.4	5.2	1.2	0.5	0.5
sd	1.0	0.6	1.7	1.9	0.9	0.4	0.2
plus sd	4.7	1.8	3.1	7.1	2.1	0.9	0.7
minus sd	2.8	0.6	-0.3	3.3	0.3	0.1	0.3

APPENDIX H - Control Group

Table H5							
	comb		RANGE OF MOTION				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	78	54	59	83	88	25	19
2_n	33	71	110	80	42	24	46
3_n	77	50	38	58	55	8	32
4_n	82	42	33	80	38	14	43
5_n	71	36	23	51	15	7	11
6_n	59	46	41	101	36	16	7
7_n	61	34	31	95	54	23	19
8_n	41	43	37	97	34	8	17
9_n	42	63	59	73	48	29	25
10_n	59	40	45	72	39	5	18
MEAN	60	48	48	79	45	16	24
SD	17	12	25	16	19	9	13
	77	60	72	95	64	25	37
	43	36	23	63	26	7	11
	COMB HAIR		MINIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	13	7	-36	67	-46	-11	-1
2_n	-1	16	-69	78	-5	-20	-25
3_n	-8	-2	-35	89	-42	-8	-9
4_n	-24	-2	-24	65	-25	-15	-23
5_n	0	2	-13	88	-26	-23	-5
6_n	-2	-1	-24	47	-30	-23	9
7_n	5	-1	-9	55	-39	-20	-3
8_n	2	7	-13	52	-43	-19	-14
9_n	1	1	-53	79	-45	-17	-19
10_n	-1	0	-27	74	-48	-6	-11
MEAN	-2	3	-30	69	-35	-16	-10
SD	10	6	19	15	13	6	11
	8	8	-11	84	-21	-10	0
	-11	-3	-49	55	-48	-22	-21
	COMB HAIR		MAXIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	91	61	23	150	42	14	18
2_n	32	87	41	158	37	4	21
3_n	69	48	3	147	13	0	23
4_n	58	40	9	145	13	-1	20
5_n	71	38	10	139	-11	-16	6
6_n	57	45	17	148	6	-7	16
7_n	66	33	22	150	15	3	16
8_n	43	50	24	149	-9	-11	3
9_n	43	64	6	152	3	12	6
10_n	58	40	18	146	-9	-1	7
MEAN	59	51	17	148	10	-0	14
SD	17	16	11	5	18	9	7
	76	67	28	153	28	9	21
	42	34	6	143	-8	-10	6

APPENDIX H - Control Group

Table H6							
	COMB HAIR		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	108	62	109	123	134	27	27
2_n	36	52	126	63	38	24	41
3_n	86	59	64	60	54	9	60
4_n	133	38	29	134	72	21	77
5_n	77	55	37	54	20	8	12
6_n	75	58	67	168	48	21	9
7_n	74	32	41	118	63	23	25
8_n	39	35	42	130	63	9	17
9_n	60	78	84	119	75	49	37
10_n	89	40	61	127	78	4	23
MEAN	78	51	66	110	65	20	33
SD	29	14	32	38	30	13	22
radians	1.4	0.9	1.2	1.9	1.1	0.3	0.6
sd	0.5	0.3	0.6	0.7	0.5	0.2	0.4
plus sd	1.9	1.1	1.7	2.6	1.7	0.6	1.0
minus sd	0.8	0.6	0.6	1.3	0.6	0.1	0.2
	COMB HAIR		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	261	125	451	314	532	60	64
2_n	133	79	314	96	94	54	57
3_n	226	126	214	234	210	19	147
4_n	388	77	70	106	64	70	274
5_n	165	145	109	175	52	17	22
6_n	187	130	218	513	114	33	22
7_n	150	57	94	284	183	51	69
8_n	69	70	80	299	254	25	27
9_n	129	185	284	330	215	158	120
10_n	308	139	164	403	334	6	55
MEAN	202	113	200	275	205	49	86
SD	95	41	123	129	145	44	78
radians	3.5	2.0	3.5	4.8	3.6	0.9	1.5
sd	1.7	0.7	2.1	2.3	2.5	0.8	1.4
plus sd	5.2	2.7	5.6	7.1	6.1	1.6	2.9
minus sd	1.9	1.3	1.3	2.5	1.0	0.1	0.1

APPENDIX H - Control Group

Table H7							
	scapula			RANGE OF MOTION			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	88	24	57	38	31	12	15
2_n	69	27	30	64	41	33	21
3_n	84	29	52	41	81	34	28
4_n	83	17	52	56	79	41	32
5_n	115	22	84	40	38	40	37
6_n	74	25	58	51	60	42	58
7_n	61	24	46	74	50	7	22
8_n	69	22	52	59	62	10	26
9_n	86	13	50	49	54	14	22
10_n	74	32	40	62	55	4	29
MEAN	80	24	52	53	55	24	29
SD	15	5	14	12	16	16	12
	95	29	66	65	71	39	41
	65	18	38	42	39	8	17
	TOUCH OPPOSITE SCAPULA			MINIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	-6	-12	1	77	-25	6	-14
2_n	10	-9	31	61	-23	-15	-13
3_n	7	-25	8	80	-45	6	-14
4_n	0	-1	12	65	-42	-5	-17
5_n	-1	-13	-6	78	-29	-11	-38
6_n	6	-21	10	75	-17	-13	-31
7_n	6	-21	16	51	-13	1	-7
8_n	14	-7	12	56	-32	-7	-18
9_n	2	-6	5	77	-34	-4	-16
10_n	17	-22	25	68	-23	7	-7
MEAN	6	-14	11	69	-28	-3	-18
SD	7	8	11	10	10	8	10
	13	-6	22	79	-18	5	-8
	-2	-22	1	59	-39	-12	-27
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	82	12	58	115	6	18	1
2_n	79	18	61	125	18	18	8
3_n	91	4	60	121	36	40	14
4_n	83	16	64	121	37	36	15
5_n	114	9	78	118	9	29	-1
6_n	80	4	68	126	43	29	27
7_n	67	3	62	125	37	8	15
8_n	83	15	64	115	30	3	8
9_n	88	7	55	126	20	10	6
10_n	91	10	65	130	32	11	22
MEAN	86	10	63	122	27	20	12
SD	12	5	6	5	13	13	9
	98	15	70	127	40	33	20
	74	4	57	117	14	8	3

APPENDIX H - Control Group

Table H8							
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGULAR VELOCITY			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	120	37	84	53	47	17	17
2_n	71	27	20	52	46	31	15
3_n	134	42	63	71	110	64	50
4_n	130	28	81	66	185	47	45
5_n	181	41	102	86	67	70	62
6_n	107	29	77	52	94	80	62
7_n	84	34	57	89	65	6	24
8_n	102	35	63	63	141	11	36
9_n	134	23	57	57	89	15	43
10_n	114	48	44	71	93	8	36
MEAN	118	34	65	66	94	35	39
SD	31	8	23	13	43	28	17
radians	2.1	0.6	1.1	1.2	1.6	0.6	0.7
sd	0.5	0.1	0.4	0.2	0.8	0.5	0.3
plus sd	2.6	0.7	1.5	1.4	2.4	1.1	1.0
minus sd	1.5	0.5	0.7	0.9	0.9	0.1	0.4
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGULAR ACCELERATION			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	262	168	470	129	192	69	37
2_n	160	75	36	80	106	69	14
3_n	351	129	193	340	864	484	458
4_n	371	102	255	172	1250	135	140
5_n	468	112	238	539	284	388	491
6_n	273	76	162	114	300	503	159
7_n	198	108	149	177	168	10	51
8_n	257	124	166	147	759	24	93
9_n	355	92	136	105	238	30	202
10_n	277	147	91	151	239	13	78
MEAN	297	113	190	195	440	173	172
SD	90	30	118	140	381	203	169
radians	5.2	2.0	3.3	3.4	7.7	3.0	3.0
sd	1.6	0.5	2.1	2.4	6.7	3.5	3.0
plus sd	6.8	2.5	5.4	5.9	14.3	6.5	6.0
minus sd	3.6	1.5	1.3	1.0	1.0	-0.5	0.0

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Table H9							
	sacrum			RANGE OF MOTION			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	55	9	40	12	154	16	16
2_n	65	24	50	19	118	31	30
3_n	57	22	42	26	131	30	2
4_n	59	43	42	56	123	38	74
5_n	61	13	61	5	111	36	29
6_n	55	26	64	35	132	31	27
7_n	55	32	106	42	95	60	26
8_n	80	28	24	43	104	36	54
9_n	59	17	69	22	136	14	21
10_n	69	17	64	22	110	8	6
MEAN	62	23	56	28	121	30	29
SD	8	10	22	16	17	15	21
	69	33	79	44	139	45	50
	54	13	34	13	104	15	7
	TOUCH SACRUM			MINIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	-33	11	9	66	-90	1	3
2_n	-43	-1	20	69	-89	-8	4
3_n	-42	-1	13	81	-79	-14	15
4_n	-53	-28	-27	65	-90	-25	-33
5_n	-49	1	0	91	-87	-7	-32
6_n	-40	7	-1	83	-90	-9	-5
7_n	-43	-14	-24	36	-73	-45	-11
8_n	-49	3	38	49	-90	-11	-16
9_n	-48	-7	-11	78	-90	-4	-15
10_n	-40	6	9	78	-90	0	7
MEAN	-44	-2	3	70	-87	-12	-8
SD	6	12	20	17	6	14	16
	-38	9	22	86	-81	2	8
	-50	-14	-17	53	-93	-26	-24
	TOUCH SACRUM			MAXIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	22	20	49	78	64	17	19
2_n	22	23	70	88	29	23	34
3_n	15	21	55	107	52	16	17
4_n	6	15	15	121	33	13	41
5_n	12	14	61	96	24	29	-3
6_n	15	33	63	118	42	22	22
7_n	12	18	82	78	22	15	15
8_n	31	31	62	92	14	25	38
9_n	11	10	58	100	46	10	6
10_n	29	23	73	100	20	8	13
MEAN	18	21	59	98	35	18	20
SD	8	7	18	15	16	7	14
	26	28	77	113	51	25	34
	9	14	41	83	19	11	6

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Table H10							
	TOUCH SACRUM			MAXIMUM ANGULAR VELOCITY			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	76	10	72	21	285	26	37
2_n	69	24	61	14	251	17	35
3_n	98	30	99	39	245	38	3
4_n	98	61	106	115	260	67	91
5_n	91	12	111	7	144	49	37
6_n	76	54	150	66	157	44	32
7_n	78	51	225	50	117	159	27
8_n	102	52	39	109	281	41	77
9_n	80	27	134	44	263	16	43
10_n	109	39	150	41	245	12	9
MEAN	88	36	115	51	225	47	39
SD	14	18	54	37	61	43	27
radians	1.5	0.6	2.0	0.9	3.9	0.8	0.7
sd	0.2	0.3	0.9	0.6	1.1	0.7	0.5
plus sd	1.8	0.9	2.9	1.5	5.0	1.6	1.2
minus sd	1.3	0.3	1.1	0.2	2.9	0.1	0.2
	TOUCH SACRUM			MAXIMUM ANGULAR ACCELERATION			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	201	21	271	89	1511	111	379
2_n	133	48	217	45	3084	86	179
3_n	455	93	720	120	2265	121	3
4_n	271	183	583	441	1246	313	226
5_n	234	25	440	22	400	100	107
6_n	155	155	964	283	410	141	136
7_n	134	105	1097	181	338	1165	67
8_n	247	214	126	756	3372	106	236
9_n	191	90	534	176	1170	35	198
10_n	283	135	917	173	1303	32	19
MEAN	230	107	587	229	1510	221	155
SD	95	65	334	222	1083	341	114
radians	4.0	1.9	10.2	4.0	26.4	3.9	2.7
sd	1.7	1.1	5.8	3.9	18.9	5.9	2.0
plus sd	5.7	3.0	16.1	7.9	45.3	9.8	4.7
minus sd	2.4	0.7	4.4	0.1	7.4	-2.1	0.7

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Table H11							
	LIFTING BOTTLE		RANGE OF MOTION				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	15	5	3	9	5	6	7
2_ra	9	4	3	14	6	6	3
3_ra	78	26	11	54	11	5	14
4_ra	84	22	23	59	13	7	12
5_ra	88	19	19	73	18	13	17
6_ra	91	25	36	76	18	8	8
7_ra	73	27	20	44	12	10	19
8_ra	62	32	13	50	19	7	5
9_ra	54	15	24	45	19	11	12
10_ra	59	28	20	40	20	11	11
MEAN	61	20	17	46	14	8	11
SD	29	10	10	22	6	3	5
plus sd	90	30	27	68	20	11	16
minus sd	33	11	7	25	9	6	6

SUBJECT	shd fl	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	-10	-2	-4	103	-19	8	10
2_ra	-5	-4	16	78	-8	-4	20
3_ra	-10	-2	-7	39	-43	-2	-21
4_ra	-12	2	8	42	-23	-33	-3
5_ra	-11	8	6	20	-34	-11	-16
6_ra	-12	1	-4	34	-7	-33	1
7_ra	-4	2	4	55	-20	-33	-2
8_ra	0	1	-2	51	-23	-7	-1
9_ra	2	15	11	40	-51	-19	13
10_ra	5	1	0	62	-10	-41	5
MEAN	-6	2	3	52	-24	-18	1
SD	6	6	7	24	15	17	12
plus sd	1	8	10	76	-9	-1	13
minus sd	-12	-3	-5	28	-39	-34	-12

	LIFTING BOTTLE		MAXIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	5	3	-1	112	-14	14	17
2_ra	4	0	19	92	-2	2	23
3_ra	68	24	4	93	-32	3	-7
4_ra	72	24	31	101	-10	-26	9
5_ra	77	27	25	93	-16	2	1
6_ra	79	26	32	110	11	-25	9
7_ra	69	29	24	99	-8	-23	17
8_ra	62	33	11	101	-4	0	4
9_ra	56	30	35	85	-32	-8	25
10_ra	64	29	20	102	10	-30	16
MEAN	56	23	20	99	-10	-9	11
SD	28	11	12	8	15	16	10
plus sd	83	34	32	107	5	6	21
minus sd	28	11	8	90	-24	-25	1

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Table H12							
	LIFTING BOTTLE		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	10	3	3	6	4	4	4
2_ra	22	5	3	31	9	13	3
3_ra	95	23	18	86	18	5	12
4_ra	95	24	28	79	11	7	12
5_ra	91	26	26	105	24	8	15
6_ra	105	27	53	121	15	10	7
7_ra	58	31	23	52	28	11	15
8_ra	46	26	13	47	16	5	3
9_ra	66	22	22	56	25	12	12
10_ra	90	44	36	83	24	14	14
MEAN	68	23	23	67	17	9	10
SD	33	12	15	35	8	4	5
radians	1.2	0.4	0.4	1.2	0.3	0.2	0.2
sd	0.6	0.2	0.3	0.6	0.1	0.1	0.1
plus sd	1.8	0.6	0.7	1.8	0.4	0.2	0.3
minus sd	0.6	0.2	0.1	0.6	0.2	0.1	0.1
	LIFTING BOTTLE		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	11	4	5	13	12	13	7
2_ra	46	6	7	60	21	26	4
3_ra	210	45	57	297	60	11	33
4_ra	166	48	70	210	19	16	16
5_ra	172	59	68	267	60	10	15
6_ra	200	66	170	421	21	15	13
7_ra	98	66	54	127	53	13	23
8_ra	52	43	26	92	23	9	5
9_ra	118	45	27	122	42	26	28
10_ra	212	124	135	519	53	31	29
MEAN	129	51	62	213	36	17	17
SD	74	34	54	164	19	8	10
radians	2.2	0.9	1.1	3.7	0.6	0.3	0.3
sd	1.3	0.6	0.9	2.9	0.3	0.1	0.2
plus sd	3.5	1.5	2.0	6.6	1.0	0.4	0.5
minus sd	0.9	0.3	0.1	0.9	0.3	0.2	0.1

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Table H13

SUBJECT	LIFTING CAN shd flex	shd abd	RANGE OF MOTION shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	19	9	13	55	15	13	20
2_ra	54	9	11	17	26	15	12
3_ra	78	30	17	62	8	6	13
4_ra	81	11	10	60	16	7	11
5_ra	98	19	15	86	42	6	28
6_ra	87	22	33	73	19	13	13
7_ra	67	38	18	39	28	7	14
8_ra	57	33	14	54	10	7	7
9_ra	61	18	14	61	24	8	16
10_ra	55	26	10	37	15	6	13
MEAN	66	22	16	54	20	9	15
SD	22	10	7	19	10	3	6
plus sd	88	32	22	74	30	12	20
minus sd	44	11	9	35	10	5	9

SUBJECT	LIFTING CAN shd flex	shd abd	MINIMUM ANGLE shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	2	-15	-8	85	-7	-7	1
2_ra	-17	-5	2	67	-56	-2	22
3_ra	-1	0	-5	31	-37	-8	-24
4_ra	-12	7	17	42	-21	-32	0
5_ra	-14	3	2	10	-21	-12	-6
6_ra	-11	3	-1	32	-14	-22	-1
7_ra	-16	-9	0	51	-26	-33	5
8_ra	1	-1	-8	46	-11	-4	1
9_ra	2	8	15	31	-41	-37	1
10_ra	0	0	1	59	-23	-32	-15
MEAN	-7	-1	2	45	-26	-19	-2
SD	8	7	9	21	15	14	12
plus sd	1	6	10	67	-11	-5	11
minus sd	-15	-8	-7	24	-41	-33	-14

SUBJECT	LIFTING CAN shd flex	shd abd	MAXIMUM ANGLE shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	21	-6	5	140	8	6	21
2_ra	37	4	13	84	-30	13	34
3_ra	77	30	12	93	-29	-2	-11
4_ra	69	18	27	102	-5	-25	11
5_ra	84	22	17	96	21	-6	22
6_ra	76	25	32	105	5	-9	12
7_ra	51	29	18	90	2	-26	19
8_ra	58	32	6	100	-1	3	8
9_ra	63	26	29	92	-17	-29	17
10_ra	55	26	11	96	-8	-26	-2
MEAN	59	21	17	100	-5	-10	13
SD	19	12	9	15	16	15	13
plus sd	78	33	26	115	11	5	26
minus sd	40	8	8	84	-22	-25	0

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Table H14							
	LIFTING CAN		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	16	11	15	47	12	12	11
2_ra	28	8	9	16	26	11	16
3_ra	96	40	33	117	11	8	16
4_ra	107	14	15	102	14	7	10
5_ra	107	27	26	131	56	7	24
6_ra	102	30	52	116	15	14	11
7_ra	53	38	25	45	23	13	11
8_ra	56	27	18	72	10	5	7
9_ra	76	27	12	89	29	9	17
10_ra	84	39	25	89	25	8	21
MEAN	73	26	23	82	22	9	14
SD	33	12	13	37	14	3	5
radians	1.3	0.5	0.4	1.4	0.4	0.2	0.3
sd	0.6	0.2	0.2	0.6	0.2	0.1	0.1
plus sd	1.8	0.7	0.6	2.1	0.6	0.2	0.3
minus sd	0.7	0.3	0.2	0.8	0.1	0.1	0.2
	LIFTING CAN		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	16	17	22	68	10	18	16
2_ra	78	10	12	24	31	54	16
3_ra	248	107	142	466	26	30	35
4_ra	247	19	54	362	23	17	17
5_ra	218	89	110	386	157	15	44
6_ra	193	64	192	378	22	16	23
7_ra	103	85	69	100	42	23	19
8_ra	95	50	43	214	18	10	9
9_ra	145	70	20	227	61	14	29
10_ra	245	106	139	624	58	28	58
MEAN	159	62	80	285	45	23	27
SD	83	37	62	192	43	13	15
radians	2.8	1.1	1.4	5.0	0.8	0.4	0.5
sd	1.5	0.6	1.1	3.3	0.7	0.2	0.3
plus sd	4.2	1.7	2.5	8.3	1.5	0.6	0.7
minus sd	1.3	0.4	0.3	1.6	0.0	0.2	0.2

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Table H15							
	COMB HAIR		RANGE OF MOTION				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	9	9	23	47	52	22	13
2_ra	41	10	29	93	60	33	11
3_ra	43	58	60	94	23	12	18
4_ra	102	68	43	71	44	18	50
5_ra	66	14	41	71	51	18	13
6_ra	51	42	38	85	44	14	14
7_ra	79	45	47	60	43	24	20
8_ra	65	36	44	89	35	10	16
9_ra	78	61	16	58	30	30	33
10_ra	55	32	29	83	45	18	45
MEAN	59	38	37	75	43	20	23
SD	26	21	13	16	11	7	14
plus sd	84	59	50	91	54	27	38
minus sd	33	16	24	59	32	12	9
	COMB HAIR		MINIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	2	-1	-20	89	-52	5	14
2_ra	-4	0	-15	49	-63	-6	21
3_ra	5	-4	-44	52	-40	-17	-20
4_ra	0	-1	-28	69	-37	-23	8
5_ra	-2	1	-26	68	-39	-13	-9
6_ra	13	0	-23	60	-40	-23	-10
7_ra	-5	5	-36	75	-31	-32	12
8_ra	0	-3	-31	62	-40	-8	-7
9_ra	3	3	-3	85	-26	-47	-5
10_ra	10	-2	-14	60	-26	-28	-26
MEAN	2	-0	-24	67	-39	-19	-2
SD	6	3	12	13	11	15	15
plus sd	8	2	-12	80	-28	-4	13
minus sd	-4	-3	-36	54	-51	-34	-18
	COMB HAIR		MAXIMUM ANGLE				
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	11	8	3	136	0	27	27
2_ra	37	10	14	142	-3	27	32
3_ra	48	54	16	146	-17	-5	-2
4_ra	102	67	15	140	7	-5	58
5_ra	64	15	15	139	12	5	4
6_ra	64	42	15	145	4	-9	4
7_ra	74	50	11	135	12	-8	32
8_ra	65	33	13	151	-5	2	9
9_ra	81	64	13	143	4	-17	28
10_ra	65	30	15	143	19	-10	19
MEAN	61	37	13	142	3	1	21
SD	25	22	4	5	10	15	18
plus sd	86	59	17	147	14	16	39
minus sd	36	16	9	137	-7	-14	3

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Table H16							
	COMB HAIR		MAXIMUM ANGULAR VELOCITY				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	7	5	14	27	28	12	8
2_ra	27	6	24	59	57	14	8
3_ra	57	71	94	148	25	19	38
4_ra	124	72	93	85	56	32	22
5_ra	81	14	39	99	57	19	13
6_ra	64	39	44	117	51	16	15
7_ra	76	42	73	90	23	32	20
8_ra	69	28	46	102	34	8	17
9_ra	104	69	19	63	40	39	30
10_ra	99	55	47	163	83	27	83
MEAN	71	40	49	95	45	22	25
SD	35	26	29	41	19	10	22
radians	1.2	0.7	0.9	1.7	0.8	0.4	0.4
sd	0.6	0.5	0.5	0.7	0.3	0.2	0.4
plus sd	1.8	1.2	1.4	2.4	1.1	0.6	0.8
minus sd	0.6	0.2	0.4	0.9	0.5	0.2	0.1
	COMB HAIR		MAXIMUM ANGULAR ACCELERATION				
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	8	6	22	33	33	16	12
2_ra	57	5	35	164	78	49	18
3_ra	143	189	283	447	70	36	111
4_ra	284	169	489	235	147	78	37
5_ra	179	27	69	255	133	35	17
6_ra	142	67	112	295	100	31	25
7_ra	135	91	199	232	54	86	35
8_ra	134	51	88	204	57	13	25
9_ra	247	128	43	104	103	129	59
10_ra	418	164	142	604	307	89	307
MEAN	175	90	148	257	108	56	65
SD	117	69	145	165	78	38	90
radians	3.0	1.6	2.6	4.5	1.9	1.0	1.1
sd	2.0	1.2	2.5	2.9	1.4	0.7	1.6
plus sd	5.1	2.8	5.1	7.4	3.3	1.6	2.7
minus sd	1.0	0.4	0.1	1.6	0.5	0.3	-0.4

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Table H17							
	TOUCH OPPOSITE SCAPULA			RANGE OF MOTION			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	33	5	43	69	43	7	9
2_ra	39	12	18	93	50	18	10
3_ra	68	29	34	88	30	16	17
4_ra	56	21	37	62	69	29	27
5_ra	95	33	28	45	55	18	12
6_ra	57	13	42	45	68	9	21
7_ra	68	19	22	89	11	24	10
8_ra	54	30	53	80	48	6	19
9_ra	81	14	57	61	115	110	46
10_ra	34	18	48	67	52	31	9
MEAN	59	19	38	70	54	27	18
SD	20	9	13	17	27	30	12
plus sd	79	28	51	87	81	57	30
minus sd	38	10	25	53	27	-4	6
	TOUCH OPPOSITE SCAPULA			MINIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	1	2	9	69	-18	11	16
2_ra	-2	-4	8	46	-14	-6	24
3_ra	-1	1	9	56	-34	-10	-20
4_ra	5	-15	17	61	-38	-5	9
5_ra	5	-13	25	72	-40	-9	-8
6_ra	5	-9	11	76	-27	2	-10
7_ra	17	-5	39	33	-22	-23	19
8_ra	15	-23	14	52	-9	2	-11
9_ra	7	7	-10	59	-27	-26	-8
10_ra	17	-19	18	49	-36	-13	-19
MEAN	7	-8	14	57	-27	-8	-1
SD	7	10	13	13	11	11	16
plus sd	14	2	27	70	-16	4	15
minus sd	-0	-18	1	44	-37	-19	-17
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	34	7	52	138	25	18	25
2_ra	37	8	26	139	36	12	34
3_ra	67	30	43	144	-4	6	-3
4_ra	61	6	54	123	31	24	36
5_ra	100	20	53	117	15	9	4
6_ra	62	4	53	121	41	11	11
7_ra	85	14	61	122	-11	1	29
8_ra	69	7	67	132	39	8	8
9_ra	88	21	47	120	88	84	38
10_ra	51	-1	66	116	16	18	-10
MEAN	65	12	52	127	28	19	17
SD	21	9	12	10	28	24	17
plus sd	87	21	64	137	55	43	35
minus sd	44	2	40	117	0	-5	-0

APPENDIX H - RA Group

Table H18							
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGULAR VELOCITY			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	23	4	32	51	31	6	6
2_ra	29	9	16	80	43	12	8
3_ra	113	34	62	119	59	23	19
4_ra	69	21	36	78	96	37	40
5_ra	123	39	33	52	82	16	11
6_ra	77	16	49	54	72	9	18
7_ra	68	25	22	87	12	26	9
8_ra	56	25	57	102	53	9	14
9_ra	116	14	68	85	115	223	57
10_ra	57	29	84	128	102	60	16
MEAN	73	22	46	84	67	42	20
SD	35	11	22	27	33	66	16
radians	1.3	0.4	0.8	1.5	1.2	0.7	0.3
sd	0.6	0.2	0.4	0.5	0.6	1.1	0.3
plus sd	1.9	0.6	1.2	1.9	1.7	1.9	0.6
minus sd	0.7	0.2	0.4	1.0	0.6	-0.4	0.1
	TOUCH OPPOSITE SCAPULA			MAXIMUM ANGULAR ACCELERATION			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	39	11	41	77	61	11	14
2_ra	71	13	34	207	57	18	11
3_ra	391	73	274	401	284	71	42
4_ra	136	63	56	180	240	84	126
5_ra	240	100	51	77	189	27	14
6_ra	194	55	81	92	145	14	27
7_ra	115	73	49	167	18	48	19
8_ra	93	58	108	233	96	17	20
9_ra	272	30	141	195	1131	1432	154
10_ra	174	91	269	517	362	210	46
MEAN	173	57	110	215	258	193	47
SD	106	30	91	143	326	439	51
radians	3.0	1.0	1.9	3.7	4.5	3.4	0.8
sd	1.9	0.5	1.6	2.5	5.7	7.7	0.9
plus sd	4.9	1.5	3.5	6.2	10.2	11.0	1.7
minus sd	1.2	0.5	0.3	1.3	-1.2	-4.3	-0.1

APPENDIX H - RA Group

Table H19							
	TOUCH SACRUM			RANGE OF MOTION			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	52	5	34	30	70	18	18
2_ra	44	12	17	18	118	51	6
3_ra	64	18	79	42	106	26	12
4_ra	64	11	52	19	107	8	6
5_ra	50	15	34	22	119	18	13
6_ra	55	16	46	8	132	21	15
7_ra	83	19	11	45	103	12	10
8_ra	76	21	61	39	60	43	17
9_ra	55	53	60	23	112	61	19
10_ra	71	19	45	50	98	28	17
MEAN	61	19	44	30	103	29	13
SD	12	13	21	14	22	17	5
plus sd	74	32	65	43	125	46	18
minus sd	49	6	23	16	80	11	9
	TOUCH SACRUM			MINIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	-51	0	-11	69	-63	0	14
2_ra	-40	-3	6	47	-90	-23	26
3_ra	-48	1	2	58	-90	-25	-14
4_ra	-39	7	20	73	-90	-13	17
5_ra	-52	-1	20	54	-76	-6	-8
6_ra	-42	-1	20	71	-90	-13	-1
7_ra	-62	7	50	56	-83	-23	6
8_ra	-59	2	4	61	-47	-21	-3
9_ra	-49	-15	-11	60	-90	-87	13
10_ra	-42	1	29	49	-90	-33	-34
MEAN	-48	-0	13	60	-81	-24	2
SD	8	6	19	9	15	24	18
plus sd	-41	6	32	69	-66	-0	19
minus sd	-56	-6	-6	51	-96	-48	-16
	TOUCH SACRUM			MAXIMUM ANGLE			
SUBJECT	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	1	5	23	99	7	18	32
2_ra	4	9	23	65	28	28	32
3_ra	16	19	81	100	16	1	-2
4_ra	25	18	72	92	17	-5	23
5_ra	-2	14	54	76	43	12	5
6_ra	13	15	66	79	42	8	14
7_ra	21	26	61	101	20	-11	16
8_ra	17	23	65	100	13	22	14
9_ra	6	38	49	83	22	-26	32
10_ra	29	20	74	99	8	-5	-17
MEAN	13	19	57	89	22	4	15
SD	10	9	20	13	13	17	16
plus sd	23	28	77	102	34	21	31
minus sd	3	9	37	77	9	-12	-1

APPENDIX H - RA Group

Table H20							
	TOUCH SACRUM			MAXIMUM ANGULAR VELOCITY			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_n	37	5	34	22	63	12	7
2_n	35	12	14	19	39	30	4
3_n	55	17	125	76	134	24	16
4_n	85	19	100	22	129	9	6
5_n	59	25	56	29	176	22	13
6_n	71	21	72	10	204	38	16
7_n	106	31	14	43	153	11	10
8_n	74	25	98	34	47	48	17
9_n	65	57	76	36	153	94	31
10_n	103	40	96	77	230	58	28
MEAN	69	25	69	37	133	35	15
SD	24	15	38	23	65	26	9
radians	1.2	0.4	1.2	0.6	2.3	0.6	0.3
sd	0.4	0.3	0.7	0.4	1.1	0.5	0.2
plus sd	1.6	0.7	1.9	1.0	3.5	1.1	0.4
minus sd	0.8	0.2	0.5	0.2	1.2	0.1	0.1
	TOUCH SACRUM			MAXIMUM ANGULAR ACCELERATION			
SUBJEC	shd flex	shd abd	shd rot	elb flex	elb pro	wst flex	wst dev
1_ra	63	12	74	45	112	20	13
2_ra	43	22	19	40	101	69	6
3_ra	129	28	474	345	257	32	13
4_ra	206	52	428	43	260	19	14
5_ra	103	56	236	82	392	50	23
6_ra	146	49	241	24	986	302	32
7_ra	231	95	36	85	493	28	15
8_ra	109	65	282	44	66	97	34
9_ra	123	101	152	143	621	352	110
10_ra	314	152	485	283	1465	349	132
MEAN	147	63	243	113	475	132	39
SD	82	43	176	112	448	142	44
radians	2.6	1.1	4.2	2.0	8.3	2.3	0.7
sd	1.4	0.7	3.1	2.0	7.8	2.5	0.8
plus sd	4.0	1.8	7.3	3.9	16.1	4.8	1.5
minus sd	1.1	0.4	1.2	0.0	0.5	-0.2	-0.1

APPENDIX I

Figure 11. Pain Change Score.
Lift Bottle

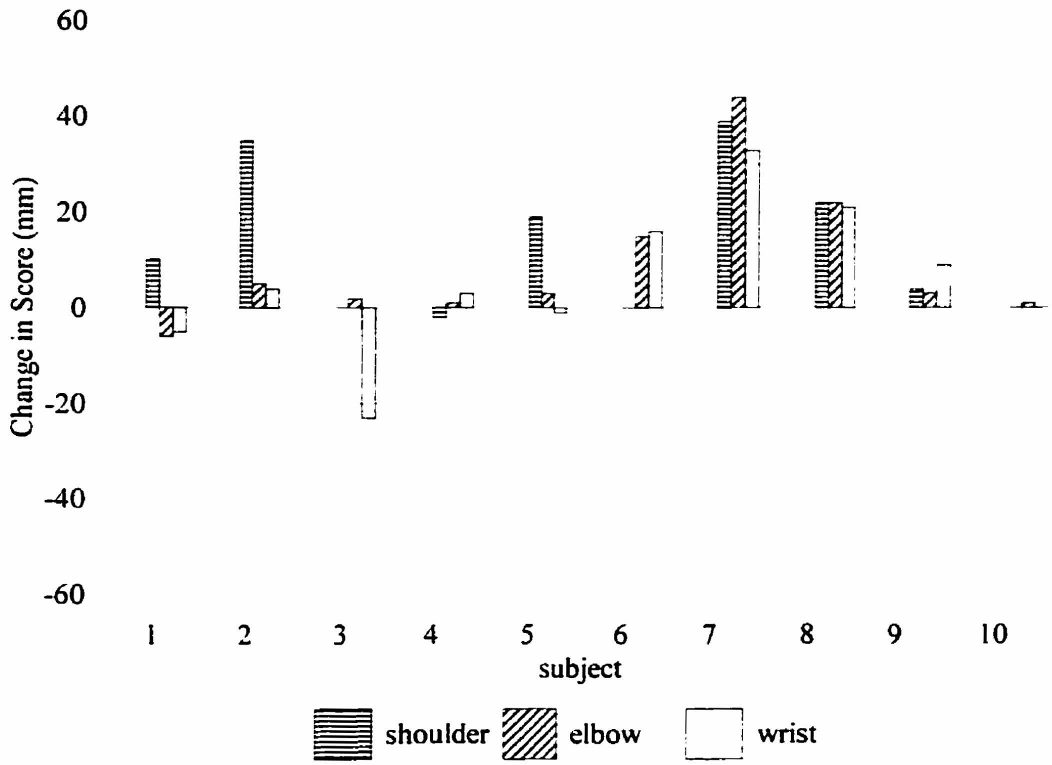


Figure I2. Pain Change Score
Lift Can

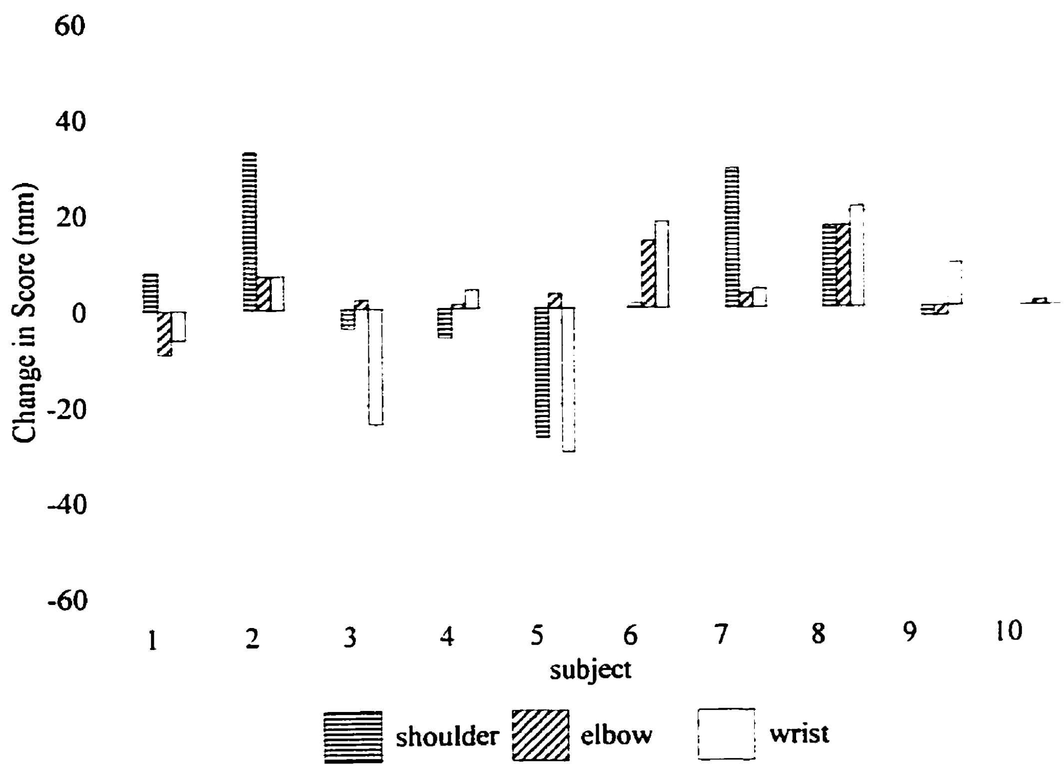


Figure 13. Pain Change Score.
Comb Hair

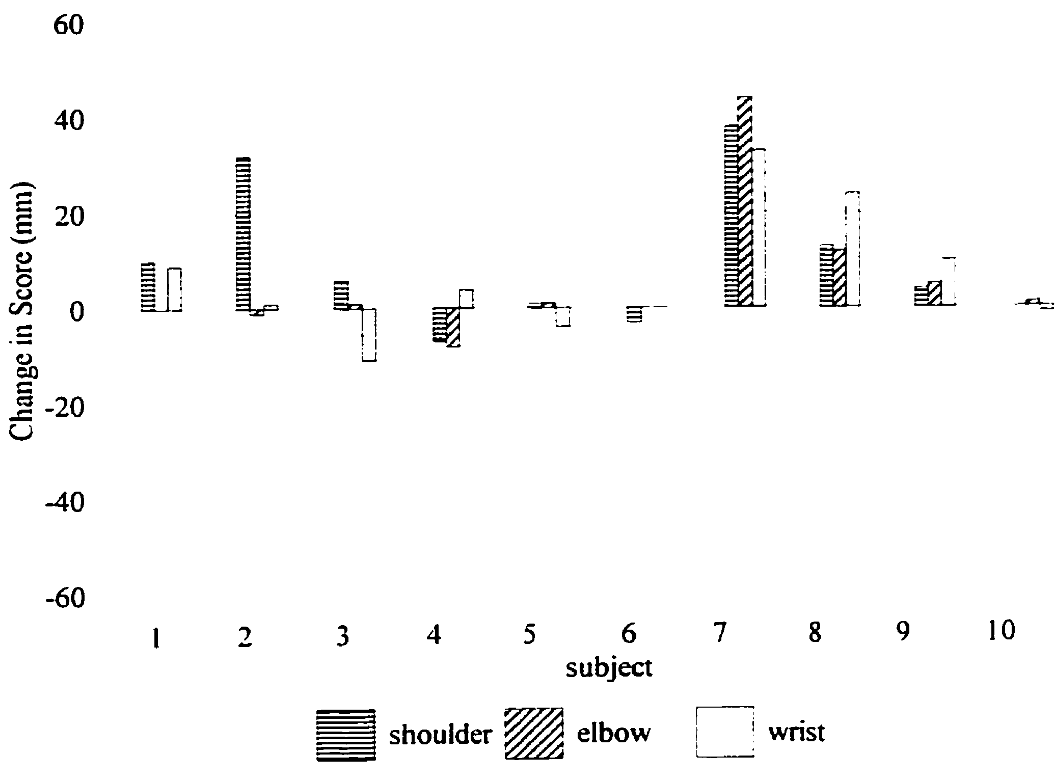


Figure I4. Pain Change Score.
Touch Opposite Scapula

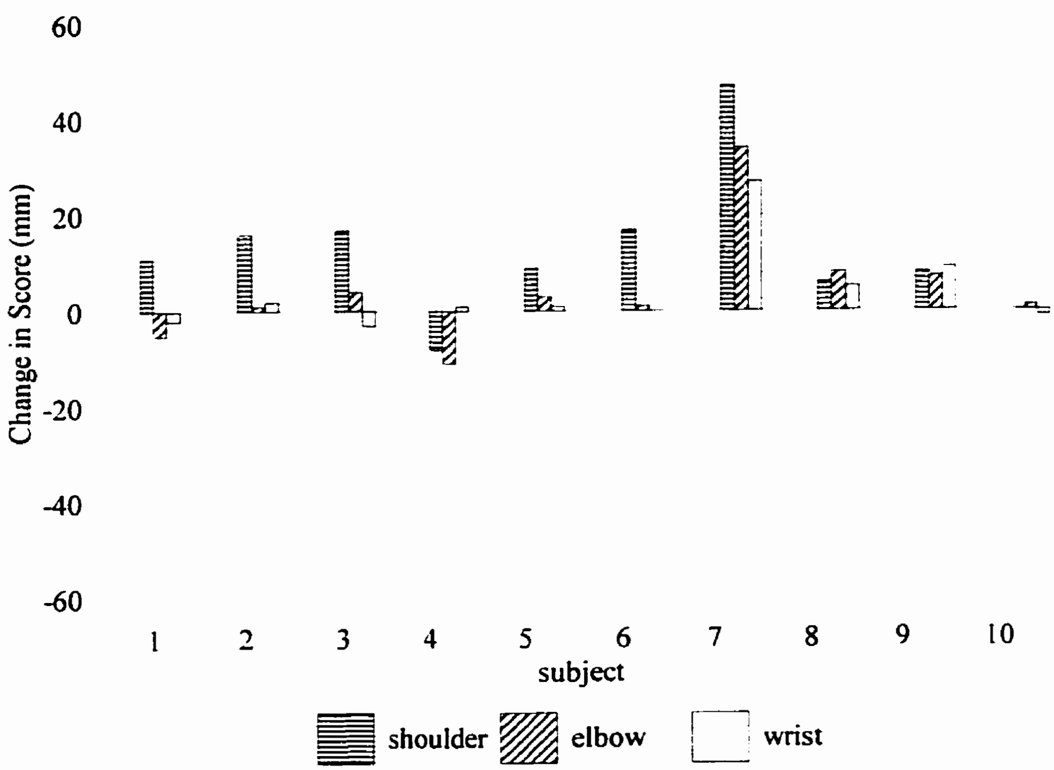


Figure 15.
Pain Change Score.Touch Sacrum

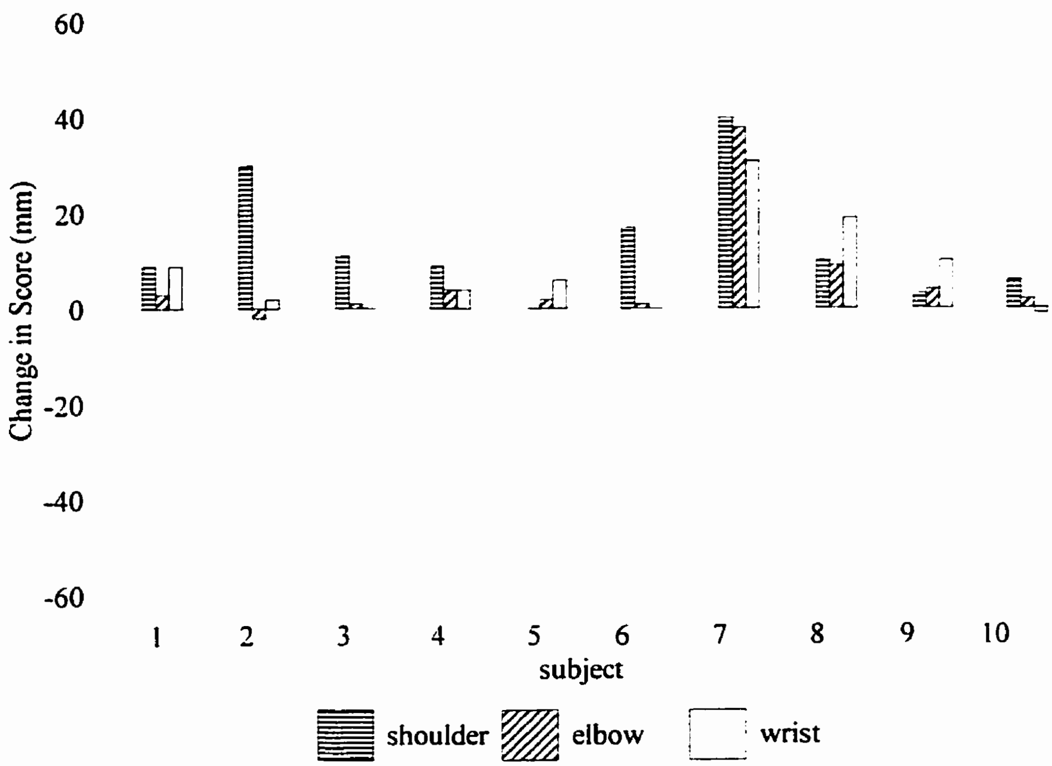


Figure I6. Post-Task Pain score.
Lift Bottle.

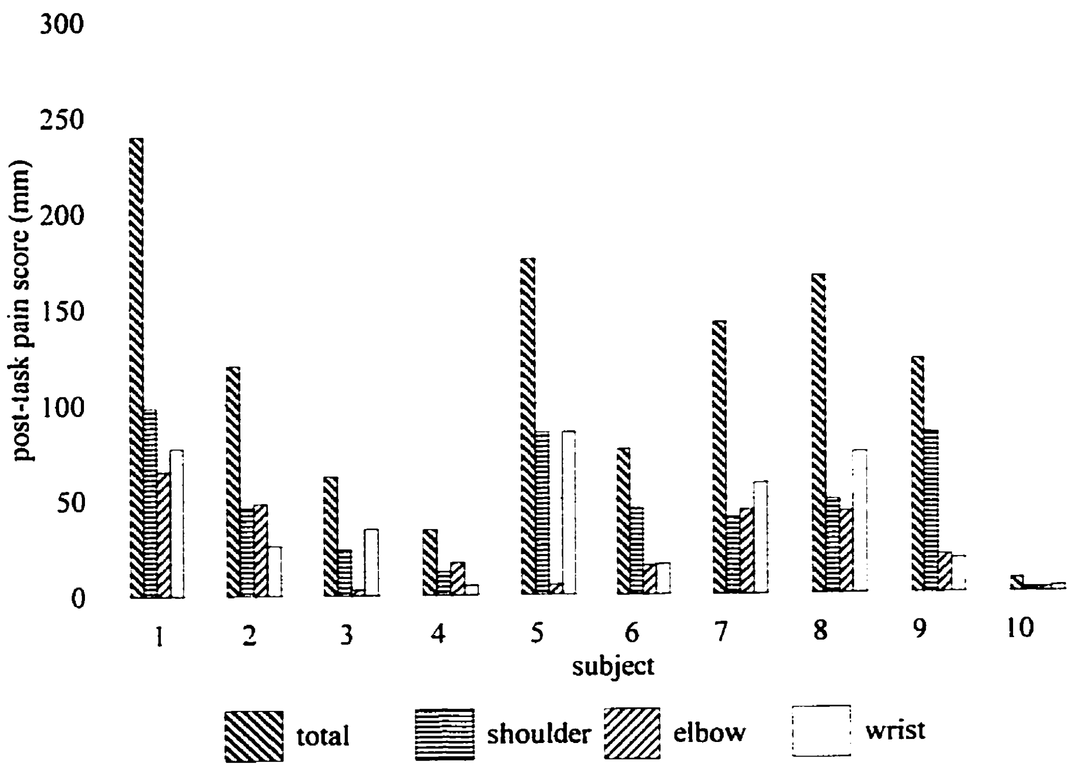


Figure I7. Post-Task Pain Score.
Lift Can.

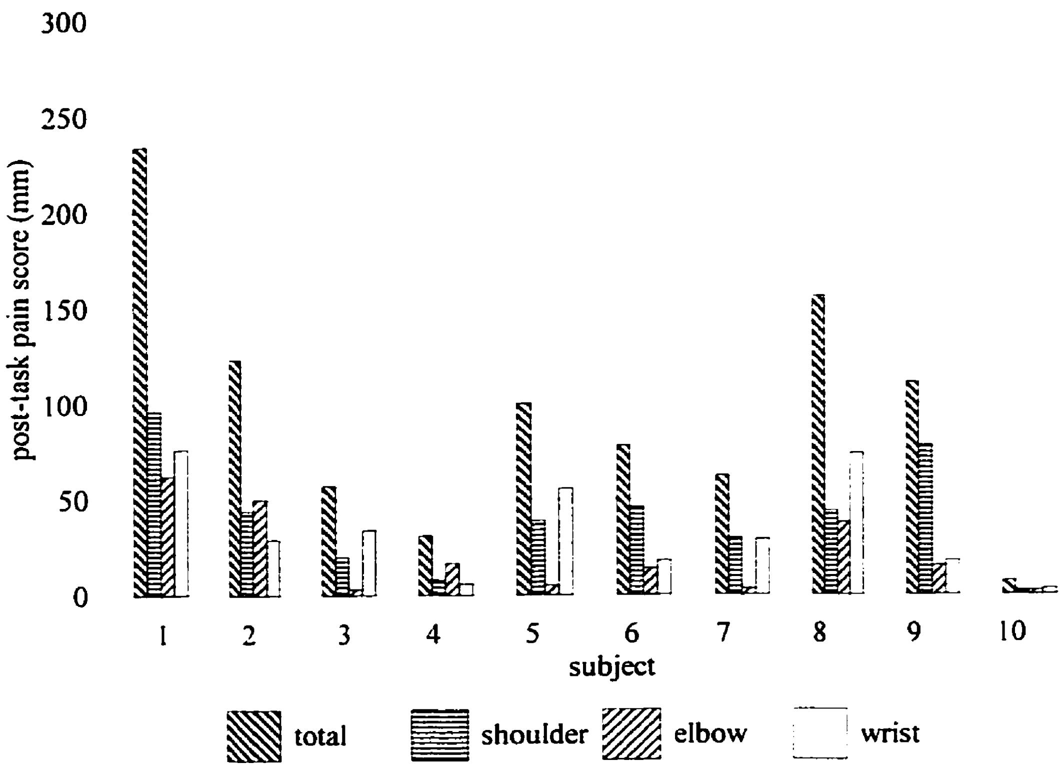


Figure I8. Post-Task Pain Score.
Comb Hair.

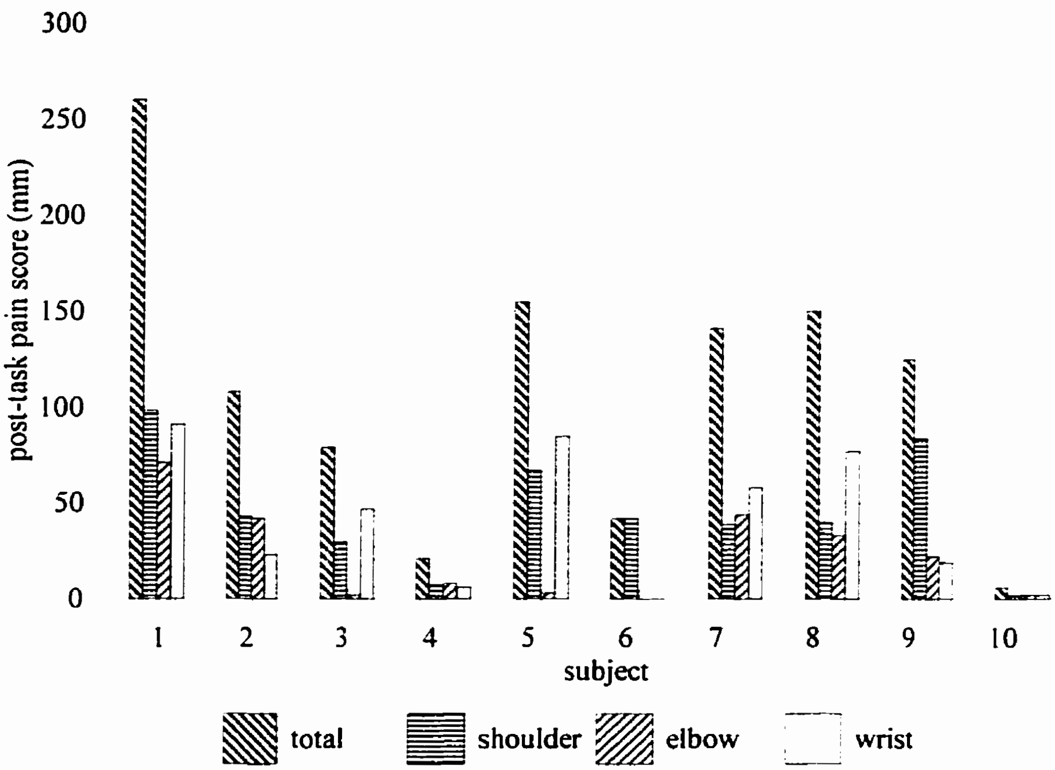


Figure I9. Post-Task Pain Score.
Touch Opposite Scapula.

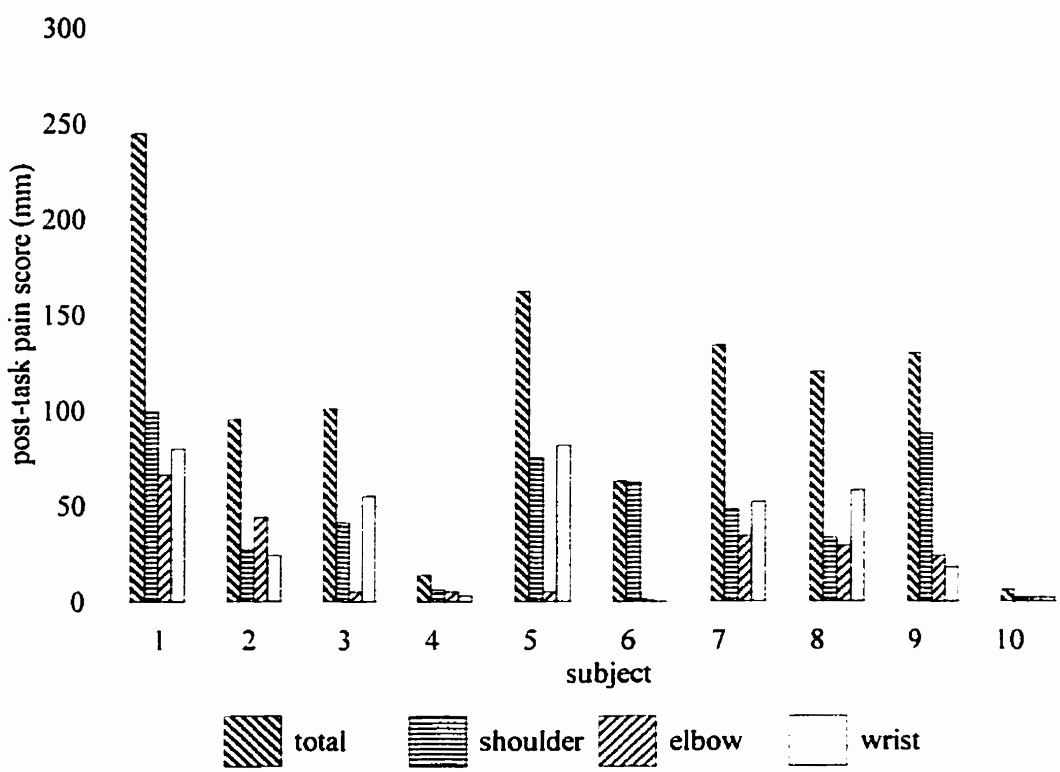
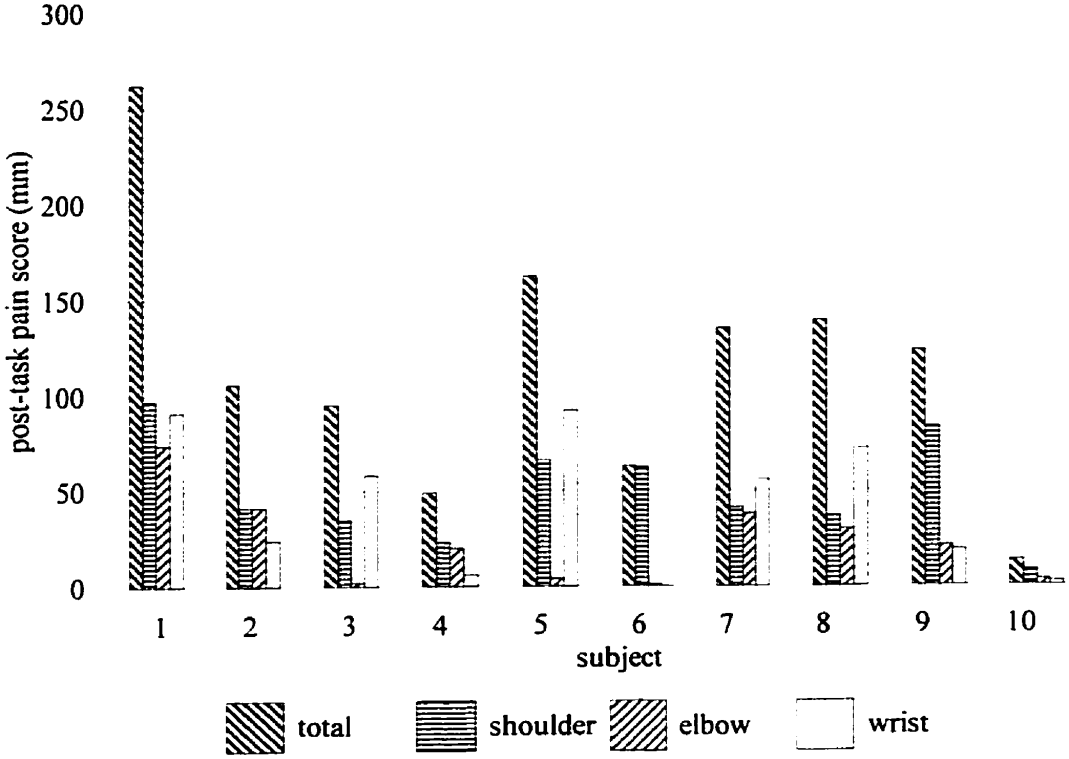


Figure I10. Post-Task Pain Score.
Touch Sacrum.



APPENDIX J

Table J1. Lift Bottle - Correlation Between Joint Rotation Angular Acceleration and Visual Analog Pain Scale Scores.

BOTTLE	MAXIMUM ANGULAR ACCELERATION						
	shoulder joint			elbow region		wrist region	
VAS	**flexion/ extension**	**abduction/ adduction**	**int/external rotation**	**flexion**	**pronation/ supination**	**flexion/ extension**	**ulnar/radial deviation**
change in pain (CPS)	r=-0.61 p=0.061	r=-0.31 p=0.38	r=-0.49 p=0.15				
post-task pain (PTP)	r=-0.55 p=0.10	r=-0.56 p=0.091	r=-0.49 p=0.15				
change in pain (CPS)				r=-0.13 p=0.72	r=0.12 p=0.73		
post-task pain (PTP)				r=-0.83 p=0.0032*	r=-0.62 p=0.053		
change in pain (CPS)						r=-0.38 p=0.28	r=0.27 p=0.45
post-task pain (PTP)						r=-0.70 p=0.023*	r=-0.41 p=0.24

*significant at $p<0.05$

Table J2. Lift Can - Correlation Between Joint Rotation Angular Acceleration and Visual Analog Pain Scale Score.

CAN	MAXIMUM ANGULAR ACCELERATION						
	shoulder joint			elbow region		wrist region	
VAS	flexion/ extension	abduction/ adduction	int/external rotation	flexion	pronation/ supination	flexion/ extension	ulnar/radial deviation
change in pain (CPS)	r=-0.67 p=0.033*	r=-0.39 p=0.27	r=-0.44 p=0.20				
post-task pain (PTP)	r=-0.75 p=0.013*	r=-0.41 p=0.24	r=-0.48 p=0.16				
change in pain (CPS)				r=-0.067 p=0.85	r=-0.11 p=0.77		
post-task pain (PTP)				r=-0.71 p=0.022*	r=-0.46 p=0.18		
change in pain (CPS)						r=-0.097 p=0.79	r=-0.54 p=0.10
post-task pain (PTP)						r=-0.26 p=0.46	r=-0.38 p=0.28

*significant at $p<0.05$

Table J3. Comb Hair - Correlation Between Joint Rotation Angular Acceleration and Visual Analog Pain Scale Scores.

COMB HAIR	MAXIMUM ANGULAR ACCELERATION						
	shoulder joint			elbow region		wrist region	
VAS	flexion/ extension	abduction/ adduction	int/external rotation	flexion	pronation/ supination	flexion/ extension	ulnar/radial deviation
change in pain (CPS)	r=-0.52 p=0.13	r=-0.42 p=0.24	r=-0.30 p=0.40				
post-task pain (PTP)	r=-0.60 p=0.067	r=-0.61 p=0.062	r=-0.68 p=0.032*				
change in pain (CPS)				r=-0.080 p=0.82	r=-0.31 p=0.39		
post-task pain (PTP)				r=-0.70 p=0.023*	r=-0.59 p=0.071		
change in pain (CPS)						r=-0.15 p=0.68	r=-0.309 p=0.41
post-task pain (PTP)						r=-0.55 p=0.10	r=-0.43 p=0.22

*significant at p<0.05

Table J4. Touch Opposite Scapula - Correlation Between Joint Rotation Angular Acceleration and Visual Analog Pain Scale Score.

SCAPULA							
	shoulder joint			elbow region		wrist region	
VAS	flexion/ extension	abduction/ adduction	int/external rotation	flexion	pronation/ supination	flexion/ extension	ulnar/radial deviation
change in pain (CPS)	r=-0.036 p=0.92	r=-0.014 p=0.97	r=-0.210 p=0.57				
post-task pain (PTP)	r=0.081 p=0.82	r=-0.37 p=0.30	r=-0.33 p=0.35				
change in pain (CPS)				r=-0.0023 p=0.99	r=-0.072 p=0.61		
post-task pain (PTP)				r=-0.37 p=0.29	r=-0.22 p=0.54		
change in pain (CPS)						r=0.18 p=0.61	r=0.03 p=0.94
post-task pain (PTP)						r=-0.28 p=0.44	r=-0.51 p=0.13

*significant at p<0.05

Table J5. Touch Sacrum - Correlation Between Joint Rotation Angular Acceleration and Visual Analog Pain Scale Scores.

SACRUM	MAXIMUM ANGULAR ACCELERATION						
	shoulder joint			elbow region		wrist region	
VAS	flexion/ extension	abduction/ adduction	int/external rotation	flexion	pronation/ supination	flexion/ extension	ulnar/radial deviation
change in pain (CPS)	r=0.042 p=0.91	r=-0.10 p=0.78	r=-0.55 p=0.10				
post-task pain (PTP)	r=-0.65 p=0.042*	r=-0.41 p=0.24	r=-0.61 p=0.062				
change in pain (CPS)				r=-0.13 p=0.72	r=-0.033 p=0.93		
post-task pain (PTP)				r=-0.48 p=0.16	r=-0.56 p=0.094		
change in pain (CPS)						r=-0.29 p=0.41	r=-0.16 p=0.66
post-task pain (PTP)						r=-0.634 p=0.049*	r=-0.45 p=0.19

*significant at $p<0.05$

Table J6. Correlation Between Task Joint Maximum Angular Acceleration and Sum of Post-Task Pain Scores (ΣPTP).

	lift bottle	lift can	combhair	touch scapula	touch sacrum
shoulder flex/extension	r=-0.77 p=0.0091*	r=-0.84 p=0.0023*	r=-0.73 p=0.017*	r=-0.19 p=0.60	r=-0.66 p=0.039*
shoulder abd/adduction	r=-0.63 p=0.05*	r=-0.55 p=0.10	r=-0.69 p=0.028*	r=-0.40 p=0.26	r=-0.51 p=0.13
shoulder int/ext rotation	r=-0.63 p=0.047*	r=-0.56 p=0.093	r=-0.57 p=0.085	r=-0.41 p=0.24	r=-0.63 p=0.052
elbow flexion	r=-0.74 p=0.015*	r=-0.70 p=0.024*	r=-0.73 p=0.018*	r=-0.56 p=0.089	r=-0.37 p=0.30
forearm pron/supination	r=-0.24 p=0.50	r=-0.18 p=0.61	r=-0.68 p=0.030*	r=-0.10 p=0.78	r=-0.62 p=0.058
wrist flexion/extension	r=-0.48 p=0.16	r=-0.13 p=0.71	r=-0.38 p=0.28	r=-0.026 p=0.94	r=-0.048 p=0.16
wrist rad/ulnar deviation	r=-0.56 p=0.096	r=-0.54 p=0.10	r=-0.56 p=0.096	r=-0.34 p=0.34	r=-0.41 p=0.24

***significant at p<0.05**

Table J7. Linear Regression Equation of Angular Acceleration and Post-Task Pain (PTP) Score (degrees of freedom = 1,8).

		linear regression	r value	r^2 value	F value	p value
lift bottle	***shoulder flexion/extension***	VAS sh bot = 78.8 - (0.24 * sh fl/ex bot)	0.55	0.30	3.40	0.10
	shoulder abduction/adduction	VAS sb bot = 75.5 - (0.53 * sh ab/ad bot)	0.56	0.32	3.69	0.091
	shoulder int/ext rotation	VAS sh bot = 66.6 - (0.29 * sh rot bot)	0.49	0.24	2.54	0.15
	elbow flexion	VAS elb bot = 50.0 - (0.11 * el flexbot)	0.83	0.68	17.20	0.0032*
	forearm pron/supination	VAS elb bot = 52.7 - (0.73 * pron bot)	0.62	0.39	5.13	0.053
	wrist flexion/extension	VAS wst bot = 87.7 - (2.82 * wst flex bot)	0.70	0.50	7.87	0.023*
	wrist radial/ulnar deviation	VAS wst bot = 60.9 - (1.22 * wst dev bot)	0.41	0.17	1.63	0.24
lift can	***shoulderflexion/extension***	VAS sh can = 82.3 - (0.26 * sh fl/ex can)	0.75	0.56	10.20	0.013*
	shoulder abduction/adduction	VAS sh can = 60.8 - (0.33 * sh ab/ad can)	0.41	0.17	1.61	0.24
	shoulder int/external rotation	VAS sh can = 59.0 - (0.23 * sh rot can)	0.48	0.23	2.45	0.16
	elbow flexion	VAS elb can = 43.6 - (0.080 * el flex can)	0.71	0.50	8.01	0.022*
	forearm pron/supination	VAS elb can = 31.2 - (0.23 * pron can)	0.46	0.21	2.11	0.18
	wrist flexion/extension	VAS wst can = 46.5 - (0.54 * wst flex can)	0.26	0.070	0.60	0.46
	wrist radial/ulnar deviation	VAS wst can = 51.9 - (0.66 * wst dev can)	0.38	0.15	1.37	0.28

*significant at $p<0.05$

		linear regression	r value	r^2 value	F value	p value
comb hair	***shoulder flexion/extension***	VAS sh com = 72.5 - (0.27 * sh fl/ex com)	0.60	0.36	4.48	0.067
	shoulder abduction/adduction	VAS sh com = 69.2 - (0.27 * sh ab/ad com)	0.61	0.37	4.69	0.062
	shoulder int/external rotation	VAS sh com = 66.4 - (0.14 * sh rot com)	0.68	0.46	6.77	0.032*
	elbow flexion	VAS el com = 49.3 - (0.10 * el flex com)	0.70	0.50	7.88	0.023*
	forearm pron/supination	VAS el com = 42.4 - (0.18 * pron com)	0.59	0.35	4.33	0.071
	wrist flexion/extension	VAS wst com = 69.8 - (0.52 * pron com)	0.55	0.30	3.45	0.10
	wrist radial/ulnar deviation	VAS wst com = 51.7 - (0.17 * pron com)	0.43	0.18	1.79	0.22
touch opposite scapula	***shoulder flexion/extension***	VAS sh opp = 43.8 - (0.025 * sh fl/ex opp)	0.081	0.0066	0.053	0.82
	shoulder abduction/adduction	VAS sh opp = 70.6 - (0.40 * sh ab/ad opp)	0.37	0.14	1.25	0.30
	shoulder int/external rotation	VAS sh opp = 61.2 - (0.12 * sh rot opp)	0.33	0.11	0.97	0.35
	elbow flexion	VAS el opp = 33.7 - (0.057 * el flex opp)	0.37	0.14	1.27	0.29
	forearm pron/supination	VAS el opp = 25.3 - (0.015 * pron opp)	0.22	0.048	0.40	0.54
	wrist flexion/extension	VAS wst opp = 41.2 - (0.020 * wst flex opp)	0.28	0.077	0.66	0.44
	wrist radial/ulnar deviation	VAS wst opp = 52.7 - (0.32 * wst dev opp)	0.51	0.26	2.86	0.13

*significant at $p<0.05$

		linear regression	r value	r^2 value	F value	p value
touch sacrum	***shoulder flexion/extension***	VAS sh sac = 81.1 - (0.22 * sh fl/ex sac)	0.65	0.42	5.83	0.40
	shoulder abduction/adduction	VAS sh sac = 65.9 - (0.26 * sh ab/ad sac)	0.41	0.17	1.61	0.24
	shoulder int/external rotation	VAS sh sac = 72.3 - (0.095 * sh rot sac)	0.61	0.37	4.71	0.062
	elbow flexion	VAS el sac = 34.7 - (0.10 * el flex sac)	0.48	0.23	2.38	0.16
	forearm pron/supination	VAS el sac = 37.2 - (0.029 * pron sac)	0.56	0.31	3.61	0.094
	wrist flexion/extension	VAS wst sac = 63.2 - (0.16 * wst flex sac)	0.63	0.40	5.38	0.049*
	wrist radial/ulnar deviation	VAS wst sac = 56.5 - (0.37 * wst dev sac)	0.45	0.21	2.07	0.19

*significant at $p<0.05$

APPENDIX K

Tables K1-K3 . Lift Bottle - Correlation between ROM, pain and perceived disability.

shoulder flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.35 p=0.32	r=-0.34 p=0.34	r=-0.73 p=0.016*
change in pain (CPS)		1.0		r=0.59 p=0.074
post-task pain (PTP)			1.0	r=0.62 p=0.055
disability				1.0

shoulder abd/adduction	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.19 p=0.59	r=-0.57 p=0.084	r=-0.68 p=0.032*
change in pain (CPS)		1.0		r=0.59 p=0.074
post-task pain (PTP)			1.0	r=0.62 p=0.055
disability				1.0

shoulder int/ext rotation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.41 p=0.23	r=-0.22 p=0.54	r=-0.55 p=0.10
change in pain (CPS)		1.0		r=0.59 p=0.074
post-task pain (PTP)			1.0	r=0.62 p=0.055
disability				1.0

*significant at $p<0.05$

Tables K4-K5 . Lift Bottle - Correlation between ROM, pain and perceived disability.

elbow flexion	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.19 p=0.61	r=-0.73 p=0.017*	r=-0.59 p=0.07
change in pain (CPS)		1.0		r=0.060 p=0.87
post-task pain (PTP)			1.0	r=0.82 p=0.0034*
disability				1.0

forearm pronation/supination	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.17 p=0.64	r=-0.32 p=0.36	r=-0.56 p=0.094
change in pain (CPS)		1.0		r=0.060 p=0.87
post-task pain (PTP)			1.0	r=0.82 p=0.0034*
disability				1.0

*significant at $p<0.05$

Tables K6-K7. Lift Bottle - Correlation between ROM, pain and perceived disability.

wrist flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.15 p=0.68	r=0.073 p=0.84	r=-0.38 p=0.29
change in pain (CPS)		1.0		r=0.20 p=0.58
post-task pain (PTP)			1.0	r=0.42 p=0.22
disability				1.0

wrist ulnar/radial deviation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.30 p=0.39	r=0.12 p=0.74	r=-0.60 p=0.066
change in pain (CPS)		1.0		r=0.20 p=0.58
post-task pain (PTP)			1.0	r=0.42 p=0.22
disability				1.0

*significant at p<0.05

Tables K8 - K10 . Lift Can - Correlation between ROM, pain and perceived disability

shoulder flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.55 p=0.10	r=-0.52 p=0.12	r=-0.51 p=0.13
change in pain (CPS)		1.0		r=-0.58 p=0.076
post-task pain (PTP)			1.0	r=0.73 p=0.016*
disability				1.0

shoulder abd/adduction	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.17 p=0.63	r=-0.31 p=0.39	r=-0.32 p=0.37
change in pain (CPS)		1.0		r=0.58 p=0.076
post-task pain (PTP)			1.0	r=0.73 p=0.016*
disability				1.0

shoulder int/ext rotation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.056 p=0.88	r=0.12 p=0.74	r=-0.0027 p=0.99
change in pain (CPS)		1.0		r=0.58 p=0.076
post-task pain (PTP)			1.0	r=0.73 p=0.016*
disability				1.0

*significant at p<0.05

Tables K11 - K12. Lift Can - Correlation between ROM, pain and perceived disability

elbow flexion	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.019 p=0.96	r=-0.52 p=0.13	r=-0.33 p=0.36
change in pain (CPS)		1.0		r=0.086 p=0.81
post-task pain (PTP)			1.0	r=0.84 p=0.0026*
disability				1.0

forearm pronation/supination	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.087 p=0.81	r=-0.21 p=0.56	r=0.12 p=0.74
change in pain (CPS)		1.0		r=0.086 p=0.81
post-task pain (PTP)			1.0	r=0.84 p=0.0026*
disability				1.0

*significant at p<0.05

Tables K13 - K14. Lift Can - Correlation between ROM, pain and perceived disability

wrist flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.36 p=0.30	r=0.13 p=0.73	r=0.75 p=0.012*
change in pain (CPS)		1.0		r=0.29 p=0.42
post-task pain (PTP)			1.0	r=0.57 p=0.87
disability				1.0

wrist ulnar/radial deviation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.71 p=0.020*	r=0.29 p=0.42	r=-0.0085 p=0.98
change in pain (CPS)		1.0		r=0.20 p=0.58
post-task pain (PTP)			1.0	r=0.57 p=0.87
disability				1.0

*significant at p<0.05

Tables K15-K17. Comb Hair -Correlation between ROM, pain and perceived disability.

shoulder flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.15 p=0.67	r=-0.44 p=0.21	r=-0.48 p=0.16
change in pain (CPS)		1.0		r=0.58 p=0.081
post-task pain (PTP)			1.0	r=0.64 p=0.048*
disability				1.0

shoulder abd/adduction	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.33 p=0.36	r=-0.40 p=0.26	r=-0.56 p=0.094
change in pain (CPS)		1.0		r=0.58 p=0.081
post-task pain (PTP)			1.0	r=0.64 p=0.048*
disability				1.0

shoulder int/ext rotation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.051 p=0.88	r=-0.50 p=0.14	r=-0.37 p=0.29
change in pain (CPS)		1.0		r=0.58 p=0.081
post-task pain (PTP)			1.0	r=0.64 p=0.048*
disability				1.0

*significant at $p<0.05$

Tables K18-K19 . Comb Hair -Correlation between ROM, pain and perceived disability.

elbow flexion	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.26 p=0.47	r=-0.52 p=0.13	r=-0.12 p=0.74
change in pain (CPS)		1.0		r=0.078 p=0.83
post-task pain (PTP)			1.0	r=0.64 p=0.048*
disability				1.0

forearm pronation/supination	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.13 p=0.73	r=0.37 p=0.30	r=0.41 p=0.24
change in pain (CPS)		1.0		r=0.077 p=0.083
post-task pain (PTP)			1.0	r=0.64 p=0.048*
disability				1.0

***significant at p<0.05**

Tables K20-K21. Comb Hair -Correlation between ROM, pain and perceived disability.

wrist flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.13 p=0.71	r=-0.16 p=0.65	r=-0.49 p=0.15
change in pain (CPS)		1.0		r=0.29 p=0.42
post-task pain (PTP)			1.0	r=0.39 p=0.26
disability				1.0

wrist ulnar/radial deviation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.063 p=0.86	r=-0.60 p=0.068	r=-0.70 p=0.025*
change in pain (CPS)		1.0		r=0.29 p=0.41
post-task pain (PTP)			1.0	r=0.39 p=0.26
disability				1.0

*significant at $p<0.05$

Tables K22-K24. Touch Opposite Scapula-Correlation between ROM, pain and disability.

shoulder flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.19 p=0.61	r=0.37 p=0.29	r=-0.22 p=0.54
change in pain (CPS)		1.0		r=0.27 p=0.45
post-task pain (PTP)			1.0	r=0.45 p=0.19
disability				1.0

shoulder abd/adduction	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.095 p=0.79	r=-0.28 p=0.43	r=-0.43 p=0.21
change in pain (CPS)		1.0		r=0.27 p=0.45
post-task pain (PTP)			1.0	r=0.45 p=0.19
disability				1.0

shoulder int/ext rotation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.52 p=0.12	r=-0.11 p=0.77	r=-0.20 p=0.59
change in pain (CPS)		1.0		r=0.27 p=0.45
post-task pain (PTP)			1.0	r=0.45 p=0.19
disability				1.0

*significant at $p<0.05$

Tables K25-K26.Touch Opposite Scapula-Correlation between ROM, pain and disability.

elbow flexion	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.40 p=0.24	r=0.46 p=0.18	r=-0.33 p=0.36
change in pain (CPS)		1.0		r=0.058 p=0.87
post-task pain (PTP)			1.0	r=0.82 p=0.0034*
disability				1.0

forearm pronation/supination	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.44 p=0.21	r=-0.21 p=0.56	r=-0.014 p=0.97
change in pain (CPS)		1.0		r=0.058 p=0.87
post-task pain (PTP)			1.0	r=0.82 p=0.0034*
disability				1.0

*significant at $p<0.05$

Tables K27-K28. Touch Opposite Scapula-Correlation between ROM, pain and disability.

wrist flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.25 p=0.48	r=-0.34 p=0.34	r=-0.11 p=0.76
change in pain (CPS)		1.0		r=0.091 p=0.80
post-task pain (PTP)			1.0	r=0.35 p=0.32
disability				1.0

wrist ulnar/radial deviation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.063 p=0.86	r=-0.40 p=0.25	r=-0.094 p=0.80
change in pain (CPS)		1.0		r=0.091 p=0.80
post-task pain (PTP)			1.0	r=0.35 p=0.32
disability				1.0

***significant at p<0.05**

Tables K29-K31. Touch Sacrum -Correlation between ROM, pain and disability.

shoulder flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.28 p=0.44	r=-0.54 p=0.10	r=-0.45 p=0.19
change in pain (CPS)		1.0		r=0.36 p=0.32
post-task pain (PTP)			1.0	r=0.56 p=0.092
disability				1.0

shoulder abd/adduction	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.23 p=0.52	r=0.20 p=0.58	r=-0.082 p=0.82
change in pain (CPS)		1.0		r=0.36 p=0.32
post-task pain (PTP)			1.0	r=0.56 p=0.092
disability				1.0

shoulder int/ext rotation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.64 p=0.045*	r=-0.11 p=0.77	r=-0.40 p=0.25
change in pain (CPS)		1.0		r=0.36 p=0.32
post-task pain (PTP)			1.0	r=0.56 p=0.092
disability				1.0

***significant at p<0.05**

Tables K32 -K33. Touch Sacrum -Correlation between ROM, pain and disability.

elbow flexion	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.045 p=0.19	r=-0.036 p=0.92	r=-0.34 p=0.33
change in pain (CPS)		1.0		r=-0.040 p=0.91
post-task pain (PTP)			1.0	r=0.72 p=0.018*
disability				1.0

forearm pronation/supination	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.17 p=0.64	r=-0.57 p=0.085	r=-0.22 p=0.54
change in pain (CPS)		1.0		r=-0.040 p=0.091
post-task pain (PTP)			1.0	r=0.72 p=0.018*
disability				1.0

*significant at $p<0.05$

Table K34 - K35. Touch Sacrum -Correlation between ROM, pain and disability.

wrist flexion/extension	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=-0.043 p=0.90	r=-0.17 p=0.64	r=0.45 p=0.19
change in pain (CPS)		1.0		r=0.24 p=0.50
post-task pain (PTP)			1.0	r=0.35 p=0.32
disability				1.0

wrist ulnar/radial deviation	ROM	change in pain (CPS)	post-task pain (PTP)	disability
ROM	1.0	r=0.15 p=0.68	r=0.20 p=0.59	r=-0.017 p=0.96
change in pain (CPS)		1.0		r=0.24 p=0.50
post-task pain (PTP)			1.0	r=0.35 p=0.32
disability				1.0

*significant at $p<0.05$

Table K36. Correlation between ROM and Sum of Post-Task Pain Scores (ΣPTP).

	lift bottle	lift can	comb hair	touch scapula	touch sacrum
shoulder flex/extension	r=-0.42 p=0.22	r=-0.61 p=0.062	r=-0.48 p=0.16	r=-0.17 p=0.64	r=-0.25 p=0.49
shoulder abd/adduction	r=-0.46 p=0.19	r=-0.26 p=0.47	r=-0.54 p=0.11	r=-0.16 p=0.65	r=-0.14 p=0.69
shoulder int/ext rotation	r=-0.47 p=0.17	r=-0.048 p=0.89	r=-0.24 p=0.51	r=-0.060 p=0.87	r=-0.25 p=0.48
elbow flexion	r=-0.36 p=0.31	r=-0.030 p=0.93	r=-0.56 p=0.080	r=-0.062 p=0.86	r=-0.026 p=0.49
forearm pron/supination	r=-0.35 p=0.32	r=-0.02 p=0.94	r=-0.18 p=0.61	r=-0.17 p=0.64	r=-0.48 p=0.16
wrist flexion/extension	r=-0.10 p=0.98	r=-0.53 p=0.12	r=-0.21 p=0.56	r=-0.069 p=0.85	r=-0.011 p=0.98
wrist rad/ulnar deviation	r=-0.12 p=0.74	r=-0.23 p=0.52	r=-0.63 p=0.052	r=-0.15 p=0.68	r=-0.29 p=0.42

*significant at p<0.05

APPENDIX L

1. There will be a difference in the arc of motion in each of seven upper limb rotations during performance of functional tasks between the control and the RA groups.

There will be a difference in the arc of motion of shoulder flexion/extension during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder abduction/adduction during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder internal/external rotation during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of elbow flexion during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of forearm pronation/supination during the lifting the bottle task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of wrist flexion/extension during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist ulnar/radial deviation during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder flexion/extension during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder abduction/adduction during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder internal/external rotation during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of elbow flexion during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of forearm pronation/supination during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist flexion/extension during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist ulnar/radial deviation during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder flexion/extension during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder abduction/adduction during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder internal/external rotation during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of elbow flexion during thecombing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of forearm pronation/supination during the combing the hair task between the control and the RA groups.*REJECT*

There will be a difference in the arc of motion of wrist flexion/extension during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist ulnar/radial deviation during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder flexion/extension during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of shoulder abduction/adduction during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder internal/external rotation during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of elbow flexion during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of forearm pronation/supination during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist flexion/extension during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist ulnar/radial deviation during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of shoulder flexion/extension during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder abduction/adduction during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of shoulder internal/external rotation during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of elbow flexion during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of forearm pronation/supination during the touch the sacrum task between the control and the RA groups. *ACCEPT*

There will be a difference in the arc of motion of wrist flexion/extension during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the arc of motion of wrist ulnar/radial deviation during the touch the sacrum task between the control and the RA groups. *REJECT*

2. There will be a difference in maximum angular velocity in each of seven upper limb rotations during performance of functional tasks between control and RA groups.

There will be a difference in the maximum angular velocity of shoulder flexion/extension during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder abduction/adduction during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder internal/external rotation during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of elbow flexion during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of forearm pronation/supination during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist flexion/extension during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist ulnar/radial deviation during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder flexion/extension during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder abduction/adduction during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder internal/external rotation during the lifting the can task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular velocity of elbow flexion during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of forearm pronation/supination during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist flexion/extension during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist ulnar/radial deviation during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder flexion/extension during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder abduction/adduction during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder internal/external rotation during the combing the hair task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular velocity of elbow flexion during thecombing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of forearm pronation/supination during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist flexion/extension during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist ulnar/radial deviation during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder flexion/extension during the touch the opposite scapula task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular velocity of shoulder abduction/adduction during the touch the opposite scapula task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular velocity of shoulder internal/external rotation during the touch the opposite scapula task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular velocity of elbow flexion during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of forearm pronation/supination during the touch the opposite scapula task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular velocity of wrist flexion/extension during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist ulnar/radial deviation during the touch the opposite scapula task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular velocity of shoulder flexion/extension during the touch the sacrum task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular velocity of shoulder abduction/adduction during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of shoulder internal/external rotation during the touch the sacrum task between the control and the RA groups*ACCEPT*

There will be a difference in the maximum angular velocity of elbow flexion during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of forearm pronation/supination during the touch the sacrum task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular velocity of wrist flexion/extension during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular velocity of wrist ulnar/radial deviation during the touch the sacrum task between the control and the RA groups. *ACCEPT*

3. There will be a difference in the maximum angular acceleration of each of seven upper limb rotations during performance of functional tasks between the control and the RA groups.

There will be a difference in the maximum angular acceleration of shoulder flexion/extension during the lifting the bottle task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular acceleration of shoulder abduction/adduction during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of shoulder internal/external rotation during the lifting the bottle task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of elbow flexion during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of forearm pronation/supination during the lifting the bottle task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist flexion/extension during the lifting the bottle task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular acceleration of wrist ulnar/radial deviation during the lifting the bottle task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of shoulder flexion/extension during the lifting the can task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of shoulder abduction/adduction during the lifting the can task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of shoulder internal/external rotation during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of elbow flexion during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of forearm pronation/supination during the lifting the can task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of wrist flexion/extension during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist ulnar/radial deviation during the lifting the can task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of shoulder flexion/extension during the combing the hair task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of shoulder abduction/adduction during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of shoulder internal/external rotation during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of elbow flexion during thecombing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of forearm pronation/supination during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist flexion/extension during the combing the hair task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist ulnar/radial deviation during the combing the hair task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of shoulder flexion/extension during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular acceleration of shoulder abduction/adduction during the touch the opposite scapula task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular acceleration of shoulder internal/external rotation during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of elbow flexion during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of forearm pronation/supination during the touch the opposite scapula task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist flexion/extension during the touch the opposite scapula task between the control and the RA groups.*REJECT*

There will be a difference in the maximum angular acceleration of wrist ulnar/radial deviation during the touch the opposite scapula task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular acceleration of shoulder flexion/extension during the touch the sacrum task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular acceleration of shoulder abduction/adduction during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of shoulder internal/external rotation during the touch the sacrum task between the control and the RA groups.*ACCEPT*

There will be a difference in the maximum angular acceleration of elbow flexion during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of forearm pronation/supination during the touch the sacrum task between the control and the RA groups. *ACCEPT*

There will be a difference in the maximum angular acceleration of wrist flexion/extension during the touch the sacrum task between the control and the RA groups. *REJECT*

There will be a difference in the maximum angular acceleration of wrist ulnar/radial deviation during the touch the sacrum task between the control and the RA groups.*ACCEPT*

4. There will be a correlation between the maximum angular acceleration at each of the seven upper limb rotations and pain (at each of the three upper limb regions).

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PCS during the lifting the bottle task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PTP during the lifting the bottle task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PCS during the lifting the can task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PCS during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PTP during the lifting the can task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PTP during the lifting the can task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PTP during the lifting the can task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PCS during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PCS during the combing the hair task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PCS during the combing the hair task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PCS during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PCS during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PCS during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PCS during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PTP during the combing the hair task.*ACCEPT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PTP during the combing the hair task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PCS during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PCS during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PCS during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PCS during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PTP during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PTP during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PTP during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PTP during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PCS during the touching the sacrum task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PCS during the touching the sacrum task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and shoulder region PTP during the touching the sacrum task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and shoulder region PTP during the touching the sacrum task.*REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and shoulder region PTP during the touching the sacrum task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and elbow region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and elbow region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and wrist region PTP during the touching the sacrum task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and wrist region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and ∑ PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and ∑ PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and ∑ PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of elbow flexion and ∑ PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and ∑ PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and ∑ PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and ∑ PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and ∑ PTP during the lifting the can task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and ∑ PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and ∑ PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and ∑PTP during the lifting the can task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and ∑ PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and ∑ PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and ∑ PTP during the lifting the can task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and $\sum$ PTP during the combing the hair task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and $\sum$ PTP during the combing the hair task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and $\sum$ PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and $\sum$ PTP during the combing the hair task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and $\sum$ PTP during the combing the hair task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and $\sum$ PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and $\sum$PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and $\sum$ PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and $\sum$ PTP during the touching the opposite scapula task.*REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and $\sum$ PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and $\sum$ PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and $\sum$PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and $\sum$ PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder flexion/extension and $\sum$ PTP during the touching the sacrum task. *ACCEPT*

There will be a correlation between the maximum angular acceleration of shoulder abduction/adduction and $\sum$ PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of shoulder internal/external rotation and $\sum$ PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of elbow flexion and $\sum$PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of forearm pronation/supination and $\sum$ PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist flexion/extension and $\sum$PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the maximum angular acceleration of wrist ulnar/radial deviation and $\sum$ PTP during the touching the sacrum task. *REJECT*

5. There will be a correlation between upper limb arc of motion (at each of the seven joint rotations), pain (at each of three regions of the upper limb) and disability in the individuals with RA for each of the five tasks.

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PCS during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PTP during the lifting the bottle task. *ACCEPT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PCS during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PCS during the lifting the can task. *ACCEPT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PCS during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PCS during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PCS during the touching the sacrum task. *ACCEPT*

There will be a correlation between the ROM of elbow flexion and elbow region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PCS during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and shoulder region PTP during the touching the sacrum task.*REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and shoulder region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and shoulder region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of elbow flexion and elbow region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and elbow region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and wrist region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist ulnar/radial deviation and wrist region PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and disability during the lifting the bottle task. *ACCEPT*

There will be a correlation between the ROM of shoulder abduction/adduction and disability during the lifting the bottle task. *ACCEPT*

There will be a correlation between the ROM of shoulder internal/external rotation and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of elbow flexion and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of elbow flexion and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and disability during the lifting the can task. *ACCEPT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and disability during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of elbow flexion and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and disability during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and disability during the combing the hair task. *ACCEPT*

There will be a correlation between the ROM of shoulder flexion/extension and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of elbow flexion and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and disability during the touching the opposite scapula task *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of elbow flexion and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the shoulder region PCS and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the shoulder region PTP and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the elbow region PCS and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the elbow region PTP and disability during the lifting the bottle task. *ACCEPT*

There will be a correlation between the wrist region PCS and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the wrist region PTP and disability during the lifting the bottle task. *REJECT*

There will be a correlation between the shoulder region PCS and disability during the lifting the can task. *REJECT*

There will be a correlation between the shoulder region PTP and disability during the lifting the can task. *ACCEPT*

There will be a correlation between the elbow region PCS and disability during the lifting the can task. *ACCEPT*

There will be a correlation between the elbow region PTP and disability during the lifting the can task. *REJECT*

There will be a correlation between the wrist region PCS and disability during the lifting the can task. *REJECT*

There will be a correlation between the wrist region PTP and disability during the lifting the can task. *REJECT*

There will be a correlation between the shoulder region CPS and disability during the combing the hair task. *REJECT*

There will be a correlation between the shoulder region PTP and disability during the combing the hair task. *ACCEPT*

There will be a correlation between the elbow region PCS and disability during the combing the hair task. *ACCEPT*

There will be a correlation between the elbow region PTP and disability during the combing the hair task. *REJECT*

There will be a correlation between the wrist region PCS and disability during the combing the hair task. *REJECT*

There will be a correlation between the wrist region PTP and disability during the combing the hair task. *REJECT*

There will be a correlation between the shoulder region PCS and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the shoulder region PTP and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the elbow region PCS and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the elbow region PTP and disability during the touching the opposite scapula task. *ACCEPT*

There will be a correlation between the wrist region PCS and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the wrist region PTP and disability during the touching the opposite scapula task. *REJECT*

There will be a correlation between the shoulder region CPS and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the shoulder region PTP and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the elbow region PCS and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the elbow region PTP and disability during the touching the sacrum task. *ACCEPT*

There will be a correlation between the wrist region PCS and disability during the touching the sacrum task. *REJECT*

There will be a correlation between the wrist region PTP and disability during the touching the sacrum task. *REJECT*

There will be a correlation between $\sum$ PTP and disability during the lifting bottle task. *ACCEPT*

There will be a correlation between $\sum$ PTP and disability during the lifting can task. *ACCEPT*

There will be a correlation between $\sum$ PTP and disability during the comb the hair task. *ACCEPT*

There will be a correlation between $\sum$ PTP and disability during the touch the opposite scapula task. *REJECT*

There will be a correlation between $\sum$ PTP and disability during the touching the sacrum task. *ACCEPT*

There will be a correlation between the ROM of shoulder flexion/extension and $\sum$PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and $\sum$ PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and $\sum$PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of elbow flexion and $\sum$PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and $\sum$PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and $\sum$PTP during the lifting the bottle task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and $\sum$PTP during the lifting the bottle task.*REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of elbow flexion and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and $\sum$PTP during the lifting the can task.*REJECT*

There will be a correlation between the ROM of wrist flexion/extension and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and $\sum$PTP during the lifting the can task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of elbow flexion and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and $\sum$PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and ∑PTP during the combing the hair task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of elbow flexion and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of forearm pronation/supination and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist flexion/extension and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of wrist ulnar\radial deviation and ∑PTP during the touching the opposite scapula task. *REJECT*

There will be a correlation between the ROM of shoulder flexion/extension and ∑PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder abduction/adduction and ∑PTP during the touching the sacrum task. *REJECT*

There will be a correlation between the ROM of shoulder internal/external rotation and ∑PTP during the touching the sacrum task. *REJECT*

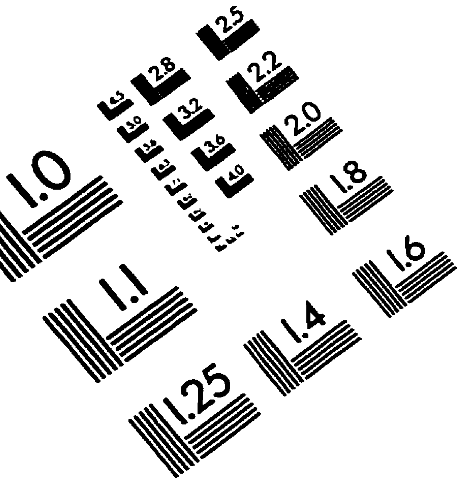
There will be a correlation between the ROM of elbow flexion and ∑PTP during the touching the sacrum task. *REJECT*

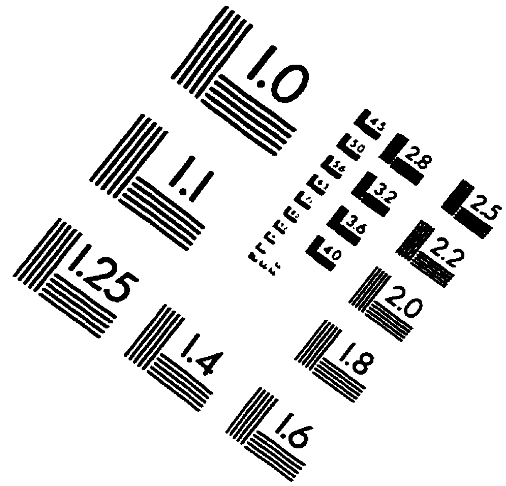
There will be a correlation between the ROM of forearm pronation/supination and ∑PTP during the touching the sacrum task. *REJECT*

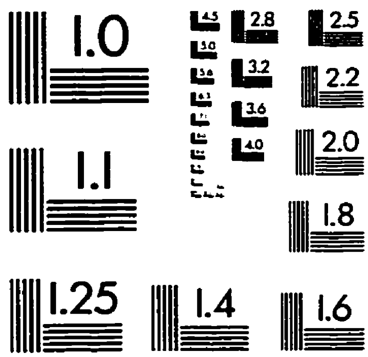
There will be a correlation between the ROM of wrist flexion/extension and ∑PTP during the touching the sacrum task. *REJECT*

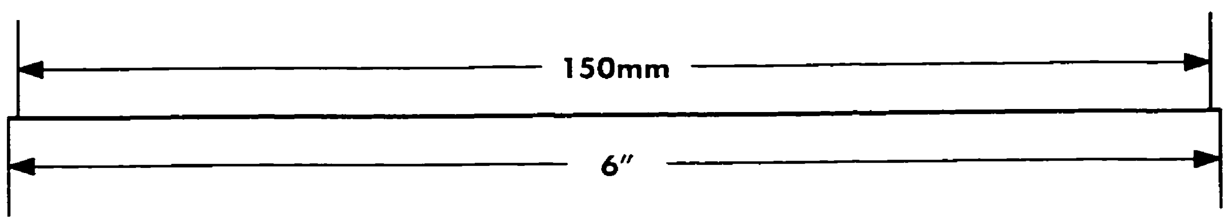
There will be a correlation between the ROM of wrist ulnar\radial deviation and ∑PTP during the touching the sacrum task. *REJECT*

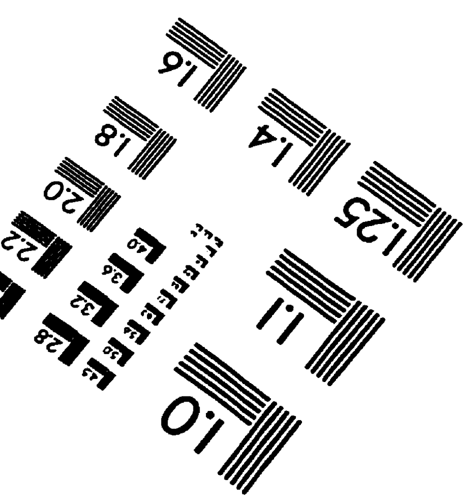
IMAGE EVALUATION TEST TARGET (QA-3)

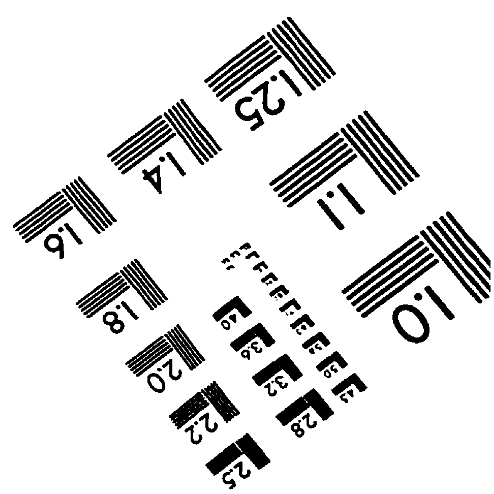












APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989