WHIPLASH ASSOCIATED DISORDERS

acute and chronic consequences
with some implications for rehabilitation

Ylva Sterner

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AKADEMISK AVHANDLING

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av

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WHIPLASH ASSOCIATED DISORDERS acute and chronic consequences
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ABSTRACT

Background: Whiplash associated disorders (WAD) account for a large proportion of the overall impairment and disability from traffic injuries and causes substantial bio psychosocial consequences for some individuals.

Aims: To increase the knowledge about factors described in terms of either function /impairment, activity/disability and life satisfaction in acute and chronic WAD as well as possible implications for rehabilitation. Within this aim the incidence and recovery rate of whiplash injury and prognostic factors of interest for early rehabilitation have been studied.

Subjects and Methods: Fifty-five healthy controls and 34 WAD subjects were analysed within and between groups concerning a) biomechanical output, endurance, fatigue and muscle tension (EMG activity of trapezius, infraspinatus and deltoideus) during repetitive shoulder forward flexion b) impairments and activity/disability and life satisfaction. 356 subjects seeking medical attention due to whiplash trauma, 296 were available at follow up, mean 16 months post injury. Incidence and odds ratio of accident and other background factors on disability were determined. Thirty-four out of 43 patients with whiplash injury were investigated through quantitative sensory tests at six weeks and 71 months after injury. 62 WAD participated in an interdisciplinary rehabilitation program (a pilot study) designed to evaluate such rehabilitation program for patients with chronic (in relatively early stage) WAD. Program evaluation of impairment, disability and life satisfaction (prospective and retrospective) was carried out before and after program and at 6 months.

Results: No significant effects of sex or age on the ability to relax between repetitive muscle contractions (SAR) were found in healthy subjects (study I). Significantly higher inability to relax between contractions was found for the two portions of trapezius and infraspinatus in the WAD group compared to the healthy group (study II). Significantly lower levels of activity preferences were noted for three out of five indices in females with WAD The WAD group had significantly higher prevalence of neuropsychological and emotional symptoms. Both pain related symptoms and neuropsychological symptoms were of significant importance for aspects of disability and life satisfaction in this group (study IV). Sensory disturbances over the trigeminal skin area persisted over the years. At follow-up a significant correlation was found between the sensory disturbances and the symptoms related to the central nervous system while no significant relationship was found with the musculoskeletal symptoms (study III). The annual incidence according to the grading of the Quebec Task Force on Whiplash-Associated Disorders (WAD 1-3) was 3.2/1000 and 4.2/1000 when WAD 0 was included. Seventy-eight percent of the patients recovered during the follow-up Pre-traumatic neck pain, low educational level, female gender and WAD grade II-III were significantly associated with a poor prognosis (study IV). Participants in the rehabilitation program reported increased coping ability. Stress reactions seemed rather frequent (32 %). Pain intensity in the neck and upper back were significantly decreased at 6 months follow-up. However, for most of the functional and psychological markers, no significant changes were found (study V).

Conclusion: The higher prevalence of musculoskeletal complaints of the neck shoulder region in females cannot be explained by higher muscle tension and clinical assumption of increased muscle tension seems correct in whiplash patients Results indicate heterogeneity among WAD subjects. Females are at risk after a whiplash trauma but the severity of initial symptoms and signs also affect outcome as well as low education. High levels of neuropsychological symptoms and pain, signs of posttraumatic stress, fear and avoidance, loss of control, anxiety, bio-mechanical and psychosocial factors at work (studies) and social support are potential factors to be aware of. Extensive and costly investigations are in most cases not necessary. However most persons will recover a whiplash injury. Multidisciplinary/interdisciplinary assessment should be considered at three months if substantial negative effect on the person’s ability to function and health situation exists.

Key words: whiplash, WAD, impairment, disability, life satisfaction, trigeminal sensibility, electromyography, rehabilitation, neuropsychological, pain, prognostic factor
WHIPLASH ASSOCIATED DISORDERS

acute and chronic consequences
with some implications for rehabilitation

Ylva Sterner
To my father

If a man will begin with certainties
    he shall end in doubts
but if he will be content to begin with doubts
    he shall end in certainties.

Francis Bacon
ABSTRACT

Background: Whiplash associated disorders (WAD) account for a large proportion of the overall impairment and disability from traffic injuries and causes substantial bio psychosocial consequences for some individuals.

Aims: To increase the knowledge about factors described in terms of either function /impairment, activity/disability and life satisfaction in acute and chronic WAD as well as possible implications for rehabilitation. Within this aim the incidence and recovery rate of whiplash injury and prognostic factors of interest for early rehabilitation have been studied.

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Key words: whiplash, WAD, impairment, disability, life satisfaction, trigeminal sensibility, electromyography, rehabilitation, neuropsychological, pain, prognostic factor
ORIGINAL STUDIES

This thesis is based on the following studies that will be referred to by the Roman number


II. Fredin (Sterner) Y, Elert J, Britschgi N, Nyberg V, Vahler A, Geerdle B. A decreased ability to relax between repetitive muscle contractions in patients with chronic symptoms after whiplash trauma of the neck. J Musculoskel Pain 1997;5; 55-705


V. Sterner Y, Löfgren M, Nyberg V, Karlsson A K, Bergström M, Gerdle B. Early Interdisciplinary Rehabilitation program for Whiplash Associated Disorders. Accepted for publication in Disability and Rehabilitation.


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Introduction

Railway spine, whiplash, neck sprain, soft tissue injury, whiplash syndrome, or WAD are all names to describe a condition that is still confusing for patients, paramedics, and physicians. Since the end of the 18th century when railway accidents began to cause neck pain and other symptoms, different terms have been proposed to identify such an injury. These terms attempted to convey the physical cause, the compensation neurosis, a pure psychogenic, or a post-traumatic stress disorder.

In 1928, Crowe introduced the term whiplash injury to describe eight injuries caused from rear-end motor vehicle accidents (Crowe 1928). This “injury” has usually been associated with motor vehicle accidents (mva) in particular rear-end accidents, although several authors include other injury mechanisms (Hohl 1989, Spitzer et al 1995). During the First World War, it became clear that the violence to the cervical spine caused during catapulting was great enough to cause a blackout for several seconds and accidents occurred that were due to a whiplash effect. This understanding resulted in headrest and shoulder harness protection. Although much bio-mechanical research have been done and much effort has been spent trying to diminish forces acting on the head and neck (Hoek van Dijke 1993), a substantial number of the pilots report neck pain (50%). Higher g forces (>5 g) and increased age are significant risk factors (Vanderbeek 1988, Jones et al 2000).

In 1955, Severy and his co-workers reported that even in low impact (20 km) rear-end collisions the head and neck were exposed to acceleration forces that could cause injuries that present symptoms 12 to 24 hours later (Severy et al 1955). Furthermore, when a car is hit and accelerated by 17 km/h within 100 ms, the car and the driver experience 5 g (Ommaya and Hirsch 1971). Although minor traffic accidents and whiplash injuries have increased (Versteegen et al 1998, Richter et al 2000, Björnstig et al 1993) over the past several decades, major injuries have decreased due to the use of seatbelts and safer car design. Although not all patients who suffer a whiplash trauma/injury develop disabling symptoms, the epidemiological literature concludes that there is a substantial risk of developing chronic symptoms after whiplash trauma (Freeman et al 1999). This accounts for a large proportion of the overall impairment and disability from traffic injuries (Holm et al 1999, Bylund et al 1998). In addition, whiplash injuries have led to an increasingly high annual cost for the community in terms of medical care, disability pension, income-loss, loss income tax, and an

Due to the heterogeneity of definitions and classification in the literature concerning sc. whiplash, Scientific Monograph of the Quebec Task Force on Whiplash Associated Disorders (QTF) in 1995 adopted the following definitions (Spitzer et al 1995):

*Whiplash* is an acceleration-deceleration mechanism of energy transfer to the neck. It may result from rear or side impact motor vehicle, but can occur during diving or other mishaps. The impact can result in bony or soft tissue injuries (*Whiplash injury*) which in turn can lead to a variety of clinical manifestations (*Whiplash Associated Disorders, WAD*).

### Different Classifications of “whiplash”

#### The classification of The Quebec Task Force (QTF)

The Quebec Task Force (QTF) proposed the following classification of WAD:

**Anatomical-clinical axis**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No neck pain.</td>
</tr>
<tr>
<td>1</td>
<td>Neck pain but no signs.</td>
</tr>
<tr>
<td>2</td>
<td>Neck pain and musculoskeletal sign(s) (sore muscles, decreased range of motion (ROM)).</td>
</tr>
<tr>
<td>3</td>
<td>Neck pain and neurological sign(s) (i.e. loss of motor activity/or impaired sensory function).</td>
</tr>
<tr>
<td>4</td>
<td>Neck pain and fracture.</td>
</tr>
</tbody>
</table>

Symptoms and disorders that can be presented in all grades include deafness, dizziness, tinnitus, headache, memory loss, dysphagia and temporomandibular joint pain.

**Time axis**

Ranging from less than 4 days too duration of more than 6 month. The latter meant too guide the clinical management of WAD.

<table>
<thead>
<tr>
<th>Time axis</th>
<th>Symptoms or clinical signs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) 4-21 days</td>
</tr>
<tr>
<td></td>
<td>b) 22-45 days</td>
</tr>
<tr>
<td></td>
<td>c) 46-180 days</td>
</tr>
<tr>
<td></td>
<td>d) &gt; 180 days</td>
</tr>
</tbody>
</table>

Reassessment at 7 days, 3 weeks, 6 weeks, and 12 weeks depending on grade.
The classification of Radanov and co-workers

A Swiss group suggested another classification based on subjective complaints and formal testing of self-estimated cognitive impairment, divided attention, and speed of information processing:

1) Lower cervical spine syndrome (LCS) accompanied by cervical and cervicobrachial pain.
2) Cervicoencephalic syndrome (CES) characterised by headache, fatigue, dizziness, poor concentration, disturbed accommodation, and impaired adaptation to light intensity (Radanov et al 1992).

The classification of Gerdle and co-workers

This classification is based on clinical experience and the literature (Gerdle et al 1998). The classification of the injuries is based on the following information:

Anatomical axis

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Head, neck and shoulder</td>
</tr>
<tr>
<td>B</td>
<td>Head, neck and shoulder and arm ¹</td>
</tr>
<tr>
<td>C</td>
<td>Head, neck and shoulder and CNS ²</td>
</tr>
<tr>
<td>D</td>
<td>Head, neck and shoulder arm and CSN</td>
</tr>
</tbody>
</table>

¹ Numbness, pain, and motor weakness
² Dizziness, visual problems, sensitivity to light and sound, stress intolerance, cognitive problems

Time axis

<table>
<thead>
<tr>
<th>Time axis</th>
<th>Number of weeks with complaints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>≤ 12 weeks</td>
</tr>
<tr>
<td>Chronic</td>
<td>≥ 12 weeks</td>
</tr>
</tbody>
</table>

The QTF WAD Classification of QTF is most frequently used. The QTF WAD classification assumes to provide information about prognosis; however, very little data supports this. Recently, it was concluded that the usefulness of the WAD classification for the prediction of prognosis is limited (Kivioja et al 1998). The present study uses Quebec Task Force classification.
Acute WAD

Symptoms

Inflammation and tissue response to an injury take place within the first 72 hours (Spitzer et al 1995) of the initial trauma. Symptoms of an injury will develop in the first 72 hours and most of the symptoms will develop in the first 24 hours (Severy et al 1955, Hildingsson & Toolanen 1990, Dvorak et al 1989, Deans et al 1987).

According to several studies, the most common symptoms reported in the first week of an accident are as follows: pain in the neck and head together with stiffness followed by interscapulare pain, parestesias in arms and hands, dizziness, visual and auditory symptoms, cognitive problems, and emotional/psychological disturbances (Table 1).

Table 1 Prevalence of symptoms in acute WAD or within 1 week based on the following studies: 1) Hildingsson & Toolanen 1990 (n = 93), 2) Norris & Watt 1983 (n = 61), 3) Radanov et al 1991 (n = 78), 4) Maimaris et al 1988 (n = 102), 5) Drottning et al 1995 (n = 107).

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Prevalence (%)</th>
<th>Studies (n in total sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain</td>
<td>94</td>
<td>1-4 (334)</td>
</tr>
<tr>
<td>Neck Stiffness</td>
<td>96</td>
<td>1&amp;3 (195)</td>
</tr>
<tr>
<td>Inter scapulare pain</td>
<td>35</td>
<td>5 (107)</td>
</tr>
<tr>
<td>Headache</td>
<td>44</td>
<td>1-4 (334)</td>
</tr>
<tr>
<td>Numbness/parestesias</td>
<td>22</td>
<td>1,3,4 (232)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>15</td>
<td>1,3,4 (232)</td>
</tr>
<tr>
<td>Visual symptoms</td>
<td>12</td>
<td>1,3,4 (232)</td>
</tr>
<tr>
<td>Auditory symptoms</td>
<td>13</td>
<td>1,3,4 (232)</td>
</tr>
<tr>
<td>Sleeping problems</td>
<td>35</td>
<td>3 (78)</td>
</tr>
<tr>
<td>Memory problems</td>
<td>15</td>
<td>3 (78)</td>
</tr>
<tr>
<td>Intrusion /avoidance (impact of event scale)</td>
<td>30</td>
<td>5 (107)</td>
</tr>
</tbody>
</table>
Pain (the most common symptom)

The IASP definition of pain:

Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such.

Note that pain always is subjective. Each individual learns the application of the word through experiences related to injury in early life. Biologists recognise that those stimuli, which cause pain, are liable to damage tissue. Accordingly, pain is that experience we associate with actual or potential tissue damage. It is unquestionably a sensation in a part or parts of the body, but it is also always unpleasant and therefore also an emotional experience. Experiences that resemble pain but are not unpleasant, e.g., pricking should not be called pain. Unpleasant abnormal experiences (dysesthesias) may also be pain but are not necessarily so because, subjectively, they may not have the usual sensory qualities of pain (IASP 1994).

Signs

There are few clinical objective signs to apply to pain; however, decreased ROM and pain in muscles and bony structures when palpated can be useful indicators of pain (Hagström & Carlsson 1996, Hildingsson & Toolanen 1990). Neurological deficits seem to be rare (Norris & Watt 1983, Hildingsson & Toolanen 1990), however, more discrete deficits seem more frequent (Petterson et al 1994, Ettlin et al 1992) but with no significant correlation with MRT. The prevalence of positive signs from plain X-rays and flexion-extension projections (used to detect segmental instability) are rare in WAD. Signs of straight or kyphotic curve and degenerative spondylosis are seen in about 25% of the cases (Hildingsson & Toolanen 1990).

Spinous process tenderness in the neck, intoxication, altered level of alertness, or other severely painful injuries can indicate a fracture (Hoffman et al 1992). MRT in the sub-acute situation have detected herniated disc (Petterson et al 1994), but this was not present in another study (Voyvodic et al 1997). Scintigraphy shows no signs of injuries (Hildingsson et al 1989).

Emotional disturbance has been reported in the acute stage (Drottning et al 1995) and influence the intensity of pain. Signs of major psychological distress may reflect traumatic stress from the accident (Jaspers 1998, Mayou et al 1993).
Aetiology of acute WAD

Post-mortem studies of victims killed in car accidents (Jonsson et al 1991, Schonström et al 1993, Taylor & Taylor 1996) report high frequencies of injuries to the intervertebral joints. The majority of injuries were not obvious using X-ray or MRT techniques but became obvious using cryo-sectioning, which discovered injuries to soft tissue, capsule bleeding, affection of the small joints, and disc rifts, etc (Figure 1). When interpreting these injuries, one must realise that high-energy forces acted on the neck and the head. Post-mortem studies on a few non-accidental deaths of subjects with chronic WAD partly support this assumption (Bring 1996, Rauschning et al 1989). Sternocleidomastoid muscles and the cervical paraspinal muscle contract rapidly in response to impact and potential muscle injury exists due to this lengthening contraction (Brault et al 2000).

Figure 1
Possible lesions after whiplash trauma excluding muscle injuries. (a) Endplate fracture, (b) inter vertebral joint bleeding, (c) inter vertebral j capsule rupture, (d) inter vertebral j fracture, (e) ventral ligament and disc rupture, (f) disc contusion, and (g) rim lesion (Inter vertebral joint = zygapophysial joint).

Epidemiology of WAD

Barnsley et al approximate the annual incidence of WAD to 1/1000 but state that most of the estimates are derived from insurance or compensation claims and are therefore an inadequate outcome measure (1994). In two Swedish hospital based (emergency department) studies, the
incidence was estimated to 1/1000 and 1.9/1000 (Björnstad et al 1990, Bring et al 1996). Barnsley et al reported a variation from 14% to 42% of acute WAD that developed chronic neck pain and that approximately 10% will report constant severe pain. They estimate the prevalence for severe chronic pain due to WAD to be 0.4/1000 (Barnsley et al 1994). In the series of prospective studies shown in Table 2, a considerable proportion of the remaining complaints (chronic WAD) were found but there is a considerable variation between the studies (1% to 56%). In part, this variation might be due to factors such as study population, sample size, and outcome variables. Outcome variables in these studies include neck pain, headache, dizziness, not recovered, affecting work or leisure, not working, to quality of life.
**Table 2** Identified prospective studies of WAD. Follow up time (months), outcome variables and the prevalence (%) of outcome variables (i.e., those with remaining symptoms, disability etc). In some of the studies, regression analysis has been made and the prognostic factors are given.

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Follow up (months)</th>
<th>Outcome variables</th>
<th>Prevalence of outcome (%)</th>
<th>Prognostic factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norris &amp; Watt (1983)</td>
<td>24</td>
<td>Neck pain Affecting work or leisure</td>
<td>19-56 20</td>
<td>Neurological signs, Neck stiffness, Muscle spasm &amp; Pre-existing degenerative spondyls</td>
</tr>
<tr>
<td>Hildingsson &amp; Toolanen (1990)</td>
<td>25</td>
<td>Neck pain Affecting work capacity Not working</td>
<td>26 29 14</td>
<td>None identified</td>
</tr>
<tr>
<td>Björnstig et al (1990)</td>
<td>12</td>
<td>Sick leave</td>
<td>4</td>
<td>Not reported</td>
</tr>
<tr>
<td>Ettlin et al (1992)</td>
<td>12</td>
<td>Neck pain Headache Employment disability</td>
<td>35 41 24</td>
<td>Not reported</td>
</tr>
<tr>
<td>Gargan &amp; Bannister (1994)</td>
<td>24</td>
<td>Symptoms in four grades (not recovered completely)</td>
<td>38</td>
<td>Not reported</td>
</tr>
<tr>
<td>Radanov et al (1994)</td>
<td>12</td>
<td>Symptomatic Disabled =not working</td>
<td>24 (12 months) 18 (24 months) 4 (24 months)</td>
<td>At 12 months: age, previous head trauma, sleep disturbances, intensity of neck pain, pre traumatic headache, intensity of initial headache, nervousness, radicular irritation, speed of information processing, poor concentration.</td>
</tr>
<tr>
<td>Drottning et al (1995)</td>
<td>1</td>
<td>Intensity of symptoms</td>
<td>42</td>
<td>Emotional response to the accident, Intensity of neck pain acute</td>
</tr>
<tr>
<td>Karlsborg et al (1997)</td>
<td>7</td>
<td>Index of 13 symptoms</td>
<td>71</td>
<td>None identified</td>
</tr>
<tr>
<td>Obelieni et al (1999)</td>
<td>12</td>
<td>Neck pain, Headache (&gt;7 days/ month)</td>
<td>4‡ 4‡</td>
<td>Not reported</td>
</tr>
<tr>
<td>Partieni et al (2000)</td>
<td>6</td>
<td>Different symptoms</td>
<td>0-1</td>
<td>Not reported</td>
</tr>
<tr>
<td>Brison et al (2000)</td>
<td>24</td>
<td>Ongoing symptoms Modify work /leisure (at 6 months)</td>
<td>34 35-36</td>
<td>Not reported</td>
</tr>
<tr>
<td>Galako et al (2000)</td>
<td>48</td>
<td>Recovery (not defined)</td>
<td>46</td>
<td>Nervousness WAD grading</td>
</tr>
<tr>
<td>Bonk et al (2000)</td>
<td>3</td>
<td>Different symptoms</td>
<td>0-16‡</td>
<td>Not reported</td>
</tr>
</tbody>
</table>

‡47% had symptoms in acute phase. A control group was included in the study.

‡ Not different from control group.
Chronic pain

Chronic pain as defined by IASP

IASP defines chronic pain as “Pain that persist beyond the normal time of healing”. In this concept, one must know what the normal healing time is for different types of injuries. Pain for over 6 months is defined as chronic. In acute pain, there is a straightforward relationship between nociception, pain suffering, and pain behaviour, which in chronic pain is not always present. Chronic pain always involves psychological and behavioural responses (Figure 2). For some individuals, the behavioural responses are less pronounced and thus minimally effect an individual’s life style.

![Figure 2. Loeser's multifaceted model of the components of pain](image)

Chronic pain in the general population

Most studies on the prevalence of non-malignant chronic pain do not specifically report neck pain. A Dutch study (Verhaak et al 1998) found a wide range of definitions and methods and none of them could explain the variation of the prevalence of chronic pain between 2% and 40%. They estimated a median point prevalence of chronic pain of 15 % in the adult population. According to a Swedish study (Andersson 1994) of chronic pain (>3 months), 55% (no gender difference) perceived pain and in 13% it was associated with reduced functional capacity (disability). The neck and shoulder area was the most common site of pain (women 32.9%, men 27.5%). Bovim et al in a study from Norway report that 34%
experienced neck pain that lasted for a year and that 13.8% reported neck pain that lasted for more than 6 months (1994). They concluded, although with some reservation, that this latter prevalence is of the same magnitude as reported by subjects which have sustained whiplash injuries. However, one recent study reports significant correlation with a history of whiplash injury, neck pain, and disability (Cote et al 2000). Berglund et al (2000) report that people who have been in a rear-end accident have nearly 3 times higher the risk of having future neck pain than people who have not been involved in a rear-end accident.

Chronic WAD

The cause of persistent chronic pain, motor dysfunction, and other symptoms are not so easily explained; however, there are some indications that trauma can cause injuries (see above) that might not easily heal. Some chronic WAD patients with severe persistent and radiating pain had large disc protrusions (Jonsson et al 1994). Autopsy findings, MRT findings, and physical assessments indicate that whiplash injury can be the cause of chronic WAD (Jonsson, 1992, Bring 1996, Petterson 1996). Barnsley et al believe that there is no evidence that chronic WAD emanates from muscle damages (1994). Although this can occur, it would normally heal in a few weeks and cause no more pain. There is more evidence that chronic pain is due to injuries to the zygapophysial joints and intervertebral discs—including rim lesions and upper cervical ligaments (Barnsley et al 1994, Ryan 2000). An Australian group notes that in 60% of chronic WAD, the zygapophysial joints are the cause of pain (Lord et al 1996). Recent research has led to a new understanding of chronic pain and its underlying physiological mechanisms. It has been proposed that an alteration in the threshold for terminal activation of primary nociceptors may be responsible for chronic pain. Plastic properties and changes in excitability in the central nervous system and central sensitisation may also cause chronic pain (Woolf 1999). In addition, long-term potentiation and decreased pain inhibition mechanisms may affect chronic pain (Lundeberg 1995).

Studies on claimants' recovery rates after litigation settlements in the 1950s noted that most individuals recover (80% to 90%) after their settlement (Gotten 1956); however, Mendelsson (1995) and Mayou (1995) have found no support for this. Mendelsson concludes that 75% of claimants continued to be of work after receiving their settlement (1995). Exaggerating symptoms during the litigation process is probably due to frustration and anger and this stress could increase the perception of pain (Swartzman et al 1996).
Causes of chronic pain and other associated symptoms are often seen in a multifactorial context in the literature. Therefore, musculoskeletal dysfunction (Bogduk 1998) together with psychosocial and psychological factors, such as post-traumatic stress (Mayou et al 1997, Drottning et al 1995, Jaspers 1998) and previous stressful life events (Smed 1997), might interact and prevent recovery.

Long-term studies show that only a few people recover between 1 and 2 years (Gargan and Bannister 1997) and that symptoms do not change significantly after several years (Robinsson & Cessar Pulpicino 1993). One study (Olivegren et al 1999), however, reports that patients with prolonged disability after a whiplash injury can improve even after a long time of decreased feelings of well-being and constant pain intensity.

Risk factors for WAD

Crash (CAR)

Recently, bio-mechanical research has identified possible mechanisms behind short or long-term consequences (WAD) of rear-end and frontal impacts in car accidents. The magnitude of the peak acceleration (g) according to crash pulse registration and the frequency of tow bar in rear end have been identified as risk factors for WAD (Krafft et al 2000, Kullgren et al 2000). Car design and construction also effects the risk for chronic WAD (Krafft 1999). A car seat’s ability to transfer the energy associated in a crash to the occupant’s neck and head is an important factor in determining the risk for WAD (Svensson 1993). Car seats being developed today will probably be constructed so an occupant’s head and neck will absorb less energy during a crash (Jakobsson et al 2000). In recent years, the theory of a plain hyperextension flexion injury has more or less been abandoned. Theories based on both human and “dummy” experiments reveal a more complex mechanism of injury associated with the “S” shaped curve of the vertebra and forces which act (retraction) on the neck rather than a pure hyperextension/flexion injury mechanism (Castro et al 1997, Svensson et al 2000). Pressure injuries on the spinal-cord that have been registered in experiments have not been linked to real life injuries (Eichberger et al 2000). Krafft, in an interview in Dagens Nyheter, pointed out that almost all dummies used in crash experiments are based on male anatomy and size (25/11 2001). The person’s position in a car and its effects on injuries has not been reported;
however, head position (rotated or inclined) and awareness of the accident have been proposed to influence injuries (Ryan et al 1994, Sturzenegger et al 1994).

**Individual risk factors**

Unfortunately, there are few epidemiological studies that examine the natural course of WAD based on non-selected populations and therefore the figures presented in the literature are probably both over estimating and under estimating risk factors associated with chronic disabling symptoms.

**Table 2** summarises prospective studies. Factors that increase the probability for chronic symptoms are as follows: age, gender, rotated/inclined head position, pre-traumatic headache, intensity of acute neck pain, number of symptoms in the acute situation/stage, emotional response to the accident, neurological signs/radicular deficit, nervousness, neck stiffness/muscle spasm, pre-existing degenerative spondylos/osteoarthritis, high neuroticism, and consultation for psychological problems before trauma.

In some retrospective and cross-sectional studies the following factors were associated with a poor prognosis: older age, female gender, low professional status, symptoms over two months pre-existing degenerative spondylosis, interscapulare pain, truck accidents, and medical impairment >15% (Spitzer et al 1995, Holm et al 199, Borscgrevink et al 1996, Maimaris et al 1988).

The studies from Lithuania, Greece, and Germany noted in **Table 2** found a low non-significant risk for having disabling symptoms after an accident. Moreover, the authors suggest that chronic WAD has little validity (Obelieniene et al 1999, Partheni et al 2000, Bonk et al 2000).

**Impairments (symptoms and signs) in chronic WAD**

**Pain**

The most prevalent symptoms in subjects who suffer chronic WAD that last from 3 months to 2 years are neck pain (65%-100%), headache (34%-70%), and shoulder (interscapulare) pain (36%-53%) (Norris & Watt 1983, Provinciali et al 1996, Hagström and Carlsson 1996, Hildingsson & Toolanen, Kiscka et al 1991). Arm pain is less prevalent (19%-26%).
Visual and Vestibular disturbances

Persisting symptoms (Hildingsson et al 1993), dizziness/vertigo, self-reported reading problems (Gimse et al 1996), and driving problems (Gimse et al 1997) correlate with disturbed eye movement. These findings suggest that injuries to the neck can cause distortion of the posture control system as the result of disorganised neck proprioceptive activity in the cervicocranial area (Gimse et al 1997). Kinaesthetic tests (Heikkilä et al 1998, Loudon et al 1997) partly confirm this. A recent study suggests dysfunction of prefrontal and frontal cortical structure as a cause of these findings (Mosimannet et al 2000). However, eye movement disturbances are seen in other conditions such as fibromyalgia syndrome (Rosenhall et al 1987) and tension headaches (Carlsson & Rosenhall 1988), but were more pronounced in some WAD subjects (Hildingsson et al 1993) and rheumatoid patients with upper cervical dislocation (Wenngren et al 1998). Eye disturbances have been associated with pre-menstrual syndrome as well (Sundstrom et al 1998).

Pathological electronystagmography (ENG) in traumatic brain injury (TBI) patients, normal findings in WAD patients, together with pathologic computerised dynamic posturography (CDP) in both groups indicate different sites of damages (Mallinson et al 1998).

Sensory disturbances

Sensory disturbance symptoms (tingling and or numbing) are relatively prevalent in the arm (19%-55 %) (Provincially et al 1996, Norris & Watt 1983, Hildingsson & Toolanen1990). Neurological signs are reported to occur in low (Norris & Watt 1983, Hildingsson & Toolanen 1990) and high frequencies (Petterson et al 1997, Jonnson et al 1994), but were not correlated with MRI findings (Petterson et al 1997). One EMG study found slowing in the median and ulnar nerve motor and sensory conduction velocity (Serra et al 1994). Sensory disturbances in the face have been detected in a group of chronic WAD subjects compared to subjects who have recovered (Knibenstöl et al 1990).

Psychological problems

Radanov and his co-workers have pointed out that psychosocial factors are not significant in predicting the outcome (Radanov et al 1991) and that psychological problems are a result rather than a cause of somatic symptoms in WAD (Radanov et al 1996). In contrast to this, stressful life events unrelated to the accident and a high level of stress one month after the injury have been linked to a poor prognosis (Karlsborg et al 1997, Smed 1997). Psychometric
test profiles in chronic WAD subjects using SCL-90 R, a 90 item self-report multidimensional symptom checklist, were similar to profiles obtained from patients suffering from rheumatoid arthritis and low back pain (Wallis et al 1996). The authors interpreted this as strong support for the hypothesis that psychological stress is secondary to pain. Psychological stress measured by SCL 90 was resolved following radio frequency neurotomy of zygopophysial nerve in 9 pain free subjects (with one single painful cervical zygopophysial joint) (Wallis et al 1997). In the placebo group, all but one individual remained stressed according to SCL 90.

Neuropsychological and cognitive impairments

About 50% of WAD subjects, 3 months to 2 years post injury, reported cognitive disturbances (memory and concentration difficulties) (Kitcka et al 1991, Radanov al 1995, Provinciali et al 1996). Ettlin et al suggest that their findings of impaired attention and EEG abnormalities in WAD patients indicate possible damage to basal frontal and upper brain stem structures (1992). Another study found no perfusion or metabolism changes in the brain but found a significant relationship between indices of impaired emotional functioning (anxiety) and divided attention (Radanov et al 1999). Pain intensity influenced cognitive test results at the time of testing (Radanov et al 1999). Two studies (Radanov and Dvorak 1996, Kessels et al 2000) corroborated these results. Twenty-two neuropsychological studies on whiplash were quantitatively analysed, focusing on working memory, attention, immediate and delayed recall, visuomotor tracking, and cognitive flexibility (Kessels et al 2000). WAD patients showed an overall significant lowered performance compared to healthy subjects in all six domains; however, compared to asymptomatic WAD (i.e., recovered WAD sufferers) the difference was somewhat lowered. There are several possible explanations such as pain intensity (Radanov et al 1999), failure to use effective coping strategies leading to post traumatic stress-like symptoms or depression (Asmundson et al 2000). Symptoms such as memory loss, concentration problems, and fear and avoidance of driving can reflect an emotional response to intrusive memories of the accident (Mayou et al 1993, Jaspers 1998) (i.e., post-traumatic stress disorder (PTSD)) and might remain for years for some subjects. In a two year follow up, half of the respondents still reported travel anxiety, pain, fear, and fatigue (Andersson et al 1997).
Muscle tension

Muscle tension, muscle tone, muscle spasm, and muscle stiffness are words often used synonymously to describe myalgic muscles. According to Simons and Mense, measurable sources of muscle tension include viscoelastic tone, contracture, voluntary contraction, and muscle spasm (1998). They suggest the following definitions:

- Resting muscle tone is defined as the elastic or viscoelastic stiffness in the absence of contractile activity
- Physiological contracture is a state of muscle contractile activity without electric activity
- Muscle spasm is electromyographic (EMG) activity that is not under voluntary control. It may or may not be painful.

Some WAD patients report a substantial worsening of their symptoms (muscle pain and fatigue) when going back to full time work, which might place demands on the neck, shoulder or arm, and take up some leisure activity. Some WAD patients report increased muscle tension and low levels of endurance, which increases their stress. Their symptoms have changed the way they live by making tasks they performed easily before their injury much more difficult. For some, locomotor symptoms increase over time and lead to “new” symptoms.

Muscle hyperactivity has been considered the main cause of musculoskeletal pain and the cause of a viscous symptom circle however, there is no convincing evidence of increased EMG activity (muscle spasm) to support this assumption (Lund et al 1991, Simons & Mense 1998, Graven-Nielsen et al 2000,).

Neck and shoulder posture and movement influence EMG activity even in contralateral muscles during sitting work (Harms Ringdahl & Schuldt 1990, Schuldt 1988). Extreme positioning causes pain but it does not cause EMG activity in healthy subjects (Harms Ringdahl & Ekholm 1986). Induced acute pain and chronic low back pain (CLB) affect both static and dynamic EMG activity and modulate motor performance (Arendt-Nielsen et al 1996, Graven Nielsen et al 1997). The Danish group found unnecessary lumbar muscle activity during a normal silent gate phase in CLB (Arendt-Nielsen et al 1996). An inability to relax between maximum dynamic shoulder flexion (i.e., an increased signal amplitude ratio (SAR)) has been reported in patients with work-related trapezius myalgia and fibromyalgia syndrome (Elert et al 1992). This was also found in a sub-sample of clinically healthy young...
subjects (Gerdle et al 1989). The fibromyalgia group showed significant elevations of SAR in all four investigated muscles (trapezius descendence, infraspinatus, deltoid and biceps brachii). A work-related myalgia group only had increased SAR in the trapezius muscle. In a study of healthy teachers and cleaners with and without myalgia, age and being a cleaner were associated with an increased SAR (Larsson et al 2000).

**Chronic pain conditions and coping**

In 1976, Lazarus introduced the concept of coping and stated “that every instance of adaptive commerce between a person and the environment is appraised cognitively as to its significance for the person's well-being”. Moreover, he continued, environmental stressors lead to different coping processes, emotional states, and stress disorders (Lazarus 1976). He stated that “self-regulatory processes as well as cognitive appraisals are key mediators of the person's reactions to stressful transactions and hence shape the somatic outcome” (Lazarus 1976). He distinguished two types of self-regulatory processes:

1. Coping which refers to any action or intrapsychic attempt to alter the person's troubled relationship with the environment sc. emotional coping

2. Direct control activities, illustrated by drugs, relaxation training, meditation, biofeedback procedures etc., which are employed in an effort to moderate the bodily concomitants of stress emotion. sc. problem solving coping

Examples of instruments that measure aspects of coping are the Coping Resource Index (CRI) consisting of 60 questions that classifies five coping areas: 1) Cognitive, 2) Social, 3) Emotional, 4) Philosophic, and 5) Physical (Hammer 1988). The Coping Strategy Questionnaire (CSQ) (Rosenstiel & Keefy 1983) has 50 questions that measure six different cognitive coping strategies: 1) increasing pain behaviour, 2) distraction, 3) catastrophizing, 4) hope and pray, 5) reinterpreting pain sensations, 6) coping self-statements. This instrument also measures two behavioural coping strategies: 1) diverting attention and 2) increasing activity level. Recent research and multivariate analyses propose a somewhat revised version of 27 questions and 6 areas (Robinson et al 1997).

In a study of chronic WAD patients, CSQ items on the original Coping Self-Statements and the Increasing Pain Behaviour sub-scales failed to load consistently for any factor. This suggests that they do not reliably measure distinct coping strategies (Swartzman et al 1994).
In the behavioural analysis of chronic pain, Fordyce pointed out that the learning process has a substantial influence on the development of chronic pain and outlines three basic processes:

1) direct (positive) reinforcement of pain behaviour (increased attention /sympathy);
2) indirect but positive reinforcement of pain behaviour, for example, avoidance;
3) failure to reinforce “good” behaviour.

Linton (1984) points out that fear/avoidance and pain behaviour probably account for only a small part of the total behaviour of a chronic pain patient. Rather, reinforcement in passive behaviour (passive coping) over time leads to a new life style. Contradictory pain-related fear and avoidance appear to be an essential feature of the development of a chronic problem for a substantial number of patients with musculoskeletal pain (Vlayen & Linton 2000).

Catastrophizing measured by CSQ (hopelessness) have been linked to anxiety and negatively to abilities to control and reduce pain (Hallberg & Carlsson 1998) and are associated with pain interference and depression (Engel et al 2000, Turner et al 1998). Passive coping (Mercado et al 2000, Covic et al 2000) and coping style (Bryant et al 1999, Feuerstein et al 2000) have been associated with pain interference and physical disability. Coping flexibility and self-statements influence the perception of pain control (Haythornthwaite et al 1998) and are assumed to be an important factor in rehabilitation.

Treatment

Acute WAD
Many therapies such as heat, ice, ultrasound, acupuncture, massage, subcutaneous sterile water, and soft collar have not been evaluated or show little or no evidence of efficacy (Spitzer et al 1995). Adequate information and successive mobilisation without a collar as early as possible supported by a physiotherapy are the best treatments for reducing pain and increasing range of motion (ROM); however, no significant difference in sick leave at 6 months has been reported (Rosenfeld et al 2000). There are still some patients at 6 months that have severe pain whatever the treatment (Borchgrevink et al 1998). Acute treatment with high-doses methylprednisolone may be beneficial in preventing extensive sick leave after whiplash injury (Petterson et al 1996). However, the number of patients studied was small, and no further studies have confirmed this.
Chronic WAD

So far, no convincing evidence exists for any treatment for chronic WAD (Spitzer et al 1995). Long-term follow up of different kinds of nerve blocks with local anaesthetics and corticosteroids in patients with chronic pain show short periods of pain relief (Johansson & Sjolund 1996). Many authors (Spitzer et al 1995, Barnsley et al 1994, Levander & Gerdle 1998, Ketroser 2000) consider the findings of the Australian group promising. This group reports that in their controlled trials of nerve blocks that 60% of the studied WAD subjects (59) had cervical zygapophyseal-joint pain from C2 to C3 or below (Lord et al 1996 aug). They showed that in WAD subjects with chronic cervical zygapophyseal-joint pain percutaneous radio-frequency neurotomy with multiple lesions of target nerves can provide lasting relief (Lord et al 1996 dec). They have also proposed that nerve coagulation can be repeated with increasing time of pain relief for at least some WAD patients (McDonald et al 1999). However, only a few subjects seem to have longer periods of pain relief and the pain always returns. These findings have not been confirmed in other studies. In a randomised pilot study to test whether muscle relaxation affects pain in subjects with chronic WAD (grade 2) and daily headache, botoxine injections were used and resulted in a decrease in neck pain and an increase in range-of-motion (Freund & Schwartz 2000).

A model for classification of disability and health

The World Health Organisation (WHO) has recently (December 2000) proposed a new version of the international Classification of Functioning, Disability and Health (ICIDH 2) (Figure 3) to provide a unified standard language and frame work for the description of health states. Health and health related components (domains) of well-being are described here. These domains are described from body, individual, and societal perspectives. Functioning refers to all body function, activities, and participation. Disability serves as an umbrella term for impairments, activity limitation, and participation restriction. The earlier version ICIDH (1980) has been criticised for being too static and not functioning as a model for evaluation of different efforts to enhance health.

Proposed definitions of components in ICIDH 2 are as follows:

A. **Body function** (physiological and psychological function of body system) and

**Body structure** (anatomical parts, organ limb, etc).

**Impairments** are problems (symptoms and sign(s)) in body function or structure
B. Participation (execution of task or action by an individual) and Activities (involvement in a life situation)

Activity limitation (difficulties in executing activities)

Participation restrictions (experienced problems in involvement)

This study uses the following terms: Impairment (see above), Disability (difficulties in executing activities and participation restrictions), and Life satisfaction (covering health related domains).

Figure 3: Current understanding of interactions between the constructs of ICIDH-2

Rehabilitation and some definitions

Rehabilitation is the process of enhancing an individual’s ability to reach or regain an optimal desired quality of life and perception of health consistent with his or her impairments and disabilities. Rehabilitation medicine is based on a holistic and comprehensive approach to the complex problems associated with long standing disabilities. The team approach is the key to successful rehabilitation. The patient’s unique point of expertise should be referred to when setting goals. Patient autonomy should be supported and encouraged and the patient should be encouraged to be an active team member (Rehabilitation medicine 1998).
**Basic/unimodal rehabilitation approach**

Different treatments such as occupational therapy or physiotherapy are in many situations sufficient medical care, but when acute pain becomes sub-acute and disability markedly decreases a person’s well-being, then there is a call for a more thorough assessment of the individual’s problem. Long lasting basic rehabilitation approaches do not seem to be beneficial for most chronic pain patients and the need for a multidisciplinary pain rehabilitation approach is strongly supported by health authorities, National Health Board (SoS report 1994), and the Swedish Council on Technology Assessment in Health Care (SBU 2000). The QTF group concludes that most treatments in the chronic state of WAD need a multidisciplinary approach and states that this approach should take place during the sub-acute phase at the latest 3 months after injury. Others also support this approach (Drottning et al 1995, Mayou 1993, Parmar & Raymarker 1993, Lee et al 1993, Gargan et al 1997).

**Multidisciplinary rehabilitation team**

A multidisciplinary team includes several professions working with the primary attending physician as leader of the team. Information is often exchanged in reports and recommendations and the primary consultant determines the solution (assessment) and forms a treatment plan. Communication is mostly vertical; in a team with more lateral communication the cut point between this multidisciplinary and interdisciplinary rehabilitation team becomes not so obvious.

**Interdisciplinary rehabilitation team**

In an interdisciplinary rehabilitation team, communication is lateral, the patient is considered a team member, and the patient has a central role. Decision and responsibility are based on group interaction. Free communication and the exchange of ideas enhances the possibilities of forming adequate goals and rehabilitation plans. Depending on patient stock (i.e., TBI, spinal cord injury chronic pain, or other severe disorders), psychologist, social worker, occupational therapist, physiotherapist rehabilitation specialist, speech therapist, orthopaedic specialists, and neurologists participate in the team. The main goals are focused on reducing participation restriction and enhancing perception of health.
Rehabilitation program

Chronic back pain

In a meta-analysis of chronic back pain, Flor and Turk (1992) concluded that multidisciplinary rehabilitation pain programs are superior to single discipline approaches or no rehabilitation. Both subjective ratings and more objective measures, such as return to work and use of health care system, are affected. Morley and his co-workers (1999) found that active psychological treatments based on the principle of cognitive behavioural therapy for chronic pain patients are effective compared with the waiting list/control condition. Cognitive-behavioural treatments are associated with significant effect sizes in all domains of measurement when compared with other active treatments but it is still unknown what type of patients benefit most from what type of behavioral treatment (van Tulder et al 2001).

Pain and early cognitive-behaviour group intervention can lower the risk of a long-term disability developing and can be used in primary care (Linton & Andersson 2000).

In a recent report (2000) from the Swedish council on Technology Assessment in Health Care (emphasis on chronic back pain), multidisciplinary approaches focusing on behavioural changes as well as encouraging the patient to increase physical activity seemed to provide the best results. Although most of the referred studies do not focusing on chronic neck pain (especially WAD), one can assume that some of the recommendations also relate to WAD.

Chronic WAD

So far, three studies have evaluated rehabilitation programs for WAD. One as early as 3 months, one < 6 months and one over 2 years after the injury (Table 3). Inclusion criteria differed between the studies. Results varied but a trend towards better results (back to work) for earlier interventions is present (Provinciali et al 1996, Vendrig et al 2000). Individuals with low life satisfaction and few coping resources predicted a poor prognosis (Heikillä et al 1998).
<table>
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<th>Authors (year)</th>
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<th>Population Inclusion criteria</th>
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<td>24 months (41%)</td>
<td>Consecutive patients with and without WAD</td>
<td>4 week</td>
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<td>Time of work, low life satisfaction, and no increase in CRI. Predicted poor vocational outcome for both WAD and non WAD</td>
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<td>Proviciali et al 1996</td>
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<td>WAD &lt; 60 days, rear end, regular job no radiating arm pain no severe X Rays findings</td>
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AIMS

The general aims of the present thesis are as follows:

- To increase knowledge about factors described in terms of either function /impairment, activity/disability and life satisfaction in acute and chronic WAD and possible implications for rehabilitation.
- To identify the incidence and recovery rate of whiplash injury and prognostic factors of interest for early rehabilitation.

Specific aims of the studies

Study I
- To compare males and females in a population based sample of clinically healthy subjects with respect to 1) their ability to relax between maximum isokinetic shoulder forward flexion test and signal amplitude ratio (SAR) of the surface EMG, 2) strength, endurance, and perception of fatigue and 3) mean frequency (MNF)

Study II
- To investigate whether chronic WAD was associated with increased muscle tension (unnecessary EMG activity) during relaxation between repetitive maximum shoulder forward flexion.

Study III
- To study the long-term prognosis of cutaneous sensibility for temperature and vibration in the trigeminal area in WAD patients. The study analyses the relationship between cutaneous sensibility and the prevalence of different clinical symptoms several years after the trauma.

Study IV
- To compare aspects of disability (activity preferences and sick leave) and perceived global situation (life satisfaction) in WAD with healthy subjects. Moreover, to analyse if and how symptoms and signs influence the investigated aspects of disability and global situation in the WAD group.

Study V
- To assess the clinical outcomes of a multidisciplinary rehabilitation program for early intervention of chronic whiplash associated disorders (WAD). The primary aim of the program was to increase levels of activity and independence in patients suffering WAD.
Study VI

- To describe the incidence of whiplash injuries in a well-defined small town area and to identify prognostic factors for disability and recovery.
MATERIAL AND METHODS

Subjects

Control group (studies I, II and IV)
The control group consisted of 28 men and 27 female (study II) range 20-60 years without complaints from the neck and shoulder regions, randomly selected from the official census lists of the northern Swedish city of Umeå.

WAD group (studies II and IV)
32 patients (22 females (study I) and 10 males, age between 21-60 years, mean age: 37±11 years) referred to the department of Rehabilitation Medicine at the University hospital of Umeå. In most cases, chronic WAD was reported to be due to automobile accidents (N=28; 7 rear-end, 14 front-end, 3 sidewise collisions, 4 single accidents and 4 other causes). The criteria for inclusion in the WAD group were whiplash trauma, chronic WAD, and that more than 6 months and less than 10 years had passed since the trauma. Patients with clinically diagnosed brain injury and signs of dischemia were excluded.

WAD group (study III)
The prospective study included 43 patients admitted to the Department of Orthopedics, University hospital of Umeå because of WAD related to whiplash trauma due to car accidents with no head injury or signs of concussion. The radiographic examination revealed no abnormalities. The patients were examined with quantitative sensory tests in the trigeminal skin area with a mean of six weeks after the accident (range: 1-17 weeks).

At follow-up with a mean of 71 months (range: 61-77 months) after the injury 34 patients, 10 men and 24 women with a mean age of 36.2 years (range 23-62 years) were available for reinvestigation. Five patients were excluded from the study because they had been involved in new accidents: four patients had experienced a new car accident with a whiplash trauma and one patient had had a severe face injury with following facial sensory disturbances. Two patients without symptoms declined the offer of a follow-up and another two were lost.

WAD group (study V)
The subjects were generally referred from their general practitioner. There were totally 90 patients (age: 33±10 years, days of sick leave previous 365 days: 143±121 days, time since active at work: 9.4±14.7 months); 50 patients at the Umeå center and 40 at the Linköping
center. Two of the subjects that participated in the program in Linköping did not answer any questionnaires. There was no randomization or blinding of subjects or investigators. Inclusion criteria were a) complaints consistent with WAD 1 to 3 according to Quebec Task Force classification (Spizer et al 1995), b) onset of WAD within 3 days of purported injury, c) symptoms persistent greater than 3 months but under 1 year, d) age 18 to 65 years, e) no former neck/shoulder complaints that interfered with usual activities, f) no indications of brain injury, g) no severe or systemic debilitating diseases, h) no indications of drug abuse or abuse of analgesics, and i) no difficulties in understanding Swedish. All patients were examined over 1-2 days by an interdisciplinary team consisting of a physician, physiotherapist, occupational therapist, and social worker/psychologist. After the assessment patients considered having beneficial possibilities of the program were offered to participate. There were overall very few who did not consent.

WAD group (study VI)
During a period of 13 months (January 1997 to February 1998) 356 subjects (16-64 years) seeking medical attention, because of whiplash trauma after a car or a bus accident, at the hospitals' emergency room or general practitioner in the community of Umeå were registered. The primary catchments area population for the actual age group served by the hospital and the general practitioner included in the study was 80,000 inhabitants. Patients with head injury, unconsciousness, fracture or dislocation of the cervical spine (i.e. WAD grade 4) were excluded, as well as patients on sick leave due to neck pain. 296 of 356 (83%) cases (155 women 141 men), with a mean age 33.8 (range 18-64) years, were followed up mean 16 months since accident and 176 of these were also analysed in aspects of initial reported symptoms on outcome.
Clinical tests

Neurophysiological investigations (study III)
The cutaneous temperature sensibility was tested with a "Marstock" thermostimulator (Thermostat, Somedic AB) based on the Peltier principal (Fruhstorfer 1976). All three trigeminal divisions bilaterally (i.e., 6 test points) were tested (first and second divisions was 3-4 cm lateral to the midline in the forehead and the chin, for the third division at the middle of the body of the mandibula). The subject was instructed to change the temperature of the plate in either warming or cooling directions by pressing a switch (ten times). The neutral zone between warm and cold thresholds, the difference limen (DL (in degrees) was noted. Vibration thresholds were determined for the first and third division (i.e., 4 test points) with an electro-mechanical vibrator (Vibrameter, Somedic AB), according to a method described by Goldberg & Lindblom (Goldberg & Lindblom 1979). A probe with 13-mm diameter vibrating at a frequency of 100 Hz was held at constant pressure in contact with the skin. An accelerometer monitored the vibration amplitude, which was presented on a digital display. The amplitude was increased until the subject just noticed the vibration (vibration perception threshold, VPT), and decreased until vibration disappeared (vibration disappearance threshold, VDT). This procedure was repeated three times, and the vibration threshold (VT (in microns)) was determined as the mean value of VPT and VDT. The equipment was routinely used in the clinic and was continuously calibrated. The normal temperature and vibration values were based on a control group of healthy subjects (Knibestöl et al 1990).

The test results for temperature and vibration thresholds were scored in four groups according to the severity of the disturbances. The actual threshold interval for pathological temperature and vibration scores are given in terms of DL and VT:

1 = normal threshold
2 = slight threshold elevation (DL = 2.4-5.0 °C, VT = 2.2-5 um)
3 = moderate threshold elevation (DL = 5.0-10.0 °C, VT = 5.0-10.0 um)
4 = pronounced elevation (DL > 10.0 °C, VT > 10.0 um)

Thus, temperature (6 test points) had a possible range between 6 and 24; >6 defined as deviating from normal values. Corresponding values for vibration (4 test points) were 4-16 and >4 defined as deviating from normal values. For each patient a total sensory score was also calculated, including both temperature and vibration scores (possible range 10-40, >10 defined as pathological).
Isokinetic dynamic endurance test and EMG (studies I and II)
The subjects performed maximum dynamic shoulder (dominant arm) flexions using an isokinetic dynamometer (Cybex II, Lumex Inc., New York). They were seated in a specially constructed chair, which enabled comfortable fixture. The arm was held with the elbow extended and the hand pronated, gripping a handle, the length of the lever arm being adjusted for each subject. The subjects were informed about the intentions of the experiment, but not about the number (100) of repeated maximum forward flexion scheduled in the protocol.
Before the test started the subjects were instructed using sub maximal contractions and then rested. Each contraction cycle started with the hand against the thigh. After having performed a maximal shoulder flexion from 30°-90° (i.e. the active flexion part of the contraction cycle) the subject was instructed to relax completely while the arm was passively extended, following the lever arm/handle down through gravitational torque (i.e. the passive relaxation part of the contraction). When the lever arm/handle reached the thigh the subject was instructed to immediately perform a new shoulder forward flexion (figure 4). The contraction frequency was thus standardized (i.e. 30 contraction cycles per minute). The subjects were frequently encouraged verbally throughout the experiment to perform maximally during each flexion and to relax completely during the passive extension. An eleven graded (0-10) category scale with ratio properties was used for rating the perception of muscular fatigue in the shoulder muscles throughout the test (Borg, 1982). The subjects rated their perceived muscular fatigue at every fifth contraction during the initial 50 contractions and for every tenth contraction throughout the remaining 50 contractions.
EMG signals using surface electrodes (Medicotest, Ølstykke, Denmark; centre to centre distance: 20 mm) were obtained from the cervical and descending parts of the trapezius, the anterior part of the deltoid, and the infraspinatus muscles. Before the electrodes were attached, the skin area was dry shaved and rubbed with alcohol and ether (4:1). A bipolar multi-channel EMG amplifier (EMGAmp, Braintronics BV ISO-2104, Almere, the Netherlands) (CMMR higher than 100dB, input noise less than 1 microV) was used to register the surface EMG activity. The skin impedance was checked with the purpose of achieving balance between the electrodes using the common mode test of the amplifier. Test contractions before the test were also made to secure good electrode-skin contact and RMS noise levels less than 10 microV. The preset angular velocity chosen was 1.05 rad s⁻¹ (60° s⁻¹).
All signals were amplified and analogue-to-digital converted with 12-bit accuracy in the signal range ± 5 V, with a sampling rate of 2 kHz. Analogue low-pass filters of 800 Hz were
used to eliminate aliasing of sampled EMG signals. For the biomechanical signals i.e. torque and position, 40 Hz low-pass filters was used. A high-pass filter of 16 Hz was used to avoid the influence of movement artefacts and low-frequency noise of the EMG signals. The power-density spectrum was obtained, after Hamming windowing, using the fast Fourier transform (FFT) technique. To yield a spectral resolution of approximately 2 Hz, a 1024 point FFT (512 msec) was selected.

Each contraction cycle starts with the hand against the thigh.

Figure 4. Endurance test. Schematic drawing of the shoulder movement investigated. Each contraction cycle consisted of a active maximum shoulder forward flexion followed by a passive shoulder extension. The subjects were instructed to completely relax the muscles during the passive extension. No rest was allowed between the two parts of the contraction cycle or between the contraction cycles. The location of the EMG surface electrodes. Tc denotes the superior part of m. trapezius at the C2-level [trapezius cervicalis]. Td denotes the superior part of m. trapezius at anterolateral margin [trapezius descending]. Is denotes m. infraspinatus. Da denotes m. deltoid anterior part.

Calculated parameters from EMG and torque signals were MNF (Hz), RMS (µV) and peak torque (Nm) and work (J). The isokinetic part of a phase during the contraction cycle was used to verify that a contraction has a minimum range, and at the same time eliminating values outside the active part of the contraction cycle. During repetitive maximal isokinetic contractions the mechanical output will decrease steeply during the initial 20-60 contractions.
(in the following: the fatigue phase) followed by a stable level (in the following: the endurance level). The ability to relax in-between the maximum shoulder forward flexions was calculated as a ratio of the RMS during the passive extension phase and the RMS during the active flexion phase of each contraction cycle: the signal amplitude ratio (SAR). A high SAR means a high activity during the passive shoulder extensions and hereby a relative inability to relax.

The following variables of main interest were used in the study I and some in study II:

- **Peak torque initially (PTi):** the highest value of one of the five initial contractions (Nm).
- **Peak torque initially BW (PTi_bw):** PTi normalised for body weight (Nm/kg).
- **Peak torque endurance level (PTe):** mean of peak torque of contraction nos.: 51-100 (Nm).
- **Relative peak torque level (PTer):** the ratio between the PTe and PTi.
- **Relative work level (Wer):** the ratio between We and Wi.

Perception of fatigue according to Borg: ratings every 10 nth contraction

Note that ≥10 on this scale denotes perception of maximum fatigue.

**EMG variables:**

- **MNF initially (MNFi):** mean of MNF of contraction nos.: 1-5 (Hz).
- **MNF endurance level (MNFe):** mean of MNF of contraction nos.: 51-100 (Hz).
- **MNF shift (MNFsh):** the difference between MNFi and MNFe (Hz).
- **Relative MNF level (MNFer):** the ratio between MNFe and MNFi.
- **SAR:** the ratio between RMS of the passive phase and RMS of the flexion phase for each contraction cycle, the mean of contraction cycle nos.: 51-100 or last 20 in those not reaching 100 contractions.

**Questionnaires (impairment, activity and life satisfaction) (study IV)**

All subjects with WAD answered questionnaires concerning aspects of the subjects’ trauma, medication, pain, support from the social net work, understanding of whiplash causes and effects, and belief in future possibilities for work. Questions concerning pain localization, pain characteristics, and pain intensity were also included in the version of the questionnaire answered by the WAD group.
Impairment – Symptoms
For the rating of pain intensity a visual analogue scale (VAS) was used; the scale was 100 mm long with defined end points ("no pain" and "worst pain imaginable") but without marks in between. In study IV all the questions regarding pain concerned the previous 7 days of four pre-defined anatomical regions head, neck, shoulder, upper back and lower back. A number of symptoms were also listed concerning the musculoskeletal system and different neuropsychological symptoms (studies II – V). Subjects without or with WAD choose among the following alternatives for each symptom: "no, never", "no, seldom", "yes, occasionally", "yes, often".

In study III twelve symptoms were divided in two subgroups. These two subgroups groups were formed mainly according to Radanov (Radanov et al 1992). Five symptoms (neck pain, stiffness and impaired mobility, radiating pain and paraesthesias in the arms and hands) were classified as the musculo-skeletal symptoms and summarized into a Musculo Skeletal-index (MS-index; possible range: 5-20). The other seven symptoms (face pain and numbness, dizziness, sensitivity to light, sensitivity to sound, memory and concentration problems) were considered to be related to cognitive functioning and the central nervous system; i.e. symptoms related to the cervicoencephalic syndrome (CES-index; possible range: 7-28). In the regression analysis the 12 symptoms were dichotomized; never or seldom versus occasionally or often. In study VI the answering alternatives concerning symptoms were presented according to a four graded scale (none, slight, moderate and severe). For the univariate and multivariate statistical analysis all the available data were dichotomized.

Signs- Physical examination (studies II and IV)
The physical examination of the WAD groups and controls was performed in the same manner. A check list consisting of three parts was used: 1) neurological examination; 2) pain provocation and stiffness; 3) range of motion of relevant joints. Usually the subjects were examined in the sitting position except for bony palpation (supine position). All tests performed were categorised according to one of the alternatives: 1) normal; 2) suspect non-normal (a suspect sign); 3) non-normal findings (a definite sign).

1. Neurological examination. This examination focused on the peripheral nervous system. The following tests were made: deep tendon reflexes (Bannister, 1985); light skin touch (sensibility) (Bannister, 1985); touch with needle in the n. trigeminus area; foramina intervertebrale compression (Hoppenfeld, 1976); Tinell’s test of ulnaris and medianus. The
Hands up test (Roos test, a test for thoracic outlet syndrome) was regarded as a sign if the duration was <30 sec. Plexus brachialis was investigated by palpation in the fossa supraclavicularis and radiating sensation below the elbow was regarded as a sign. Neck laseque (stretching of the whole plexus brachialis and its branches from the neck) was performed through 90 shoulder abduction, maximal shoulder extension, and maximal neck rotation to the opposite side; radiating sensation below the elbow was regarded as a sign.

2. Palpation and Stiffness. This part included palpation of muscles (m. trapezius; the cervical and the descendent portions), m. levator scapulae, m. scalenius, m. masseter and m. erector spinae thoracalis and cervical and thoracal spinous processes (Hoppenfeld, 1976). Through palpation the examiners estimated stiffness and pain reaction. Extreme stiffness was regarded as a sign. If slightly increased pressure of the muscle caused a withdrawal reaction or a grimace, it was regarded as a positive sign at the muscle palpation.

3. Range of motion. The range of motion of neck, shoulders, and upper back were examined. If the range of motion was decreased >50% of normal average range it was considered as a sign (Hoppenfeld 1976).

Disability/Activity (studies II, IV-VI)

Disability in study VI related to the accident was used as the outcome variable for the assessment of prognostic factor. The disability was graded in four levels; 1; none or minor 2; complaints affecting work or leisure but no sick leave 3; change of work tasks 4; sick leave due to the accident. In the regression analyse disability was dichotomized into none/minor disability versus disability affecting work or leisure including sick-leave.

Activity preferences (study IV)

Activity preferences covered four areas; 1) manual activities; 2) physical activities; 3) social activities; 4) activities of daily life.

This part of the questionnaire is a modified version of the instrument used by Brännholm & Fugl-Meyer (1994). For the WAD group each item had the following alternatives: 0=the activity is not interesting; 1= cannot perform due to complaints; 2= perform with some difficulties; 3=perform without difficulties. In the control group the following answering alternatives were used: 0=never perform the activity; 1= do not perform but interested; 2=perform somewhat interested; 3= perform very interested. When comparing the two groups each item was dichotomised and thus alternatives 2 and 3 (the subjects that actually performed the activity) versus alternatives 0 and 1 (the subjects that did not perform the activity whatever
the cause) were used in the analysis. Based on the dichotomised items four indices were computed.

The **Manual Activity Index** included the following activities: embroidery, knitting, sewing, weaving, drawing/painting, ceramics, birch-bark, construction of models, carpentry and car repairer (range: 0-10).

The **Physical Activity Index** included the following activities: jogging, swimming, cycling, skiing, gymnastics, soccer/ice-hockey, tennis/badminton, week-end cottage, hunting, and fishing (range: 0-10).

The **Social Activity Index** included the following activities: socialising, dancing, club activities, travelling, and dinner and tea party (range: 0-5)

The **Daily Activity Index** included the following activities: home repairs, cooking, baking, cleaning, care of one’s clothes, shop, car maintenance, and work in the garden (range: 0-8).

The **Total Activity Index** the four indices summarized (range: 0-33).

**Sick-leave (studies II, IV and V)**

Sick-leave was reported the last year in study (studies II, IV and V), and at 6 month after rehabilitation program (Study V).

**Life Satisfaction (studies IV and V).**

The instrument consists of one item about life as a whole and 10 specific domains: satisfaction with vocational situation, financial situation, leisure situation, contact with friends and acquaintance, sexual life, Activity of Daily Life (ADL), family life, partnership, physical health, and psychological health (Fugl-Meyer 1998). Each item has six possible answers: 1= very dissatisfying; 2= dissatisfying; 3= fairly dissatisfying; 4= fairly satisfying; 5= satisfying; 6= very satisfying. In study IV we have used the dichotomization used by Fugl-Meyer et al (1991); i.e., 1-4 and 5-6.

**Rehabilitation program evaluation (study V)**

**Retrospective data**

Retrospective data was collected immediately and after the interdisciplinary program and at 6-month follow-up:

a) 32 questions concerning different aspects of pain and other symptoms, pain management, disabilities, and life quality; the patients compared their situation with their functioning
immediately before the start of the rehabilitation program (better or worse). The questions were clustered (sorted in groups with similar questions; F1-F8) according to a principal component analysis (PCA).

b) 12 questions covering aspects of satisfaction with the rehabilitation program.

c) A semi-structured end-of-program patient satisfaction interview (in Umeå only).

d) Stress reactions and crisis disorders, including post traumatic stress disorder (PTSD, defined according to DSM-IV) were collected from the medical records (in Umeå only).

Prospective data
Collected before, after, and at 6 month follow-up were a) self reported questionnaires (see above) b) Beck Depression Index (BDI) (Beck et al 1961) c) Multidimensional Pain Inventory (MPI) (Kerns et al 1985), d) Coping Resource Index (CRI) (Hammer 1988), and e) sick-leave. BDI, MPI, and CRI were not included at 6 month follow up.

Statistics
Statistical packages SPSS for Windows (release 7.5, 8.0 or 9.0) and SIMCA-S for Windows (release 6.01 or 7.01) were used in study I, III, IV to VI. In study II SYSTAT for the Macintosh (version 5.2; Systat Inc., Evanston, Illinois, USA) was used. \( p \leq 0.05 \) has been considered significant in all statistical tests. In several studies variables were dichotomized; for details see the individual papers.

Univariate analysis
See the individual papers.

Multivariate analyses
Multiple linear regression was used to quantify the effect of sex, age and body mass index (BMI) for each measurement variable separately (study I). Univariate and multiple logistic regression were used to test association between the outcome and the background and acute variables in study VI. Missing data for education, pre-injury pain and marital status were coded as separate categories in the logistic regressions.

Principal Component Analysis of the retrospective questions using SIMCA-S (PCA, missing data tolerance = 50%; components/factors with Eigen values \( \geq 2.00 \) were considered as nontrivial factors) was made in order to sort the questions in groups (F1-F8) in study V (Gerdle et al 1998). Regression analyses (discriminante analysis) was also made according to
the partial least square technique (PLS) (Eriksson et al 1995). The aim of using PLS regression in study I, III IV and VI was to regress one or several Y-variables using several other variables (X-variables). The influence of each explanatory variable was measured as a variable influence on projection (VIP) (Eriksson et al 1995). VIP ≥ 1 was considered as significant. Outliers were identified using the two methods available in SIMCA-P: 1) score plots in combination with Hotelling’s $T^2$ (identifies strong outliers) and 2) distance to model in X-space (identifies moderate outliers). Logistic regression or multiple regression might have been alternative methods but they assumes for stable coefficients that the regressor variables (X variables) are mathematically relatively independent and high subjects to variables ratios are needed. However that was not the case since many regressors were related. If multicollinearity (high correlations) occurs among the X-variables the calculated regression coefficients can become unstable and their interpretability breaks down (Eriksson et al 1995) or no model at all can be established.
Main Results

Isokinetic performance (studies I and II)

Healthy subjects (study I)
As expected from previous studies output showed a pattern with two phases for both men and women; an initial steep decrease followed by a phase with no significant change (figure 5).

![Graph showing peak torque (Nm) for men and women versus numbers of maximal isokinetic shoulder flexions.](image)

Figure 5: Mean values of peak torque (Nm) of men and women versus numbers of maximal isokinetic shoulder flexions.

Perception of fatigue throughout the test was similar for males and females. Men were significantly stronger than women and on average females had approximately 60% of the output of males and 76 % after normalization for body weight (Table 4). No significant gender differences existed between the number of contraction to the breakpoint (Bp-no or Bp-deg) and no significant differences were found in PTer and Wer between the two groups.

Regression of the biomechanical variables controlling for age, BMI and gender, age was non significant and the gender differences remained.

Female WAD subjects compared to healthy females (study II)
A pattern with a steep decrease in peak torque followed by a steady state level (the endurance level) was seen in the both groups although the WAD group had significantly lower absolute endurance level. All but one of subjects in the control group managed to perform 100
contractions. Only 6 out of 22 WAD subjects were able to perform one hundred contractions. Hence, 16 subjects stopped because of severe fatigue/pain. The control group were significantly stronger. A greater proportion (18 out of 22; 82%) of the WAD group than the control group (15 out of 27; 56%) rated maximum fatigue (≥10) at the end of the test.

**EMG**

**MNF of healthy subjects (study I)**

No significant differences existed in MNFi and MNFsh of the four muscles between the two sexes. Males had significantly lower MNFe for three of the investigated muscles (i.e. trapezius cervicalis, trapezius descendens and infraspinatus). But for absolute MNFer level only trapezius descendens differed significantly between the two sexes. No significant gender differences in any of the MNF variables were found for the deltoid in the univariate analyze but it became evident in the multiple regression that age and BMI had significant effect on the prime mover deltoid.

**SAR of Healthy subjects (study I)**

The patterns of SAR throughout the test were very similar for the two sexes. Thus, a more or less constant curve throughout the test. No significant differences existed between males and females in ability to relax between the contractions (SAR) in the four muscles or in the mean of the four muscles (table 4). These results were confirmed in the multiple regressions; SARE of the four muscles were independent of sex, age, BMI and biomechanical output.

**SAR of Female WAD subjects compared to healthy females (study II)**

The WAD subjects exhibited significantly higher SAR value for trapezius cervicalis, trapezius descendens and infraspinatus than the control group (table 5).

The patients who stopped before 100 performed contractions (N=16) had a significantly higher SAR of the trapezius cervicalis (21.5 % ± 15.7 versus 9.6 % ± 7.9), deltoid (18.5 % ± 12.2 versus 6.6 % ± 3.6) and infraspinatus (18.9 % ± 9.8 versus 8.9 % ± 5.4) than did those who were able to perform all contractions (N=6). No significant differences existed for the trapezius descending even though a similar trend was observed (18.1 % ± 13.2 versus 11.1 % ± 7.8)
Table 4: Mean values ± 1SD of the strength, endurance, and perception of fatigue variables and SARE of the isokinetic shoulder forward flexion test in men and women. Furthest to the right are given the result of the statistical evaluation (p-value), * denotes significant difference between men and women.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group</th>
<th>Men</th>
<th>Women</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>PTi (Nm)</td>
<td></td>
<td>116.6</td>
<td>20.9</td>
<td>67.4</td>
</tr>
<tr>
<td>PTi BW (Nm/kg)</td>
<td></td>
<td>1.4</td>
<td>0.2</td>
<td>1.1</td>
</tr>
<tr>
<td>PTe (Nm)</td>
<td></td>
<td>64.4</td>
<td>12.9</td>
<td>39.6</td>
</tr>
<tr>
<td>PTe BW (Nm/kg)</td>
<td></td>
<td>0.8</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>PTer</td>
<td></td>
<td>0.6</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Borg100</td>
<td></td>
<td>13.2</td>
<td>15.6</td>
<td>11.6</td>
</tr>
<tr>
<td>SARE:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>trapezius cervicalis</td>
<td>0.12</td>
<td>0.07</td>
<td>0.11</td>
<td>0.05</td>
</tr>
<tr>
<td>trapezius descendens</td>
<td>0.10</td>
<td>0.07</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>infraspinatus</td>
<td>0.08</td>
<td>0.05</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>deltoid</td>
<td>0.11</td>
<td>0.08</td>
<td>0.16</td>
<td>0.10</td>
</tr>
<tr>
<td>mean of the four muscles</td>
<td>0.10</td>
<td>0.06</td>
<td>0.11</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 5: Results (mean ± 1 SD) from the endurance tests of the shoulder flexors of the WAD patient group (N=22) and the control group (N=27). The results of the statistical comparisons between the two groups are in the far right column.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient group (N=22)</th>
<th>Control group (N=27)</th>
<th>Statistics (P value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak torque, initial (Nm)</td>
<td>52.8 (±14.0)</td>
<td>67.3 (±12.1)</td>
<td>0.000</td>
</tr>
<tr>
<td>Peak torque, endurance level (Nm)</td>
<td>28.9 (±10.6)</td>
<td>39.6 (±7.8)</td>
<td>0.000</td>
</tr>
<tr>
<td>SAR Trapezius M cervicalis (%)</td>
<td>18.1 (±14.8)</td>
<td>11.0 (±5.5)</td>
<td>0.030</td>
</tr>
<tr>
<td>SAR Trapezius M descending (%)</td>
<td>16.9 (±12.1)</td>
<td>8.3 (5.6)</td>
<td>0.002</td>
</tr>
<tr>
<td>SAR Deltoid M (%)</td>
<td>14.8 (±11.8)</td>
<td>15.7 (10.1)</td>
<td>ns</td>
</tr>
<tr>
<td>SAR Infraspinatus M (%)</td>
<td>17.1 (±16.2)</td>
<td>8.7 (6.6)</td>
<td>0.020</td>
</tr>
<tr>
<td>Borg, middle of the test</td>
<td>8.1 (±4.4)</td>
<td>7.7 (±3.0)</td>
<td>ns</td>
</tr>
<tr>
<td>Borg, terminal part</td>
<td>18.5 (±17.8)</td>
<td>11.6 (±7.2)</td>
<td>ns</td>
</tr>
</tbody>
</table>

Neurophysiological measurements and clinical symptoms (study III)

A significant correlation existed for the total sensibility score between the two test occasions (r=0.764, p=0.001). Thirteen of the 43 patients tested at the first occasion after the trauma had
impaired cutaneous sensibility (total score >10 for temperature and vibration) over the trigeminal area. Twelve of these 13 patients were available at follow up 5-6 years later (Table 6) and 11 of them remained pathological at follow up. Five patients with initial normal test results changed to pathological results at follow up. Three patients had initially pronounced sensory disturbances which persisted over time and five patients had changed to pronounced sensory impairment at follow up. The sensory tests revealed an increase of the pathological thermometry scores in 14 cases. The vibrametry scores showed a mixed pattern with an increase in four cases and a decrease in seven cases. The two indices (CES-index and MS-index) intercorrelated positively (r=0.736, p<0.000). Pain intensity of the neck correlated significantly with MS-index (r=0.664; p<0.000) and CES-index (r=0.595; p<0.000).

Table 6: Numbers of patients at initial assessment, at follow-up and number of dropouts with normal and pathological total sensory scores of the trigeminal sensibility.

<table>
<thead>
<tr>
<th></th>
<th>Total number</th>
<th>Trigeminal sensibility (total sensory score)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N)</td>
<td>Normal (N)</td>
</tr>
<tr>
<td>Initial assessment</td>
<td>43</td>
<td>30</td>
</tr>
<tr>
<td>Follow up</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>Dropouts (initial data only)</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>

A significant correlation was found between CES-index and the total sensory score at follow up (r=0.614; p<0.000) but not for MS-index or pain intensity of the neck. The PLS regression (R^2=0.636) using MS-index and CES index together with pain intensity and total sensory score of the acute phase as regressors of the total sensory score at follow up, showed that CES-index (VIP=1.18) followed by the total sensory score of the acute phase (VIP=1.14) were the significant regressors. Numbness and pain of the face, dizziness, concentration and memory problems (in descending order of importance) were significant when 12 symptoms (in dichotomized form) were used as regressors (X-variables) of the total sensory score at follow up (a two component solution;R^2=0.617). None of the symptoms of MS-index were significant regressors.
Impairment, disability and life satisfaction (study IV)

A significantly higher proportion of women than men in study IV reported complaints from all four regions: 3.6±0.7 regions for women and 2.4±1.1 for men. All patients reported pain in the neck, 88% in the shoulder, 75% in the upper back, and 64% in the lower back. In these anatomical regions, 67%, 63%, 39%, and 44% respectively, reported that they had perceived pain every day during the past 7 days. Pain characteristics were perceived simultaneously and the predominant reported was deep pain (59%) and fatigue (56%). The intensities of pain (VAS) for the last 7 days were of the same magnitude for the 94 WAD subjects in studies IV and V. Generally the WAD patients reported somewhat higher pain intensity in the neck (57±21) than in the lower regions (47±21) (table 7).

Table 7: Seven days period prevalence of pain (absolute and in per cent), proportion with complaints during all of recent 7 days (%) (denoted proportion all 7 days), pain intensities (according to VAS; ordinary and at worst) and the prevalence of different permanent pain qualities (i.e. according to the alternative “Yes, always”) of neck, shoulders, upper back and lower back reported by the WAD group (N=32). No difference between the two sexes existed.

<table>
<thead>
<tr>
<th>Anatomical Region</th>
<th>Neck</th>
<th>Shoulder</th>
<th>Upper back</th>
<th>Lower back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of complaints (absolute number)</td>
<td>32</td>
<td>28</td>
<td>24</td>
<td>19</td>
</tr>
<tr>
<td>Prevalence of complaints (%)</td>
<td>100</td>
<td>88</td>
<td>75</td>
<td>64</td>
</tr>
<tr>
<td>Proportion all 7 days (%)</td>
<td>67</td>
<td>63</td>
<td>39</td>
<td>44</td>
</tr>
<tr>
<td>VAS ordinary (mean ± 1SD)</td>
<td>57 ± 21</td>
<td>52 ± 22</td>
<td>46 ± 21</td>
<td>47 ± 21</td>
</tr>
<tr>
<td>VAS at worst (mean ± 1SD)</td>
<td>82 ± 15</td>
<td>77 ± 21</td>
<td>67 ± 24</td>
<td>76 ± 19</td>
</tr>
</tbody>
</table>

Frequency of permanent pain qualities (%)

<table>
<thead>
<tr>
<th>Pain Quality</th>
<th>Neck</th>
<th>Shoulder</th>
<th>Upper back</th>
<th>Lower back</th>
</tr>
</thead>
<tbody>
<tr>
<td>deep pain</td>
<td>56</td>
<td>38</td>
<td>44</td>
<td>32</td>
</tr>
<tr>
<td>burning</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>numbing</td>
<td>13</td>
<td>18</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>thrilling</td>
<td>17</td>
<td>7</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>picking</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>cramping</td>
<td>22</td>
<td>31</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>fatigue</td>
<td>59</td>
<td>48</td>
<td>50</td>
<td>53</td>
</tr>
</tbody>
</table>

Different neuropsychological symptoms correlated significantly stronger with the pain intensities in the neck than with the presence of pain in the other anatomical regions and pain duration for WAD subjects (table 8). Impairment (symptoms and signs) showed significant differences between the two groups on most variables. Disability (activity preference) showed significant differences between the C group and the WAD group in 3 out of 5 indices for the females. Similar trends were noted for the men but these differences were not significant.
Fifty per cent of the patients had been sick-listed for 180 days or more during the previous 12 months; corresponding figures for < 60 days and 61-180 days were 31% and 19%, respectively. Ten patients reported low levels (<30 days) of sick-listing the previous year and 22 patients reported relatively high levels (>60 days). Physical activity index and the daily activity index were significantly lower in the group with long sick leave compared to those with short sick leave.

Major significant differences excited concerning satisfaction with life as a whole, physical and psychological health for the two groups. Only 6% of the WAD group rated their situation as satisfying/very satisfying with physical health versus 75% in the C –group. Satisfaction with one’s vocational situation and with one’s leisure and activity of daily life (ADL) were also significantly lower in the WAD group.

Relationships between impairments, disability and life satisfaction in WAD

PLS regressions were made in order to investigate how symptoms, signs, disability, and aspects of life satisfaction interacted. When signs were added to the X-variables in the analysis there was very little influence and there was no marked increase in the explained variance of the models ($R^2$).

No significant relationships were found between symptoms and/or signs and sick leave the previous year. Significant relationships existed between total-index and different symptoms ($R^2 = 0.53$, 3 multivariate outliers excluded). The most important symptoms were a combination of pain intensity variables and cognitive symptoms. It was not possible to regress the other activity preference indices. Significant relationships existed between certain symptoms and life as a whole and with the physical health. Symptoms with strongest association with satisfaction with life as a whole were neuropsychological symptoms and an increase in neck pain intensity and with physical health were vertigo, light and sound intensity variables, together with different pain related variables.
Table 8: Regression of pain intensities of the neck (Y-variables) of the WAD group using the different—not directly pain related—symptoms shown as X-variables. Three multivariate outliers excluded. For each variable is given VIP, and coefficients (i.e. PLS scaled and centred regression coefficients; denoted Coeff). VIP > 1.0 is significant. Only the significant regressors are shown (i.e. VIP>1.0). At the bottom row is given explained variance (R²).

<table>
<thead>
<tr>
<th>X-variables</th>
<th>VIP</th>
<th>VAS ordinary (Coeff)</th>
<th>VAS worst (Coeff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory problem</td>
<td>1.83</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Vertigo</td>
<td>1.70</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>Light sensitivity</td>
<td>1.50</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Changes in light intensity</td>
<td>1.38</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Concentration problems</td>
<td>1.23</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Feeling of fullness of ear</td>
<td>1.12</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>R²</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant regression models were possible to establish for life as a whole, leisure and activities of daily living and as regressors activity indices, sex and age. Social activity indices were of importance for all three domains and age for life as a whole.

In a series of PLS regression we investigated how signs, symptoms (including pain during the most recent 7 days), and indices of activity preferences influenced the different items of the life satisfaction instrument. For 5 out of 11 items it was possible to establish significant models. The neuropsychological symptoms appeared more important than the pain related symptoms in the regressions of satisfactions with life as a whole, leisure, and contacts with friends (table 9).
Table 9: Regression of different items of the life satisfaction instrument of the WAD group using the different signs, symptoms, leisure indices and items regarding future and ability to influence complaints as X-variables. Only the ten most important and significant variables are given for the regressions that resulted in significant models. For analysis are reported VIP and coefficients (i.e. PLS scaled and centred regression coefficients; denoted Coeff). VIP > 1.0 is significant. At the bottom row is given explained variance ($R^2$). For the other items of the instrument of life satisfaction it was not possible to establish significant regressions.

<table>
<thead>
<tr>
<th>Y-variables Life as a whole</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
<th>X-Variables</th>
<th>VIP</th>
<th>Coeff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Changes in light intensity</td>
<td>2.47</td>
<td>-0.06</td>
<td>Shoulder pain duration 7 days</td>
<td>2.12</td>
<td>-0.05</td>
<td>Changes in light intensity</td>
<td>2.08</td>
<td>-0.05</td>
<td>Changes in light intensity</td>
<td>2.51</td>
<td>-0.07</td>
<td>Neck intensity ordinary</td>
<td>2.04</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light sensitivity</td>
<td>1.99</td>
<td>-0.05</td>
<td>Neck pain duration 7 days</td>
<td>2.07</td>
<td>-0.05</td>
<td>Memory problem</td>
<td>2.07</td>
<td>-0.05</td>
<td>Sleeping difficulties</td>
<td>2.20</td>
<td>-0.06</td>
<td>Memory problem</td>
<td>1.87</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neck intensity worst</td>
<td>1.88</td>
<td>-0.04</td>
<td>Neck intensity worst</td>
<td>1.98</td>
<td>-0.05</td>
<td>Total activity index</td>
<td>1.99</td>
<td>0.05</td>
<td>Light sensitivity</td>
<td>1.90</td>
<td>-0.05</td>
<td>Light sensitivity</td>
<td>1.87</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Future reduction of complaints</td>
<td>1.70</td>
<td>-0.04</td>
<td>Headache</td>
<td>1.83</td>
<td>-0.4</td>
<td>Shoulders intensity worst</td>
<td>1.97</td>
<td>-0.05</td>
<td>Concentration problems</td>
<td>1.87</td>
<td>-0.05</td>
<td>Total activity index</td>
<td>1.81</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shoulders duration 7 days</td>
<td>1.69</td>
<td>-0.04</td>
<td>Changes in light intensity</td>
<td>1.81</td>
<td>-0.04</td>
<td>Light sensitivity worst</td>
<td>1.78</td>
<td>-0.04</td>
<td>Anxiousness</td>
<td>1.68</td>
<td>-0.05</td>
<td>Hand numbness</td>
<td>1.79</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentration problems</td>
<td>1.69</td>
<td>-0.04</td>
<td>Vertigo</td>
<td>1.77</td>
<td>-0.04</td>
<td>Physical activity index</td>
<td>1.76</td>
<td>0.04</td>
<td>Pain in the leg</td>
<td>1.68</td>
<td>-0.05</td>
<td>Changes in light intensity</td>
<td>1.72</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Memory problem</td>
<td>1.67</td>
<td>-0.04</td>
<td>Upper back pain duration 7 days</td>
<td>1.66</td>
<td>-0.04</td>
<td>Neck intensity worst</td>
<td>1.73</td>
<td>-0.04</td>
<td>Future reduction of complaints</td>
<td>1.64</td>
<td>-0.04</td>
<td>Difficulties with peeling</td>
<td>1.61</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social activity index</td>
<td>1.54</td>
<td>0.03</td>
<td>Change of hand sensitivity</td>
<td>1.65</td>
<td>-0.04</td>
<td>Upper back intensity worst</td>
<td>1.71</td>
<td>-0.04</td>
<td>Difficulties with swallowing</td>
<td>1.62</td>
<td>-0.04</td>
<td>M scalenus stiffness</td>
<td>1.61</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper back intensity worst</td>
<td>1.52</td>
<td>-0.03</td>
<td>Fatigue</td>
<td>1.60</td>
<td>-0.04</td>
<td>Neck lateral flexion</td>
<td>1.68</td>
<td>0.04</td>
<td>Hoarseness</td>
<td>1.62</td>
<td>-0.04</td>
<td>M scalenus pain</td>
<td>1.53</td>
<td>-0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total activity index</td>
<td>1.51</td>
<td>0.03</td>
<td>Feeling of fullness of ear</td>
<td>1.60</td>
<td>-0.04</td>
<td>Concentration problems</td>
<td>1.68</td>
<td>-0.04</td>
<td>Low back intensity ordinary</td>
<td>1.62</td>
<td>-0.04</td>
<td>Physical activity index</td>
<td>1.52</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$R^2$ | 0.53 | $R^2$ | 0.52 | $R^2$ | 0.51 | $R^2$ | 0.55 | $R^2$ | 0.71
Early interdisciplinary rehabilitation (study V)

Medium inclusion into the program was 8 months post trauma. Sixty-two out of 88 patients completed questionnaires after the rehabilitation. However, the 24 patients that did not answer the questionnaires after the program participated in the programs. Those who did not answer the questionnaires after the program perceived significantly less control according to MPI (2.6±1.1 vs. 3.2±1.0), rated significantly lower according to the cognitive scale of CRI (23.7±4.4 vs.26.4±4.0) and two of the scales of LSQ (family life: 4.5±1.2 vs. 5.0±1.0 and partnership relations: 4.2±1.8 vs. 5.2±0.9) at the beginning of the program. For the other items and scales no differences were found.

91.5 % of the patients reported that they had contacts due to their WAD with a lawyer, regional social insurance office, or insurance company. For the majority (85%), this meant waiting for a certificate needed for financial compensation or for a decision concerning the future financial situation. 6.4 % had appealed or were going to appeal a decision from the insurance company or the social insurance authorities.

Retrospective evaluations

A definitely higher proportion reported better situations than worse situations within the areas “Pain management” (F3), “Control pain” (F5), and to a certain degree within “Psychological aspects” (F1). Prominent similar differences also existed for “Family life” at the 6 month follow-up (F6). For “Pain intensity” the proportions between better and worse were rather equal. For “Cognitive impact” (F7) and “Fitness” (F8) the proportion with a worse situation was higher than the proportion that reported a better situation.

The majority of patients rated the rehabilitation program as a whole and different other aspects of it as “satisfactory/rather satisfactory” both immediately after and at 6 months follow-up. The semi-structured interview also indicated that the patients considered the program valuable. Patients spoke of improved handling, control, increased knowledge, and optimism. Verbal patient feedback proposed more individual time with team members, more theoretical sessions, and more discussion groups. According to the medical records in Umeå, stress reactions and crisis disorders were present in 32% patients and 8% fulfilled the criteria for post traumatic stress disorder (PTSD).
Prospective evaluations
Neck and upper back pain intensity had decreased significantly at 6 months. The Beck Depression Index (BDI) showed that most patients (mean 12, SD 6.4) were slightly depressed (value 10 was cut off point), a finding that remained unchanged after the program. The indices of MPI were unchanged after the program, except one index that showed a significantly increased distraction behavior from “spouses/significant others” after the program (P=0.039). CRI showed a tendency towards increased ability to cope philosophically (P=0.058) but cognitive, social, emotional, and physical indices were not effected. No significant changes occurred for the items of the LSQ immediately after the program (table 10). However, at 6 months follow-up, significant decreases had occurred in satisfaction with the financial situation, with the family situation, and with the marriage. None of the significant changes reported above in the prospective results will be significant after Bonferonni correction.

Sick leave (≥ 50 %) had increased from 55.9 % before the program to 80.3% at the 6 months follow-up and the proportions working (≥ 50 %) changed from 36.3% to 21.3%, a drop of 15%. Twelve percent more were training for work at the 6 month follow-up.
Table 10: Results of the modified version of Life Satisfaction Questionnaire (LSQ) before, after, and at 6 month follow-up from a WAD rehabilitation program. Each item has six alternatives (1= very dissatisfying, 2= dissatisfying, 3= fairly dissatisfying, 4= fairly satisfying, 5= satisfying, and 6= very satisfying). * denotes significant difference.

<table>
<thead>
<tr>
<th>Satisfaction with</th>
<th>Before Mean [SD]</th>
<th>After Mean [SD]</th>
<th>6 months Mean [SD]</th>
<th>Before -after P-value</th>
<th>Before -6 months P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life as a whole</td>
<td>3.8 [1.4]</td>
<td>3.9 [1.2]</td>
<td>3.6 [1.2]</td>
<td>0.484</td>
<td>0.709</td>
</tr>
<tr>
<td>Work situation</td>
<td>3.0 [1.7]</td>
<td>2.7 [1.6]</td>
<td>2.3 [1.4]</td>
<td>0.197</td>
<td>0.066</td>
</tr>
<tr>
<td>Financial situation</td>
<td>3.6 [1.3]</td>
<td>3.5 [1.2]</td>
<td>3.2 [1.4]</td>
<td>0.701</td>
<td>0.034*</td>
</tr>
<tr>
<td>Leisure</td>
<td>3.4 [1.6]</td>
<td>3.3 [1.4]</td>
<td>3.2 [1.3]</td>
<td>0.668</td>
<td>0.371</td>
</tr>
<tr>
<td>Friends</td>
<td>4.7 [1.2]</td>
<td>4.6 [1.0]</td>
<td>4.1 [1.3]</td>
<td>0.906</td>
<td>0.060</td>
</tr>
<tr>
<td>Sexual life</td>
<td>4.3 [1.4]</td>
<td>4.0 [1.5]</td>
<td>3.8 [1.6]</td>
<td>0.109</td>
<td>0.081</td>
</tr>
<tr>
<td>Activity Daily Living</td>
<td>4.7 [1.4]</td>
<td>4.7 [1.2]</td>
<td>4.8 [1.3]</td>
<td>0.906</td>
<td>0.137</td>
</tr>
<tr>
<td>Family life</td>
<td>5.0 [1.1]</td>
<td>4.8 [1.0]</td>
<td>4.5 [1.3]</td>
<td>0.333</td>
<td>0.034*</td>
</tr>
<tr>
<td>Partnership relations</td>
<td>5.1 [1.1]</td>
<td>5.0 [1.1]</td>
<td>4.5 [1.4]</td>
<td>0.533</td>
<td>0.035*</td>
</tr>
<tr>
<td>Somatic health</td>
<td>2.5 [1.3]</td>
<td>2.5 [1.2]</td>
<td>2.6 [1.3]</td>
<td>0.914</td>
<td>0.799</td>
</tr>
<tr>
<td>Psychological health</td>
<td>4.0 [1.3]</td>
<td>4.2 [1.1]</td>
<td>3.9 [1.3]</td>
<td>0.272</td>
<td>0.398</td>
</tr>
</tbody>
</table>

Prognostic factors of disability (study VI)

356 cases (34.1 ± 12.1 years) fulfilled the inclusion criteria during the study period. A nearly equal sex distribution was found: 51.1% men and 48.9% women. The 356 cases had the following distribution according to the acute QTF grading based on the medical record and accident report: WAD 0: 21.1%, WAD 1: 12.9%, WAD 2: 59.8%, WAD 3: 1.4% and not possible to classify: 4.8%. No difference in this grading was found between the genders. The annual total incidence of whiplash trauma (i.e., WAD 0-3) was 4.1/1000. The incidence of symptomatic WAD (i.e., WAD 1-3) was 3.2/1000. 60 cases dropped out from the study of
various reasons after the first contact with the health care system. A male dominance (68.3%) was found in the drop out group but no significant difference for WAD Grade or age.

Sixty-eight percent of the 296 (141 male and 155 female WAD 0-3) recovered during the follow-up period. Thus, 32% suffered from persistent trauma-related symptoms at follow-up; i.e., 26% reported that symptoms affected work and leisure but were not on sick-leave, 2.0% were working with other tasks due to symptoms and 3.7% of the subjects were on sick-leave. The recovery rate decreased with increasing WAD grade; WAD 0: 84.7%, WAD 1: 68.4% and WAD 2: 63.0%.

Both the univariate and multivariate logistic regression analysis (table 11) identified the following factors as significantly associated with a poor prognosis with respect to disability: previous neck pain, low educational level, female gender and acute WAD grade 2-3. Thus, the type of accident, age, previous head or back pain did not influence the outcome more than one year later according to these analyses.

176 cases (60%) of the prospective group (N=296) completed the acute questionnaire with different acute symptoms. No significant differences in the variables shown in table 11 as regressors were found between the prospective group who completed all parts (N=176) and those who did not answer the part concerning the acute symptoms (N=120).

PLS regression of acute symptoms which also included pre injury pain, the following complex of symptoms had significant influence upon disability on average 16 months later (R²=16): concentration difficulties (VIP=1.48), fatigue (VIP =1.46), problems with reading (VIP =1.32), sleeping difficulties (VIP =1.29), interscapular pain (VIP=1.22), numbness in the arm (VIP= 1.14), headache (VIP=1.07) and neck stiffness (VIP=1.03).
Table 11: Estimated effects\(^1\) of different factors on reported outcome\(^2\) in 296 Whiplash subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate</th>
<th>Multivariate (all variables)</th>
<th>Multivariate (only significant variables)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>141</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>155</td>
<td>2.32</td>
<td>1.36-3.91</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University</td>
<td>91</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Lower education</td>
<td>174</td>
<td>1.87</td>
<td>1.05-3.30</td>
</tr>
<tr>
<td>Marital status</td>
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<td></td>
</tr>
<tr>
<td>Married/cohabitant</td>
<td>160</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>101</td>
<td>1.21</td>
<td>0.54-2.90</td>
</tr>
<tr>
<td>Children at home (n)</td>
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</tr>
<tr>
<td>1-0</td>
<td>131</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>≥2</td>
<td>67</td>
<td>0.93</td>
<td>0.49-1.75</td>
</tr>
<tr>
<td>WAD grade</td>
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<td></td>
</tr>
<tr>
<td>0 and 1</td>
<td>97</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>2 and 3</td>
<td>184</td>
<td>2.17</td>
<td>1.23-3.83</td>
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<tr>
<td>Accident type</td>
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</tr>
<tr>
<td>Non rear ends</td>
<td>160</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Rear end</td>
<td>132</td>
<td>0.77</td>
<td>0.45-1.92</td>
</tr>
<tr>
<td>Prior neck complaints</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>204</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Sometimes/often</td>
<td>204</td>
<td>2.63</td>
<td>1.42-4.88</td>
</tr>
<tr>
<td>Prior headache</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>200</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Sometimes/often</td>
<td>54</td>
<td>1.35</td>
<td>0.74-2.45</td>
</tr>
<tr>
<td>Prior back complaints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>171</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Sometimes/often</td>
<td>68</td>
<td>1.07</td>
<td>0.41-1.79</td>
</tr>
</tbody>
</table>

\(^1\) Odds ratio and 95% Confidence intervals (CI)
\(^2\) Complaints affecting work or spear time versus none, at follow-up (mean 16 months)
Discussion

Acute and chronic WAD: incidence and prevalence

Does WAD exist? Is it a modern epidemic in the western world? Is it due to the insurance system? Spitzer et al. (1995) note that patients still symptomatic after 6 months are designated as chronic and they conclude that whiplash injuries that result in temporary discomfort are usually self limited and that pain resulting from the injury is not harmful.

Lithuanian (Schrader et al. 1996, Obelieniene et al. 1999), Greek, and German (Partheni et al. 2000, Bonk et al. 2000) studies conclude that almost no one had persistent severe symptoms (chronic WAD) after a rear end traffic accident and propose a cultural/socio-economic explanation for the high figures in other countries. Freeman et al. (1998) evaluated the Quebec Task Force monograph and found some methodological error biases and inappropriate generalisation. The same author suggested in 1999 that there is no epidemiological or scientific basis to conclude that without vehicle damages no injury would result and that the injury does not lead to chronic pain. Nygren et al. (2000) believe that neck injury can lead to chronic complaints and that the Lithuania study (Schrader et al. 1996) has some major statistical problems. The Lithuania studies were both based on police reports and there were mainly men involved in these accidents. The study from Germany was rather small (n=97) and subjects with WAD grade 3 and 4, prior injuries, X-ray changes (old fracture skeletal, malformation, and spondyloarthropathy), and not living in the area were excluded.

Our prospective study on the incidence and recovery were based on persons seeking medical attention following a whiplash trauma without head injury and major ongoing neck problems and other severe disease. All kinds of mva accidents were included, as there is evidence that other types of trauma mechanisms (e.g., non rear-end) can cause injury (Kullgren et al. 2000). No major gender difference was found in this study (51.1% men and 48.9% women). In contrast, Brison et al. (2000) and Mayou and Bryant (1996) find a female dominance. In a cohort of 246 subjects involved in rear-end mva, two factors were identified as independent risk factors for 'whiplash' injury': a history of neck injury and female sex (Dolinis 1997).
The annual incidence of WAD grades 1-3 (3.2/1000) (i.e., symptomatic WAD) in the present study is higher than earlier reported from the same area (Björnstad et al. 1990). However, the annual incidence rate is somewhat lower than the annual incidence rate in the UK 1995/96 study (4.2/1000) and the estimated annual incidence rate in the USA 1992 study (3.9/1000) (Galasko et al. 2000). In a recent Canadian study based on rear-end motor vehicle accidents and emergency room visits, an annual incidence of 0.8/1000 was reported (Brison et al. 2000). In the present study, 55% of the accidents were rear-end accidents. In the Canadian study, minor daily pain (neck or shoulder) was not classified as WAD; this left 61% of the subjects affected by WAD. Barnsley et al. (1994) estimate the annual incidence to be 1/1000 in the western world, but most of the estimates they used were derived using insurance or compensation claims and therefore the results are not comparable.

From 1985 to 1992, incidence in the catchments area doubled (Björnstad et al. 1992) as evidenced by the emergency room visits to treat WAD. Other researchers (Richter et al. 2000, Galasko et al. 2000) have also reported similar figures. Such increases might be explained by the awareness of the mechanisms and symptoms concerning WAD in the general population as well as by paramedics and the police, which in turn might be due to increased information about this topic in the media. The number of mild and moderate traffic injuries has increased in Sweden (National Social Insurance Board 1997, Statistics Sweden 1994). An evolution in how society views WAD have occurred and for many other medical conditions. What the health care system are willing to diagnose and treat and what help and care citizens seek from the health care system differ with respect to the victim's medical, historical, and cultural situation. Such circumstances influence others and influence our estimates of the incidence of acute WAD and probably other conditions as well.

The present incidence of a whiplash trauma (4.1/1000) is probably an underestimation since people with low intensity of symptoms or without symptoms often do not seek medical care. Fifteen percent of the group exposed to a whiplash trauma had a soft tissue injury (WAD) (Otremski et al. 1989). According to Ryan (2000), approximately 35% sustain an injury after whiplash trauma. On the other hand, because of increasing awareness in society, police or other health care providers often strongly encourage traffic victims to seek medical care as soon as possible whether they exhibit symptoms or not. Signs of an injury might therefore not be present at the time of the emergency visit. Some people might experience only stiffness,
which is often not considered in an acute situation. Most of the subjects came to the emergency department within a few hours after an accident and therefore WAD 0 was included in the long-term follow up. WAD 4 was excluded from the present study due to a very low incidence and a markedly different clinical management. In order to determine the precise incidence of whiplash trauma, data from the insurance companies within the catchments area should have been collected. However, this was not possible due to the project’s lack of resources.

Long-term studies show that symptoms do not alter significantly after two years (Gargan and Bannister 1994 Robinsson et al. 1993). Some authors suggest that the chronic state may be reached two or three months after the injury (Maimaris et al. 1988, Gargan & Bannister1997). Our follow-up time was more than one year. One-third of the patients in the present study reported that their disability due to persisting symptoms affected their work or leisure activity and so did the subjects in the Canadian study where only 7.4 % sought compensation (Brison et al 2000). In a Swiss study of 117 WAD cases with two year follow up, 14 % were symptomatic and 4 % were symptomatic and had reduced work capacity (Radanov et al. 1995); the latter figure is in line with the present study. A previous study from our area reported higher figures. This may be explained by the different study design, only persons with a definite injury were included; the majority had signs of muscle spasm, tenderness, and restricted range of movement (Hildingsson & Toolanen 1990). Furthermore, it is interesting to note that a higher number of patients on sick leave and who had changed work tasks were found in this latter study. This may be due to the lowered compensation in the general insurance system in Sweden since 1993 and a more restrictive law for compensation of occupational complaints.

In Study VI, 68 % reported no major problems because of the accident. Galasko et al. (2000) at 4 year follow found an overall recovery of WAD grades 1-3 of 64 %; it was lowest in WAD 3 (46 %) and highest in WAD 1-2 (74 %).

Prognostic factors
In our prospective study group, female gender, low education, former neck pain, WAD grade, and severity of symptoms and signs were independent prognostic factors of disability. Hartling et al. (2001) found prognostic value of the QTF WAD grading (the cohort of Brison et al. 2000, with a few WAD grade 3). In WAD grade 2 with both point tenderness and
restricted range of movement, the highest risk was seen for long-term symptoms (Hartling et al. 2001). Prior headache has earlier been identified as a risk factor (Radanov et al. 1995). In this study, prior neck pain was a risk factor in agreement with Schrader et al. (1996) and Parmar & Raymarker (1993). There is some evidence that a history of neck pain, such as second whiplash injury in subjects who had recovered, was associated with a poor prognosis (Khan et al. 2000). In a meta-analyse of 6 studies of prognostic factors on the development of non-specific chronic neck pain, a previous neck pain worsened the prognosis (Borghouts et al. 1998).

Patients with higher education levels were less disabled than those with lower education levels; these findings were in agreement with Holm et al. (1999). There is a relationship between social position and sickness absent rates (North et al. 1997) and there seems to also be a relationship between social position and WAD. Moreover, the absolute demands upon the neck and shoulders at work might be more strenuous for manual labourers (i.e., a higher prevalence of highly repetitive and static work tasks).

Female gender has been found to adversely affect the outcome in WAD (Barnsley et al. 1994, Borchgrevink et al. 1996, Spitzer et al. 1995, Hohl 1989), which was also confirmed in this study. Females can be more vulnerable to WAD due to smaller muscle mass of the neck and smaller cross-sectional areas of muscle fibres than men can (Lindman et al. 1991). Moreover, females are probably more exposed to static contractions at low force levels and repetitive manual tasks (known to increase the risk for myalgia in the neck and shoulder regions) at work and at home (Lundberg et al. 1994). Poor position sense acuity found in healthy females after low repetitive work, might be another risk factor (Björklund et al. 2000). Furthermore, females have higher levels of stress at home than men (Lundberg et al. 1994 and Lundberg & Frankenheuser 1999) which might affect the ability to recover (Jensen et al. 1994). It has also been reported that women more are less often offered rehabilitation than men (Hall 1990). The male dominance in the group of dropouts probably resulted in an underestimated gender effect. Two prospective studies have tested prediction value of their observed risk factors and both found 80% accuracy (Radanov & Sturzenegger 1996, Gargan et al. 1997). The risk factors for the former are seen in Table 2. In the latter, neck stiffness and psychological score at three months predicted outcome at two years. One prerequisite for use of such models in
clinical practise is that they are easy to apply without being too time-consuming in the acute situation and have high predictability.

**Chronic WAD contra other chronic pain disorders. What is the difference?**

In many ways, chronic WAD resembles other chronic musculoskeletal disorders in terms of disability, general dysfunction, depression, and anxiety (Söderlund & Lindberg 1999). Compared to rheumatoid arthritis psychosocial problems were more pronounced in both WAD and other chronic pain conditions (Söderlund & Lindberg 1999). Self-efficacy, on the other hand, was significantly lower in chronic WAD compared to low back pain and some evidence that high rates of catastrophizing is associated with less well being (Söderlund & Lindberg 1999). The latter might indicate some underlying fear of movement and thus worsening the "injury".

The development and maintenance of chronic WAD is complex and this thesis does not reflect all aspects. One can expect that chronic WAD is under the same influence of probable potential risk factors as other "non-acceptable disabling conditions" (Linton 1999), such as fear, depression, distress, pain severity, and stress. The individual’s social/vocational situation and former experiences of dysfunction are also important factors. Behavioural coping strategies/responses and self-efficacy have been found associated with a poor outcome in chronic pain condition. Linton points out that psychological factors account for only a portion of the variance in the development of chronic pain (2000). He proposes that future research should focus on improving quality and should address new questions such as the mechanism, the developmental time factor, and the relevance that these risk factors have for intervention (Linton 2000).

WAD subjects differ from most other chronic pain conditions on the time factor. A sudden physical and sometimes threatening trauma causes symptoms immediately or in most cases within 24 hours. We did not measure any major stress reactions to the event but the neuropsychological symptoms reported by the subgroup after the accident can reflect post-traumatic stress, fear, or a high intensity of neck pain.
Compensation
Compared to other chronic pain conditions compensation rates are much higher in this group depending of the traffic insurance systems. Before the rehabilitation program, 91.5% of the patients in our study reported that they had had contact with a lawyer, regional social insurance office, or insurance company. For the majority (85.1%), this meant waiting for a certificate needed for financial compensation or for a decision concerning the future financial situation: 6.4% had appealed or were going to appeal a decision from the insurance company or the social insurance authorities. This might have influenced the outcome but there is no convincing evidence so far that if these issues are resolved the subjects recover (Mendelsson 1995). However, Cassidy et al. (2000) conclude in their study of insurance claims that the elimination of compensation for pain and suffering is associated with a decreased incidence and improved prognosis of whiplash injuries. However, some believe that the use of time-loss payments as an indicator of recovery is inappropriate (Freeman and Rossignol 2000). Recurrences were not included (Merskey 2000) in the time-to-event analyses (32% of those under the no-fault system were reopened). Certainly, different insurance systems will have different and substantial effects on the incidence rate and on what the health care system is willing to diagnose/treat.

Impairments
In the clinical practice it has become evident that some WAD subjects describe not only increasing pain in the head, neck or shoulders but also the spreading of pain to other regions and seem to develop a more generalised pain assembling fibromyalgia. Although we have not investigated the prevalence of widespread pain and/or fibromyalgia, females reported significantly more pain areas than men (pain from the whole spine) in Study IV. In agreement, neck injury (Buskila et al. 1997) or intense neck/shoulder pain (Ektor-Andersen et al. 1999) has been reported as risk factors for developing pain in other parts of the body. Maybe peripheral input from the neck (discs muscles and joints) to the spinal cord with its large convergence, complex neuronal organisation and communication with higher cerebral regions are more prone to cause neuronal alteration such as central sensitisation than pain in other anatomical regions. Munglani (2000) proposes a model of ongoing peripheral input, individual genetic difference response to an injury, and psychological disorders that causes sensitisation, at least for some WAD subjects. In subjects with spinal cord injuries (SCI) and pain, neuropathic pain was more frequent in incomplete cervical lesions rather than thoracic spinal cord lesions (Siddall et al. 1999). In another group of SCI, identical sensory
impairments led to chronic pain in one subject but not in another implicating either genetic predisposition or subtle differences in the nature of spinal injury (Defrin et al. 2001). Exaggerated response to pain has been observed in chronic WAD (Lee 1993, Koelbaek Johansen et al. 1999) and the latter authors suggest that the pain might be considered as a neurogenic type of pain, and new pharmacological treatments should be investigated accordingly.

In our prospective study of trigeminal sensibility, sensory disturbance remained over the years. Against a nociceptive origin of the sensory disturbances and in favour of a neurogenic-central explanation were the positive correlation between CES-index and total sensory score and lack of significant correlation with MS-index and neck pain intensity, respectively. However, when we analysed individual symptoms, pain of the face and numbness of the face showed the strongest relationships with total sensory score. In addition, some of the cognitive variables were of significant importance. The individual variation indicates heterogeneous origin and moderate sensory impairment at follow-up could be a consequence of nociceptive pain emanating from structures of the neck (Hansson 1994, Leffler et al. 2000). A dysfunction of the central nervous system may be a possible explanation in the patients with pronounced trigeminal sensory impairment (Hildingsson et al. 1993, Knibenstöl et al. 1990).

The findings of increased SAR in WAD females during repetitive muscle activity confirm the clinical experience of increased stiffness/tension in patients with chronic symptoms after whiplash trauma. Whether males with WAD show the same pattern has not been investigated here. There was, however, no gender difference in the healthy subjects concerning SAR. Increased SAR has been found in fibromyalgia, work related myalgia (Elert et al. 1992, Larsson et al. 2000), in a subgroup of healthy individuals (Gerdle et al. 1989) and among healthy female cleaners with or without trapezius myalgia. In all these studies including the 55 healthy subjects in Study II, the subjects performed 100-150 maximal shoulder contractions but a high frequency of early interruption was noted in the WAD group. This might indicate that there are different mechanisms behind localised myalgia and WAD. Different levels of EMG activity during different conditions in healthy and WAD patients have recently been demonstrated (Nederhand et al. 1999). Above all was the inability to relax the trapezius to base line and noted was a high co-activation of the resting trapezius (passive side) (Nederhand et al. 1999).
A positive correlation has been found in patients with chronic muscle pain between inhibition of aggression and SAR (Elert et al. 1993). The fear of more pain/avoidance is another explanation of the early interruption. Hence, different psychological symptoms associated with pain might lead to an increase in muscle tension (Elert 1991). Another factor behind our findings of a high SAR could be that the test was too painful for the patients and that alone caused the increased tension. However, the concept of a viscous circle (Figure 6 A) of pain - spasm - pain (feedback loop to alpha-motor neurones) has not been proven to exist, according to a recent review of Simons & Mense (1998). Sufficient spasm on the other hand can cause pain (Simons and Mense 1998). Increase in alpha or gamma-activity is more likely to occur if the site of the lesion is outside the muscle, e.g., a neighbouring joint (Mense 1993). It is likely that receptors in capsules and ligaments play a part in the regulation of muscular stiffness and tension in the human neck (Johansson 1990). Very recent experiments on cats show influences on the fusimotor-muscle spindle system from chemosensitive nerve endings in cervical facet joints supporting the assumption (Thunberg et al. 2001).

Johansson & Sojka’s 1991 neurophysiological model (Figure 6 B) based on animal data suggests that muscular hyperactivity is due to facilitation of muscle spindles by muscle pain. Both static and dynamic gamma motoneurons projecting to homonymous as well as heteronymous muscle are proposed to cause the spreading of muscular tension stiffness and/or pain. Graven Nielsson et al. recently (2000) reviewed the two models above and found no convincing evidence for either of them. According to their experimental research, they instead propose the pain adaptation model of Lund (1991) (Figure 6 C) to describe the link between activity in nociceptive afferents, central pattern generator, and locomotor function. Muscle pain activates group III and IV fibres and in an adaptive way, depending of the specific fibre activated, the reflex is inhibitory or excitatory causing decreased agonist activity and /or increased antagonist muscle activity. They point out that during hard work the other hypothesis might be acceptable.
As for our WAD group, this might explain the decreased maximal voluntary strength due to decreased agonist activity. The high interruption rate might be due to increasing spasm/stiffness (facilitated muscle spindles), increasing pain, and a "viscous circle" feedback loop. The assumption is that depending on intensity of pain, workload, dynamic or static (including stress), concentric or eccentric muscle contractions, different pathways in the sensory motor neural system are activated as proposed by Birch et al. (2000).

**Figure. 6.** Proposed models on the sensory-motor interaction. (A) Muscular hyperactivity, (B) Muscular hyperactivity based on facilitation of the γ motor system and (C) the pain adaptation model. From Graven Nielsen (2000) with permission.
Disability

In a real life situation, the above findings of dys-coordination, weakness, and increasing pain/subjective muscle tension are often reported by both female and male WAD patients especially during neck/shoulder/arm dependent activities. The physical activity index and the daily activity index were also significantly lower in the WAD group with longer sick leave compared to those with shorter sick leave in Study IV. WAD females reported significantly lower levels of physical activity index and the daily activity index compared to healthy females. Larger sample sizes are needed to find out whether that also is the fact for men. Posture and work situation, high psychological demands, and at the same time little opportunity to influence decisions increase the risk of disability (Schuldt 1986, Harms-Ringdahl & Schuldt 1990, Theorell et al. 1991). Many therapists report that treatment strategies for whiplash patients often fail. This is probably due to the fact that the mechanisms behind the pain and other symptoms in whiplash patients seem confusing and are unclear, and the fact that there is little proof of single treatment efficacy for many musculoskeletal chronic pain conditions (SBU 2000). The present results of increased muscle tension (SAR) open up the possibility of using relaxation and EMG biofeedback techniques as one treatment strategy for WAD patients; this is supported by the Nederland group (Nederhan et al. 1999). Hand dystonia (writers cramp) (Deepak & Behari 1999) and torticollis (Jahanshahi 1991) improved using biofeedback; the latter including graded neck exercises. Hence, future studies have to evaluate whether it is possible to reduce SAR and pain/fatigue intensity using such interventions in patients with chronic WAD.

Disability and life satisfaction

Marked differences existed in our cross-sectional study between the WAD group and the C group of Study IV for several aspects of the life satisfaction instrument and the indices of activity preferences. Moreover, our results indicated that coping strategies were not sufficient if present. The satisfaction with life as a whole was significantly lower in the WAD group. In addition, other studies using the same instrument for patients with chronic WAD have reported low levels of satisfaction (Heikkilä et al. 1998). Heikkilä et al. reported that satisfaction with life as a whole at entry was one of several significant regressors for poor vocational outcome at a 2 year follow-up, which might indicate that a deeper knowledge of the factors that influence satisfaction with life as a whole is important. In addition, the two other more global items
(satisfaction with physical health and psychological health) were significantly lowered in the WAD group. In fact, physical health was the item in this instrument with the lowest degree of satisfaction in the WAD group; less than 10% in the WAD group were satisfied compared to 74.5% in the C group. Although the prevalence of many symptoms as expected was significantly increased, the WAD group did not have a homogenous increase in symptoms: 15 to 25% reported neuropsychological/cognitive symptoms, thus the WAD group is heterogeneous with respect to such symptoms. Since neuropsychological symptoms significantly correlate with pain intensity rather than with the presence of pain per se in different anatomical regions or pain duration, it can indicate that high pain intensity in the long term increases the risk of neuropsychological symptoms.

As expected, Study IV found a relatively high prevalence of marked decreases in range of motion of the neck. Such restrictions could have been due to muscular affection. However, it could also reflect chronic injuries in cervical zygapophysial joints. In addition, a significant increased prevalence of nerve affection signs (4 out of 6 signs) was found. Consistent with many other studies we found that signs had very little influence on the disability level and the global level (Wadell et al. 1992). If we used a goniometer ad modum Myrin to measure range of movement and a pressure algometer to evaluate pain threshold in the neck and shoulder we would probably have achieved a greater degree of accuracy than the standards used here.

In contrast to the signs, the different symptoms (pain intensity and neuropsychological symptoms) significantly intercorrelated with aspects of activity preferences (total activity index), satisfaction with life as a whole, and physical health in the WAD group. For instance, among the 6 most important significant symptoms in the regression of satisfaction with life as a whole, 5 of the symptoms were neuropsychological/cognitive symptoms. A situation with both pain and neuropsychological/cognitive symptoms will indicate a worse situation both at disability and global levels than if “only” pain is present. Cognitive complaints are not limited to subjective reports (Kessel et al. 2000) but the cause of it is not fully clear and they do not exist exclusively for WAD subjects. So far, there is no evidence of any detectable traumatic brain injury (TBI) in the literature for WAD subjects. For the patients in all these different studies TBI was an exclusion criteria, although we cannot be sure that some of the subjects had minor signs of TBI (short duration of altered consciousness).
According to our experience, neuropsychological/cognitive symptoms are often seen in clinical practise. Such symptoms are often reported in the early chronic state after some months of pain. From the present cross sectional study, it cannot be ruled out that both pain and neuropsychological/cognitive symptoms are in fact due directly to a more severe trauma. Our prospective study indicates that this can be the case. The reactions to a stressful situation acute or chronic can probably result in the same symptoms.

Self efficacy (belief in ones own ability to manage pain, cope and function despite persistent pain) has in WAD (Söderlund & Lindberg 1999) and in chronic pain (Arnstein et al. 1999) been linked to disability and depression, but not to pain intensity. In chronic pain patents with no prior depression regression analysis supported self-efficacy as a mediator of the relationship between pain intensity and disability (Arnstein 2000). In a clinical perspective, our findings and others indicate that it is important to concentrate on pain aspects as well as include neuropsychological/cognitive symptoms when examining the situation of the patient as well as coping resources and strategies.

Rehabilitation

According to the present study on rehabilitation (Study V), we found both positive and negative results. The subjects reported an improved understanding of pain management, philosophical aspects of pain control, general psychological issues, and satisfaction with the program. Pain intensities in the neck and upper back were somewhat improved, but pain intensity elsewhere was not changed, and cognitive impact and fitness were worse. During the program, and additional 15 % stopped working, but 12 % were seeking work. Markers for psychosocial stress were high in the group. Cognitive, social, emotional, and physical indices were not affected, and significant decreases in satisfaction had occurred with their financial situation, with their family situation, and with their marriage. The study reflects the diversity between retrospective reported outcome and objective data. On the one hand, WAD subjects report a better family situation; on the other hand, the life satisfaction quality instrument on this item shows a significant decrease.

Markers for psychosocial stress were high among chronic WAD and these complex issues may confound efforts to rehabilitate patients suffering from chronic whiplash related
complaints, Moreover, future interventions in a more explicit way have to involve these problems. The awareness of this has also influenced the rehabilitation program.

The rehabilitation program did not have any major objective changes at a group level but follow up should have been longer than 6 months, at least 1 year. For many of the patients, acceptance/adjustment started at the end of the program and one can assume that this process needs time. Outcome at a group level should preferably be based on specific goals achieved by the patients at follow up.

The cost benefit for society for each person going back to work after rehabilitation is high. According to a new Swedish Report (Larsson SOU 2000), 1 Swedish crown for rehabilitation gives 9 back. The studies from Italy and the Netherlands (Provinciali et al. 1996, Vendrig et al. 2000) reported overall much better results indicating that a much earlier approach is needed. The Italian study (Provinciali et al. 1996) reported effects on emotional problems, pain intensity, postural disturbance, and a sooner return to work. The authors conclude that cognitive and postural symptoms probably reflect post-traumatic disability. The main difference between our study and these two lies in selection and this might explain the different results.

We propose that rehabilitation and treatment efforts for prolonged disability, whatever the cause, after whiplash injury aim at encouraging patients to adopt an active, positive, and realistic attitude and strategies at all stages after an injury. Most injuries with increasing pain during or after physical activity should not be equated with a worsening of the injury. We should avoid extensive investigations in most cases as these interfere with the rehabilitation process and promote ideas that something serious has occurred. Completion of investigation/assessment is strongly recommended before participation in rehabilitation to minimise distraction and enhance focus on the problem solving and goal setting. Adequate examination and assessment of all circumstances such as fear and avoidance, loss of control, anxiety signs of post-traumatic stress, high intensity pain, bio-mechanical and psychosocial factors at work (studies) and social support (positive or negative) are important. Advice and proper medication (bearing in mind the nervous system) are essential including information to the patients about the mechanisms both physical and psychological behind their symptoms. For all individuals with symptoms at 3 months and major problems in participation in
different activities to the extent they desire, there is a need for interdisciplinary evaluation/rehabilitation.

Proper measurements in research to distinguish different subgroups are recommended to find what is most effective (cost effective). For instance, the first and second section of the MPI can identify three subgroups (dysfunctional, interpersonal distressed, and adaptive) (Bergström 2000) in non-specific spinal pain and might be of value for WAD as well.
Conclusions

Study I
The higher prevalence of musculoskeletal complaints of the neck shoulder region in females cannot be explained by higher muscle tension. Age, sex, BMI, and biomechanical output can significantly affect MNF. These effects are important considerations in the interpretation of this variable, for instance, in ergonomic situations.

Study II
The results confirm the clinical experience of increased stiffness/tension in patients with chronic symptoms after whiplash trauma. Damage to sensory structures in ligaments and joints causing alterations in the regulation of muscle stiffness around the joints and/or secondary effects of chronic pain might be responsible for the increased tension for some persons with WAD.

Study III
Trigeminal sensory impairment can be detected in the early period after whiplash trauma and remain several years after trauma. Such impairment at follow up is related to certain clinical symptoms. Our results indicate that the sensory disturbances described have a heterogeneous origin. The group with initially normal or slightly decreased sensibility and with moderate sensory impairment at follow-up could be a consequence of nociceptive pain emanating from structures of the neck, while a dysfunction of the central nervous system may be a possible explanation in the patients with pronounced trigeminal sensory impairment.

Study IV
Chronic WAD was associated with marked negative consequences with respect to activity preferences and satisfaction with life as a whole and physical health when compared to pain free healthy subjects. When planning rehabilitation it is important to have a broad screening technique with respect to the different categories (impairment, disability, and global level) as well as coping strategies. In future studies, it would be interesting to compare chronic WAD
with non-traumatic chronic neck pain in order to evaluate if chronic WAD is associated with more symptoms and greater consequences with respect to disability and health.

**Study V**

Following a 5 and 8 week newly implemented interdisciplinary rehabilitation program for chronic WAD, positive outcomes at 6 months with improved understanding of pain management, philosophical aspects of pain control, general psychological issues, and satisfaction with the program were found. Pain intensities in the neck and upper back were somewhat improved, but pain intensity elsewhere was not changed, and cognitive impact and fitness were worse. During the program, and additional 15% stopped working, but 12% were seeking work. Markers for psychosocial stress were high among the group. Cognitive, social, emotional, and physical indices were not affected. Before the program, 91.5% of patients were already involved in compensation or litigation issues, which may confound efforts to rehabilitate patients suffering from chronic whiplash related complaints.

**Study VI**

The annual incidence of whiplash injuries seems to be high in sparsely populated areas. A substantial part recovers, however. The present study identified risk factors for disability more than one year after the trauma. High-risk patients—pre-traumatic neck pain, low education, a WAD grade of 2 or 3, female gender—may deserve a close follow-up in primary care. Based on our results we want to point out the need to create clinical algorithms for the early identification of people with a high risk for disability.
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Finally I will remind you all of Winnie the POOH and his friends lost in the forest. When trying to find their way back home they always ended up at the same spot. Winnie the Pooh said "LETS TRY TO FIND THIS PLACE INSTEAD OF FINDING HOME and so he did and came home.

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