Evidence Report

Musculoskeletal Disorders and Commercial Motor Vehicle Driver Safety

Presented to

The Federal Motor Carrier Safety Administration

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Prepared for

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Evidence reports are sent to the Federal Motor Carrier Safety Administration's (FMCSA) Medical Review Board (MRB) and Medical Expert Panels (MEP). The MRB and MEP make recommendations on medical topics of concern to the FMCSA.

The FMCSA will consider all MRB and MEP recommendations; however, all proposed changes to current standards and guidelines will be subject to public notice and comment and relevant rulemaking processes.

Policy Statement

This report was prepared by ECRI Institute under subcontract to MANILA Consulting Group, Inc., which holds prime GS-10F-0177N/DTMC75-06-F-00039 with the Department of Transportation's Federal Motor Carrier Safety Administration. ECRI Institute is an independent, nonprofit health services research agency and a Collaborating Center for Health Technology Assessment of the World Health Organization. ECRI Institute has been designated an Evidence-based Practice Center by the U.S. Agency for Healthcare Research and Quality. ECRI Institute's mission is to provide information and technical assistance to the healthcare community worldwide to support safe and cost-effective patient care. The results of ECRI Institute's research and experience are available through its publications, information systems, databases, technical assistance programs, laboratory services, seminars, and fellowships. The purpose of this evidence report is to provide information regarding the current state of knowledge on this topic. It is not intended as instruction for medical practice, or for making decisions regarding individual patients.

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Executive Summary

Purpose of Evidence Report

Of all occupations in the United States, workers in the trucking industry experience the third highest fatality rate, accounting for 12 % of all worker deaths. About two-thirds of fatally injured truck workers were involved in highway crashes. According to statistics from the U.S. Department of Transportation (DOT), there were 4,932 fatal crashes involving a large truck in 2005 for a total of 5,212 fatalities. In addition, there were 137,144 nonfatal crashes; 59,405 of these were crashes that resulted in an injury to at least one individual (for a total of 89,681 injuries).

The purpose of this evidence report is to address several key questions posed by the Federal Motor Carrier Safety Administration (FMCSA). Each of these key questions was developed by the FMCSA so that the answers to these questions provide information that would be useful in updating its current medical examination guidelines. The four key questions addressed in this evidence report are as follows:

Key Question 1: Does amputation of an extremity increase crash risk and/or affect driving ability?

Key Question 2: Does inflammatory arthritis (e.g., rheumatoid arthritis, similar condition) increase crash risk and/or affect driving ability?

Key Question 3: Does decreased angle of rotation at the level of the spine and neck (as might be the result of ankylosis and/or other vertebral injury) increase crash risk and/or affect driving ability?

Key Question 4: Do vehicle modifications and/or appropriate limb prosthetics decrease crash risk in disabled individuals?

Identification of Evidence Bases

Separate evidence bases for each of the key questions addressed by this evidence report were identified using a process consisting of a comprehensive search of the literature; an examination of abstracts of identified studies in order to determine which articles would be retrieved; and the selection of the actual articles that would be included in each evidence base.

A total of seven electronic databases (MEDLINE, PubMed (pre MEDLINE), EMBASE, PsycINFO, CINAHL, TRIS, and the Cochrane Library) were searched (through August 14, 2007). In addition, we examined the reference lists of all obtained articles with the aim of identifying relevant articles not identified by our electronic searches. Hand searches of the “gray literature” were also performed. Admission of an article into an evidence base was determined by formal retrieval and inclusion criteria that were determined *a priori.*

Grading the Strength of Evidence

Our assessment of the quality of the evidence took into account not only the quality of the individual studies that comprise the evidence base for each key question; we also considered the interplay between the quality, quantity, robustness, and consistency of the overall body of evidence.

Analytic Methods

The set of analytic techniques used in this evidence report was extensive. Random- and fixed-effects meta-analyses were used to pool data from different studies.(1-5) Differences in the findings of studies (heterogeneity) were identified using the Q-statistic and I^2.(6-8) Sensitivity analyses, aimed at testing the robustness of our findings, included the use of cumulative fixed- and random-effects meta-analysis.(9-11) The presence of publication bias was tested for using the "trim and fill" method.(12-14)

Presentation of Findings

In presenting our findings we made a clear distinction between qualitative and quantitative conclusions, and we assigned a separate "strength-of-evidence" rating to each conclusion format. The strength-of-evidence ratings assigned to these different types of conclusions are defined in Table 1.

Table 1. Strength of Evidence Ratings for Qualitative and Quantitative Conclusions

Strength of Evidence	Interpretation
Qualitative Conclusion	
Strong	Evidence supporting the qualitative conclusion is convincing. It is highly unlikely that new evidence will lead to a change in this conclusion.
Moderate	Evidence supporting the qualitative conclusion is somewhat convincing. There is a small chance that new evidence will overturn or strengthen our conclusion. ECRI Institute recommends regular monitoring of the relevant literature for moderate-strength conclusions.
Minimally acceptable	Although some evidence exists to support the qualitative conclusion, this evidence is tentative and perishable. There is a reasonable chance that new evidence will either overturn or strengthen our conclusions. ECRI Institute recommends frequent monitoring of the relevant literature.
Unacceptable	Although some evidence exists, the evidence is insufficient to warrant drawing an evidence-based conclusion. ECRI Institute recommends frequent monitoring of the relevant literature.
Quantitative Conclusion (Stability of Effect-size Estimate)	
High	The estimate of treatment effect in the conclusion is stable. It is highly unlikely that the magnitude of this estimate will change substantially as a result of the publication of new evidence.
Moderate	The estimate of treatment effect in the conclusion is somewhat stable. There is a small chance that the magnitude of this estimate will change substantially as a result of the publication of new evidence. ECRI Institute recommends regular monitoring of the relevant literature.
Low	The estimate of treatment effect included in the conclusion is likely to be unstable. There is a reasonable chance that the magnitude of this estimate will change substantially as a result of the publication of new evidence. ECRI Institute recommends frequent monitoring of the relevant literature.
Unstable	Estimates of the treatment effect are too unstable to allow a quantitative conclusion to be drawn at this time. ECRI Institute recommends frequent monitoring of the relevant literature.

Evidence-based Conclusions

Key Question 1: Does amputation of an extremity increase crash risk and/or affect driving ability?

Whether amputees who drive a commercial motor vehicle (CMV) are at an increased risk for a crash cannot be determined at the present time.

Our searches did not identify any studies that examined crash risk or a surrogate marker for crash risk among CMV drivers who have undergone an amputation.

While evidence suggests that driving performance in some amputees (drawn from the general driver population) may be compromised, there is currently no compelling evidence to support the contention that such individuals are at an increased risk for a motor vehicle crash when compared to comparable individuals who do not have an amputation (Strength of Evidence: Minimally Acceptable).

Direct Evidence: To date, only two studies have examined the impact of amputation on crash risk, and neither provided evidence that individuals with an amputation who drive a motor vehicle are at increased risk for a motor vehicle crash.

Indirect Evidence: A single, moderate-quality study found that individuals with an amputation below the knee of the right leg demonstrated some reductions in foot-pedal reaction time. The use of adaptive driving techniques, however, appeared to eliminate this reduction.

Key Question 2: Does inflammatory arthritis (e.g., rheumatoid arthritis, similar condition) increase crash risk and/or affect driving ability?

Whether the presence of an arthritide is associated with an increased risk for a crash among CMV drivers cannot be determined at this time.

Our searches did not identify any studies that examined crash risk (or a surrogate marker for crash risk) among individuals who drive a CMV and have an arthritide.

Although arthritides appear to be associated with reduced driving performance and are cited as a reason for giving up driving by some individuals, it remains unclear whether those among the general driver population who choose to drive with arthritis are at an increased risk for experiencing a crash (Strength of Evidence: Minimally Acceptable).

Direct Evidence: Three included studies (Median Quality: Moderate) directly examined the relationship between the arthritides and crash risk using a case-control design. None of these studies provided evidence to support the contention that arthritis is associated with an increased risk for a motor vehicle crash. Because of the small size of the included studies, and their consequent low power to detect an increase in crash risk, we cannot conclude that no association between arthritides and crash exists. It remains unclear whether drivers with arthritis are at an increased risk for a crash.

Indirect Evidence: Because the findings of the only studies to have examined the risk for a crash among individuals with arthritis are inconclusive, we looked for other sources of evidence that may provide some insight into the relationship between arthritis and driver safety. Our searches identified four such studies. One study found that elderly individuals with arthritic disorders were more likely to fail a driving test. Another study found that many individuals with rheumatoid arthritis (RA) gave up driving as a direct consequence of their disorder, thus suggesting that this arthritide does impact driving ability. A third study found that rheumatoid or osteoarthritis (OA) had a deleterious impact on driving ability. Individuals with RA appeared to experience the highest percentages of driving disabilities, with the disorder affecting several important driving tasks, including steering and cornering, mirror adjustment, use of the gears, and use of the handbrake. Individuals with OA experienced the second highest percentages of driving disabilities, with OA impacting driving tasks such as reversing (where it exceeded the RA percentages) and steering/cornering. In addition the latter group experienced significant problems with attaining seat comfort. The final study demonstrated that individuals who underwent an exercise-based rehabilitation program designed to improve mobility showed improvements in range of motion (ROM) and in one driving task (observing) when compared to similar individuals who did not receive rehabilitation training.

Key Question 3: Does decreased angle of rotation at the level of the spine and neck (as might be the result of ankylosis and/or other vertebral injury) increase crash risk and/or affect driving ability?

While it is plausible that the presence of a disorder that limits spinal/cervical (ROM), such as ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, or spinal stenosis, may have a deleterious impact on driving ability, one cannot determine whether these disorders are associated with an increased risk for a motor vehicle crash at this time (Strength of Evidence: Minimally Acceptable).

Three studies met the inclusion criteria for Key Question 3. No included studies directly assessed the impact of restricted spinal/cervical ROM on crash risks.

Indirect Evidence: The first included study used a cross-sectional design to establish that functional limitations introduced with spinal and/or cervical structural changes may be a factor in reduced driving performance, including a diminished ability to turn the head while driving. The second included study used a prospective crossover design to determine the relationship between cervical immobility (as imposed by the use of a cervical orthosis) and driver performance. It was found that the orthosis did alter driving performance, including a decrease in lateral acceleration and slower driving speed overall. The final included study used a cohort study design to determine whether increased functional impairment to the cervical spine was associated with increased decision time at T-intersection. This study found an inverse association between the degree of functional impairment and driving performance: the greater the functional impairment reported, the longer the decision time associated with negotiating a T-intersection. The longest decision time was among impaired drivers in the older age group (age 60-80).

Key Question 4: Do vehicle modifications and/or appropriate limb prosthetics decrease crash risk in disabled individuals?

Because no studies met the inclusion criteria for Key Question 4, we are precluded from drawing an evidence-based conclusion pertaining to the relationship between vehicle modifications and appropriate limb prosthetics and decreased crash risk at this time.

None of the studies identified by our searches fulfilled the inclusion criteria for this key question. The primary reason for exclusion was that no identified study examined a decrease in crash risk associated with the use of vehicle modifications or appropriate limb prosthetics.

Preface

Organization of Report

This evidence report contains three major sections: (1) *Background*; (2) *Methods;* and (3) *Evidence Synthesis.* These major sections are supplemented by extensive use of appendices.

In the *Background* section, we provide general information about musculoskeletal disorders and driving. Also included in the *Background* section is information pertaining to current regulatory standards and guidelines from the FMCSA and three other government transportation safety agencies: the Federal Aviation Administration (FAA), the Federal Railroad Administration, and the Maritime Administration. In addition, we summarize equivalent information from other countries that are generally considered to have well developed medical fitness programs.

In the *Methods* section, we detail how we identified and analyzed information for this report. The section covers the key questions addressed, details of literature searching, criteria for including studies in our analyses, evaluation of study quality, assessment of the strength of the evidence base for each question, and methods for abstracting and synthesis of clinical study results.

The *Evidence Synthesis* section of this report is organized by key question. For each question, we report on the quality and quantity of the studies that provided relevant evidence. We then summarize available data extracted from included studies either qualitatively or, when the data permit, qualitatively and quantitatively (using meta-analysis). Each section in the *Evidence Synthesis* section closes with our evidence-based conclusions that are based on our assessment of the available evidence.

Scope

Commercial driving is a hazardous occupation. The trucking industry has the third highest fatality rate of all occupations (12%) in the United States. About two-thirds of fatally injured truck workers were involved in highway crashes. According to the U.S. DOT, there were 137,144 nonfatal crashes involving a large truck in 2005. Of those, 59,405 crashes resulted in an injury to at least one individual, for a total of 89,681 injuries, and 4,932 of all crashes caused 5,215 fatalities. In 2006, the U.S. DOT *Brief Statistical Summary* reported a total of 805 motorists killed in large truck crashes, which amounted to an increase of 0.1% over the statistics for 2005 (n = 804). The total number of motorists injured in large truck crashes was 23,000, which represented a decrease of 15% when compared to 2005 figures (n = 27,000).(15)

The purpose of this evidence report is to address several key questions posed by the FMCSA. Each of these key questions was carefully formulated by the FMCSA so that each answer will provide it with the information necessary for the process of updating its current medical examination guidelines. The key questions addressed in this evidence report are as follows:

Key Question 1: Does amputation of an extremity increase crash risk and/or affect driving ability?

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Background

Commercial driving is a hazardous occupation. The trucking industry has the third highest fatality rate of all occupations (12%) in the United States (http://www.bls.gov/iif/oshcfoiarchive.htm#2004charts). About two-thirds of fatally injured truck workers were involved in highway crashes. According to the U.S. DOT, there were 137,144 nonfatal crashes involving a large truck in 2005. Of those, 59,405 crashes resulted in an injury to at least one individual, for a total of 89,681 injuries, and 4,932 of all crashes caused 5,215 fatalities (http://ai.volpe.dot.gov/CrashProfile/CrashProfileMainNew.asp?dy=2005). In 2006, the U.S. DOT *Brief Statistical Summary* reported a total of 805 motorists killed in large truck crashes, which amounted to an increase of 0.1% over 2005 (n = 804). The total number of motorists injured in large truck crashes was 23,000, which represented a decrease of 15% when compared to 2005 figures (n = 27,000).(15)

The purpose of this evidence report is to summarize the available data pertaining to the relationship between musculoskeletal disorders, driving performance, and CMV driver crash risk.

Musculoskeletal Disorders

The musculoskeletal system functions to facilitate support and motion. The system also provides the primary mechanism by which the multidirectional demands of loading—which occur as a consequence of everyday activity—can be managed. For example, the spinal column acts to support the weight of the body; the intervertebral discs of the spine act as "shock absorbers," protecting the vertebrae from the jarring motions of walking. The musculoskeletal system provides this function via a collection of tissues uniquely adapted to the requirements of these different but interrelated tasks. When these tissues are injured, the mechanical function of the system is affected, and the ability to perform a variety of activities, such as turning, bending, and lifting, may be compromised.(16)

Musculoskeletal disorders may culminate in problems in mechanical function, which can increase the potential for a reduction in driving ability and motor vehicle crash. Typical driving-related mechanical-function problems associated with musculoskeletal disorders include problems maintaining an adequate grip on the steering wheel, and difficulties with seating, reversing, and using the foot pedals. It is important to remember that musculoskeletal conditions may not only affect the CMV operator's ability to drive; these disorders may also affect his/her ability to secure loads, or to load or unload the vehicle. Taking this into consideration, the ability to drive safely is not the only factor that needs to be considered when examining the impact of musculoskeletal disorders on CMV drivers.

Musculoskeletal disorders encompass a broad category of disorders that affect the muscles, nerves, tendons, ligaments, joints, cartilage and vertebrae, and soft tissues that surround these structures. The musculoskeletal disorders considered in the present evidence report include the following:

- Amputation
- Osteoarthritis
- Rheumatoid arthritis

- Psoriatic arthritis
- Septic arthritis
- Ankylosing spondylitis
- Metabolic arthritis (gout)
- Scoliosis
- Systemic lupus erythematosus

The reader should note that the etiology and/or impact on driving performance of work-related strain injuries, neuromuscular disorders and acute musculoskeletal conditions or injuries are not addressed in this evidence report.

Regardless of underlying etiology, musculoskeletal disorders generally share the same characteristic symptomology (chronic pain) and reductions in functional ability. Reductions in functional ability include limited mobility in the joints, reduced ROM, and reduced muscular strength in the limbs. The extent of functional impairment depends on a variety of factors, including the type of musculoskeletal disorder, area(s) affected, and the severity of tissue damage.

Amputation

Amputation can be congenital or acquired. Congenital amputation (or congenital limb deficiency) describes a condition where an individual is born without a body part. Acquired amputation is the removal of a body part that is enclosed by skin (i.e., removal of a finger is an amputation; removal of tonsils would not be an amputation). Amputation can be the consequence of a traumatic event, such as machinery entrapment or a crushing injury, or it can occur as a consequence of surgery. Surgical amputation is usually performed as a treatment for severe, irreparable damage to a body part or to prevent complications associated with infection, disease, or circulatory impairments.

Arthritis

Arthritis encompasses a group of disorders characterized by joint and musculoskeletal pain, stiffness, and swelling associated with inflammation of the synovium, bones, cartilage, and supporting tissues of the joint. Arthritic disorders encompass over 100 different conditions, including bursitis, psoriatic arthritis (PsA), reactive arthritis, metabolic arthritis, OA, lupus, and RA. The type of arthritis and its natural history is determined by the cause of the disorder, which may include injury, infection, hemophilia, autoimmune dysfunction, and crystalline diseases such as metabolic arthritis (gout) and pseudogout.(17) Understanding the specific cause of the arthritic condition is essential in directing an appropriate course of treatment—particularly as some arthritides respond well to treatment, while others are progressive and can be disabling.(18,19)

For the purposes of the present evidence report, we focus on inflammatory arthritis (RA, PsA, reactive arthritis, and metabolic arthritis) and OA.

Other Disorders of the Spinal Column and Cervical Spine that Limit Movement and Functionality

Movement and function in the human body are defined as ROM, which is the normal range of movement for a joint in flexion and extension. This normal ROM can be reduced by a number of factors, including arthritis, infection, and injury. Specific conditions related to compromised trunk kinematic status (a decrease in the angle of rotation at the level of the spine and neck) include ankylosing spondylitis, traumatic injury (fracture or dislocation), syphilis, and congenital torticollis. This section of the report will focus on the rotational disorders of the spine associated with conditions such as ankylosing spondylitis, cervical spondylosis, osteoporosis, spinal stenosis, and degenerative disc disease.

Risk Factors for Musculoskeletal Disorders

When considering musculoskeletal disorders, risk factors are of key importance, since interventions that may prevent or ameliorate the development and/or progression of some disorders need to take these factors into account. Risk factors include the following:

- Genetic predisposition
- Body mass index (BMI)
- Height
- Weight
- Obesity(20,21)
- Age
- Socioeconomic status (poverty)(22)
- Disease
- Lifestyle factors (i.e., diet, physical activity, smoking, excessive alcohol consumption)(23)
- Work-related factors, including: posture, vibration, repetition, and force(20)

The Epidemiology of Musculoskeletal Disorders

Precise estimates of the prevalence and incidence of the musculoskeletal disorders are difficult to ascertain. This is in part because of the lack of standardization in the way that these disorders are categorized.(24) However, some estimates, while not precise, are available.

The U.S. Department of Health and Human Services statistics for the years 2003 through 2005 reported that 46.4 million adults (or 1 in 5) in the United States had a physician-diagnosed arthritic condition, with numbers projected to rise with the aging population to 67 million in 2030.(25) They also reported that musculoskeletal disorders of any cause affect approximately 7% of the total U.S. population, and account for 14% of all physician visits and 19% of all hospital stays.

In contrast to the figures presented above from the United States, a Canadian health survey found that approximately 16% of the population (or double that of the United States) reported having a musculoskeletal disorder, with 85% of the cases being present for more than 1 year. Arthritis was the most commonly reported disorder (27.2/1,000), with prevalence rates in individuals over 20 years of age estimated at 14.2%.(26,27) Similar arthritis rates were reported for Australia (15%). European estimates for musculoskeletal disease found that approximately 25% of all adults were affected by chronic musculoskeletal disease.(28) Statistics regarding musculoskeletal disorders in developing nations are more difficult to obtain. However, a study from Rwanda found population musculoskeletal disorder prevalence rates of 8.1% (95% confidence interval[CI] 5.6–10.6), with the highest rates among individuals aged 50 years and older (18.0%; 95% CI 7.0–290.0).(29)

The Burden of Musculoskeletal Disorders

Worldwide, musculoskeletal disorders are considered the most common cause of chronic disability, making up an estimated 2% of the global burden of disease.(30) Information on musculoskeletal disease as calculated by The World Health Organization (WHO) is featured in Table 2.(28,31)

Table 2. Estimated Burden of Musculoskeletal Conditions[1], by Gender and Region, 2001 (Disability Adjusted Life Years in Thousands)

Condition	Total	Males	Females	Developing Countries	Industrialized Countries
Osteoarthritis	16,372	6,621	9,750	11,049	5,323
Rheumatoid arthritis	4,757	1,353	3,404	3,238	1,520
Other musculoskeletal conditions	8,699	5,033	3,638	6,679	1,880
All musculoskeletal conditions	29,798	13,007	16,792	21,076	8,723

A survey by Yee, of drivers aged 55 or older in the United States, found that 35% stated they had arthritis. A total of 83% of all individuals surveyed stated that stiff or painful joints “never” interfered with driving; 11% stated that joint problems “seldom” interfered with driving; and 3% claimed that joint dysfunction “sometimes” interfered with driving. Weak, stiff, or painful joints required approximately 7% of the individuals surveyed to use an automobile with automatic transmission; 9% required a vehicle with power steering for the same reason.(32)

[1] Primary musculoskeletal dysfunctions according to WHO include osteoarthritis, osteoporosis, other metabolic bone disease, inflammatory arthritis, back pain, musculoskeletal injuries (e.g., sports injuries), and crystal arthritis (metabolic arthritis).

Treatments for Musculoskeletal Disorders

The treatments available for musculoskeletal disorders vary according to the disorder, its etiology, and its severity. While some of the treatments can alter the progression of the disease or illness, others function solely to relieve symptoms.(33) Treatments include the following:

- Conservative treatment (physical therapy, exercise, and behavioral modification)
- Pharmacotherapy
- Surgery
- Combination approaches

Conservative Treatment

Typical conservative treatments associated with musculoskeletal disorders include exercises that incorporate stretching, strengthening, and ROM movements designed to improve overall strength, muscle mass, balance, and flexibility, and reduce pain and stiffness. Other conservative treatments may include the following:

- Heat or cold applied to the affected area(s)
- Weight loss to decrease stress on load-bearing joints
- Rest
- Assistive devices (crutches, braces, canes, etc.)
- Diet modification

Pharmacotherapy

Pharmacotherapy is used to address musculoskeletal disorder symptoms, prevent damage or systemic illness, produce remission of the disorder, and assist in the retention of functional ability. Drug therapies for musculoskeletal disorders include the following:

- Analgesics (oral and topical)
- Opiates (codeine, oxycodone)
- Nonsteroidal anti-inflammatory drugs (NSAIDs)
- Local corticosteroid injections
- Tricyclic antidepressants
- Anticonvulsants
- Muscle relaxants
- Disease-modifying antirheumatic drugs (DMARDs) (biologic response modifiers [BRMs])
- Viscosupplementation (hyaluronic acid injections to the joint)

Surgery

When conservative and pharmacotherapeutic treatments have failed to provide relief from symptoms and quality of life has diminished, surgery for musculoskeletal disorders is a treatment option. The decision to treat a musculoskeletal disorder with surgery requires considering many factors, including the risks associated with surgery and the progression of the disease in the absence of surgery. Complications of surgery include blood clots and infection, and the recovery period can be long and physically demanding. Delaying surgery, however, may result in additional pain and loss of function, which may exacerbate the need for surgical intervention and prolong recovery while reducing the efficacy of the procedure. Surgical options include the following:

- Arthroscopy
- Osteotomy
- Hemicallotasis
- Arthrodesis
- Arthroplasty
- Synovectomy
- Bone resection
- Tendon and ligament reconstruction
- Amputation

Combination Treatment

Combination treatment brings together a variety of elements—exercise, pharmacotherapy, behavioral modification, surgery, and psychologic services—to provide optimal care through an approach that encompasses the etiology of the disorder and the psychologic and social issues that interact within the individual's experience of illness.

CMV Drivers and Musculoskeletal Disorders

In this section of the evidence report we examine the interaction between musculoskeletal disorders and CMV drivers.

Are CMV drivers at an increased risk for developing musculoskeletal disorders?

The degree to which operating a CMV is associated with the onset of musculoskeletal disorders is unknown. However, the interaction between lifestyle factors and occupational factors associated with such individuals may predispose CMV drivers to the development of musculoskeletal disorders.(34-38) Lifestyle factors that might contribute to the development of musculoskeletal disorders include the following:

- Unhealthy eating habits
- Smoking
- Alcohol consumption
- Physical inactivity
- Overweight/obese BMI

Occupational factors that may contribute to the development of musculoskeletal disorders in CMV drivers include the following:

- Sedentary nature of the job
- Exposure to certain types of materials handling tasks
- Work-related factors, including posture

What are the physical demands associated with CMV operation that potentially limit the ability of an individual with musculoskeletal disorders to operate a CMV safely?

The act of CMV driving places a number of demands on the human body: if a condition compromises the ability to perform the tasks required to safely operate a motor vehicle, the results may include crash, injury, or death. The interplay of functional abilities with the safe operation of a motor vehicle was explored by Mazer et al. (2004), who noted that shifting gears, use of the emergency brake, and the ability to use the steering wheel in both directions was largely a product of sufficient ROM.(39)

A list of functional abilities required for motor vehicle operation, the component of the driving process they involve, and the proposed solutions for individuals with disabilities was created by Jones et al. as a way of assessing driver performance.(40) It was considered necessary to have satisfactory performance in two or more of these functional abilities in order to drive. These functional abilities were divided into primary and secondary areas of importance for each of the tasks required to operate a motor vehicle, which are featured in Table 3.

Table 3. Tasks Required to Operate a Motor Vehicle

Primary Area of Function	Secondary Area of Function	Component of Driving Process	Proposed Solutions
Hand	Upper limb	Seat belt manipulation Manipulation of key Use of hand brake	Non-inertia reel. Extend stem of seat belt attachment. Modify seat belt clip. Build up key. Convert of vertical lever for knock on/off action. Keep car in gear when parked. Use accelerator/clutch for hill start. Buy automatic transmission car.
Upper limb	Hand	Open and close door Adjustment of mirror Use of gears	Keep door hinges and handles oiled. Modify buttons. Enlarge door handles. Ask other car drivers to reposition mirror. Increase length of gear stick. Modify hand piece. Buy automatic transmission car. Modify automatic gear stock to "push down" type.
Upper limb	Upper spine	Reaching seat belt Steering/cornering	Hook belt around seat lever. Prevent full recoil of seat belt. Steering wheel cover to increase bulk of wheel. "Threading" steering technique. Increase front tire pressure. Power steering.
Upper spine	Upper limb	Reversing	Undo seat belt when reversing. Install wide rear view mirror. Install near and off side mirrors. "Reversing" with mirrors.
Lower spine	Lower limb	Seat comfort and position	Extend seat runners. Alter seat back position. Wedge cushions. Lumbar cushion.
Lower limb	Lower spine	Vehicle exit and entry Use of foot pedals	Enter buttocks rather than legs first. Extend seat runners. Pedal modification. Automatic transmission car.
Supratentorial		Awareness of traffic and pedestrians Confidence	Practice with experienced driver in quiet streets. Limit driving to familiar streets. Take lessons with qualified driving instructor.
Pain and fatigue on long drives			Frequent stops on long trips. Judicious use of NSAIDs and analgesics. Establish a relaxed driving position.

Adapted from Jones et al.(40)

NSAIDs - Nonsteroidal anti-inflammatory drugs.

Musculoskeletal Disorders and Driving Regulations

As indicated by the National Highway Traffic Safety Administration, stiff and or swollen joints limit how far an individual can bend, move his/her shoulders, grasp a steering wheel, brake immediately, or look over a shoulder to check for blind spots. Consequently, drivers with musculoskeletal disorders may be at increased risk for a motor vehicle crash. To provide for public safety, U.S. federal and state laws have been created that set physical standards for individuals with lost or impaired limbs. Further information on this topic is available at: http://www.nhtsa.dot.gov/.

Current Medical Fitness Standards and Guidelines for CMV drivers in the United States

Current Medical Fitness Standards

The FMCSA Regulations, found in 49 Code of Federal Regulations (CFRs) 301 through 399, cover businesses that operate CMVs in interstate commerce. The FMCSA regulations that pertain to fitness to drive a commercial vehicle are found in 49 CFR 391 Subpart E. Only motor carriers engaged purely in intrastate commerce are not directly subject to these regulations. However, intrastate motor carriers are subject to state regulations, which must be identical to, or compatible with, the federal regulations in order for states

to receive motor carrier safety grants from the FMCSA. States have the option of exempting CMVs with a gross vehicle weight rating of less than 26,001 lbs.

The current medical qualification standard for fitness to drive a CMV (49 CFR 391.41(b) subpart 5) states the following (see: http://www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrruletext.asp?section=391.41):

A person is physically qualified to drive a CMV if that person—

- Has no loss of a foot, a leg, a hand, or an arm, or has been granted a skill performance evaluation certificate pursuant to § 391.49.
- Has no impairment of:
    - a hand or finger that interferes with prehension or power grasping; or
    - an arm, foot, or leg that interferes with the ability to perform normal tasks associated with operating a CMV; or any other significant limb defect or limitation that interferes with the ability to perform normal tasks associated with operating a CMV; or has been granted a skill performance evaluation (SPE) certificate pursuant to § 391.49.
- Has no established medical history or clinical diagnosis of rheumatic, arthritic, orthopedic, muscular, neuromuscular, or vascular disease that interferes with his/her ability to control and operate a CMV safely.

49 CFR 349 Alternative Physical Qualification Standards for the Loss or Impairment of Limbs

49 CFR 349 states the following:

(a) A person who is not physically qualified to drive under § 391.41(b)(1) or (b)(2) and who is otherwise qualified to drive a commercial motor vehicle, may drive a commercial motor vehicle, if the Division Administrator, the FMCSA, has granted a Skill Performance Evaluation (SPE) Certificate to that person.

(b) *SPE certificate.* -- (b)(1) *Application.* A letter of application for an SPE certificate may be submitted jointly by the person (driver applicant) who seeks an SPE certificate and by the motor carrier that will employ the driver applicant, if the application is accepted.

(b)(2) *Application address.* The application must be addressed to the applicable field service center, the FMCSA, for the State in which the co-applicant motor carrier's principal place of business is located. The address of each, and the States serviced, are listed in § 390.27 of this chapter.

(b)(3) *Exception.* A letter of application for an SPE certificate may be submitted unilaterally by a driver applicant. The application must be addressed to the field service center, the FMCSA, for the State in which the driver has legal residence. The driver applicant must comply with all the requirements of paragraph (c)

of this section except those in (c)(1)(i) and (iii). The driver applicant shall respond to the requirements of paragraphs (c)(2)(i) to (v) of this section, if the information is known.

(c) A letter of application for an SPE certificate shall contain:

(c)(1) Identification of the applicant(s):

(c)(1)(i) Name and complete address of the motor carrier coapplicant;

(c)(1)(ii) Name and complete address of the driver applicant;

(c)(1)(iii) The U.S. DOT Motor Carrier Identification Number, if known; and

(c)(1)(iv) A description of the driver applicant's limb impairment for which SPE certificate is requested.

(c)(2) Description of the type of operation the driver will be employed to perform:

(c)(2)(i) State(s) in which the driver will operate for the motor carrier coapplicant (if more than 10 States, designate general geographic area only);

(c)(2)(ii) Average period of time the driver will be driving and/or on duty, per day;

(c)(2)(iii) Type of commodities or cargo to be transported;

(c)(2)(iv) Type of driver operation (*i.e.,* sleeper team, relay, owner operator, etc.); and

(c)(2)(v) Number of years experience operating the type of commercial motor vehicle(s) requested in the letter of application and total years of experience operating all types of commercial motor vehicles.

(c)(3) Description of the commercial motor vehicle(s) the driver applicant intends to drive:

(c)(3)(i) Truck, truck tractor, or bus make, model, and year (if known);

(c)(3)(ii) Drive train;

(A) Transmission type (automatic or manual -- if manual, designate number of forward speeds);

(B) Auxiliary transmission (if any) and number of forward speeds; and

(C) Rear axle (designate single speed, 2 speed, or 3 speed).

(c)(3)(iii) Type of brake system;

(c)(3)(iv) Steering, manual or power assisted;

(c)(3)(v) Description of type of trailer(s) (*i.e.,* van, flatbed, cargo tank, drop frame, lowboy, or pole);

(c)(3)(vi) Number of semitrailers or full trailers to be towed at one time;

(c)(3)(vii) For commercial motor vehicles designed to transport passengers, indicate the seating capacity of commercial motor vehicle; and

(c)(3)(viii) Description of any modification(s) made to the commercial motor vehicle for the driver applicant; attach photograph(s) where applicable.

(c)(4) Otherwise qualified:

(c)(4)(i) The coapplicant motor carrier must certify that the driver applicant is otherwise qualified under the regulations of this part;

(c)(4)(ii) In the case of a unilateral application, the driver applicant must certify that he/she is otherwise qualified under the regulations of this part.

(c)(5) Signature of applicant(s):

(c)(5)(i) Driver applicant's signature and date signed;

(c)(5)(ii) Motor carrier official's signature (if application has a coapplicant), title, and date signed. Depending upon the motor carrier's organizational structure (corporation, partnership, or proprietorship), the signer of the application shall be an officer, partner, or the proprietor.

(d) The letter of application for an SPE certificate shall be accompanied by:

(d)(1) A copy of the results of the medical examination performed pursuant to § 391.43;

(d)(2) A copy of the medical certificate completed pursuant to § 391.43(h);

(d)(3) A medical evaluation summary completed by either a board qualified or board certified physiatrist (doctor of physical medicine) or orthopedic surgeon. The coapplicant motor carrier or the driver applicant shall provide the physiatrist or orthopedic surgeon with a description of the job-related tasks the driver applicant will be required to perform;

(d)(3)(i) The medical evaluation summary for a driver applicant disqualified under § 391.41(b)(1) shall include:

(A) An assessment of the functional capabilities of the driver as they relate to the ability of the driver to perform normal tasks associated with operating a commercial motor vehicle; and

(B) A statement by the examiner that the applicant is capable of demonstrating precision prehension (*e.g.,* manipulating knobs and switches) and power grasp prehension (*e.g.,* holding and maneuvering the steering wheel) with each upper limb separately. This requirement does not apply to an individual who was granted a waiver, absent a prosthetic device, prior to the publication of this amendment.

(d)(3)(ii) The medical evaluation summary for a driver applicant disqualified under § 391.41(b)(2) shall include:

(A) An explanation as to how and why the impairment interferes with the ability of the applicant to perform normal tasks associated with operating a commercial motor vehicle;

(B) An assessment and medical opinion of whether the condition will likely remain medically stable over the lifetime of the driver applicant; and

(C) A statement by the examiner that the applicant is capable of demonstrating precision prehension (*e.g.,* manipulating knobs and switches) and power grasp prehension (*e.g.,* holding and maneuvering the steering wheel) with each upper limb separately. This requirement does not apply to an individual who was granted an SPE certificate, absent an orthotic device, prior to the publication of this amendment.

(d)(4) A description of the driver applicant's prosthetic or orthotic device worn, if any;

(d)(5) Road test:

(d)(5)(i) A copy of the driver applicant's road test administered by the motor carrier coapplicant and the certificate issued pursuant to § 391.31(b) through (g); or

(d)(5)(ii) A unilateral applicant shall be responsible for having a road test administered by a motor carrier or a person who is competent to administer the test and evaluate its results.

(d)(6) Application for employment:

(d)(6)(i) A copy of the driver applicant's application for employment completed pursuant to § 391.21; or

(d)(6)(ii) A unilateral applicant shall be responsible for submitting a copy of the last commercial driving position's employment application he/she held. If not previously employed as a commercial driver, so state.

(d)(7) A copy of the driver applicant's SPE certificate of certain physical defects issued by the individual State(s), where applicable; and

(d)(8) A copy of the driver applicant's State Motor Vehicle Driving Record for the past 3 years from each State in which a motor vehicle driver's license or permit has been obtained.

(e) *Agreement.* A motor carrier that employs a driver with an SPE certificate agrees to:

(e)(1) File promptly (within 30 days of the involved incident) with the Medical Program Specialist, the FMCSA service center, such documents and information as may be required about driving activities, accidents, arrests, license suspensions, revocations, or withdrawals, and convictions which involve the driver applicant. This applies whether the driver's SPE certificate is a unilateral one or has a coapplicant motor carrier;

(e)(1)(i) A motor carrier who is a coapplicant must file the required documents with the Medical Program Specialist, the FMCSA for the State in which the carrier's principal place of business is located; or

(e)(1)(ii) A motor carrier who employs a driver who has been issued a unilateral SPE certificate must file the required documents with the Medical Program Specialist, the FMCSA service center, for the State in which the driver has legal residence.

(e)(2) Evaluate the driver with a road test using the trailer the motor carrier intends the driver to transport or, in lieu of, accept a certificate of a trailer road test from another motor carrier if the trailer type(s) is similar, or accept the trailer road test done during the Skill Performance Evaluation if it is a similar trailer type(s) to that of the prospective motor carrier. Job tasks, as stated in paragraph (e)(3) of this section, are not evaluated in the Skill Performance Evaluation;

(e)(3) Evaluate the driver for those nondriving safety related job tasks associated with whatever type of trailer(s) will be used and any other nondriving safety related or job related tasks unique to the operations of the employing motor carrier; and

(e)(4) Use the driver to operate the type of commercial motor vehicle defined in the SPE certificate only when the driver is in compliance with the conditions and limitations of the SPE certificate.

(f) The driver shall supply each employing motor carrier with a copy of the SPE certificate.

(g) The State Director, the FMCSA, may require the driver applicant to demonstrate his or her ability to safely operate the commercial motor vehicle(s) the driver intends to drive to an agent of the State Director, the FMCSA. The SPE certificate form will identify the power unit (bus, truck, truck tractor) for which the SPE certificate has been granted. The SPE certificate forms will also identify the trailer type used in the Skill Performance Evaluation; however, the SPE certificate is not limited to that specific trailer type. A driver may use the SPE certificate with other trailer types if a successful trailer road test is completed in accordance with paragraph (e)(2) of this section. Job tasks, as stated in paragraph (e)(3) of this section, are not evaluated during the Skill Performance Evaluation.

(h) The State Director, the FMCSA, may deny the application for SPE certificate or may grant it totally or in part and issue the SPE certificate subject to such terms, conditions, and limitations as deemed consistent with the public interest. The SPE certificate is valid for a period not to exceed 2 years from date of issue, and may be renewed 30 days prior to the expiration date.

(i) The SPE certificate renewal application shall be submitted to the Medical Program Specialist, the FMCSA service center, for the State in which the driver has legal residence, if the SPE certificate was issued unilaterally. If the SPE certificate has a coapplicant, then the renewal application is submitted to the Medical Program Specialist, the FMCSA field service center, for the State in which the coapplicant motor carrier's principal place of business is located. The SPE certificate renewal application shall contain the following:

(i)(1) Name and complete address of motor carrier currently employing the applicant;

(i)(2) Name and complete address of the driver;

(i)(3) Effective date of the current SPE certificate;

(i)(4) Expiration date of the current SPE certificate;

(i)(5) Total miles driven under the current SPE certificate;

(i)(6) Number of accidents incurred while driving under the current SPE certificate, including date of the accident(s), number of fatalities, number of injuries, and the estimated dollar amount of property damage;

(i)(7) A current medical examination report;

(i)(8) A medical evaluation summary pursuant to paragraph (d)(3) of this section, if an unstable medical condition exists. All handicapped conditions classified under § 391.41(b)(1) are considered unstable. Refer to paragraph (d)(3)(ii) of this section for the condition under § 391.41(b)(2) which may be considered medically stable.

(i)(9) A copy of driver's current State motor vehicle driving record for the period of time the current SPE certificate has been in effect;

(i)(10) Notification of any change in the type of tractor the driver will operate;

(i)(11) Driver's signature and date signed; and

(i)(12) Motor carrier coapplicant's signature and date signed.

(j)(1) Upon granting an SPE certificate, the State Director, the FMCSA, will notify the driver applicant and co-applicant motor carrier (if applicable) by letter. The terms, conditions, and limitations of the SPE certificate will be set forth. A motor carrier shall maintain a copy of the SPE certificate in its driver qualification file. A copy of the SPE certificate shall be retained in the motor carrier's file for a period of 3 years after the driver's employment is terminated. The driver applicant shall have the SPE certificate (or a legible copy) in his/her possession whenever on duty.

(j)(2) Upon successful completion of the skill performance evaluation, the State Director, the FMCSA, for the State where the driver applicant has legal residence, must notify the driver by letter and enclose an SPE certificate substantially in the following form:Skill Performance Evaluation Certificate Name of Issuing Agency:Agency Address:Telephone Number: ( ) Issued Under 49 CFR 391.49, subchapter B of the Federal Motor Carrier Safety Regulations Driver's Name:Effective Date: SSN:DOB:Expiration Date:Address:Driver Disability:Check One:_New_Renewal Driver's License:_____ (State) (Number)

In accordance with 49 CFR 391.49, subchapter B of the Federal Motor Carrier Safety Regulations (FMCSRs), the driver application for a skill performance evaluation (SPE) certificate is hereby granted authorizing the above-named driver to operate in interstate or foreign commerce under the provisions set forth below. This certificate is granted for the period shown above, not to exceed 2 years, subject to periodic review as may be found necessary. This certificate may be renewed upon submission of a renewal application. Continuation of this certificate is dependent upon strict adherence by the above-named driver to the provisions set forth below and compliance with the FMCSRs. Any failure to comply with provisions herein may be cause for cancellation.

CONDITIONS: As a condition of this certificate, reports of all accidents, arrests, suspensions, revocations, withdrawals of driver licenses or permits, and convictions involving the above-named driver shall be reported in writing to the Issuing Agency by the EMPLOYING MOTOR CARRIER within 30 days after occurrence.

LIMITATIONS: 1. Vehicle Type (power unit):* 2. Vehicle modification(s): 3. Prosthetic or Orthotic device(s) (Required to be Worn While Driving):4. Additional Provision(s):

NOTICE: To all MOTOR CARRIERS employing a driver with an SPE certificate. This certificate is granted for the operation of the *power unit only.* It is the responsibility of the employing motor carrier to evaluate the driver with a road test using the trailer type(s) the motor carrier intends the driver to transport, or in lieu of, accept the trailer road test done during the SPE if it is a similar trailer type(s) to that of the prospective motor carrier. Also, it is the responsibility of the employing motor carrier to evaluate the driver for those non-driving safety-related job tasks associated with the type of trailer(s) utilized, as well as, any other non-driving safety-related or job-related tasks unique to the operations of the employing motor carrier.

The SPE of the above named driver was given by a Skill Performance Evaluation Program Specialist. It was successfully completed utilizing the above named power unit and _____(trailer, if applicable)

The tractor or truck had a _____ transmission.

Please read the *NOTICE* paragraph above. Name:Signature:Title:Date:

(k) The State Director, the FMCSA, may revoke an SPE certificate after the person to whom it was issued is given notice of the proposed revocation and has been allowed a reasonable opportunity to appeal.

(l) Falsifying information in the letter of application, the renewal application, or falsifying information required by this section by either the applicant or motor carrier is prohibited.

[65 FR 25287, May 1, 2000, as amended at 65 FR 59380, Oct. 5, 2000; 67 FR 61824, Oct. 2, 2002]

More extensive information on this topic is available at the *Conference on Neurological Disorders and Commercial Drivers* at: http://www.fmcsa.dot.gov/

Medical Fitness Standards and Guidelines for Individuals Performing Transportation Safety in the United States

Current medical fitness standards and guidelines for individuals performing transportation safety in the United States are summarized in Table 4. Included in the table are pertinent rules and guidelines for pilots, railroad workers, and merchant mariners.

Table 4. Standards and Guidelines Pertaining to Individuals with Musculoskeletal Disorders: FAA, Railroad, and Merchant Marine

Condition	FAA* (all classes of airmen)	Railroad†	Merchant Marine‡
Musculoskeletal Disorders	Examiners may reissue an airman medical certificate under the provisions of an Authorization, if the applicant provides the following: • An Authorization granted by FAA • The type of arthritis • A general assessment of condition and effect on daily activities • The name and dosage of medication(s) used for treatment and/or prevention with comment regarding side effects • Comments regarding ROM of neck, upper and lower extremities, hands, etc. **Guide for Aviation Medical Examiners** **Decision Considerations** **Disease Protocols** **Musculoskeletal Evaluation** The Examiner should defer issuance. An applicant with a history of musculoskeletal conditions must submit the following if consideration for medical certification is desired: • Current status report • Functional status report • Degree of impairment as measured by strength, ROM, and pain **Note**: If the applicant is otherwise qualified, FAA may issue a limited certificate. This certificate will permit the applicant to proceed with flight training until ready for a medical flight test. At that time, and at the applicant's request, FAA (usually AMCD) will authorize the student pilot to take a medical flight test in conjunction with the regular flight test. The medical flight test and regular private pilot flight test are conducted by an FAA inspector. This affords the student an opportunity to demonstrate the ability to control the aircraft despite the handicap. The FAA inspector prepares a written report and indicates whether there is a safety problem. A medical certificate and SODA, without the student limitation, may be provided to the inspector for issuance to the applicant, or the inspector may be required to send the report to the FAA medical officer who authorized the test. When prostheses are used or additional control devices are installed in an aircraft to assist the amputee, those found qualified by special certification procedures will have their certificates limited to require that the device(s) (and, if necessary, even the specific aircraft) must always be used when exercising the privileges of the airman certificate.	No specific standards or guidelines	Potentially disqualifying conditions listed in the Physical Evaluation Guidelines for Merchant Mariner's Documents and Licenses included any disease or constitutional defect that would result in gradual deterioration of performance of duties, and sudden incapacitation or otherwise compromise shipboard safety— including required response in an emergency situation. Orthopedic conditions, including amputation, deformity, or arthritis, resulting in impairment of motion or use of limbs or back would require the following: • Requests for waivers should include a report of a practical demonstration of mobility • Details of the test shall be determined by the OCMI using the Marine Safety Manuel as a guide • The test should be conducted under conditions appropriate for the credential, route, and tonnage the applicant is applying for • Applicant should be able to respond adequately in emergency situations

AMCD – Aerospace Medical Certification Division
FAA – Federal Aviation Association
OCMI – Officer in charge, marine inspection
ROM – Range of motion
SODA – Statement of demonstrated ability

*Source of information for FAA Regulations and Guidelines:
http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/ame/guide/special_iss/all_classes/arthritis/
http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/ame/guide/dec_cons/disease_prot/musculoskeletal/
†Source of information for Federal Railroad Administration Guidelines: http://www.fra.dot.gov/us/content/1586
‡Source of information for Merchant Mariner Guidelines: http://www.uscg.mil/hq/g-m/nvic/2_98/n2-98.pdf

Regulatory Medical Fitness Standards for the United States and Selected Countries

The United States and other countries have established regulatory medical fitness standards for the protection and safety of the public interest, including licensed drivers. The medical standards are used to assess and determine the fitness of drivers operating CMVs. Likewise, musculoskeletal disorders are defined, and the criteria for establishing these standards are constructed. Each state and country demonstrates its interpretation of musculoskeletal disorders through definition and by determining the relevant population(s). Medical fitness standards and guidelines for each state are summarized in Table 5.

Regulatory standards and guidelines pertaining to musculoskeletal disorders and CMV driving in several selected countries are presented in Table 6 and Table 7.

Table 5. Medical Standards for Musculoskeletal Disorders for CMV Drivers by U.S. State

State	Reference	Requirements for Musculoskeletal Disorders
ALABAMA	Alabama Department of Public Safety Motor Carrier Safety Unit/FAQ www.dps.state.al.us/public/highwaypatrol	Please refer to Federal Regulations 391.45 for persons who must be medically examined and certified. Please refer to Federal Regulations 391.43 for guidelines on obtaining a medical card.
ALASKA	Title 2 Administration Chapter 90 Driver Licensing and Safety Responsibility Article 6 Standards for Licensing of Drivers 2 AAC.90.440 Medical Standards	2(b) The department will not issue a commercial driver's license to a person with a disqualifying medical condition as defined by the 49 C.F.R. Part 391, Subpart E (Federal Motor Carrier Safety Relations), revised as of October 1, 2005. (d) The department will not issue a commercial driver's license to a person with a disqualifying progressive disease or condition as defined by 49 C.F.R. Part 391, Subpart E (Federal Motor Carrier Safety Regulations), revised as of October 1, 2005.
ARIZONA	Arizona State Legislature Chapter 8 Motor Vehicle Driver Licensing Article 5 Commercial Driver Licensing 28-3223. Original applicant; requirements; expiration; renewal examination	A. In addition to the requirements applicable to all driver license applicants, an original applicant for a class A, B or C license is subject to the following requirements: 1. The applicant shall submit evidence of compliance with medical standards and requirements that the department adopts by rule.
	Article 4 General Licensing Provisions 28-3159. Restricted licenses	A. With good cause, the department may issue the following restricted driver license: 2. A class A, B or C driver license that restricts the driver from operating: (b) a vehicle in interstate commerce, if the applicant is not subject to 49 Code of Regulations part 391
	Arizona Driver License Manual and Customer Service Guide Motor Vehicle Division D.O.T. Medical Examination Report Commercial Driver Fitness Determination	Physical Examination **Item 10: Extremities-Limb impaired**. Driver may be subject to SPE certificate if otherwise qualified. Check for: loss of impairment of leg, foot, toe, arm, hand, finger. Perceptible limp, deformities, atrophy, weakness, paralysis, clubbing, edema, hypotonia, insufficient grasp and prehension in upper limb to maintain steering wheel grip. Insufficient mobility and strength in lower limb to operate pedals properly. **Item 11: Spine, other musculoskeletal**. Previous surgery, deformities, limitation of motion, tenderness. Please note if the driver "meets standards in 49 CFR 391.41: qualifies for 2-year certificate
ARKANSAS	Arkansas Code Title 27. Transportation Chapter 23. Commercial Drivers License Also known as Arkansas Uniform Commercial Drivers License Act	No mention of medical qualifications
	Arkansas Dept. of Finance Administration Including CDL Driver's Examination Manual	No mention of medical qualifications
CALIFORNIA	Department of Motor Vehicles Medical Report for Commercial Driver License (CDL) www.dmv.ca.gov/commercial/commercial.htm	A medical form completed by a U.S. licensed doctor of medicine (M.D.), osteopathy (D.O.), licensed physician assistant (P.A.), a nurse practitioner (N.P.), advance practice nurse, or chiropractor who is clinically competent to perform the medical examination, must be given to the DMV with your original application for a driver license or instruction permit. The medical form must be dated within the last 2 years and on a form approved by the Federal Highway Administration, the Federal Aviation Administration, DMV, or on the DMV Report of Medical Examination Report form DL 51 (examiners asked to refer to Federal Regulations 49 C.F.R. 391.41).

State	Reference	Requirements for Musculoskeletal Disorders
COLORADO	Revised statutes Division of Motor Vehicles Motor Carrier Services/Forms DOT Medical Form (CDL Drivers)	No mention of medical qualifications Medical Examination Report for Commercial Driver Fitness Determination. No additional explanation is listed.
CONNECTICUT	Department of Motor Vehicles www.ct.gov Obtaining a Commercial Driver's License/Documents required when appearing for CDL Knowledge testing Connecticut Code Title 14 – Motor Vehicles Chapter 246/Section 14-44E	Physical examination by a physician dated within the last two years, reported on an Examination to Determine Physical Condition of Driver (form R-323) or a U.S. D.O.T. Medical Examiner's Physical Examination Form CO730, which meets D.O.T. requirements in 49 C.F.R. 391.41-391.49 **Sec 14-44E. Limitations on issuance of commercial driver's license. Qualification standards. Waiver of skills test. Requirements for license endorsement to operate vehicle transporting hazardous materials. Commercial driver's instruction permit**. (b) The commissioner shall not issue a commercial driver's license to any person who has a physical or psychobehavioral impairment that affects such person's ability to operate a CMV safely. In determining whether to issue a commercial driver's license in any individual case, the commissioner shall apply the standards set forth in 49 C.F.R 391.41, as amended, unless it is established that the person will operate such vehicle only in this state, in which case the commissioner shall apply the standards set forth in this chapter and in regulations adopted thereunder.
DELAWARE	Delaware Code Title 21 Motor Vehicles Chapter 47. Motor Carrier Safety-Responsibility	**4702. Adoption of federal requirements – In general.** (a) The State hereby adopts the following parts of the Code of Federal Regulations, Title 49, Chapter III, Subchapter B, except as modified by this chapter:.. Part 391..adopted pursuant to the Transportation Article of the U.S. Code (49 U.S.C. §101 et seq.).
	Chapter 220 Formerly Bill No. 156 As Amended by Senate Amendment No.1	Section 1. Amend Section 4704(b) [Effective September 30,2005] of Title 21 of the Delaware Code by deleting said subsection in its entirety and substituting in lieu thereof a new subsection (b) to read as follows: **(b) Intra-State Only Restricted Commercial Driver License Medical Waiver Program.** Persons who are not physically qualified to drive a CMV per 49 C.F.R. Section 391.41 may apply for an intra-State only restricted commercial driver license waiver provided they are otherwise qualified to drive a motor vehicle, other than a motor vehicle which requires endorsements to transport passengers or hazardous materials, and meet the other provisions of this subsection, Title 21 and the Federal Motor Carrier Regulations….The Division will establish policy to administer the CDL medical waiver program. The applicant must provide recent physical examinations signed by the driver's primary physician and, if appropriate, from a medical specialist. The Division may require the applicant to successfully complete a training course and evaluation by a physical rehabilitation center. The Division may refer individual applications to the Medical Advisory Board for their advice concerning the applicant's ability to safely operate motor vehicles weighing more than 26,000 pounds…A "K" restriction will be added to the CDL driver license once a medical waiver is granted. The CDL medical waiver expires on the CDL expiration date or upon a date determined by the Division..once an applicant is initially granted a CDL medical waiver, the Division may issue a 90-day temporary CDL medical waiver pending the results of medical or rehabilitation examinations. Section 2. Amend Section 4704 [Effective September 30, 2005] of Title 21 of the Delaware Code by adding a new subsection (c) to read as follows: "State, county and local government employees who hold a commercial driver license and operate CMVs as defined by §2603(6) as part of their official duties for the State or any political subdivision therein, shall meet the Federal physical qualifications and examination requirements found in 49 C.F.R. Part 391, Subsection E unless approved by an intra-State only restricted commercial driver license in accordance with Section 4704(b).
	Commercial Driver's Manual Delaware – Version 2.0	Basic CDL License Requirements: - Able to obtain Medical certification under the Federal Motor Carrier Safety Regulations (Part 391.41 – Physical Qualifications for Drivers) - If you do not meet part 391.41 Physical Qualifications for Drivers, you may be able to obtain a Delaware intrastate only restricted CDL medical waiver, if otherwise qualified to drive a motor vehicle (excluding transporting passengers or hazardous materials)

State	Reference	Requirements for Musculoskeletal Disorders
DISTRICT OF COLUMBIA	District of Columbia Municipal Regulation Title 18 Vehicle and Traffic Chapter 13 Classification and Issuance of Commercial Driver's Licenses	**1327 Physical Qualifications and Examinations** 1327.1 No person shall be issued a new or renewed commercial driver's license unless he or she is physically qualified and, except as provided in the Federal Motor Carrier Safety Regulations (FMCSR), 49 CFR 391.49, possesses an original of a medical examiner's certificate, not more than two (2) years old, reflecting that he or she is physically qualified to drive a commercial vehicle. 1327.2 A person shall be considered physically qualified to drive a motor vehicle if that person meets the requirements in 49 CFR 391. 1327.3 Except as otherwise provided in this section, a medical examination to determine an applicant's physical qualification to operate a CMV shall be performed by a licensed doctor of medicine. 1327.8 Any CMV driver whose ability to perform his or her normal duties has been impaired by a physical or mental injury or disease must be reexamined and submit the certification required by §1327.3.
FLORIDA	Florida Department of Highway Safety & Motor Vehicles www.hsmv.state.fl.us	CDL Medical Information linked to FMCSA web site Medical Advisory Criteria for Evaluation Under 49 CFR Part 391.41. CDL Medical Information/Medical Report Form "Medical Exam Report for Commercial Driver Fitness Determination"
	2006 Florida Statutes Title XXIII Motor Vehicles Chapter 322 Drivers' Licenses	**322.12 Examination of applicants.** (4) The examination for an applicant for a commercial driver's license shall include an actual demonstration of the applicant's ability to exercise ordinary and reasonable control in the safe operation of a motor vehicle or combination of vehicles of the type covered by the license classification which the applicant is seeking.. **322.59 Possession of medical examiner's certificate.** (1) The department shall not issue a commercial driver's license to any person who is required by the laws of this state or federal law to possess a medical examiner's certificate, unless such person presents a valid certificate prior to licensure.
GEORGIA	Georgia Department of Driver Services Commercial Driver's License Rules Chapter 1 Commercial Driver's Licensing Requirements www.dds.ga.gov	**1-1-.04 Minimum Physical Requirements Required to Obtain a Commercial Driver's License. Amended.** (1) Applicants for a commercial driver's license must comply with minimum Federal requirements as set forth in 49 C.F.R. § 391.41 **1-1-.05 Exemptions from Medical Requirements**. (1) Operators of city, county, state or federal vehicles are exempt from the medical requirements. (2) Drivers who operate on an occasional basis receive no compensation and are not involved in commercial enterprise. **1-1-.06 Driver Qualifications. Amended.** In order to be eligible for issuance of a commercial driver's license, each applicant must: (4) Comply with the minimum federal standards as set forth in C.F.R. § 391.41
	Georgia Department of Driver Services Application for Georgia Commercial Driver's License	**Part 4. Medical Certification** **Medical Qualifications:** Unless specifically exempted, you must possess a valid medical examiner's certificate in order to operate a CMV (49 CFR § 391.41). Government employees (e.g., federal, state, county, or city employees) while operating government owned vehicles are exempt from this medical requirement
	Georgia Department of Driver Services Forms and Manuals	Medical Examination Report for Commercial Driver Fitness Determination with accompanying 49 CFR 391.41 available
HAWAII	Hawaii Revised Statutes Title 17 Motor and other Vehicles Chapter 286 Highway Safety Part XIII Commercial Driver Licensing	§ **286-236 Commercial driver's license qualification standards.** (a) No person shall be issued a commercial driver's license unless that person meets the qualification standards of 49 Code of Federal Regulations, Part 391, Subparts B and E…..A person who is not physically qualified to drive under 49 Code of Federal Regulations Section 391.41 (b) (1), (2), or (3) and who is otherwise qualified to driver a motor vehicle may be granted an intrastate waiver by the director. The process for granting intrastate waivers shall be the same as that for interstate waivers in 49 Code of Federal Regulations, Part 391.49, except that the intrastate waiver requests shall be submitted to the director; provided that the director shall adopt rules under chapter 91 to establish a screening process, including approval by a licensed physician, for granting an intrastate waiver to persons who are not physically qualified under 49 Code of Federal Regulations Section 391.41 (b)(3). (e) A commercial driver's instruction permit may be issued to an individual who holds a valid driver's license, meets the qualification standards of 49 Code of Federal Regulations, Part 391, Subparts B and E, and has passed the written tests required for the desired class of a commercial driver's license.

State	Reference	Requirements for Musculoskeletal Disorders
IDAHO	Commercial Driver's License Manual Idaho 2007 ltd.idaho.gov/dmv/driverservices/cdl_manual	**1.4 How to Get a CDL** You will be asked if you are subject to and in compliance with the requirements of Part 391 of the Federal Motor Carrier Safety Regulations (Qualifications of Drivers). These include the DOT medical card requirements. Information regarding who is subject to these requirements may be found in Section 13 of this manual. **Section 13: Forms/General Qualifications of Driver Requirements** Unless exempt, every person who operates a CMV in interstate, foreign or intrastate commerce is subject to the Qualifications of Driver Requirements. (Refer to Federal Motor Carrier Safety Regulations, 49 CFR 391.11 for exact wording) B. An individual is qualified to drive a commercial vehicle if he/she: 4. Carries a current medical examiner's certificate (DOT medical card) stating that he/she is physically qualified to drive a commercial vehicle. (391 Subpart E)
	Idaho Administrative Code IDAPA 11.13.01 Motor Carrier Rules	**019. Carrier Safety Requirements** **01. Adoption of Federal Regulations**. Adoption of Federal Regulations 49 CFR Parts….and 390 through 399 are hereby adopted by reference. Whenever any one (1) of these federal regulations (except Section 391.11(b)(1) exempts intrastate carriers from any of their requirements, this Rule at IDAPA 11.13.01, "The Motor Carrier Rules", Section 019, removes that exemption and subjects the intrastate carrier to the same requirements. a. All interstate and foreign carriers and intrastate carriers, except those carriers listed in Subsection 019.01.b., subject to the safety authority of the Idaho State Police while operating in Idaho that transport passengers or property, must comply with 49 CFR Parts…and 390 through 399, and the law and rules of the state of Idaho (except 391.11(b)(1) for intrastate carriers). b. Intrastate carriers operating CMVs transporting property with a GVW, GVWR, GCW or GCWR greater than ten thousand (10,000) pounds and up to twenty-six thousand (26,000) pounds, subject to the authority of the Idaho State Police, must comply with 49 CFR part 390 Subpart A, Part 391.15, Parts 392, 393, and Part 396.1, 396.3(a), (a)(1), and (a)(2), and 396.5 through 396.9 and the law and rules of the state of Idaho.
ILLINOIS	Illinois Administrative Code Title 92 Transportation Chapter 1: Department of Transportation Subchapter D: Motor Carrier Safety Regulations Part 391: Qualification of Drivers	**Section 391.2000 Incorporation by Reference of 49 CFR 391** 7) 49 CFR 391.49(a) is not incorporated and the following substituted therefore: A person who is not physically qualified to drive under 49 CFR 391, and who is otherwise qualified to drive a CMV, may drive a CMV in interstate or intrastate transportation if the Division Administrator, FMCSA, has granted a Skill Performance Evaluation (SPE) Certificate to that person.
	Illinois Commercial Driver's License Study Guide cyberdriveillinois.com	Federal Motor Carrier Safety Regulations are listed in Table C, pgs 131-132
INDIANA	Indiana Administrative Code Title 140 Article 7 Driver's License Division	Rule 3. Commercial Driver's Licensing 140 IAC 7-3-3 Applicant Sec. 3 (7) The applicant must pass a physical examination prior to applying for an initial commercial driver's license and every two (2) years thereafter. In fulfilling this requirement, the applicant must meet the guidelines outlined in section 6 of this rule. Proof of passage of the physical examination within two (2) years prior to application must be presented to the bureau at the time of any application for a commercial driver's license or endorsement. (11) The applicant shall be issued his commercial driver's license subject to any restrictions on his driving privileges at the time of application. 140 IAC 7-3-5 Learner's permit Sec. 5 (a) Any person who is a resident of Indiana may apply for a commercial driver's license learner's permit. The applicant must (3) meet all visual and physical examination requirements; and.. 140 IAC 7-3-6 Physical examination requirements Sec. 6. Every applicant or holder of a commercial driver's license must pass a physical examination described as follows: (1) For interstate operation, a physical examination as described by the U.S. Department of Transportation, 49 C.F.R. 391.43. (2) For intrastate operation, a physical examination as prescribed by the bureau.

State	Reference	Requirements for Musculoskeletal Disorders
	Indiana Department of Revenue Motor Carrier Services Division Commercial Driver's License Section	IDOR Physical Examination Instructions and Information for Physical Examination Forms of CDL Holders
	Indiana Commercial Driver's License Test Booklet (contents only for CDL testing on or after July 1, 2007)	**Exemption of Certain Physical Defects** A person who is not physically qualified to drive under FMCSR 391.41 (b)(1) or (2) and who is otherwise qualified to drive a CMV, may drive a CMV if the Regional Director of Motor Carrier Safety has granted an exemption to that person. An example would be a person requiring a prosthetic or orthotic device. Such a driver is not automatically disqualified from operating a CMV. The State of Indiana, in conjunction with the Federal Highway Administration, will conduct a physical exemption evaluation, provided all exemption requirements are met.
IOWA	Iowa Code 2001 Section 321.188 Commercial driver's license requirements	1. Before the department issues, renews, or upgrades a commercial driver's license and in addition to the requirements of section 321.182, the license applicant shall do all of the following: (a) Certify whether the applicant is subject to and meets applicable driver qualifications of 49 C.F.R. part 391 as adopted by rule by the department.
	Iowa Code Section 321.449 Motor Carrier Safety Rules	1. A person shall not operate a commercial vehicle on the highways of this state except in compliance with rules adopted by the department under chapter 17A. The rules shall be consistent with the federal motor carrier safety regulations promulgated under U.S. Code, Title 49, and found in 49 CF.R. pts. 390 – 399 and adopted under chapter 17A. 5.a.Notwithstanding other provisions of this section, rules adopted under this section concerning physical and medical qualifications for drivers of commercial vehicles engaged in intrastate commerce shall not be construed as disqualifying any individual who was employed as a driver of commercial vehicles engaged in intrastate commerce whose physical or medical condition existed prior to July 29, 1996.
	Iowa Commercial Driver's License in a Nutshell Iowa Department of Transportation November 2005 Certification for Commercial Driver's License	Applicants must notify the state of Iowa if: 1) I am subject to and meet the driver qualifications of 49 Code of Federal Regulations, Part 391.(Interstate) OR 2) I am subject to and meet the driver qualifications of 49 Code of Federal Regulations, Part 391, adopted pursuant to Iowa Code Sections 321.449 and 321.450. (Intrastate) OR 3) I am not subject to either of the above driver qualifications.(if exemptions apply)
KANSAS	Motor Carrier Regulations of the Transportation Division of The State Corporation Commission of The State of Kansas June 30, 2006	82-4-6d. Waiver of physical requirements. (a) Any person failing to meet the requirements of 49 C.F.R. 391.41 may be permitted to drive a vehicle, other than a vehicle transporting passengers, if the director finds that the granting of a waiver is consistent with highway safety and the public interest. (2) The application shall be accompanied by the following: (iii) Letters of recommendations regarding limb impairment or amputation shall include a medical summary conducted by a board of qualified, or board-certified, physiatrists or orthopedic surgeons, preferably associated with a rehabilitation center. (iv) Letters of recommendation shall include a description of any prosthetic or orthopedic devices worn by the driver applicant.
KENTUCKY	Kentucky Legislature Kentucky Administrative Regulation Title 601 Transportation Cabinet Department of Vehicle Regulation	**601 KAR 11:040 Medical waivers for intrastate operators of CMVs** NECESSITY, FUNCTION, AND CONFORMITY: The federal requirements for the issuance of a commercial driver's license to a driver operating in interstate commerce include a certification that the driver meets the qualification requirements contained in 49 C.F.R. 391. The Federal Highway Administration does not require a person who operates entirely in intrastate commerce to be subject to 49 C.F.R. 391. He is subject, however to Kentucky driver qualification requirements in 601 KAR 1:005 the Transportation Cabinet adopted the majority of the driver qualification requirements of 49 C.F.R. Part 391 on both an interstate and intrastate commerce basis. However, medical waivers in addition to those allowed in 49 C.F.R. 391.49 are allowed by the Federal Highway Administration for drivers operating exclusively in intrastate commerce. This administrative regulation sets forth the procedure and standards for obtaining an intrastate medical waiver. Section 2. (2) The following medical guidelines shall be considered by the Division of Driver Licensing in evaluating the information related to the commercial driver: (a) Paraplegics or quadriplegics. If the applicant has a loss of impairment of foot, leg, arm, hand or fingers, he shall not be issued a medical waiver unless he passes a skills test administered by the Kentucky State Police in the commercial vehicle adapted for his specific disability.

State	Reference	Requirements for Musculoskeletal Disorders
LOUISIANA	Louisiana Office of Motor Vehicles Web01.dps.louisiana.gov	FMCSA medical forms available
	Louisiana Revised Statutes Title 32 Motor Vehicles and Traffic Regulation	**§423. Restricted license** A. The department upon issuing a Class "A", "B", "C", "D", and "E" license shall have authority whenever good cause appears to impose restrictions suitable to the licensee's driving ability with respect to the type of, or special mechanical control devices required on, a motor vehicle which the licensee may operate or such other restrictions applicable to the licensee as the department may determine to be appropriate to assure the safe operation of a motor vehicle by the licensee. **§403.4 Medical evaluation report required of persons driving a CMV** A. A person applying for a Class "A", "B", or "C" commercial driver's license shall not have any physical or mental disability affecting the ability to exercise ordinary reasonable control in the operation of a CMV. Such person, unless exempted by the office of motor vehicles or by a rule or regulation, shall provide a current medical report, on a form approved by the office of motor vehicles, prepared by a duly licensed medical examiner, certifying that he is capable of exercising ordinary reasonable control in the operation of a CMV. Such person shall submit a valid medical report at every renewal and shall carry a current medical certificate on his person at all times when driving a CMV requiring either a Class "A", "B", or "C" commercial driver's license as defined herein.
MAINE	Maine Commercial Driver License Manual	Covers Vision Requirements Only
	Maine Statutes Title 29-A: Motor Vehicles Chapter 11: Driver's License Subchapter 1: General Provisions	**1253. Commercial licenses** 2. Compliance with federal law. The State must comply with the ….Federal Motor Carrier Safety Improvement Act of 1999….in issuing or suspending a commercial license. (Sec. 215. Medical Certificate states "The Secretary shall initiate a rulemaking to provide for a Federal medical qualification certificate to be made a part of commercial driver's licenses").
MARYLAND	Maryland Motor Vehicle Administration maryland.mva.com/resource/DL-171 Maryland Motor Vehicle Administration Maryland.mva.com/resources/CDLwaiver	Medical Examination Report for Commercial Driver Fitness Determination available CDL Medical Waiver Information Packet Requesting Interstate Waiver/Exemption/Requesting Intrastate Waiver 1. General B. The MVA may issue an intrastate waiver, which covers the following physical/medical conditions listed below. Vision, Amputation and loss of limb, Power grasping and prehension, Diabetes 3. Intrastate Waivers Individuals who do not meet the physical requirements of §391.41(b)(1)-(2) (3) and (10) and cannot obtain a FMCSA waiver or exemption may apply for an intrastate waiver, which is issued by the Motor Vehicle Administration. An intrastate waiver restricts the individual to driving a CMV within Maryland. Individuals with an intrastate waiver may not drive a CMV across state lines and the cargo contained in the CMV cannot cross state lines. Individuals who have suffered a loss of a hand, arm, or foot, or if they have an impairment of a hand or finger which interferes with the prehension or power grasping or an arm, leg or foot or other significant limb defect or limitation which interferes with the ability to perform normal tasks associated with the operation of a CMV, may be eligible for an interstate waiver. NOTE: It will be necessary for the applicant to have a working (not a cosmetic) prosthesis A. EXAMINATION OF INDIVIDUALS APPLYING FOR INTRASTATE WAIVER (AMPUTATION, LOSS OF LIMB OR POWER GRASPING PROBLEM). Individuals who have suffered a loss of hand, arm or foot must submit a physical examination form completed by a medical examiners and a medical evaluation summary completed by either a board qualified or board certified physiatrist (doctor of physical medicine) or orthopedic surgeon. The medical evaluation summary for a driver applicant disqualified under §391.41(b)(1) will include: • An assessment of the functional capabilities of the driver as they relate to the ability of the driver to perform normal tasks associated with operating a CMV; and • A statement by the examiner that the applicant is capable of demonstrating precision prehension (e.g. manipulating knobs and switches) and power grasp prehension (e.g. holding and maneuvering the steering wheel) with each upper limb separately.

State	Reference	Requirements for Musculoskeletal Disorders
		Individuals who have impairment of a hand or finger which interferes with prehension or power grasping or an arm, foot, or leg or other significant limb defect or limitation which interferes with the ability to perform normal tasks associated with the operation of a CMV shall submit a medical evaluation summary completed by either a board qualified or board certified physiatrist (doctor of physical medicine) or orthopedic surgeon. The medical evaluation summary for a driver applicant disqualified under §391.41(b)(2) will include: • An explanation as to how and why the impairment interferes with the ability of the applicant to perform normal tasks associated with operating a CMV • An assessment and medical opinion of whether the condition will likely remain medically stable over the lifetime of the driver applicant; and • A statement by the driver license examiner upon completion of a public road test that the applicant is capable of demonstrating precision prehension (e.g. manipulating knobs and switches) and power grasp prehension (e.g. holding and maneuvering the steering wheel) with each upper limb separately.
	Annotated Code of Maryland .06 49 CFR 391, Qualifications of Drivers – Amendments and Exemptions	**E.49 CFR§391.41(b).** (1) an intrastate driver ..who does not meet the physical qualifications of 49 CFR §391.41 (b) may drive in intrastate commerce if issued a waiver for intrastate operation by the Administrator. The waiver is valid for up to 2 years from the date of issue.
MASSACHUSETTS	Massachusetts Registry of Motor Vehicles **Arthritis Disease Policy Statement**	A...any licensee or applicant for a learner's permit or license, who is medically determined to have an arthritis condition which renders that individual unable to perform self care will be required to submit the following information from his or her physician to the Registry's Medical Affairs branch: 1. A written statement describing the status of the individual's arthritis condition; and 2. Accompanying symptomatology; and 3. A list of medications and dosages; and 4. A certification that, to a reasonable degree of medical certainty, the individual is medically qualified to operate a motor vehicle safely and the individual's medications and dosages will not interfere with the safe operation of a motor vehicle. B. The Registry's Medical Advisory Board has determined that individuals who suffer from an arthritis condition so severe as to prevent them from performing self care may be functionally unable to operate a motor vehicle safely and therefore require an individual assessment of their operating ability in the form of a medical certification from a physician
	Massachusetts Registry of Motor Vehicles	Medical Examination Report for Commercial Driver Fitness Determination available
	Massachusetts Registry of Motor Vehicles Intrastate Medical Waiver Policy Statement for CMV License Classes A, B, and C as of June 16, 1998	The Registry of Motor Vehicles will waive compliance with the federal requirements pertaining to CMVs for the purposes of driving **intrastate only** (within the borders of Massachusetts only) and will issue **intrastate** medical waivers for the following conditions only, provided the Registrar determines that the condition, in an individual case, will not interfere with the safe operation of a CMV. 4. Loss or Impairment of Limb: In accordance with the federal guidelines permitting a federal waiver for a loss of a limb, the Registry will issue intrastate waivers for individuals with a loss of limb or impairment of a limb, so long as such loss or impairment of limb is not likely to interfere with the safe operation of a CMV.
MICHIGAN	Michigan Department of State michigan.gov Michigan Code Chapter 480 Motor Carrier Safety	Medical Examination Report for Commercial Driver Fitness Determination available 480.13; Section 3. (2) A person who is not physically qualified to drive under 49 CFR 391.41 and who is otherwise qualified to drive a CMV may drive a CMV if the motor carrier division of the department of state police or the appeal board has granted a waiver to that person.

State	Reference	Requirements for Musculoskeletal Disorders
MINNESOTA	Minnesota/Department of Transportation Office of Freight and Commercial Vehicle Operations Minnesota Trucking Regulations	Section 06 Physical Qualifications for Drivers (49 CFR §391.41 and 391.43) A person is not allowed to drive a CMV unless physically qualified to do so and carries in his or her possession a current, valid copy of a medical examiner's certificate (health card) showing he or she is qualified. In general, a person is physically qualified if he or she: • Has no loss of a foot, leg, hand or arm, • Has no muscular, neuromuscular…or other organic or functional disease which would interfere with their ability to operate a CMV safely. Section 07 Minnesota Intrastate Driver Waivers The Minnesota Department of Transportation may issue a waiver to drivers who cannot meet the minimum physical qualifications as established in the Driver Qualification Rules 49 CFR part 391 and Minn. Stat. Chapter 221 There are four waiver programs available to Minnesota intrastate drivers: Hearing, insulin dependent diabetics, physical, vision
	Minnesota/Department of Transportation Office of Freight and Commercial Vehicle Operations Minnesota Intrastate Physical Waiver	The Medical Evaluation Summary states the following 2 objectives: 1. In cases involving amputation: the summary shall include an assessment of the driver's physical capabilities as they relate to the driver's ability to perform the tasks as specified in the accompanying job task description 2. In cases involving limb impairment: the summary shall include an explanation as to how and why the impaired area interferes with the driver's ability to perform the tasks as specified in the accompanying job task description. Drivers minimally must have adequate: strength, mobility, stability, and power grasp and prehension. Part 2 discusses type of vehicle/operations; environmental factors and physical demand of job. Part 3 is to be completed by a physiatrist or orthopedic surgeon with 6 questions regarding adequate muscle strength, mobility, adequate joints and truck stability, power grip and prehension, appropriate type of prosthesis/terminal device, and other medical conditions.
MISSISSIPPI	Senate Bill 3042 2007 Regular Session This act shall take effect and be in force from and after July 1, 2007.	An act to amend sections 77-7-7 and 77-7-716, Mississippi Code of 1972, to exempt certain vehicles from regulation under the Mississippi motor carrier regulatory law of 1938; to provide that the state enacts the exemption allowed under federal regulations for intrastate commerce; and for related purposes. Section 3. Notwithstanding the provisions of this chapter to the contrary, Parts 390 through 397, Title 49, Code of Federal Regulations, shall not apply to CMVs operated in intrastate commerce to transport property which have a gross vehicle weight rating or gross combination weight rating of twenty-six thousand (26,000) pounds or less.
MISSOURI	Missouri Motor Carrier Services Missouri Department of Transportation Medical Program	Medical Examination Report for Commercial Driver Fitness Determination available Exemptions: MoDOT can grant a medical exemption for intrastate commercial drivers by issuing a Skill Performance Evaluation certificate if the individual meets alternate standards which satisfy the department that the applicant can safely operate a commercial vehicle. MoDOT can only issue SPE Certificates to applicants, who are not physically qualified because of limb amputation, limb impairment, vision impairment, or insulin-treated diabetes mellitus. SPEC-1 Form for applicants with Limb Impairment or Amputation and Medical Evaluation Summary is available online. Medical Evaluation Summary similar to Minnesota (see above).however Part 1 also includes in their objectives: (3) in cases involving either an upper limb amputation or upper limb impairment the summary shall include a statement by the examiner that the applicant is capable of demonstrating precision prehension (manipulating knobs and switches) and power grasp prehension (holding and maneuvering the steering wheel) with each upper limb separately.

State	Reference	Requirements for Musculoskeletal Disorders
MONTANA	Montana Department of Transportation Motor Carrier Services Division 2003-2005 Law Book Effective October 1, 2003	61-5-10. Records check of applicants – examination of applicants – cooperative driver testing programs. (4)(a)..a resident surrendering a commercial driver's license issued by another jurisdiction shall successfully complete any examination required by federal regulations before being issued a commercial driver's license by the department. 61-5-112. Types and classes of commercial driver's licenses – classification – rulemaking – reciprocity agreements. (1) The department shall adopt rules that it considers necessary for the safety and welfare of the traveling public governing the classification of commercial driver's licenses and related endorsements and the examination of commercial driver's license applicants and renewal applicants. The rules must: (a) subject to the exceptions provided in this section, comport with the requirements of 49 CFR, part 383, and the medical qualifications of 49 CFR, part 391 (b) Allow for the issuance of a type 2 (intrastate only) commercial driver's license in accordance with medical qualification and visual acuity standards prescribed by the department.
	2005 Commercial Driver's Manual Montana Rules and Regulations	Physical Qualifications All applicants for a Group A, B or C, Interstate or Intrastate, Commercial Driver's License will be required to have a valid DOT Medical Card. "Exemption" to Physical Qualifications If the Interstate driver cannot meet the DOT requirements, but they can meet the Montana medical requirements, they will be issued a Montana medical card allowing them to driver in the State of Montana only. Drivers must meet the medical qualifications for a Commercial Drivers License (CDL): 2. A driver is not qualified to obtain a CDL if they have a physical impairment that limits or impairs their ability to safely operate a CMV. (*Interstate CDL*) 3. A federal waiver may be given for missing or paralyzed limbs only. (*Interstate CDL*) 4. Some persons with a physical impairment may obtain an Intrastate CDL if they can demonstrate their ability to safely operate a CMV. (*Intrastate CDL*)
NEBRASKA	Nebraska Administrative Code Title 291 – Nebraska Public Service Commission Chapter 3 – Motor Carrier Rules and Regulations	005 Safety Regulations 005.01 Minimum Qualifications: Each person driving a motor vehicle subject to Commission jurisdiction shall possess the following minimum qualifications, except as provided in Section 005.19: 005.01A: Sound physical and mental condition with no mental, nervous, organic, or functional disease or structural defect or limitation likely to interfere with safe driving.

State	Reference	Requirements for Musculoskeletal Disorders
	Nebraska Revised Statutes	Section 60-4,146 Application; operation on intrastate commerce; certification; restrictions. (1) Upon making applications pursuant to section 60-4, 144, any applicant who operates or expects to operate a CMV solely in intrastate commerce and who is not subject to 49 C.F.R. part 391 adopted pursuant to section 75-363 shall certify that he or she is not subject to 49 C.F.R. part 391. Any applicant making certification pursuant to this section shall meet the physical and vision requirements established in section 60-4,118 and shall be subject to the provisions of such section relating to the Health Advisory Board. (2) An applicant who certifies that he or she is exempt from the physical qualifications and examination requirements of 49 C.F.R. part 391 pursuant to subsection (4) of section 75-363 shall meet the physical and vision requirements established in section 60-4,118 and shall be subject to the provisions of such section relating to the Health Advisory Board…Two years after the initial issuance of such license and upon renewal…the holder of the commercial driver's license shall present..a statement from a physician detailing that based upon his or her examination of the applicant the medical or physical condition in existence prior to July 30, 1996, which would otherwise render the individual not qualified under federal standards, has not significantly worsened or that another non-qualifying medical or physical condition has not developed. (3) An applicant who certifies that he or she is not subject to 49 C.F.R. part 391 under subsection (1) of this section or who certifies that he or she is exempt from 49 C.F.R. part 391 under subsection (2) of this section shall answer the following questions on the application: (b) Do you experience any condition which affects your ability to operate a motor vehicle: (e.g. due to loss of, or impairment of, foot, leg, hand, arm; neurological or neuromuscular disease, etc.)…yes…no Please explain:….. (c) Since the issuance of your last driver's license/permit has your health or medical condition changed or worsened:…yes…no Please explain, including how the above affects your ability to drive:…. 60-4,118 Vision requirements; persons with physical impairments; physical or mental incompetence; prohibited act; penalty (3) If the applicant for a operator's license discloses that he or she has any other physical impairment which may affect the safety of operation by such applicant of a motor vehicle..must show the necessary ability to safely operate a motor vehicle on the highways. (4) (a) The director, may, when requested by a law enforcement officer, when the director has reason to believe that a person may be physically or mentally incompetent to operate a motor vehicle…request the advice of the Health Advisory Board and may give notice to the person to appear before an examiner, the board, or a designee of the director for examination concerning the person's ability to operate a motor vehicle safely.
NEVADA	Nevada Revised Statutes	**NRS 483.330 Examination of applicants; waiver of examination by Department.** 1. The Department may require every applicant for a driver's license, including a commercial driver's license issued pursuant to NRS 483.900 to 483.940, inclusive, to submit to an examination. The examination may include:(d) Except as otherwise provided in subsection 3, an actual demonstration of his ability to exercise ordinary and reasonable control in the operation of a motor vehicle of the type or class of vehicle for which he is to be licensed. The examination may also include such further physical and mental examination as the Department finds necessary to determine the applicant's fitness to drive a motor vehicle safely upon the highways.

State	Reference	Requirements for Musculoskeletal Disorders
	Nevada Administrative Code	**NAC 483.803** Waiver of certain physical requirements: Submission and contents of application. (NRS 483.908) 1. A person who is not physically qualified to operate a CMV pursuant to 49 C.F.R. § 391.41, but who is otherwise qualified to operate a CMV, may apply to the Department for a waiver of the physical requirements with which he does not comply. 2. An applicant for a waiver of one or more of the physical requirements described in subsection 1 must submit to the Department an application on a form prescribed by the Department. The application must include: (d) The type of transmission, braking system and steering system of the vehicle which the applicant will operate; (h) A description of any modifications made to the vehicle for the driver. 1. An applicant for a waiver of one or more of the physical requirements described in 49 C.F.R. § 391.41 must submit to the Department with his application: (a) A copy of a medical examination required pursuant to paragraph (e) of 49 C.F.R. § 391.43; (b) A copy of a medical certificate required pursuant to 49 C.F.R. § 391.43; and (c) A medical evaluation signed by a physician on a form prescribed by the Department if the applicant suffers from a physical impairment or by a physician or optometrist if the applicant suffers from a visual impairment. The medical evaluation must: (1) Identify and describe the visual or physical impairment of the applicant; (2) Indicate whether the applicant's condition is stable or progressive; (3) Certify that the applicant is able to operate a CMV; (5) If a limb of the applicant has been amputated or otherwise impaired, assess the physical capabilities of the applicant as they relate to his ability to perform the tasks specified in the description of the applicant's job which the applicant must provide to the physician; (6) If the applicant wears a prosthetic or orthotic device, include a description of the manner in which the prosthetic or orthotic device operates 3. An applicant for a waiver who wears a prosthetic or orthotic device must demonstrate his ability to operate safely the type of motor vehicle he intends to operate. The Department may require any other applicant to demonstrate his ability to operate safely the type of motor vehicle he intends to operate if the Department determines that such a demonstration is necessary. NAC 483.8032 Waiver of certain physical requirements: Approval or denial of application. (NRS 483.908) 1. The Department will, based upon the recommendation of the physician who conducted a medical evaluation of the applicant, deny an application for a waiver of one or more of the physical requirements described in 49 C.F.R. § 391.41 or grant the waiver.
NEW HAMPSHIRE	State of New Hampshire Office of Legislative Services Administrative Rules/Department of Safety Chapter Saf-C 1800 Commercial Driver Licensing	**Part Saf-C 1803 Commercial Driver License Application Requirements** Each applicant shall furnish the following on form DSMV 312: (11) The following certified statements:: f. The applicant meets the federal driver qualifications and requirements for interstate commerce Part Saf-C 909 Medical Waiver Saf-C 909.02 Waiver A person who is not physically qualified to drive due to having physical deficiency, as listed in 49 CFR 391.41(b)(1)-(13), but who is qualified to drive a CMV pursuant to 49 CFR 391.11 and has not been disqualified pursuant to 49 CFR 391.15, shall be authorized to drive a CMV if the commissioner grants a waiver pursuant to Saf-C 909.09. Saf-C 909.07 Contents of a Medical Evaluation Summary (a) Each driver-applicant, who is not physically qualified pursuant to 49 CFR 391.41(b), shall obtain a medical evaluation summary, … from a medical examiner, who has expertise with the driver-applicant's specific medical condition

State	Reference	Requirements for Musculoskeletal Disorders
		(b)For the purposes of this rule, "perform normal tasks" includes: (1) Manipulating knobs and switches; (2) Holding and maneuvering the steering wheel; (3) Shifting a manual transmission, if the CMV(s) is so equipped; (4) Having sufficient strength to operate the brakes; (5) Having sufficient strength to engage the clutch, if the CMV(s) is so equipped; (6) Having sufficient neck and head mobility to look over his/her shoulder when backing up, if necessary, and (7) Having sufficient strength to secure chains or other securement devices, if applicable. (c) Each driver-applicant who is not physically qualified pursuant to 49 CFR 391.41(b)(1) shall obtain a medical evaluation summary that includes the following: (1) Whether the impairment interferes with the driver-applicant's ability to perform normal tasks associated with driving a CMV; and (2) A description of any prosthetic device from a medical examiner or specialist (d) Each driver-applicant who is not physically qualified pursuant to 49 CFR 391.41(b)(2) shall obtain a medical evaluation summary that includes the following: (1) Whether the impairment interferes with the driver-applicant's ability to perform normal tasks associated with driving a CMV; and (2) An assessment and medical opinion of whether the condition is likely to remain medically stable for the duration of the medical waiver; (3) A recommendation as to the period of time the medical waiver shall be valid, not to exceed 2 years; and (4) A description of any prosthetic device from a medical examiner or specialist (e) Each driver-applicant who is not physically qualified pursuant to 49 CFR 391.41(b)(3)-(13) shall obtain a medical evaluation summary that includes the following: (1) Whether the impairment interferes with the driver-applicant's ability to perform normal tasks associated with driving a CMV; and (2) An assessment and medical opinion of whether the condition is likely to remain medically stable for the duration of the medical waiver; and (3) A recommendation as to the period of time the medical waiver shall be valid, not to exceed 2 years.
NEW JERSEY	New Jersey Legislature Title 39 Motor Vehicles and Traffic Regulation	39:3-10.12 Tests for commercial driver license 4.a. Notwithstanding any other provision of law to the contrary, the chief administrator shall adopt and administer a classified licensing system and a program for testing and ensuring the fitness of persons to operate CMVs in accordance with the minimum federal standards established under the federal "CMV Safety Act of 1986" 39:3-10.19. Operation of CMV in this State Notwithstanding any other provision of law to the contrary, a person may operate a CMV in this State if the person has received a waiver of the commercial driver license requirements from the Secretary of the U.S. Department of Transportation or the licensing authority of any other state, has a commercial driver license issued by any state in accordance with minimum federal standards for the issuance of a CMV driver licenses, .. 39:3019.11 Definitions relative to commercial driver licenses. "Disqualification" means either: (b) A determination by the Federal Motor Carrier Safety Administration under the rules of practice for motor carrier safety contained in 49 C.F.R.s386, that a person is no longer qualified to operate a CMV under 49 C.F.R.s 391
	Commercial Driver License Manual 2006 Edition/Requirements for Licensing in New Jersey	Under provisions of these regulations, initial commercial driver license applicants must meet the medical fitness standards and possess a medical examiner's certificate as outlined in Title 49 CFR 391:41.

State	Reference	Requirements for Musculoskeletal Disorders
NEW MEXICO	New Mexico Statutes	66-5-60. Commercial driver's license; qualifications; standards. A. The division shall not issue a commercial driver's license to a person unless that person is a resident of New Mexico and has passed a knowledge test and skills test for driving a CMV and for related endorsements, has passed a fitness test and has satisfied any other requirements of the New Mexico Commercial Driver's License Act [66-5-52 NMSA 1978] 65-3-7 Qualifications of drivers C. The driver may adopt regulations pertaining to the qualification and disqualification of commercial motor carrier vehicle drivers including documentation thereof. The regulations shall include but not be limited to background and character, road testing and written examination, physical qualification, examination and waivers of certain physical defects.
NEW YORK	New York State Department of Motor Vehicles Federal Requirements for Commercial Driver License (CDL) Applicants	Informs first-time CDL applicants about federal medical requirements
	Commercial Driver License (CDL) Certifications	When you apply for an original NYS Commercial Driver License (Class A, B or C) or a renewal, you must certify that: You meet or do not meet, the requirements of the Federal regulations in 49 CFR Part 391, which include a requirement for a medical examination. 49 CFR Part 391 Certification The federal regulations include a requirement that a commercial driver have a medical examination every 2 years and receive a Medical Examiner's Certificate.
	New York State Commercial Driver's Manual	1.3 Commercial Driver License Requirements 1.3.4 Medical Requirement The federal government requires most CMV drivers to have a medical examination in order to detect physical or mental conditions that may affect your ability to operate a motor vehicle safely. The examination requirements are found in the U.S. DOT Federal Motor Carrier Safety Regulations under 49 CFR Part 391. You are exempt from needing a medical examiner's certificate if you: are a government employee at any level of government
NORTH CAROLINA	North Carolina Department of Transportation Division of Motor Vehicles	Commercial Trucking/License Eligibility/Requirements 6. Medical and Physical Requirements iii. Illness: You must have no physical or mental illness that interferes with your ability to control and operate a motor vehicle. You must have no established medical history or clinical diagnosis of epilepsy or any other condition which is likely to cause …loss of ability to control a motor vehicle. To operate a CMV, you must have no mental, nervous, organic, or functional diseases..likely to interfere with your ability to drive a motor vehicle safely.
	North Carolina Statutes www.ncga.state.nc.us	G.S.20-37.13 sets the age qualifications for a commercial driver's license (e) The Division shall not issue a driver's license to any person when in the opinion of the Division such person is afflicted with or suffering from such physical or mental disability or disease as will serve to prevent such person from exercising reasonable and ordinary control over a motor vehicle while operating the same upon the highways..

State	Reference	Requirements for Musculoskeletal Disorders
	North Carolina Administrative Code Section .0800 – Safety Rules and Regulations	19A NCAC 03D .0801 Safety of Operation and Equipment (b) The rules and regulations adopted by the US DOT relating to safety of operation and equipment (49 CFR Parts 390-397 and amendments thereto) shall apply to all for-hire motor carriers and all for-hire motor carrier vehicles, and all private motor carriers and all private motor carriers engaged in intrastate commerce over the highways of the State of NC, if such vehicles have a GVWR of greater than 26,000 pounds; …Provided the following exceptions shall also apply to all intrastate motor carriers: (2) Persons who otherwise qualify medically to operate a CMV within the State of NC shall be exempt from the provisions of Part 391.11(b)(1) and may be exempt from provisions of Part 391.41(b)(1) through (11) where applicable and therefore shall be authorized for intrastate operation if approved by an Exemption Review Officer appointed by the Commissioner of Motor Vehicles. These drivers shall continue to be exempt upon completion of a medical examination indicating the condition has not worsened or no new disqualifying conditions have been diagnosed and upon continued approval of an Exemption Review Officer. After a medical review by the Exemption Review Officer, a driver may be granted a waiver not to exceed a period of two years based on the type and severity of the condition. The Exemption Review Officer shall follow the guidelines established for variances from the FMCSR for intrastate commerce found in 49 CFR, Part 350.341.
NORTH DAKOTA	North Dakota Century Code CHAPTER 39−08 REGULATIONS GOVERNING OPERATORS	**39−08−21. Medical qualifications exemption for intrastate drivers.** Notwithstanding the adoption by the superintendent of the state highway patrol of federal motor carrier safety regulations pursuant to subsection 3 of section 39−21−46, the provisions of 49 CFR 391.41(b)(1)−(11) do not apply to a person who is qualified through a state medical waiver program to operate a CMV within the boundaries of this state or a person who: 1. Is otherwise qualified to operate a CMV and who possesses, on March 26, 1991, a class 1 license issued pursuant to section 39−06−14, as that section existed on June 30, 1989, or a class A license issued pursuant to chapter 39−06.2; 2. Operates a CMV only within the boundaries of this state; and 3. Has a medical or physical condition that: a. Would prevent such person from operating a CMV under federal motor carrier safety regulations contained in 49 CFR, chapter III, subchapter B; b. Existed on March 26, 1991, or at the time of the first required physical examination after that date; and c. An examining physician has determined has not substantially worsened since March 26, 1991, or the time of the first required physical examination after that date
	Commercial Drivers License Guide 2005-2007	**Medical Qualifications** All commercial drivers must meet the federal commercial medical requirements in 49 CFR 391. Some of the medical conditions that may disqualify an individual from obtaining a commercial permit or license are: loss of (or impairment of) a limb. To continue to be medically qualified to operate a CMV, you must be medically examined by a U.S. licensed health care provider every 24 months. North Dakota state law requires that if any licensed Class A, B, or C operator suffers permanent loss of damage of a hand, arm, or foot, he or she must make a report of explanation to the Drivers License and Traffic Safety Division.
OHIO	Ohio Code Ohio Department of Public Safety Ohio Bureau of Motor Vehicles	**4506.10 Physical qualifications for commercial driver's license** (A) No person who holds a valid commercial driver's license shall drive a CMV unless the person is physically qualified to do so. Each person who drives or expects to drive a CMV in interstate or foreign commerce or is otherwise subject to 49 C.F.R. 391, et seq., as amended, shall certify to the registrar of motor vehicles at the time of application for a commercial driver's license that the person is in compliance with these standards. **Medical Waiver Procedures** All commercial drivers must meet minimum medical standards as established by federal (49 C.F.R. 391) and state (Ohio Revised Code, Section 4506.10) rules and regulations. Intrastate

State	Reference	Requirements for Musculoskeletal Disorders
		The Ohio Public Utilities Commission (PUCO) and the Ohio State Highway Patrol (OSP) have adopted the same medical standards for all Ohio licensed drivers who operate in intrastate commerce. Both PUCO and OSP rules and regulations authorize intrastate drivers who do not meet minimum medical standards to apply to: Public Utilities Commission of Ohio, for an intrastate medical waiver. ..drivers who need an intrastate medical waiver must send the following: • A medical evaluation summary completed by a board qualified or board certified physician or orthopedic surgeon. The medical evaluation summary must include a statement by the physician on how and why the impairment interferes with the ability of the driver to perform normal tasks associated with operating a CMV, and an assessment and medical opinion of whether the condition will likely remain medically stable for at least two years
OKLAHOMA	Oklahoma Commercial Driver's Manual Section 1.8 www.dps.state.ok.us	**Federal and State Qualifications for CMV Drivers** In order to obtain a commercial driver license, which authorizes the operation of a CMV, you must certify to and meet the following qualifications. 4. Have not suffered the loss of a foot, a leg, a hand, or an arm 5. Have no impairment of a hand or finger that interferes with prehension or power grasping 6. Have no impairment of an arm, foot, or leg that interferes with the ability to perform normal tasks associated with operating a motor vehicle; or any significant limb defect or limitation that interferes with the ability to perform normal tasks associated with operating a motor vehicle. 11. Have no established medical history or clinical diagnosis of rheumatic, arthritic, orthopedic or muscular disease that interferes with your ability to control and operate a motor vehicle safely.
OREGON	Oregon Administrative Rule	**735-074-0260 Medical Standards for Drivers of CMVs** (1) The Driver and Motor Vehicle Services Division of the Department of Transportation (DMV) adopts the U.S. Department of Transportation regulations contained in 49 CFR 391.41 through 391.49 (2004) pertaining to physical qualifications and medical examination of drivers of CMVs. (2) DMV may issue a Class A, B, or C commercial driver license to a person who does not qualify for a medical certificate under section (1) of this rule if the person is issued: (a) a waiver of physical disqualification by the Motor Carrier Transportation Division of the Oregon Department of Transportation (MCTD) under OAR 740-100-0104
	Oregon ODOT/DMV	**Physical Qualifications** Physical qualifications are listed in CFR 49 § 391.41. If you do not meet these physical qualifications due to impairment of limbs and want to operate a CMV interstate, you may be able to satisfy alternative physical examinations or qualify for an exemption. If you cannot meet the medical qualifications for interstate CMV operation, you may qualify for a Waiver of Physical Disqualification available from ODOT, Motor Carrier Transportation Division. Such a waiver would permit operation of a CMV within the State of Oregon only.
	Oregon 2006-2007 Commercial Driver License Manual	**1.6.3 Physical Examination** A medical waiver may be issued for some otherwise disqualifying conditions, but a medical waiver issued by ODOT is good for no more than two years. It applies only to intrastate drivers.
	Oregon Statutes	**740-100-0140 Oregon Waiver of Physical Disqualification** (3) Explains waiver conditions and procedures
PENNSYLVANIA	PA Public Utility Commission Motor Carrier Services and Enforcement Division	**Safety Fitness Review Program** Educational and Technical Assistance Package Part 391 – Qualifications of Drivers Motor Carriers must ensure that all drivers meet the Physical Qualifications and Examinations required in Part 391.41 and possess a valid medical certificate.

State	Reference	Requirements for Musculoskeletal Disorders
	67 PA Code § 231.61 Physical qualifications of drivers 67 PA Code § 231.65 Waiver of certain physical defects	49 CFR 391.41 (relating to physical qualifications of drivers) incorporated by reference 49 CFR 391.49 (relating to waiver of certain physical defects) incorporated by reference, except that the existing subsection (h) of the Federal rules is deleted and replaced with a new subsection (h) as follows: (H) Time Frame. Time frames for determination and waiver are as follows: (1) Upon receipt of an application..a written determination will be made within 90 days (2) The Department may deny the application for waiver or may grant it totally or in part…a waiver is valid for a period not to exceed 2 years from the date of issue and may be renewed 30 days prior to the expiration date.
RHODE ISLAND	Rules and Regulations Governing Applicants for Commercial Driver's Licenses, Permits, Renewals and Endorsements Adopted 2007 Department of Revenue/Division of Motor Vehicles Rhode Island Code	Rule 3. Minimum Eligibility for Commercial Driver's License, Permit or Endorsement 3.2 At the time of submitting the application, the applicant must be physically qualified to safely operate a CMV. In making this determination, the Division of Motor Vehicles shall follow applicable federal guidelines contained in 49 C.F.R. § 391.41 and may seek recommendations from the Medical Advisory Board pursuant to Section 31-10-44 of the Rhode Island General Laws. § 31-10.3-19 – Examination of Applicants (a) the department shall examine every applicant for a commercial driver's license. The examination shall include (4) an actual demonstration of ability to exercise ordinary and reasonable control in the operation of a motor vehicle or combination of vehicles of the type covered by the license classification..which the applicant is seeking. The examination may also include any further physical and mental examinations that the department deems necessary to determine the applicant's fitness to safely operate a motor vehicle upon the highways.
SOUTH CAROLINA	CMV Manual	Transfer of Commercial Driver's License To transfer a CDL from another state to SC: 2) Certify you have read and understand and meet the qualifications requirements under 49 CFR, Part 39 of the FMCSR's. You must also show a valid DOT physical card or long form.
SOUTH DAKOTA	South Dakota Code 49	**49-28A-3** Adoption of federal regulations—Violation as misdemeanor. The state hereby adopts Title 49 of the Code of Federal Regulations, subtitle B, chapter III, subchapter B, parts 390 to 397, inclusive as amended through January 1, 2006, with the following modifications: (3) Intrastate drivers are exempt from the physical requirements of part 391.41
TENNESSEE	Rules of TN Department of Safety Division of Driver License Issuance Chapter 1340-1-13 Classified and Commercial Drivers Licenses and certificates for Driving	**1340-1-13.09 Mental and Physical Standards** (2) Applicants for commercial driver licenses exempted from the federal standards by subparagraph (3) shall meet the following minimum physical and mental standards: (a) Applicants who have physical disabilities that can be compensated for by the use of physical controls or mechanical devices which enable the applicant to safely operate a motor vehicle may be licensed if they meet all other appropriate eligibility criteria (3) Applicants for commercial driver licenses shall meet the minimum physical and mental standards set forth in 49 C.F.R. § 391.41 (1989), except for those specifically exempted therein who are not required to have the Passenger, School Bus, or Hazardous Materials endorsement. (4) Applicants for commercial driver license involved only in intrastate commerce who do not meet the standards set forth in 49 § 391 (1989) may be eligible for special licenses restricting their operation of a CMV

State	Reference	Requirements for Musculoskeletal Disorders
TEXAS	Texas Administrative Code Title 37 Public Safety and Corrections Part 1 Texas Dept of Public Safety Chapter 16 Commercial Drivers License Subchapter A Licensing Requirements, Qualifications, Restrictions, and Endorsements	**Rule 16.9 Qualifications to Drive in Intrastate Commerce** (a) Persons who do not qualify in intrastate commerce may still qualify to drive in intrastate commerce. In such cases, the commercial driver's license (CDL) will contain an "M" restriction.. (3) An applicant may present the department's vision or limb waiver certificate in lieu of meeting the vision or physical requirements of Title 49, Code of Federal Regulations, Part 391.41. Waivers issued by the department may be renewed through the License Issuance Bureau of the department in Austin. (5) A driver who operates a CMV in intrastate commerce only may obtain a vision or limb waiver provided the following qualifications are met: (only one waiver can be used to obtain a CDL) **(B) Limb Waiver Requirements** (i) medical certificate required under Title 49, Code of Federal Regulations, Part 391.43; and (ii) pass a comprehensive driving examination in the appropriate class vehicle (equipped with all necessary vehicle medications) for the CDL the applicant is applying for. (9) applicants for a Texas Intrastate Vision or Limb Waiver must be able to meet all other physical requirements specified in 49 CFR, Part 391.41 without the benefit of any other waiver. **Rule 16.8 Qualifications to Drive in Interstate Commerce** (5) The applicant must meet the federal physical requirements set out in 49 Code of Federal Regulations, Part 391.41. The applicant must: (A) Have no loss of a foot, a leg, a hand, or an arm, or have been granted a Skill Performance Evaluation Certificate(Note: Limb waivers issued by the dept. are valid for intrastate operation only as stated in 16.9 of this title relating to Qualifications To Drive in Intrastate Commerce); (B) Have no impairment of hand or finger which interferes with prehension or power grasping, or impairment of an arm, foot, or leg which interferes with the ability to perform normal tasks associated with operating a motor vehicle, or any other significant limb defect or limitation which interferes with the ability to perform normal tasks associated with operating a motor vehicle, or have been granted a Skill Performance Evaluation certificate (C) Have no established medical history or clinical diagnosis of pneumatic, arthritic, orthopedic, muscular, neuromuscular, or vascular disease which interferes with the ability to control or operate a motor vehicle safely
	Texas Dept of Public Safety Intrastate Limb Waiver Packet	In order to take the comprehensive driving examination, you must do the following: 2. If the vehicle is equipped with a clutch, the clutch must be used when changing transmission speeds. If required, a prosthesis must be worn. If special equipment is necessary, it must be on the test vehicle.
UTAH	Utah Department of Public Safety Driver License Division Functional Ability in Driving: Guidelines and Standards for Health Care Professionals	**Application of Commercial Intrastate Medical Standards** The 2006 Functional Ability in Driving: Guidelines and Standards for Health Care Professionals has outlined the medical standards as applying to ALL commercial intrastate drivers, irrespective of the type of vehicle or cargo involved, i.e., Class A, B, C, and D of Utah's Classified License System. (2) Commercial Intrastate Drivers must be profiled in the appropriate category(ies) in order to be considered for an intrastate license. (3) Also, pursuant to Utah Code Annotated 53-3-303.5 an intrastate driver is no longer able, or required to carry a Federal DOT card. The intrastate only (K) restriction is sufficient to indicate the driver has met the State of Utah medical guidelines for the commercial license he/she will hold. **Category J/Musculoskeletal Abnormality of Chronic Medical Debility** 1. ..medical judgment may be of primary importance in determining limitations on driving, such as osteoporosis or active infectious disease, as they affect the safety of the driver or passengers or other vehicles. In others, the basis for limitation of driving privileges will be the functional motor impairment for the specific acts of operating a vehicle, such as amputations or congenital abnormalities, using compensatory devices is needed. 2. in case of obvious paralysis or absence or abnormality of limbs, etc., an applicant may be required to pass a driving test with or without

State	Reference	Requirements for Musculoskeletal Disorders
		compensatory aids. A profile level may be based on the health care professional's examination and recommendations. For stable conditions, the interval for re-evaluation may be extended to the usual re-licensing interval, but in unstable situations, the health care professional should recommend shorter intervals depending upon the nature of the problem. Profile Sheet/Commercial Profile Level 1 Musculoskeletal Abnormality: No history or full recovery for one year or more General Debility or Impairment: No history or full recovery for one year or more Profile Level 2 Musculoskeletal Abnormality: Minimal residual loss of function General Debility or Impairment: Minimal residual loss of function Profile Level 3 Musculoskeletal Abnormality: Minimal residual loss of function with or without compensatory device General Debility or Impairment: Minimal residual loss of function Profile Level 4 Musculoskeletal Abnormality: Moderate loss of function with or without compensating device General Debility or Impairment: Moderate persisting loss of function Profile Level 5 Musculoskeletal Abnormality: Congenital absence or deformity of a limb or the spine, traumatic or surgical amputations, or limitations of joint motion by fusion, arthritis, contractures, etc. General Debility or Impairment: Moderate residual loss of function Profile Level 6 Musculoskeletal Abnormality: Congenital absence or deformity of a limb or the spine, traumatic or surgical amputations, or limitations of joint motion by fusion, arthritis, contractures, etc., need for prosthetic or other device, or impairment making extended commercial driving unwise General Debility or Impairment: N/A Profile 7 Circumstances not covered by any of the above or patient under evaluation Profile 8 Chronic conditions making driving unsafe. Not fully compensated for by restorative devices.
VERMONT	Vermont Statutes Title 23 Motor Vehicles Chapter 39: Commercial Driver License Act	**4110. Application for commercial driver license** (A) for an applicant who operates or expects to operate in interstate or foreign commerce or who is otherwise subject to 49 C.F.R. part 391, the applicant meets the qualifications requirements contained in part 391; or operates or expects to operate entirely in intrastate commerce and who is not subject to part 391, that the applicant is subject to state driver qualification requirements and is not subject to part 391
	Department of Motor Vehicles CDL Manual	**Physical Examination Requirements** If you are subject to the Federal Motor Carrier Safety Regulations, you must have a physical examination every 2 years and carry the medical card at all times. To have a hazardous materials endorsement, you must meet the Federal Motor Carrier Safety regulations except for age requirements for intrastate travel.

State	Reference	Requirements for Musculoskeletal Disorders
VIRGINIA	Commonwealth of Virginia Department of Motor Vehicles Commercial Drivers Manual	**Compliance with Motor Carrier Safety Regulations** All CDL applicants must certify that they are in compliance with the federal or Virginia motor carrier safety regulations or that they do not have to comply with them.
	Virginia Code 46.2-341.12. Application for commercial driver's license	The applicant should provide the following: 2. Certifications that: he either meets the federal requirements of 49 C.F.R. Part 391, or he is exempt from or is not subject to such federal requirements
WASHINGTON	WA State Licensing: Commercial Driver Fitness Determination	**1.3 Medical Waivers** All commercial drivers must meet the medical standards established by federal and state laws, rules, and regulations. Reference: FMCSR parts 391.41 and 391.49 Intrastate If you don't meet the medical standards, you can apply to the Department of Licensing (DOL) for an Intrastate Medical Waiver. This waiver is : • Valid for operation within the state of Washington only • Valid for no more than a two-year cycle Medical Waiver Drivers with the following conditions may be eligible to apply for an intrastate waiver: • Missing or impaired use of a foot, leg, hand or arm
WEST VIRGINIA	Commercial Driver's Manual	**Age and Fitness Requirements** Federal Motor Carrier Regulations (49 CFR Part 391.41) require that drivers subject to those rules meet specific physical qualification standards and carry evidence of such qualification in the form of a medical certificate. Note: all drivers are subject to FMSCR requirements (DOT medical) except for city, county, state or federal employees.. Note: if you cannot be medically certified in accordance with the FMCSR, you may be eligible for a medical waiver.
WISCONSIN	Department of Transportation Chapter Trans 112 Medical Standards for Driver Licensing and General Standards for School Bus Endorsements	Trans 112.03 Medical review standards. (**1) UNRESTRICTED COMMERCIAL DRIVER LICENSES**. No person shall be issued an unrestricted commercial driver license unless the person complies with all the driver qualifications specified in 49 CFR 391.41, and presents a medical certificate of physical examination as required by 49 CFR 391.43 at the time of application **(2) RESTRICTED COMMERCIAL DRIVER LICENSES**. The department may not issue a commercial driver license to a driver who does not meet the physical qualifications of drivers standards under 49 CFR 391.41 or who does not present a medical certificate of examination required under 49 CFR 391.43 unless one of the following applies: (b) the commercial driver license is subject to a restriction that permits only those types of CMV operation for which drivers are exempt from the requirement of complying with 49 CFR part 391 under s. Trans 327.09 (1), 49 CFR 390.3 (f) or 49 CFR 391.2 Trans 112.10 Conditions affecting neurological or neuromuscular function. (1) With respect to conditions affecting neurological or neuromuscular function, the review boards when making recommendations, and the department when taking licensing action, may consider disorders including, but not limited to, the following: (J) spinal cord injury. (2) The department may require information on functional ability including, but not limited to, the following: (a) Episodes of altered consciousness or loss of bodily control. (b) Degree of functional impairment, including the extent to which loss of muscle tone, range of motion, spasm, or fatigue affects functional ability. *(c) Medical standards for all classes of operator licenses*. A person who applies for, renews, or holds for any classification of operator's license shall meet all of the following neuromuscular function criteria: 2. The person adequately compensates for any paralysis or sensory deficit when operating a vehicle. 3. Fatigue, weakness, muscle spasm, pain or tremor at rest does not impair safe driving

State	Reference	Requirements for Musculoskeletal Disorders
WYOMING	Wyoming Statutes Title 31 Motor Vehicles Article 3 Commercial Driver's License	**31-7-304. Issuance; classifications and endorsements.** (f) Before issuing or renewing a commercial driver's license, the department shall require that the applicant present a current federal medical qualification certificate.

Table 6. Regulations and Guidelines Pertaining to Musculoskeletal Disorders and CMV Driving from Selected Countries

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
Reference source	Assessing Fitness to Drive (For Commercial and Private Vehicle Drivers) Medical Standards for Licensing and Clinical Management Guidelines. Austroads and NTC (National Transport Commission) Australia (2006)	Determining medical fitness to Operate Motor Vehicles. CMA (Canadian Medical Association) Driver's Guide 7th edition. (2006)	At-a-glance Guide to the current Medical Standards of Fitness to Drive (for Medical Practitioners) Issued by Drivers Medical Group. Driver and Vehicle Licensing Agency (DVLA), Swansea (February 2007)	Medical aspects of fitness to drive: A Guide for Medical Practitioners. Land Transport Safety Authority. (May 2002)	European Commission on Transport and Road Safety, Annex III to Directive 91/439/EEC; Council Directive 96/47/EC July 1996 amending Directive 91/439/EEC; IP/06/381 Member States Agree on the European Driving License 27 March 2006 ▪ Countries involved include: Austria*,Finland*, Sweden*, Belgium, Ireland, Denmark, Italy, Germany, Luxembourg, Greece, The Netherlands, Spain, Portugal, France, and The United Kingdom (29 July 1991) ▪ Member states had to apply directive 91/439/EEC by 1 July 1996. ▪ European member states have to stay within a Council directive: they can be more restrictive, but not more liberal. *added in Council Directive 96/47/EC July 1996	Swedish National Road Administration (1999)
Loss of limbs, deformities and prosthetics	The criteria for an unconditional license are NOT met: • If there is an amputation or congenital absence of a limb (whole or part) required to operate a hand or foot control; or • If the thumbs are missing from both hands. A conditional license may be	Those with a loss or deformity of the upper or lower extremities may drive any vehicle provided they can demonstrate their ability to drive to the satisfaction of the driver examiner. Many people with an amputation or deformity of one arm are able to drive a private vehicle safely. Some people with an amputation below the elbow	Some disabilities may be compatible with the driving of large vehicles if mild and nonprogressive. Individual assessment will be required.	Driving should cease: ▪ If there is an amputation, congenital loss, functional loss of a limb required to operate a hand or foot control where no modification is practicable. ▪ If there is an amputation, congenital loss, functional loss of both upper or both lower limbs, or one upper	Not mentioned	License denied if ability to drive safely is impaired. May continue to drive if prosthesis and/or vehicle modifications can compensate for disability.

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
	granted by the Driver Licensing Authority, taking into account the opinion of an appropriate specialist, and the nature of the driving task, and subject to practical assessment and periodic review: • If the person has a lower limb prosthesis for a below-knee amputation and does not have to operate a brake pedal with the prosthesis, and the clutch pedal (if present) has been modified for use by a prosthesis. Automatic transmission and/or modification to hand controls may also be required. A spinner knob will be needed if a power-boosted handbrake control has been added; or • The person has the forefoot, first metatarsophalangeal joint or large toe amputated; or • The person has less than a thumb and two fingers on each hand or only one arm, provided a spinner knob or other device is fitted to the vehicle.	who are fitted with an adequate prosthesis may operate any class of vehicle provided they demonstrate their ability to a driver examiner. People who have an amputation below the knee of one or both legs are usually able to drive any class of motor vehicle safely provided they have full strength and movement in their back, hips, and knee joints and a properly fitted prosthesis or prostheses.		and one lower limb where no modification is practicable. Driving may resume or may occur in the following condition if the individual is able to demonstrate his or her ability to meet all necessary practical driving requirements: ▪ Absence of both thumbs * A full "off-road" and "on-road" driving assessment from a suitably trained occupational therapist is often necessary. Individuals with musculoskeletal conditions, such as a below-knee prosthesis or a forefoot amputation, may be considered fit for a license with conditions, provided that suitable vehicle modifications are in place, such as automatic transmission, spinner knobs, hand controls, or other necessary adaptations, and provided they have been able to show a satisfactory level of driving competence. Such people should be fully assessed on an individual basis before any decision is made.		
Arthritis	Painful joints may arise due to inflammatory or degenerative arthritis. People who have persistent pain and marked reduction in range of movement in shoulders, elbows, wrists, hands, hips, knees, ankles, or feet may not meet the criteria (listed	Degenerative or inflammatory arthritis can result in pain, loss of muscle strength, range of motion, and function of the involved joint(s). People with arthritis may have difficulty turning their head to perform safety checks due to pain and	Some disabilities may be compatible with the driving of large vehicles if mild and nonprogressive. Individual assessment will be required.	Not mentioned	Not mentioned	License denied if ability to drive safely is impaired. May continue to drive vehicle if vehicle modifications can compensate for disability.

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
	below). They may be usefully assessed by a driver assessor. The criteria for an unconditional license are NOT met: • If rotation of the cervical spine is chronically restricted to less than 45° to the left of right; or • If chronic pain and restriction of peripheral joint movement interferes with the relevant movements or concentration such that a vehicle cannot be operated safely; or • If there is ankylosis or chronic loss of joint movement of sufficient severity that control of vehicle is not safe. A conditional license may be granted by the Driver Licensing Authority, taking into account the opinion of an appropriate specialist, and the nature of the driving task, and subject to practical assessment and periodic review: • If there is pain and stiffness in any joint or a joint replacement, having regard for the range of movement and muscle power required to operate a heavy vehicle and the task of getting in and out of vehicles. A practical driver assessment is helpful for most final decisions.	stiffness of their cervical and thoracolumbar spine. Inflammatory arthritis can result in persistent pain and reduced range of movement in multiple joints, including knees, ankles, hips, shoulders, elbows, wrists, and hands. A patient should be restricted from driving if pain adversely affects their ability to drive safely or if he or she lacks range of movement or strength to execute the coordinated activities required. Most difficulties can be overcome by simple modifications to the vehicle or adjustment of driving technique. However, if there are concerns, the individual should be required to demonstrate his or her ability to a driver examiner.				

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
Ankylosing spondylitis	Not mentioned	Not mentioned	Some disabilities may be compatible with the driving of large vehicles if mild and nonprogressive. Individual assessment will be required.	Not mentioned	Not mentioned	Not mentioned
General spinal			Driving is possible in both static and progressive or relapsing disorders, but vehicle modification may be needed.			License denied if ability to drive safely is impaired. May continue to drive if vehicle modifications can compensate for disability.
Cervical	A person with severe neck pain and very reduced mobility, including that arising from wearing soft collars or braces, should be advised not to drive for the duration of their treatment. Some loss of neck movement is allowable if the vehicle is fitted with adequate outside mirrors. In the case of permanent disability, the criteria may not be met (see criteria listed under Arthritis).	Some degree of loss of movement of the head and neck may be permitted, but the driver should then be restricted to driving vehicles equipped with panoramic mirrors, which may alleviate the need to do shoulder checks. People wearing a neck brace or cast or those with severe pain or very restricted range of movement should be advised not to drive until pain and restrictions of movement are minimal or appropriate adaptive devices are in place.		Driving may resume or may occur in the following condition if the individual is able to demonstrate his or her ability to meet all necessary practical driving requirements: ▪ Reduction in rotation of the cervical spine to less than 45 degrees either to the right or left.		

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
Thoracic	People with severe pain and reduced mobility of the thoracolumbar region, including those required to wear a brace or body cast that severely limits mobility, should be advised not to drive for the duration of their treatment. In the case of permanent disability, the criteria may not be met (see criteria listed under Arthritis).	People with a marked deformity or painfully restricted motion in the thoracic vertebrae are not able to drive large commercial transport or passenger-carrying vehicles safely. Their ability to drive private vehicles can best be determined by a driver examiner. Patients wearing braces or body casts must be evaluated on the basis of their ability to move free of pain, operate the controls, and observe approaching vehicles.				
Lumbar		Applicants for a license to drive a passenger transport or heavy commercial vehicle should be free of back pain that limits movement, attention, or judgment. Less stringent standards may be applied to private-vehicle drivers. However, this group may need to be restricted to driving vehicles with power-assisted brakes.				
Paraplegia and quadriplegia		On the basis of a favorable recommendation from a medical specialist in physical medicine and rehabilitation, patients with new paraplegia or quadriplegia (below C4) may receive a learner's license. With the permit, these patients may then take driving lessons in an adapted vehicle fitted with special, modified controls.				

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
Hemiplegia/Cerebral palsy			Driving is possible in both static and progressive or relapsing disorders, but vehicle modification may be needed.			
Pain or severe discomfort	Individuals should not drive with severe pain from spinal conditions that interfere with movement of the spine or shoulder of pelvic girdles.			Some discomfort from joints may be severe enough to distract an individual's attention and thus pose a danger on the road. Acute neck pain, severe back pain, and knee or elbow problems— especially when associated with locking—may present situations where it may be necessary to recommend the individual refrain from driving— especially for drivers of heavy vehicles or those driving commercially.		
General	In the case of commercial vehicle drivers, the opinion of a medical specialist is required for recommendation of a conditional license. This requirement reflects the higher safety risk for commercial vehicle drivers and the consequent importance of expert opinion. The Driver Licensing Authority may consider issuing a conditional commercial vehicle license in certain circumstances. For example, in situations where crash risk exposure is reduced: ▪ "off road" driving of commercial vehicle (e.g., in quarries or other properties where public vehicle access is limited).		Refusal or revocation of license if muscle or movement disorder is likely to affect vehicle control because of impairment of coordination and muscle power. If driving would not be impaired and condition stable, licensing will be considered subject to satisfactory reports and annual review. At age 70, the DVLA requires confirmation that no medical disability is present. After age 70, the maximum license period is 3 years, subject to a satisfactory completion of medical questions. Drivers have an obligation to declare medical conditions that may affect driving safety.		For people with a locomotor disability: Driving licenses shall not be issued to or renewed for applicants or drivers suffering from complaints or abnormalities of the locomotor system that make it dangerous to drive a power-driven vehicle. The competent medical authority shall give due consideration to the additional risks and dangers involved in the driving of vehicles covered by the definition of this group (CMV drivers). On March 27, 2006 member states agree to one single model of license in credit card format to replace 110 different models currently in circulation. A 10-year validity	

Musculoskeletal disorder	Australia	Canada	UK	New Zealand	European Union	Sweden
					period is foreseen that member states may raise to 15 years. At the time of license renewal, member states are free to organize medical examinations.	

Table 7. Regulations and Guidelines Pertaining to Musculoskeletal Disorders and CMV Driving from Selected Countries (Continued)

Musculoskeletal disorder	Ireland	India	Malta	People's Republic of China	Singapore	Kingdom of Bahrain
Reference Source	Irish Statute Book, Statutory Instruments, S.I. No. 340/1986 – Road Traffic (Licensing of Drivers) (Amendment) (No. 2) Regulations, 1986	Government of India The Motor Vehicle Act, 1988 Delhi Traffic Police FAQs related to Disabilities and Driving Driver Checkup; Ideal Performance for a driver's health report	Malta Transport Driving License	Law of the People's Republic of China on Road Traffic Safety (Order of the President No.8) Chapter 2, Article 22	Singapore Road Traffic Act	General Directorate of Traffic and Licensing, Ministry of the Interior. Vehicle Driving License Article 231
Loss of limbs, deformities, and prosthetics	The medical examination shall cover the full range of body movements – strength, control and coordination-and, in particular, movements of the upper and lower limbs. Fitness to drive shall not be certified if the applicant has any disablement that is likely to prevent the proper and safe control of such vehicles (classes D, E, or H, which include heavy vehicles)	A person is unfit to drive if he has: ▪ physical disability with fist strength of less than 35 pounds ▪ physical disability with reaction time of less than 15 seconds in walking and returning 10 feet space ▪ reach-out test of less than 6 inches on standing A person who has undergone an amputation will need to consult with his/her doctor, who may: Issue a doctor's certificate that states the person should be restricted to an automatic vehicle and/or that the vehicle should be fitted with special mechanical devices; or refer them to a driving assessment service. There is usually no difficulty in adapting an artificial limb to a vehicle or a vehicle to a limb.	We may issue Driving Licenses, subject to certain restrictions, to drivers with special needs following consultation with a competent medical authority. A Driving License may be issued stipulating modifications to the vehicle that is to be driven by this person, if this is the case.			

Musculoskeletal disorder	Ireland	India	Malta	People's Republic of China	Singapore	Kingdom of Bahrain
Arthritis		Progressive disabilities such as arthritis may subject a person's body to changes that interfere with his/her ability to drive safely. It is important that people know of the effect these conditions may have on a person's ability to control a vehicle safely. It is not safe to assume that a person's driving will be unaffected. Someone with a progressive disability may need to adjust their driving as changes occur. If a person takes medicine, of if any medications changes, care will be needed to ensure that his/her driving is not affected. Medical guidance should be obtained.				
Paraplegia and quadriplegia	If you are suffering from a lesion with damage to the spinal cord and resultant paraplegia, a medical report is required in order to get a driving license, regardless of age. You may be allowed a 1-year license only or a 3-year or 10-year license.					

Musculoskeletal disorder	Ireland	India	Malta	People's Republic of China	Singapore	Kingdom of Bahrain
General		Before someone can start driving: ensure that you have obtained a written medical clearance to drive from a doctor or specialist. If the licensing authority has reasonable grounds to believe that the holder of the driving license is, by virtue of any disease or disability, unfit to drive a motor vehicle, and that the authority revoking a driving license is not the authority that issued the same, it shall intimate the fact of revocation to the authority that issued that license.	If, after you obtain a license, you develop a medical condition or any medical condition you may have that worsens, it is your responsibility to inform the Licensing and Testing Directorate. These include, but are not restricted, to reporting the following: locomotor disabilities.	A person who suffers from disease that prevents him/her from driving a motor vehicle safely, or who cannot drive safely due to over-fatigue, shall not drive a motor vehicle.	On an application for the grant of a driving license, the applicant shall make a declaration in the prescribed form as to whether or not he/she is suffering from any such disease or physical disability as may be specified in the form, or any other disease or physical disability that would be likely to cause the driving by him/her of a motor vehicle, being a motor vehicle of such a class or description as he would be authorized by the license to drive, to be a source of danger to the public.	The applicant must be free of any disability that would prevent him/her from driving. In case of any doubts, the officials in the Directorate of Traffic and Licensing refer him/her to the medical expert or the Public Security physician for examination and presentation of an official certificate proving that he/she is free of any disability that would prevent him/her from driving.

Methods

The *Methods* section provides a synopsis of how we identified and analyzed information for this report. The section briefly covers the key questions addressed, literature searches performed, the criteria used. The criteria includes studies, evaluation of study quality, assessment of the strength of the evidence base for each key question, and the methods used for abstracting and analyzing available data. Specific details of literature searches, study quality assessment, statistical approaches used, etc., are documented in appendices.

Key Questions

This evidence report addresses four key questions. Each of these key questions was developed by the FMCSA so that the answers would provide information that would be useful in updating its current medical examination guidelines. The four key questions addressed in this evidence report are as follows:

Key Question 1: Does amputation of an extremity increase crash risk and/or affect driving ability?

Key Question 2: Does inflammatory arthritis (e.g., rheumatoid arthritis, similar condition) increase crash risk and/or affect driving ability?

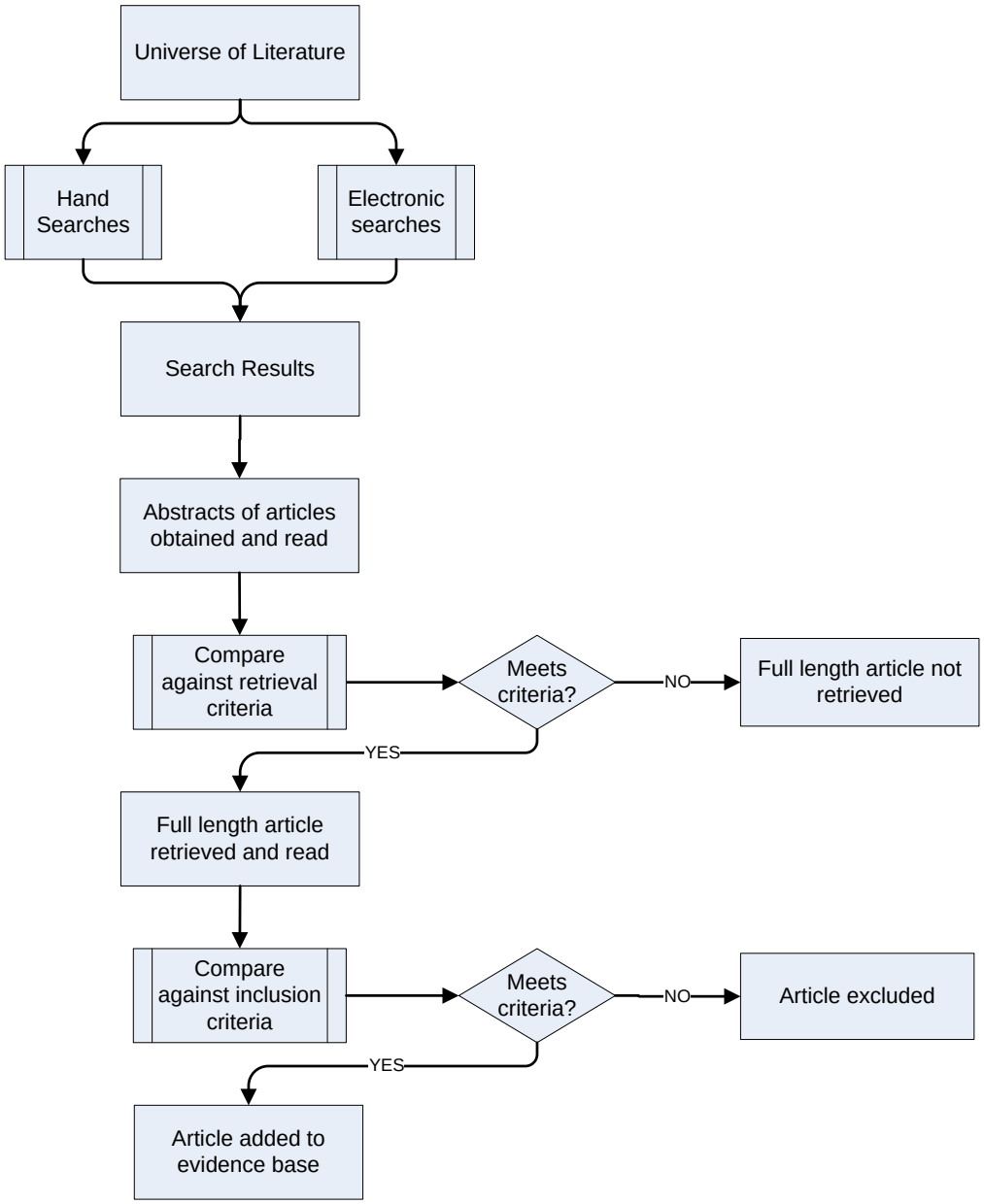
Key Question 3: Does decreased angle of rotation at the level of the spine and neck (as might be the result of ankylosis and/or other vertebral injury) increase crash risk and/or affect driving ability?

Key Question 4: Do vehicle modifications and/or appropriate limb prosthetics decrease crash risk in disabled individuals?

Identification of Evidence Bases

The individual evidence bases for each of the four key questions addressed in this evidence report were identified using the multistage process captured by the algorithm presented in Figure 1. The first stage of this process consists of a comprehensive search of the literature. The second stage of the process consists of the examination of abstracts of identified studies in order to determine which articles will be retrieved. The final stage of the process consists of the selection of the actual articles that will be included in the evidence base.

Figure 1. Evidence Base Identification Algorithm



Searches

One characteristic of a good evidence report is a systematic and comprehensive search for information. Such searches distinguish systematic reviews from traditional literature reviews, which use a less rigorous approach to identifying and obtaining literature, thereby allowing a reviewer to include only articles that agree with a particular perspective and to ignore articles that do not. Our approach precludes this potential reviewer bias, because we obtain and include articles according to explicitly determined *a priori* criteria. Full details of the search strategies used in this report are presented in Appendix A.

Electronic Searches

We performed comprehensive searches of the electronic databases listed in Table 8.

Table 8. Electronic Databases Searched

Name of Database	Date Limits	Platform/Provider
CINAHL (Cumulative Index to Nursing and Allied Health Literature)	1982 through August 14, 2007	OVID
The Cochrane Database of Systematic Reviews (Cochrane Reviews)	Through 2007 Issue 3	www.thecochranelibrary.com
The Cochrane Central Register of Controlled Trials (CENTRAL)	Through 2007 Issue 3	www.thecochranelibrary.com
The Cochrane Database of Methodology Reviews (Methodology Reviews)	Through 2007 Issue 3	www.thecochranelibrary.com
Database of Abstracts of Reviews of Effects (DARE)	Through 2007 Issue 3	www.thecochranelibrary.com
ECRI Institute Library Catalog	Searched July 24, 2007	ECRI Institute
EMBASE (Excerpta Medica)	1980 through August 14, 2007	OVID
Engineering Index	1970 through June 8, 2007	Dialog
Health Technology Assessment (HTA) Database	Through 2007 Issue 3	www.thecochranelibrary.com
MEDLINE	1950 through August 14, 2007	OVID
National Technical Information Service (NTIS)	1970 through August 14, 2007	Dialog
PsycINFO	1950 through August 14, 2007	OVID
PubMed (PreMEDLINE)	Search July 11, 2007	www.pubmed.gov
Transportation Research Information Services Database (TRIS Online)	Searched July 24, 2007	http://ntlsearch.bts.gov/tris/index.do
U.K. National Health Service Economic Evaluation Database (NHS EED)	Through 2007 Issue 3	www.thecochranelibrary.com
U.S. National Guideline Clearinghouse (NGC)	Through August 2007	www.ngc.gov

Manual Searches

We reviewed journals and supplements maintained in ECRI Institute's collections of more than 1,000 periodicals. Nonjournal publications and conference proceedings from professional organizations, private agencies, and government agencies were also screened. In addition, we examined the reference lists of all obtained articles with the aim of identifying relevant reports not identified by our electronic searches. In order to retrieve additional relevant information, we also performed hand searches of the "gray literature." Gray literature consists of reports, studies, articles, and monographs produced by federal and local government agencies, private organizations, educational facilities, consulting firms, and corporations. The latter documents do not appear in the peer-reviewed journal literature.

Retrieval Criteria

Retrieval criteria were used to determine whether a full-length version of an article identified by our searches should be ordered. Decisions pertaining to whether a full-length article should be retrieved are usually based on a review of available abstracts. For this project, retrieval criteria were determined *a priori* in conjunction with the FMCSA. The retrieval criteria are presented in Appendix B.

If an article did not meet the retrieval criteria for this evidence report, the full-length version of the article was not obtained. If it was unclear whether a potentially relevant article met our retrieval criteria (e.g., no abstract was available for evaluation), the full-length version of that article was to be obtained.

Inclusion and Exclusion Criteria

Each retrieved article was read in full by an ECRI Institute analyst who determined whether that article met a set of predetermined, question-specific, inclusion criteria. As was the case for the retrieval criteria, the inclusion criteria for this evidence report were determined *a priori* in conjunction with the FMCSA. These inclusion and exclusion criteria are presented in Appendix C.

If an article did not to meet the question-specific inclusion criteria listed in Appendix C, the article was excluded from the analysis. Each excluded article, along with the reason(s) for its exclusion, are presented in Appendix D.

Evaluation of Quality and Strength of Evidence

Rather than focus on the quality of the individual studies that comprise an evidence base, our approach to assessing the quality of evidence focused on the overall *body* of the available evidence that was used to draw an evidence-based conclusion.(41) Using this approach, which is described briefly in Appendix E, we took into account not only the quality of the individual studies that comprise the evidence base for each key question, but we also considered the interplay between the quality, quantity, robustness, and consistency of the overall body of evidence.

Our approach to assessing the strength of the body of evidence makes a clear distinction between a qualitative conclusion (e.g., “Individuals with musculoskeletal disorders are at increased risk for a motor vehicle crash”) and a quantitative conclusion (e.g., “When compared to individuals who do not have musculoskeletal disorders, the risk ratio for a motor vehicle crash among individuals with the disorder is 1.37; 95% CI: 1.03–1.74; P <0.005.”). As shown in Table 9, we assigned a separate strength-of-evidence rating to each type of conclusion. Evidence underpinning a qualitative conclusion was rated according to its strength, and evidence underpinning a quantitative conclusion was rated according to the stability of the effect-size estimate that was calculated.

Table 9. Strength of Evidence Ratings for Qualitative and Quantitative Conclusions

Strength of Evidence	Interpretation
Qualitative Conclusion	
Strong	Evidence supporting the qualitative conclusion is convincing. It is highly unlikely that new evidence will lead to a change in this conclusion.
Moderate	Evidence supporting the qualitative conclusion is somewhat convincing. There is a small chance that new evidence will overturn or strengthen our conclusion. ECRI Institute recommends regular monitoring of the relevant literature for moderate-strength conclusions.
Minimally acceptable	Although some evidence exists to support the qualitative conclusion, this evidence is tentative and perishable. There is a reasonable chance that new evidence will either overturn or strengthen our conclusions. ECRI Institute recommends frequent monitoring of the relevant literature.
Unacceptable	Although some evidence exists, the evidence is insufficient to warrant drawing an evidence-based conclusion. ECRI Institute recommends frequent monitoring of the relevant literature.
Quantitative Conclusion (Stability of Effect-size Estimate)	
High	The estimate of treatment effect in the conclusion is stable. It is highly unlikely that the magnitude of this estimate will change substantially as a result of the publication of new evidence.
Moderate	The estimate of treatment effect the conclusion is somewhat stable. There is a small chance that the magnitude of this estimate will change substantially as a result of the publication of new evidence. ECRI Institute recommends regular monitoring of the relevant literature.
Low	The estimate of treatment effect included in the conclusion is likely to be unstable. There is a reasonable chance that the magnitude of this estimate will change substantially as a result of the publication of new evidence. ECRI Institute recommends frequent monitoring of the relevant literature.
Unstable	Estimates of the treatment effect are too unstable to allow a quantitative conclusion to be drawn at this time. ECRI Institute recommends frequent monitoring of the relevant literature.

The definitions presented in the table above are intuitive. Qualitative conclusions that are supported by strong evidence are less likely to be overturned by the publication of new data than conclusions supported by weak evidence. Likewise, quantitative effect-size estimates that deemed to be stable are more unlikely to change significantly with the publication of new data than are unstable effect-size estimates.

Statistical Methods

The set of analytic techniques used in this report was extensive. In summary, random- and fixed-effects meta-analyses were used to pool data from different studies.(1-5,42-46) Important differences in the findings of different studies (heterogeneity) were identified using the Q-statistic and I^2.(6-8,42,47-49) Whenever appropriate, heterogeneity was explored using meta-regression techniques.(50-52) Sensitivity analyses, aimed at testing the robustness of our findings, were performed using cumulative fixed- and random-effects meta-analyses.(9-11,53-56) The presence of publication bias was tested for using the "trim and fill" method.(57) All meta-analyses in this evidence report were performed using Comprehensive Meta-Analysis software.(12-14)

We calculated several different estimates of effect. The choice of effect-size estimate depended on the purpose of the studies we assessed, their design, and whether reported outcome data were continuous or dichotomous. Between-group differences in outcome measured using continuous data were analyzed in their original metric (if all included studies reported on the same outcome using the same metric), or the data were standardized into a common metric known as the standardized mean difference (SMD). Dichotomous data were analyzed using the rate ratio (RR) or the odds ratio (OR). Time-to-event data were analyzed using the hazard ratio (HR). The formulae for these effect sizes and their variance are presented in Table 10. If means and standard deviations were not available for continuous data, every effort was made to determine an estimate of treatment effect from reported statistics (e.g., t-values, f-values) or from p-values using methods described in detail elsewhere.(58)

Table 10. Effect-size Estimates Used in Evidence Report and their Variance

Effect Size	Formula (Effect Size)	Formula (Variance)
WMD	$\mu_{TG} - \mu_{CG}$	$\left(\sqrt{\frac{(n_{TG}-1)(s_{TG})^2 + (n_{CG}-1)(s_{CG})^2}{n_{TG}+n_{CG}-2}}\right)\left(\frac{1}{n_{TG}} + \frac{1}{n_{cg}}\right)$
SMD	$\frac{\mu_{TG} - \mu_{CG}}{\left(\sqrt{\frac{(n_{TG}-1)(s_{TG})^2 + (n_{CG}-1)(s_{CG})^2}{n_{TG}+n_{CG}-2}}\right)}$	$\frac{n_{TG}+n_{CG}}{n_{TG}n_{CG}} + \frac{SMD^2}{2(n_{TG}+n_{CG})}$
Where: μ_{TG} = mean (treatment group); μ_{CG} = mean (control group); S_{TG} = standard deviation (treatment group); S_{CG} = standard deviation (control group); n_{TG} = enrollees (treatment group); n_{CG} = enrollees (control group)		
Event Rate	$a/a+b$	$\ln\left[\frac{1}{a} + \frac{1}{a+b}\right]$
Where: a = number of individuals in cohort experiencing an event; b = number of individuals in cohort who did not experience an event		
RR (incidence)	$\left(\frac{a_{msd}}{pt_{msd}}\right) \Big/ \left(\frac{b_{control}}{pt_{control}}\right)$	$\ln\left[\frac{1}{a_{msd}} + \frac{1}{b_{control}}\right]$
Where: a = number of individuals with musculoskeletal disorders who crashed; pt_{msd} = rate denominator (musculoskeletal disorder group); b = number of individuals without musculoskeletal disorders who crashed; $pt_{control}$ = rate denominator (control group)		
OR	$\left(\frac{a}{b}\right) \Big/ \left(\frac{c}{d}\right) = \left(\frac{ad}{bc}\right)$	$\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}$

Effect Size	Formula (Effect Size)	Formula (Variance)
RR	$\left(\frac{a}{a+c}\right) \Big/ \left(\frac{b}{b+d}\right)$	$\frac{1}{a}+\frac{1}{a+c}+\frac{1}{b}+\frac{1}{b+d}$
Where: a = number of individuals with musculoskeletal disorders who crashed; b = number of individuals without musculoskeletal disorders who crashed; c = number of individuals with musculoskeletal disorders who did not crash; d = number of individuals without musculoskeletal disorders who did not crash.		
HR	$\frac{O_{pi}/E_{pi}}{O_{ci}/E_{ci}}$	$\exp\left(\ln\left[\frac{1}{E_{pi}}+\frac{1}{E_{ci}}\right]\right)$
Where O_{pi} = observed number of events in treatment group; O_{ci} = observed number of events in control group; E_{pi} = logrank expected number of events in treatment group; E_{ci} = logrank expected number of events in control group		

HR - Hazard ratio
OR - Odds ratio
RR - Rate ratio
SMD - Standardized mean difference
WMD - Weighted mean difference

Evidence Synthesis

This section summarizes the findings of our systematic review of the evidence pertaining to each of the key questions asked by the FMCSA.

Key Question 1: Does amputation of an extremity increase crash risk and/or affect driving ability?

Amputation is a concern to those responsible for road safety, because the physical/structural changes can result in problems in mechanical function that may contribute to an increased potential for a motor vehicle crash. Coupled with concerns about the impact of amputation on crash risk is the likely increase in the number of amputees who will, in the very near future, attempt to obtain a CMV license. This increase is conjectured based on three factors: (1) the rising prevalence of amputees in the U.S. population in general; (2) the active recruitment by the trucking industry in the population most likely to have experienced, or to experience, an amputation (>55 years of age); and (3) the active recruitment by the trucking industry of veterans from the ongoing conflicts in Iraq and Afghanistan, a population in whom it is noted that the incidence of traumatic amputations has doubled (from 3% to 6%) from previous figures.[2](60-65)

The active recruitment of older individuals and military veterans by the trucking industry was initiated in response to a projected shortfall in the number of professional CMV drivers.(59,66) According to the American Trucking Association, the industry currently needs an additional 20,000 individuals to provide professional transportation; by 2014 the shortfall is expected to rise to 111,000 due to retirement, a lack of past recruitment, and increased demand.(67)

In this section we review the evidence pertaining to the crash risk and/or effect on driving ability associated with amputation. The purpose of this review is to determine whether amputation poses a risk to road safety inasmuch as it may impact the ability to perform the functions required to operate a CMV.

Background

Congenital amputation (or congenital limb deficiency) is the term used to describe the condition when an individual is born without a body part. Acquired amputation involves the removal of a body part that is enclosed by skin (i.e., removal of a finger is an amputation; removal of tonsils would not be an amputation). It can be associated with a traumatic event (accidental amputation related to entrapment or crushing injuries, or surgical amputation as a treatment for severe, irreparable damage to the body part) or may be performed to prevent complications associated with infection, disease, or impairments

[2] In testimony given before the Subcommittee on Economic Opportunity of the House Committee on Veterans Affairs (May 3, 2007) the President of the Truckload Carriers Association (TCA) North America asserted that the perceived skills military veterans brought to truck driver training made them particularly attractive to the transportation industry.(59)

to circulation in the affected body part. The types of surgical amputations performed, along with an explanation of their location and potential degree of impairment, are found in Table 11.

Table 11. Types of Amputation

Limb	Location	Degree of Impairment* (%)		
Upper Limb		**Hand**	**Upper Limb**	**Entire Person**
Forequarter	A shoulder disarticulation amputation in which the shoulder blade and collar bone are removed.	NR†	NR	70%
Shoulder Disarticulation (SD)	An amputation that is at the level of the shoulder, with the shoulder blade remaining. The collarbone may or may not be removed.	NR	100%	60%
Above-Elbow (Transhumeral; AE)	Any amputation that occurs in the upper arm from the elbow to the shoulder.	NR	95% - 100%	57% - 60%
Elbow Disarticulation (ED)		NR	95%	57%
Below-Elbow (Transradial; BE)	Any amputation that occurs in the forearm, from the elbow to the wrist.	NR	90% - 95%	54% - 57%
Hand and Wrist Disarticulation	The limb is amputated at the level of the wrist.	NR	90%	54%
Partial Hand (Transcarpal; PH)	Includes finger, thumb, or portion of the hand below the wrist.	100%	90%	54%
Lower Limb		**Foot**	**Lower Limb**	**Entire Person**
Hemipelvectomy	Amputation of the whole lower limb together with all or part of the hemipelvis.	NR	NR	50%
Hip Disarticulation (HD)	This level of amputation is at the hip joint with the entire thigh portion being removed.	NR	100%	40%
Above-Knee (Transfemoral; AK)	Amputation of the lower limb between the hip joint and the knee joint.	NR	90% - 100%	36% - 40%
Knee Disarticulation (KD)	This amputation occurs at the level of the knee joint.	NR	90%	36%
Rotationplasty (Van Nes Rotation)	A procedure where the lower portion of the leg is rotated 180° and reattached - the ankle acts like a knee joint, providing extra function.	NR	NR	NR
Proximal Femoral Focal Deficiency (PFFD)	A developmental deficiency of the femur present at birth.	NR	NR	NR
Below-Knee (Transtibial; BK)	Amputation of the lower limb between the knee joint and the ankle joint.	NR	70% - 90%	28% - 36%
Ankle Disarticulation	Amputation of the lower limb at the ankle joint.	NR	NR	NR
Symes	A disarticulation amputation of the lower limb at the ankle joint that retains the fatty heel pad portion to allow for weight bearing.	100%	70%	28%
Partial Foot (Chopart; PF)	Chopart: amputation through the tarsal (tarsus) or foot bones; allows for weight bearing without a prosthesis. Partial Foot: Amputation of the lower limb distal to the ankle joint.	30%	21%	8%
Multiple Amputation				
Bilateral Transradial amputation: below-elbow amputation (DBE)	Amputation of both upper limbs below the elbow.	NR	NR	NR
Bilateral trans-humeral: Double Above Elbow (DAE)	Amputation of both upper limbs above the elbow.	NR	NR	NR
Bilateral Transtibial amputation: below-knee amputation (DBK)	Amputation of both lower limbs below the knee joint.	NR	NR	NR
Cross Section	Amputation is performed at one level on one limb and a different level on the other.	NR	NR	NR
Cross site	Amputation of one upper limb and one lower limb.	NR	NR	NR
Quadruple Amputee	Amputation of all four limbs at any level.	NR	NR	NR

http://www.waramps.ca/nac/
http://www.limblossinformationcentre.com/content/llic/rehab/amputation/levels#ankle
*From the (Special Edition) JAMA, 1958
The percentages designate the estimated degree of impairment to the particular region of the body and to the person as a whole as assigned by the Committee on Rating of Mental and Physical Impairment. *Guides to the evaluation of a permanent impairment–the extremities and back*. For example, a forequarter amputation is estimated to give a 70% impairment to function for the individual who has undergone that amputation procedure.
NR†: Not rated in *Guides to the evaluation of a permanent impairment – the extremities and back* (Special Edition) JAMA, 1958

Pathophysiology

Amputations are performed for a variety of reasons, including severe injury without reasonable expectation of repair, cancerous bone tumors (osteosarcoma, etc.), gangrene, and circulatory dysfunction. In performing an amputation, a careful balance must be achieved between etiology, level of amputation, and desired functional outcome to provide optimal results for the individual.(68)

Traumatic Amputation

In the case of traumatic amputation, the body part is removed as a response to physical injury, such as mechanical, electrical, thermal, or chemical damage, that has caused irreparable harm. The damage seen in traumatic amputations is categorized as the following:

- Complete amputation (the total severing of a body part): if proper care of the severed body part is observed, it may be successfully reattached. Proper care currently is understood to mean that the severed part should be wrapped in a clean damp cloth, placed in a sealed plastic bag, and the bag should be immersed in ice water or very cold water.
- Partial amputation (some soft tissue connection remains intact): depending on the damage inflicted to the surrounding tissues, reattachment may be possible.

Traumatic amputations are categorized as immediate (urgent removal of the limb is required in response to catastrophic damage), early (associated with infection or ischemia), and late (associated with nonunion osteomyelitis). Trauma is the most common cause of amputation in individuals under 55 years of age, comprising approximately 75% of all upper extremity amputations.(69) Common causes of traumatic amputation include accidents involving agricultural equipment, power tools, factory equipment, and motor vehicle crashes.(70)

Acquired Amputation

The intentional surgical removal of a limb is performed in response to a variety of nontrauma-related conditions, including impaired circulation secondary to diabetes mellitus or atherosclerosis (Peripheral Arterial Disease, or PAD), arterial stenosis or occlusion, infection, and neoplasms.

The most common reason for acquired amputation is insufficient circulation related to PAD. PAD involves the gradual occlusion of the blood vessels, which restricts blood and oxygen to the affected area, causing tissue death. Individuals with PAD who progress to critical limb ischemia with little likelihood for successful revascularization may require amputation to address PAD-related pain, ulceration, and/or infection and gangrene.(71)

PAD is responsible for approximately 90% of all acquired amputations in the United States (see Table 12), particularly those occurring in the lower limbs. It is most common in individuals between the ages of 50 to 75 years, and is usually associated with diabetes mellitus, where certain clinical features such as past or current ulcers of the feet pose a high risk of vascular complications.(70,72) Approximately 60% to 80% of all diabetes-related amputations involve the legs or feet. Similar statistics are found in the United

Kingdom, where diabetes is responsible for approximately 70% of all lower-limb acquired amputations.(72)

Acquired amputation is also a response to infection or neoplasms. Frequently, infection is the result of disease processes such as diabetes. However, it can also be the result of the introduction of bacteria to an open wound at the time of injury or infection of the bone such as osteomyelitis. In these circumstances, amputation is performed to remove the damaged tissue and avoid distal limb infarction. Likewise, amputation as a response to neoplasms entails removal of a limb affected by cancer or tumors in order to arrest the progress of the condition. Table 12 lists the types of amputations performed in the United States and their etiologies.

Table 12. Type of Amputation and Etiology (United States, 1988–1996)

Limb and Level	Etiology (%)		
	Dysvascularity	Trauma	Neoplasms
Lower Limb (total)	**97**	**31.2**	**76.1**
Toe	31.5	13.9	13.4
Foot	10.5	2.3	4.4
Ankle	0.8	0.4	1.5
Transtibial	27.6	7.3	13.7
Through Knee (TK)	0.4	0.5	1.2
Transfemoral	25.8	5.5	22.8
Hip Disarticulation	0.4	0.2	6.6
Pelvic	0.1	0.03	12.5
Bilateral	0	0.8	0
Upper Limb (total)	**3**	**68.6**	**23.9**
Thumb	0.2	12.4	3.2
Finger(s)	2.2	51.2	4.8
Hand	0.1	0.5	0.8
Wrist	0.1	0.2	0.2
Transradial	0.2	2.0	1.9
Through-elbow	0.04	0.2	1.1
Transhumeral	0.2	1.5	4.4
Shoulder	0.02	0.1	3.3
Bilateral	0	0.2	0
Forequarter	0.01	0.01	4
Total	**100**	**100**	**100**

Prevalence and Incidence

In the United States it is currently estimated that 1.9 million individuals live with an amputation; approximately 82% of surgeries were related to vascular disease, 12% were trauma-related, and 6% comprised congenital amputees and amputation related to neoplasm. The prevalence rate of amputation has been estimated at 4.9 per 1,000 individuals, with individuals older than 65 years of age having the highest rate at 19.4 per 1,000 individuals. It is estimated that 113,000 lower-limb

amputations occur each year in the United States.(69) Congenital limb deficiency has a prevalence of approximately 25.64 per 100,000 births.

Amputation incidence rates in the United States were 46.2 per 100,000 individuals with vascular disease; 5.8 per 100,000 individuals with trauma-related amputations; and 0.35 per 100,000 individuals with amputations related to malignancies. Similar amputation rates were found in Sweden, where the incidence rate for 1980 to 1982 was calculated to be 46 per 100,000 individuals, with 47% of amputees in individuals over 80 years of age.(73)

Risk Factors

The risk of experiencing an amputation increases with age for all etiologies, ethnicities, and genders. This increase is probably attributable to age-related increases in the risk of developing conditions and/or diseases that may require amputation as a treatment. Feinglass et al.'s comparative study of foot, below-knee, and above-knee level amputations for 1979 to 1980 and 1995 to 1996 found that dysvascular disease-related amputation increased in the United States by 10.6% between the 2 periods.(74) A later analysis of amputations between 1988 and 1996 found a 19.5% increase, although some of this difference may be attributed to variations in sampling design, coding, and populations studied. Altogether, the rate of dysvascular disease-related amputations in 1996 was 8 times that of the second-leading cause of amputation (trauma). Trauma-related amputations declined, although this may be due in part to technologic advances that would allow for more aggressive limb-salvage surgery and a decrease in in-hospital admissions for minor trauma-based amputations involving the toes or fingers.(74)

Risk factors for amputation include the following:

- Occupation (one out of nine agricultural workers in the United States will experience amputation related to crushing, entrapment in machinery, entanglement, or postinjury infection)
- Vascular disease
- Diabetes mellitus (specific diabetes-related risk factors being increased age, male gender, African American ethnicity, presence of neuropathy or peripheral vascular disease, type of diabetes, poor glycemic control, duration of diabetes, ingrown nails, and prior history of retinopathy, previous amputations, and ulcers)
- Smoking
- Hypertension
- Hypercholesterolemia
- Age

Epidemiology

Amputation is divided into two categories: upper-extremity amputation, and lower-extremity amputation. Dillingham et al. found that dysvascular diseases were associated with a total of 97% of all lower-extremity amputations, with 54% of such surgeries occurring at the transfemoral (AK) level, 26% occurring at the transtibial (BK) level, and 31% involving removal of toes. Dysvascularity accounted for 82% of all amputations in the United States, increasing from a 1988 rate of 38.30 per 100,000 people to that of 46.19 per 100,000 people in 1996. This rise in amputations may be linked with the growing number of older individuals in of the U.S. population and the association between age and the increased likelihood of having developed a disease or diseases that increase the risk for amputation. The male/female ratio for dysvascular amputation was 1.75 (95% CI 1.74 – 1.76), with the risk ratio for traumatic amputation being even higher, at 4.94 (95% CI 4.93 – 4.95).(64)

Traumatic amputations declined during the same period (11.7 per 100,000 people to 5.86 per 100,000 people), and were generally associated with upper-extremity loss (68%): 75% of these amputations occurred at the level of the finger. Neoplasm-associated amputation, which occurred more frequently in the lower limbs, declined from a 1988 rate of 0.62 to a 1996 rate of 0.35.(64)

Ollendorf et al. estimated that 30% to 50% of individuals with a first amputation (related to diabetes) will require a second amputation in 1 to 3 years; 50% of those who have undergone an amputation will die within 5 years of the initial surgery.(75)

Identification of Evidence Base

To meet the aims of this section of the evidence report, we searched for trials that compared crash risk among individuals who had undergone an amputation and otherwise comparable individuals who had not experienced an amputation. In addition, we looked for studies that compared the prevalence of amputation among cohorts of individuals who had or had not experienced a crash. We also searched for studies that detailed amputee functional outcomes that might affect driving.

The evidence-base identification pathway for Key Question 1 is summarized in Figure 2. Our searches[3] identified a total of 1,407 articles that appeared relevant to this key question. Following application of the retrieval criteria for this question, 20 full-length articles were retrieved and read in full. Three of these 22 retrieved articles were ultimately found to meet the inclusion criteria[4] for Key Question 1 (Table 13). Table D-1 of Appendix D lists the 17 articles that were retrieved, read in full, and then excluded.

[3] See Appendix A for search strategies

[4] See Appendix C for inclusion criteria

Figure 2. Development of Evidence Base for Key Question 1

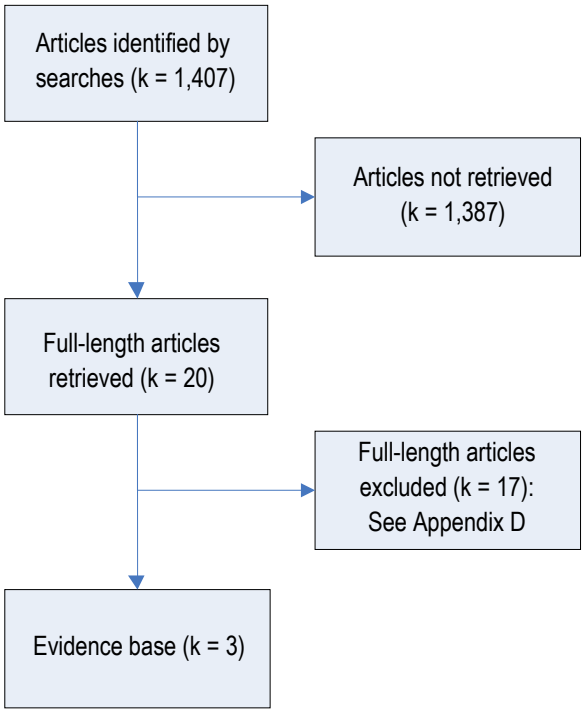


Table 13. Evidence Base for Key Question 1

Reference	Year	Study Location	Country
Studies that examined impact of amputation on crash risk			
Gresset and Meyer(76)	1994	Quebec	Canada
Ysander(77)	1970	Stockholm	Sweden
Studies of functional outcomes in amputees that may impact driving ability			
Meikle et al.(78)	2006	Ontario	Canada

The small number of studies on the impact of amputation on driver safety and performance has been noted by others. For example, Fernandez et al. stated that "Driving, which must be considered as an important aspect of the reintegration of persons with amputations into social life and work, is a subject little dealt with in the rehabilitation field. We have not found studies in the literature that specifically address driving in these patients."(79) Boulias et al. noted, "We were unable to find any studies subsequent to 2000 that addressed the issue of return to driving in people after amputation."(80)

Evidence Base

This subsection provides a brief description of the key attributes of the three studies that comprise the evidence base for Key Question 1. Here we discuss applicable information pertaining to the quality of the included studies and the generalizability of each study's findings to CMV drivers. The key attributes of each included study are presented in Table 14.

Table 14. Key Study Design Characteristics of Studies that Address Key Question 1

Reference	Year	Study Design	Objective	Type of Amputation	Factors controlled for (if compared to nonamputee controls)?	Driving exposure controlled for?	Primary Outcome	Definition of Crash	Outcome self-reported?
Amputation and Crash Risk									
Gresset and Meyer(76)	1994	Case control	To document the risk of motor vehicle crashes among elderly men with amputation	Amputation not defined	Age Miles driven Driving habits	Yes	Crash	Crash with mild bodily injury or property damage	No
Ysander(77)	1970	Case-control	To determine whether any particular type of disability was a greater crash hazard when compared to other physical disabilities	Amputation not defined	Gender Age License-holding period	Annual distance driven	Crash	No	Yes
Amputation and Its Impact on Driving Ability and Performance									
Meikle et al.(78)	2006	Prospective case series	To determine if right transtibial amputees have the potential to safely operate the foot pedals of a vehicle with a prosthetic foot	Right transtibial amputation	Not applicable (NA)	NA	Brake pedal response time	NA	No

Two of the three included studies directly assessed the impact of amputation on the motor vehicle crash risk.(76,77) Gresset and Meyer(76) attempted to ascertain the risk of motor vehicle crash for a population of males who had undergone an amputation. Cases (n = 1,400) were comprised of all males aged 70 who were registered by the Societe de l'Assurance Automobile du Quebec (SAAQ) as having had a crash with bodily injury or property damage. Age- and gender-matched controls (n = 2,636) were randomly selected from approximately 30,000 male drivers who had not experienced a motor vehicle crash who were included in the same SAAQ database.

Ysander(77) attempted to determine the extent to which physical disablement constituted a driving hazard when compared to comparable individuals who did not suffer from a physical disability. Included in this study was a subgroup of 76 amputees: 29 with an amputation of the arm or hand; 20 with an amputation of the right leg; 21 with an amputation of the left leg, and 6 with amputations of both legs, and 48 of the individuals with amputations used prostheses.

The remaining study by Miekle et al.(78) examined four different driving techniques used by individuals who had undergone a right BK amputation. The aim of the study was to determine which of these techniques was associated with the fastest reaction times/brake-pedal response times. Participants were required to view a computer screen with two gray circles; when the circles turned red, they were required to move their foot from an accelerator pedal to a brake pedal. Four different techniques for operating the foot pedals were examined:

- Right-sided accelerator - prosthesis used to operate both the accelerator and brake
- Right-sided accelerator - prosthesis used to operate the accelerator and the left foot to operate the brake
- Right-sided accelerator - using the left foot to operate both the accelerator and brake
- Left-sided accelerator - using the left foot to operate both the accelerator and brake

Testing using the four techniques took place in random order; after each trial, participants were asked to rank the techniques in order of preference. Primary outcome measures included total brake-pedal response time and movement time. The secondary outcome measure was volunteer preference. Statistical techniques employed included descriptive statistics, analysis of variance (ANOVA) (reaction time, movement time, and total response time across all four techniques), and repeated t-tests. A subgroup analysis was performed to compare braking times between individuals who used the right-foot accelerator and individuals who used the left-foot accelerator.

Quality of Evidence Base

The findings of our assessment of the quality of the studies that comprise the evidence base for Key Question 1 are summarized in Table 15. Complete details of our quality assessment can be found in the *Study Summary Tables* presented in Appendix G. Our assessment found that the quality of the included studies was not high. Two of the three included studies were graded as being of moderate quality; the third included study was graded as being of low quality.

Table 15. Quality of the Studies that Assess Key Question 1

Reference	Year	Quality Scale Used	Quality
Amputation and Crash Risk			
Gresset and Meyer(76)	1994	Revised Newcastle-Ottawa Quality Assessment Scale Case Control Studies	Low
Ysander(77)	1970	Revised Newcastle-Ottawa Quality Assessment Scale Case Control Studies	Moderate
Amputation and Its Impact on Driving Ability and Performance			
Meikle et al.(78)	2006	Revised Newcastle-Ottawa Quality Assessment Scale Cohort Studies	Moderate

Generalizability of Evidence to Target Population

Important characteristics of the individuals represented in the 3 studies that comprise the evidence base for Key Question 1 are presented in Table 16. As noted in the table, direct evidence pertaining to the impact of amputation on crash risk among CMV drivers does not exist. Consequently, our conclusions must be based on information obtained from studies of private motor vehicle license holders, an unknown number of whom may have held commercial driver licenses. The generalizability then, of our findings to CMV drivers is unclear.

Table 16. Individuals with Amputations Enrolled in Studies that Address Key Question 1

Reference	Year	Number of Individuals with an Amputation or Functional Motor Impairment*	Type of Amputation	Number Driving vs. Number not Driving	Age Distribution	% Male	% CMV Drivers	Driving Exposure	Ethnicity	Generaliz-ability to Target Population
Amputation and Crash Risk										
Gresset and Meyer(76)	1994	Cases: n = 13 Controls: n = 29	Not defined	All driving	70 years of age	100%	NR	NR	NR	Unknown
Ysander(77)	1970	n = 76	Not specified	Driving: 100%	18 - >60	NR	NR	Annual Miles Driven Postamputation: 1-4,999: 5% 5,000-9,999: 31% 10,000-19,999: 53% ≥20,000: 10% Annual Miles Driven Controls: 1-4,999: 11% 5,000-9,999: 31% 10,000-19,999: 44% ≥20,000: 7%	NR	Unknown
Amputation and its Impact on Driving Performance										
Meikle et al.(78)	2006	n = 10	Right transtibial amputation	Postamputation driving: 50%	53.1 ±9.46	70.0	NR	Postamputation Every day: 40% 4-6 times per week: 0 2-3 times per week: 10%	NR	Unknown

*Includes difficulties with muscular strength, coordination, range of motion, spinal movement and stability, amputations or the absence of body parts, and/or abnormalities affecting motor comparison.

NR - Not reported.

Findings

Our searches identified two studies that attempted to determine whether individuals with an amputation of a limb are at an increased risk for a motor vehicle crash. One further study examined the impact of amputation of the right leg below the knee on the use of foot pedal controls. The findings of these studies are presented below.

Study of Gresset and Meyer

Gresset and Meyer did not find evidence to support the contention that amputees who drive a motor vehicle are at an increased risk for a crash (OR = 0.84, 95% CI: 0.44, 1.67).

Study of Ysander

As was the case for Gresset and Meyer, Ysander did not find evidence to support the contention that amputees who drive are at an increased risk for a crash (OR = 1.36, 95% CI: 0.57 to 3.10).

Study of Meikle and Colleagues

Meikle et al. found that the longest reaction times were associated with a two-foot pedal technique that required the prosthetic foot to operate the accelerator and the left foot to operate the brake (P <0.001 for the comparator pedal conditions). The shortest reaction times were associated with using the left foot to operate the accelerator and the brake (P <0.001 for the comparator pedal conditions). Using the prosthetic foot to operate both pedals in the right-sided accelerator condition and using the left foot to operate both pedals in the left-sided accelerator condition demonstrated no difference in reaction time (P = 0.07 for the comparator pedal conditions).

The same results were found when examining total response time. The longest movement times were associated, as with reaction times, with the two-foot pedal technique (all comparisons P <0.001). There was no difference in movement times between the other three-pedal techniques (P = 0.33 for the comparator pedal conditions).

In examining usual driving technique, the investigators found that individuals who currently used their right foot for the accelerator had consistently faster reaction times in all four techniques when compared to those who had switched to using their left leg. Individuals who used their right foot to operate the accelerator demonstrated reaction times that were between 35 to 135 milliseconds (ms) faster than individuals who used their left foot to accelerate (P <0.05). In an identical investigation with brake operation, the same findings were achieved: differences were only significant when right-sided accelerator conditions used the prosthetic leg for both pedals and for left-sided accelerator conditions when the prosthetic leg was used for both pedals (individuals using the right foot for braking were between 56ms to 87ms faster (P <0.001). This trend continued for both movement time (68ms to 87ms faster for right foot, P <0.05) and total response time (114ms to 174ms faster for the right foot, P <0.001). Based on their findings, the authors suggested that right BK amputees not be encouraged to adopt a two-footed driving technique. In addition, reaction-time results indicated that similar pedal response times occurred when using a prosthesis in a normal pedal arrangement versus using the intact left limb in the modified left-sided accelerator arrangement.

Section Summary

Whether amputees who drive a CMV are at an increased risk for a crash cannot be determined at the present time.

Our searches did not identify any studies that examined crash risk or a surrogate marker for crash risk among CMV drivers who have undergone an amputation.

While evidence suggests that driving performance in some amputees (drawn from the general driver population) may be compromised, there is currently no compelling evidence to support the contention that such individuals are at an increased risk for a motor vehicle crash when compared to comparable individuals who do not have an amputation (Strength of Conclusion: Minimally Acceptable).

Direct Evidence: To date, only two studies have examined the impact of amputation on crash risk, and neither provided evidence that individuals with an amputation who drive a motor vehicle are at increased risk for a motor vehicle crash.

Indirect Evidence: A single, moderate-quality study found that individuals with an amputation below the knee of the right leg demonstrated some reductions in foot-pedal reaction time. The use of adaptive driving techniques, however, appeared to eliminate this reduction.

Key Question 2: Does inflammatory arthritis (e.g., rheumatoid arthritis, similar condition) increase crash risk and/or affect driving ability?

The arthritides are a concern to those responsible for road safety, because the physical/structural changes present in the condition(s) may culminate in problems in mechanical function which can contribute to the potential for crash, injury, and death. These mechanical problems may include difficulty gripping the steering wheel or cornering due to pain in the hands; knee pain limiting the ability to effectively use the foot pedals; or reduced ROM affecting the ability to turn the torso in order to obtain the needed field of view to reverse a vehicle. In addition, comorbidities including neuromuscular difficulties (poor balance) and cardiovascular difficulties (lack of endurance) associated with arthritis, may pose a challenge to the safe operation of a CMV.(81)

The potential increase in truck drivers with arthritic disorders is directly related to an active campaign on the part of trucking companies to recruit individuals who are in the group most likely to suffer from arthritic conditions: those people over 50 years of age.(61,63) In particular, Thompson pointed out that disability associated with RA has been demonstrated to increase at approximately 2% per year, and was associated with age and disease duration.(82) With this in mind, an understanding of the relationship between the arthritides, crash, and driving skills in general is needed to provide for the formulation of effective guidelines for medical examiners who administer physicals to the CMV driving population.

In addition to the studies in the evidence base that specifically addressed crash risk and the potential affect of arthritis on driving ability, a number of review papers that address the potential affect of the arthritides on functional ability exist.

Roberts and Roberts(83) outlined the effects of arthritis on the ability of the elderly to drive by defining the physical factors involved, including pain that produces a certain uncontrolled hesitancy related to movement, and restriction of ROM. For example, the ability to safely turn the vehicle depends in large part on peripheral vision, the ability to rotate the cervical spine, and the ability to grip the steering wheel. If arthritis affects any one of these functions (either through pain, physical alterations, or reduced ROM), the ability to steer the vehicle safely in a turn can be compromised. The ability to brake the vehicle may similarly be impacted by the affect of arthritis on the lower limbs, particularly through chronic physical alterations typical of OA and RA, or through the temporary changes introduced by metabolic arthritis or PsA.

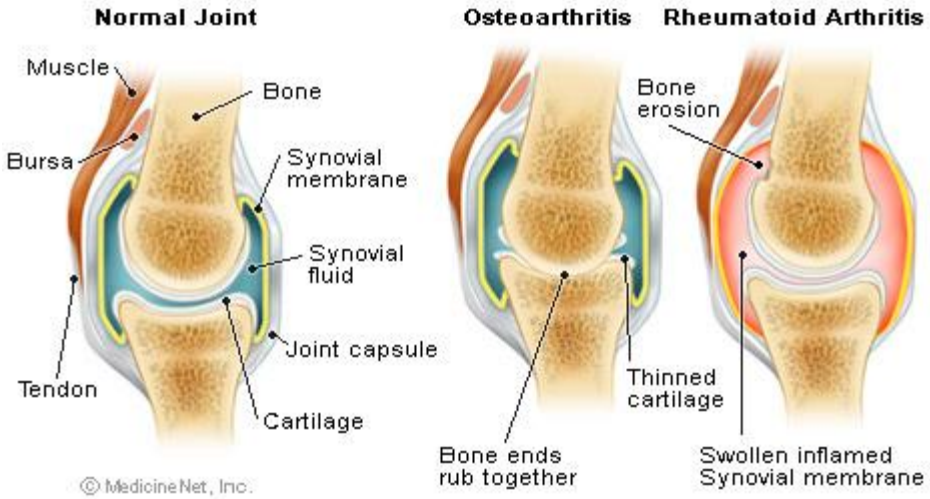
The particular challenges of driving for an individual with arthritis was discussed by C. Murray-Leslie, who stated, “Experience from assessing the needs of drivers with arthritis suggest that it is joint pain rather than stiff, weak, or deformed joints which is the biggest obstacle [to driving]. Such pain may be related to movement, loading or pressure on a joint or from maintaining a limb in a particular posture.”(84) Busteed et al. noted that even a low disability index for RA was associated with impaired driving, with many drivers reporting problems reversing, using the gear shift, engaging the clutch, and looking to the left and right at traffic junctions.(85) Badley et al. posited that pain and fatigue associated with psychosocial factors, including the desire or “will” to perform certain activities, would affect function. Their study of functional outcomes, including mobility and dexterity, found that correlations of ROM and scores for each functional activity did not explain more than half of the overall variation discovered.(86)

Background

Arthritis is a category of disorders that is characterized by joint and musculoskeletal pain, stiffness, and swelling associated with inflammation of the structures of the joint, including the synovium, bones, cartilage, and supporting tissues. (See Figure 3) It is not a distinct disease; rather, it encompasses over 100 different conditions, including bursitis, PsA, reactive arthritis, metabolic arthritis, OA, lupus, and RA. Symptoms of arthritis include: pain, loss of joint motion, fatigue, and bone enlargement and swelling. The type of arthritis and its natural history are determined by the cause of the disorder, which may include injury, infection, hemophilia, autoimmune dysfunction, and crystalline diseases such as metabolic arthritis and pseudogout. Understanding the specific cause of the arthritic condition is essential in directing an appropriate course of treatment, particularly as some forms of arthritis are known to respond well to treatment, while others continue to progress and can prove disabling.(18,87,88)

For the purposes of the FMCSA, this section of the report will focus on inflammatory arthritis (RA, PsA, reactive arthritis, and metabolic arthritis), with the addition of OA due its prevalence in the U.S. population and the increased likelihood that it would appear in the CMV driver population.

Figure 3. Normal and Arthritic Joints



From: http://www.medicinenet.com/osteoarthritis/article.htm

Osteoarthritis

Osteoarthritis (OA) is a disorder in which degenerative breakdown and loss of the cartilage of a joint, underlying bone, and surrounding joint structures may lead to pain, stiffness, and problems in movement. It is also referred to as degenerative joint disease. OA is the most common form of arthritis in the United States, with approximately 21 million individuals experiencing regional joint pain sometimes due to symptomatic OA.(89) Sites in the body most commonly affected by OA include the hips, knees, spinal column, and hands. OA has a tendency to affect joints on opposite sides of the body to different degrees.(90)

Pathophysiology

Cartilage functions as the connective tissue of a joint. Cartilage is a specialized structure of collagen, elastin fibers, water, and chondrocytes contained in a firm gel-like proteoglycan matrix that serves as smooth surface that allows joints to move over each other during motion. It also is responsible for the absorption of energy associated with movement. There are three different types of cartilage in the body: hyalin, elastic, and fibrocartilage. The focus of this section of the report will be on articular (or hyalin) cartilage, which serves the joints.

When the cartilage becomes degraded, the bones no longer have a smooth surface with which to articulate during motion. As tissues adjacent to the joint are continually irritated and/or stretched, symptoms such as pain and stiffness develop.(91,92) The cartilage continues to degrade, the joint loses its normal shape, and pieces of bone or cartilage may separate from the joint structures and become enmeshed in the cartilaginous layer, adding further pain and damage.

Individuals with OA may also experience a rubbing or grating sensation in the joint during activities such as climbing stairs or bending, or referred pain (pain in regions other than the joint) in areas such as the arms, legs, neck, thigh, or legs. Stiffness generally occurs in the morning upon awakening or after long periods of inactivity, such as sitting, and usually diminishes with activity.

The precise cause of OA is not clear, but it is most likely a combination of genetics, environmental factors, metabolic processes, and biochemical factors that affect the body's ability to properly balance the normal processes of destruction and repair in the joint.(93,94) OA is categorized as follows:

- Primary generalized arthritis
    - Heredity: primary generalized arthritis appears to run in families. It follows the basic pattern of cartilage thinning and damage.
- Secondary OA
    - Joint injury or overuse: Subjecting the joints to repeated stress or strain—for example, through sports activities or occupational requirements—will degrade the cartilage of the joints under the particular strain.
    - Inactivity: Just as overuse may result in cartilage damage, underuse may result in the same result as the muscles weaken and are unable to properly support the joints.
    - Excess body weight: body weight in excess of healthy norms creates additional stress on joints, particularly in the hips and knees, which are the major load-bearing joints in the body, resulting in wear and tear damage.

Prevalence and Incidence

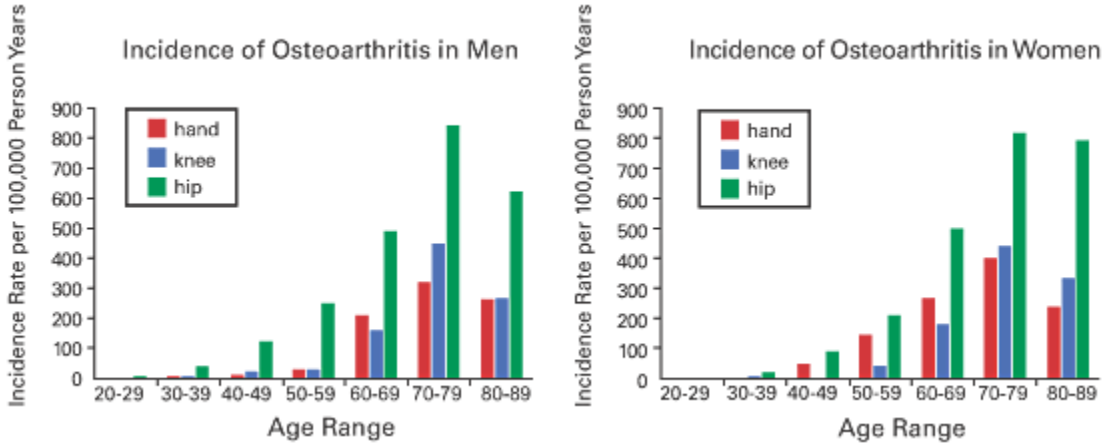
The prevalence and incidence of arthritis varies widely. Overall, approximately 46 million adults in the United States reported physician-diagnosed arthritis, including OA, RA, metabolic arthritis, lupus, or fibromyalgia. This figure translates to a prevalence of nearly 1 in 5 adults, with a total of 18.9 million adults reporting that their daily activities[5] were limited due to arthritis. Of adults aged 65 or over, 50% reported being diagnosed with arthritis. It is projected that almost 67 million individuals in the United States will have an arthritis diagnosis by the year 2030. In keeping with these projections, it is believed that 25 million adults will report arthritis-related limitation of daily activities. Of the total number of adults in the United States currently living with arthritis, almost 21 million have OA, 2.1 million have RA, and 5.1 million have been diagnosed with metabolic arthritis.(95)

Incidence rates for the United States for symptomatic knee OA range at about 1% of the population per year; radiographically confirmed knee OA occurs in 2% of the population per year. A study by Oliveria et al.

[5] These activities include sitting, standing, reaching, pushing, carrying, and walking.

(1995) demonstrated that men were more likely to develop symptomatic OA of the hip, hand, and knee before the age of 50; after that age, women were more likely to develop the condition. (See Figure 4)(96)

Figure 4. Incidence Rates for Osteoarthritis in Males and Females



From Oliveria et al., 1995(96)

Risk Factors

The risk for developing OA increases with age, most likely as a result of the cumulative effects of genetics, environment, and biochemical and metabolic factors. Risk factors for OA include:

- Nonmodifiable
  - Gender
  - Age
  - Genetics/heredity
- Modifiable
  - Obesity
  - Joint injuries
  - Infections
  - Occupation

Treatments for Osteoarthritis

The treatment options for OA depend on the etiology, severity, occupation, age, and projected progression of the condition. Treatments for OA are not able to cure or arrest the progression of the disorder. Instead, they function to decrease pain and stiffness and improve movement, thus enabling the individual to perform functions of daily living.(97) Effective treatment of OA usually involves the combination of a number of treatments, including the following:(98,99)

- Weight loss to decrease stress on joints
- Exercise to stretch and strengthen muscles and reduce stiffness
- Rest
- Pharmacotherapy (NSAIDs; aspirin; cox-2 inhibitors)
- Topical analgesics
- Thermal and cold therapy
- Physical and occupational therapy
- Assistive devices (braces, canes, etc.)
- Surgery (arthroscopy, osteotomy, hemicallotasis, arthrodesis, and arthroplasty)

Inflammatory Arthritis

Inflammatory arthritis differs from other arthritic disorders in that it arises from rheumatic conditions. The condition is associated with pain, redness, and swelling that tend to affect the same joints on both sides of the body to the same degree, along with stiffness associated with resting. This contrasts with other arthritic disorders that are generally characterized by pain that is aggravated by movement and/or weight bearing that diminishes when the affected area is rested, and asymmetrical distribution in the joints. The most common types of inflammatory arthritis appear in Table 17.

Table 17. Inflammatory Arthritides

Arthritis	Causes	Effects	Diagnosis	Treatment	Risk Factors
Rheumatoid Arthritis (RA) Chronic, systemic disease Prevalence: 2.1 million in United States (600,000 male, 1.5 million female) [1998 figures]	Exact cause unknown Autoimmune disease / diseases with common features Genetics (HLA-DR4 marker) Infection (proposed theory: immune reaction to infection triggers RA response)	Long-term joint deformity, damage, and instability Limited range of motion (ROM) Pain (especially in conjunction with long periods of sitting) Weakness Fatigue Loss of function Disability	**Medical history** **Physical exam** **Lab tests** Blood Count Erythrocyte Sedimentation Rate (ESR) C-Reactive Protein Rheumatoid Factor Antinuclear Antibodies (ANA) **Imaging Studies** Radiographs Magnetic Resonance Imaging (MRI) Joint Ultrasound Bone Densitometry (DEXA) **Functional impact** Arthritis Impact Measurement Scale (AIMS) **Genetic marker testing** (HLA-B27) **Any two of the following clinical criteria:** Recurring genital sores Eye inflammation with vision loss Characteristic skin lesions Positive pathergy test	**Pharmacotherapy** Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) Analgesics (acetaminophen, morphine) Glucocorticoids or Prednisone Disease-modifying Antirheumatic Drugs (DMARDs) (methotrexate, penicillamine, azathioprine, oral gold) Biologic Response Modifiers (etanercept, infliximab) Protein-A Immmunoadsorption Therapy Tumor necrosis factor inhibitors (e.g., etanercept, infliximab) **Surgery** Synovectomy Arthroscopic Surgery Osteotomy Joint Replacement Surgery or Arthroplasty Arthrodesis or fusion Synovectomy **Self-management** Exercise Balancing Activity and Rest Depression Awareness and Treatment	Female Gender (2:1, or 3:1) Received blood transfusion Ethnicity (higher risk if Caucasian or Native American) Obesity Diet and Behavior (use of coffee and /or cigarettes)
Inflammatory Arthritis Associated with Other Diseases					
Psoriatic Arthritis (PsA)	Unknown cause Possible associated factors include: Heredity Autoimmune Environment	Inflammatory arthritis begins about 10 years after onset of psoriasis. These include: Monoarticular or Oligoarticular arthritis Polyarthritis Arthritis mutilans Axial disease Typically affects the large joints of the lower extremities, distal joints of fingers and toes, lumbar vertebrae, and sacroiliac joints	**Imaging Studies** Radiographs **Lab tests** Joint Fluid Test ESR Rheumatoid Factor	**Pharmacotherapy** NSAIDs Analgesics (acetaminophen, morphine) Glucocorticoids or Prednisone DMARDs (methotrexate, penicillamine, azathioprine, oral gold) Immunosuppressants Tumor necrosis factor (TNF)-alpha inhibitors Biologic Response Modifiers **Self-management** Maintain healthy weight Exercise Rest Thermal or cold therapy **Surgery** Joint Replacement Surgery or Arthroplasty	Psoriasis Age Gender (males have higher rate of spondylitis; females have higher rate of symmetrical arthritis) Family history

Arthritis	Causes	Effects	Diagnosis	Treatment	Risk Factors
Reactive Arthritis (ReA)	**Infection by any of the following agents:** Neisseria Gonorrhoeae Staphylococcus Streptococcus **Infection by Gram-negative organisms:** Salmonella Pseudomonas aeruginosa Enterobacter Klebsiella Serratia **Anaerobic Infection:** Ureaplasma urealyticum Pasteurell multocida Mycobacterium marinum Mycobacterium tuberculosis Treponema Pallidum **Fungal Infections**	Inflammation of the urogenital tract Pain and swelling in affected joint(s) Tendinitis Enthesitis **Development of:** Bone spurs Spondylitis Sacroiliitis Long-term joint deformity, damage, and instability Limited ROM	**Medical History** **Physical Examination** **Lab tests** Synovial fluid count Polarized microscopy to r/o Metabolic arthritis Gram stain and culture Blood Culture **Imaging: of limited value** Radiographs MRI Ultrasound Computed tomography (CT) scan Radionuclide scan	**Drainage of affected joint** **Pharmacotherapy** Parenteral antibiotics NSAIDs **Joint immobilization**: for period of 1 – 3 days **Exercise**	Age RA diagnosis Intravenous (IV) Drug use Hemodialysis therapy HIV infection Organ transplant Prosthetic joint
Crystal-induced Arthritis					
Metabolic Arthritis	Exact cause is unknown Overproduction of uric acid Inability of kidneys to effectively eliminate uric acid	Pain and swelling in affected joints Long-term joint deformity, damage, and instability Limited ROM Tophi development in cartilage, tendons, kidneys, and soft tissue	**Joint aspiration** **Lab tests** Complete blood count (CBC) Urinalysis Serum creatinine Blood urea nitrogen Serum uric acid	**Self-management** Maintain healthy weight Decreased alcohol consumption Decreased consumption of foods with a high purine content (i.e., liver, green peas, oatmeal) Control of hyperlipidemia Control of hypertension **Pharmacotherapy** NSAIDs Colchicine Corticosteroids Uricosuric drugs	Gender (male; postmenopausal females) Hypertension Heavy alcohol use Diabetes Obesity Sickle cell anemia Kidney disease Use of pharmacotherapy that interferes with uric acid elimination

Pathophysiology

The pathophysiology of inflammatory arthritis depends on its etiology. The following subsection will give a brief overview of the pathophysiology of RA, PsA, reactive arthritis, and metabolic arthritis.

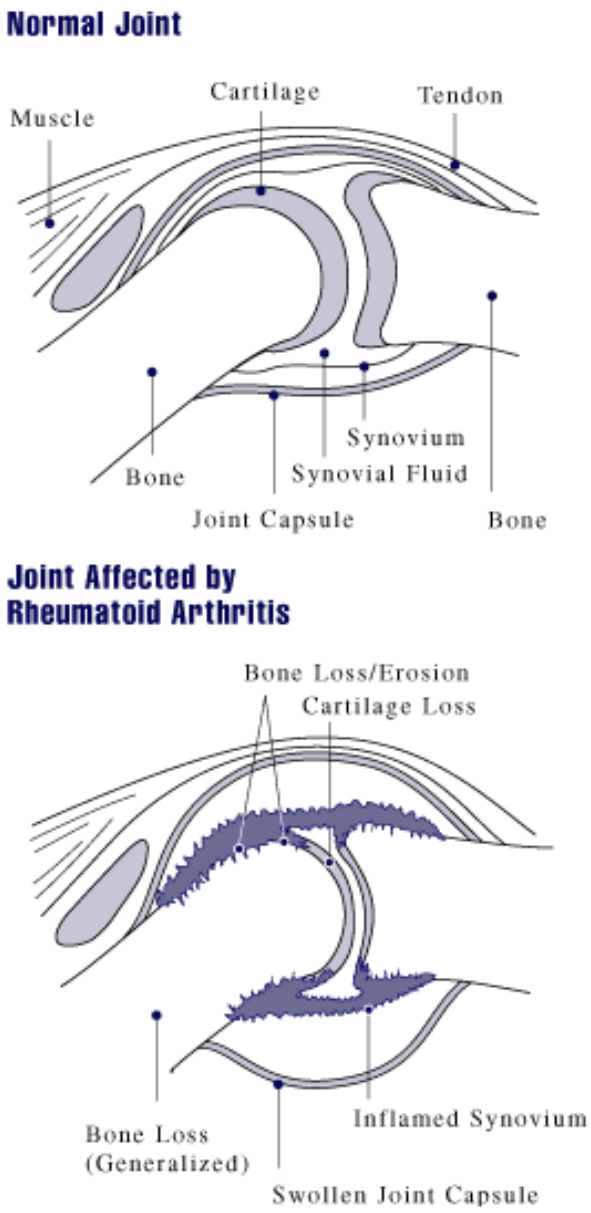
Rheumatoid Arthritis (RA)

The exact cause of RA is unknown. It is conjectured that the development of RA involves autoimmune reactions related to a complex interaction of genetic, environmental, and behavioral factors. These factors work to produce an immune reaction in the cells of the synovial lining of the joint and in nearby blood vessels.(100) In the affected joint, the synovial lining becomes thicker and develops rugae. The joint's synovial cells produce substances that act to destroy cartilage or stimulate cartilage destruction, absorb bone, and/or produce or encourage synovial inflammation. In addition, the autoimmune reaction encourages fibrin deposition, causing fibrosis and necrosis in the joint.(101) Ultimately the cartilage, subchondral bone, articular capsule, and ligaments of the joint erode, and rheumatoid nodules may develop.(102,103) RA can culminate in permanent joint deformity.(104-109) The differences between a normal joint and a joint with RA are illustrated in Figure 5.

Symptoms of RA are related to the destruction of the joint and damage to surrounding tissues. They include the following:

- Morning stiffness
- Fatigue
- Generalized weakness
- Low-grade fever
- Pain, warmth, and swelling
- Limited ROM

Figure 5. Normal Joint and Joint with Rheumatoid Arthritis



http://www.niams.nih.gov/Health_Info/Rheumatic_Disease/rheumatoid_arthritis_hoh.pdf

Psoriatic Arthritis (PsA)

The exact cause of PsA is unknown. It is believed to be a result of a complex interaction of genetic, environmental, infectious disease, and behavioral factors that work to produce an immune reaction. This reaction includes a persistent inflammation of the skin and synovium that is not present in RA. PsA is hallmarked by angiogenesis, osteoclast precursors, expanded lymphocytes, and a high level of cytokines in the skin and joint tissues. These factors work together to cause erosion of the joints, the

proliferation of bony growths, increased water content in the bone marrow that may hasten erosion, and gross destruction of small joints in the body.(110-114) Symptoms include the following:

- Swelling of the joint
- Redness
- Warmth of the joint
- Stiffness of affected joint(s)

Reactive Arthritis (ReA)

The exact cause of ReA is unknown. It is believed that ReA represents the result of immune reaction related to the introduction of a variety of "arthritogenic microbes" that colonize within the synovium and stimulate cytokines and prostroglandins, leading to overstimulation of the immune system and inflammation in the joints.(115-117) Ultimately, this immune system response may involve the skin, eyes, and joints.(118) Symptoms of ReA include the following:

- Joint pain
- Inflammation of the joint
- Inflammation of the tendons surrounding the joint

Metabolic arthritis

The exact cause of metabolic arthritis is unknown. It is believed to be a result of a complex interaction of genetic, environmental, and behavioral factors that create hyperuricemia (an elevated level of uric acid in the body).(119) The excess uric acid then goes on to form monosodium urate crystals,(120) which are deposited in the cartilage, tendons, tendon sheaths, ligaments in the distal joints (metatarsals), and larger joints such as the knees. These crystals then form nodules of uric acid crystals that limit the ability to move and cause the deformities typical of metabolic arthritis. Having an elevated level of uric acid in the body is not guaranteed to lead to metabolic arthritis: some individuals with hyperuricemia do not develop the condition.

The first signs of metabolic arthritis typically occur in a single joint, often the toes, ankles, wrists, and elbows.(119,121) Symptoms of metabolic arthritis include the following:

- Sudden, excruciating pain in the affected joint with a nocturnal onset that increases in intensity over a period of hours
- Swelling of the joint
- Warmth
- Joint becomes red
- Joint is very tender to the touch

Treatments

The treatment options for inflammatory arthritis depend on the etiology, severity, occupation, age, and projected progression of the condition. Treatments for inflammatory arthritis are not able to cure or arrest the progression of the disorder; instead, they function to decrease pain and stiffness and improve movement, enabling the individual to perform functions of daily living.(122) Effective treatment of inflammatory arthritis usually involves the combination of a number of treatments.(123) The treatments for each of the specific inflammatory arthritides in this report appear in Table 18.(124)

Table 18. Treatments for Inflammatory Arthritides

Type of Arthritis	Treatment
Rheumatoid Arthritis	**Pharmacotherapy** Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) Analgesics (acetaminophen, morphine) Glucocorticoids or Prednisone Disease-modifying Antirheumatic Drugs (DMARDs)(methotrexate, penicillamine, azathioprine, oral gold) Biologic Response Modifiers (etanercept, infliximab) Protein-A Immunoadsorption Therapy Tumor necrosis factor-alpha (TNF-alpha) inhibitors (e.g., etanercept, infliximab) **Surgery** Synovectomy Arthroscopic Surgery Osteotomy Joint Replacement Surgery or Arthroplasty Arthrodesis or fusion Synovectomy **Self-management** Exercise Balancing Activity and Rest Depression Awareness and Treatment
Psoriatic Arthritis	**Pharmacotherapy** NSAIDs Analgesics (acetaminophen, morphine) Glucocorticoids or Prednisone DMARDs (methotrexate, penicillamine, azathioprine, oral gold) Immunosuppressants TNF-alpha inhibitors Biologic Response Modifiers **Self-management** Maintain healthy weight Exercise Rest Thermal or cold therapy **Surgery** Joint Replacement Surgery or Arthroplasty
Reactive Arthritis	**Drainage of affected joint** **Pharmacotherapy** Parenteral antibiotics NSAIDs **Joint immobilization**: for period of 1-3 days **Exercise**
Metabolic arthritis	**Self-management** Maintain healthy weight Decreased alcohol consumption Decreased consumption of foods with a high purine content (i.e., liver, green peas, oatmeal) Control of hyperlipidemia Control of hypertension **Pharmacotherapy** NSAIDs Colchicine Corticosteroids Uricosuric drugs

Identification of Evidence Base

To meet the aims of this section of the evidence report, we searched for trials that compared crash risk among individuals who had OA or inflammatory arthritis with otherwise comparable individuals who did not have OA or inflammatory arthritis. In addition, we looked for studies that compared the prevalence of OA or inflammatory arthritis among cohorts of individuals who had or had not experienced a crash. We also searched for studies that detailed OA or inflammatory arthritis functional outcomes that might affect driving.

The evidence base identification pathway for Key Question 2 is summarized in Figure 6. Our searches (Appendix A) identified a total of 1,113 articles that appeared relevant to this key question. Following application of a set of retrieval criteria (Appendix B), 123 full-length articles were retrieved and read in full. Of these 123 retrieved articles, 7 were found to meet the inclusion criteria for Key Question 2 (Appendix C). Table 19 lists these 7 included studies. Table D-2 of Appendix D lists the 116 articles that were retrieved but then excluded from inclusion in the evidence base for Key Question 2, and it provides the reason for their exclusion.

Figure 6. Development of Evidence Base for Key Question 2

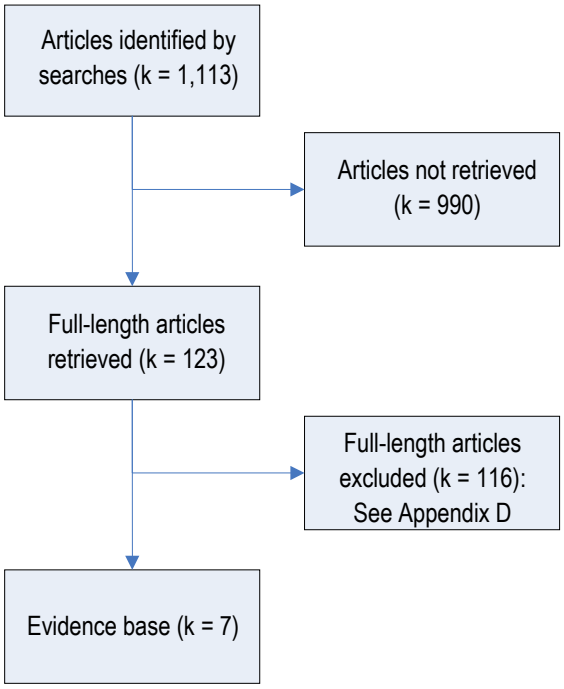


Table 19. Evidence Base for Key Question 2

Reference	Year	Study Location	Country
Cranney et al.(125)	2005	Ontario	Canada
Koepsell et al.(126)	1994	Washington	United States
McGwin et al.(127)	2000	Alabama	United States
Sims et al.(128)	2000	Alabama	United States
DiStefano et al.(129)	2003	Melbourne	Australia
Ostrow et al.(130)	1992	West Virginia	United States
Jones et al.(40)	1991	Rotorua	New Zealand

Evidence Base

This subsection provides a brief description of the key attributes of the seven studies that comprise the evidence base for Key Question 2. Here we discuss pertinent information pertaining to the quality of the included studies and the generalizability of each study's findings to drivers of commercial vehicles. Key characteristics of the 7 included studies that address Key Question 2 are presented in Table 20. More detailed information pertinent to this section is presented in the *Study Summary Tables* that can be found in Appendix G. Although all 7 studies may be considered to address the question of whether the arthritides affect driving ability from a qualitative perspective, they examine different outcomes and cannot be combined into a quantitative analysis.

Three included studies examined the relationship between the arthritides and crash risk using a case-control design.(126-128) Three included studies examined the relationship between arthritis and driving disability.(40,125,129) The final included study was a randomized controlled trial (RCT) that examined the impact of a ROM exercise rehabilitation program on drivers with arthritis.(130)

Table 20. Key Study Design Characteristics of Studies that Address Key Question 2

Reference	Year	Study Design	Comparison	Risk Factors Assessed (Method)	Primary Outcome	Definition of Crash	Driving exposure controlled for?	Comorbidities	Pharmacotherapy
Crash Studies									
Koepsell et al.(126)	1994	Case control	Individuals who had received medical care within 7 days of a motor vehicle collision vs. Individuals who had not been injured in a police-reported motor vehicle crash	Osteoarthritis (OA) Rheumatoid Arthritis (RA)	Crash	Police-reported motor vehicle collision, without or without accompanying traffic violation	No	Cardiovascular disease Neurologic disease Diabetes mellitus Fall in previous year Depression Alcohol abuse Chronic obstructive pulmonary disease Asthma Cancer	Not reported (NR)
McGwin et al.(127)	2000	Case control	Individuals involved in a minimum of one automobile crash between Jan. 1 and Dec. 31 1996 vs. Individuals identified from the Alabama Department of Public Safety database	Arthritis	Crash	Police-reported motor vehicle collision	Yes (mileage driven)	Hypertension Cardiovascular disease Stroke Cancer Cataracts Glaucoma Diabetes Kidney disease Diabetic retinopathy Diabetic neuropathy Cognitive impairment Visual impairment	Angiotensin converting enzyme inhibitors Benzodiazapines Calcium channel blockers Vasodilators Nonsteroidal anti-inflammatory drugs (NSAIDs) Anticoagulants
Sims et al.(128)	2000	Case control	Individuals involved in a minimum of one automobile crash between Jan. 1 and Dec. 31 1996 vs. Individuals identified from the Alabama Department of Public Safety database	Arthritis	Crash	Police-reported motor vehicle collision	No	Prior fracture Hypertension Cataract Pulmonary disease Gastrointestinal diseases Heart disease Peptic ulcer Diabetes mellitus Cancer history Stroke/Transient Ischemic attack	Diuretic Angiotensin converting enzyme inhibitors Benzodiazapines Calcium channel blockers Vasodilators NSAIDs Anticoagulants Beta blocker

Reference	Year	Study Design	Comparison	Risk Factors Assessed (Method)	Primary Outcome	Definition of Crash	Driving exposure controlled for?	Comorbidities	Pharmacotherapy
								Other eye disease Macular degeneration Glaucoma Renal disease Seizures Liver disease Diabetic retinopathy	Nonprescription Estrogen Hypnotic Antidepressant Sedating antihistamine Adrenocortical extract inhibitor Oral hypoglycemic Skeletal muscle relaxant Centrally acting antihypertensive Alpha blocker Anticonvulsant Insulin Barbiturate Narcotic Urinary opiates Urinary benzodiazepine
Studies of Driving Performance/Ability									
DiStefano et al.(129)	2003	Case series	Individuals referred for driving competency tests	Arthritis	Intersection negotiation Lane changing Position and speed Low speed maneuver Safety margin Car control	Not applicable (NA)	No	Cardiovascular disease Endocrine disorder Musculoskeletal disorder (other than arthritis) Mental/behavioral disorder Visual disorder	NR
Jones et al.(40)	1991	Case series	Individuals referred to hospital driving assessment program	Arthritis: RA, osteoarthritis, fibromyalgia, ankylosing spondylitis, low back pain Miscellaneous: juvenile chronic arthritis, systemic lupus erythematosus, polymyalgia rheumatica,	Seat belt manipulation Key manipulation Hand brake Open/close door Mirror adjustment Use of gears Reaching seat belt Steering/cornering Reversing	NA	No	NR	NR

Reference	Year	Study Design	Comparison	Risk Factors Assessed (Method)	Primary Outcome	Definition of Crash	Driving exposure controlled for?	Comorbidities	Pharmacotherapy
				adhesive capsulitis, arthrodesis of the hip, generalized osteoporosis, monoarthritis of the hip, stable crush fracture of cervical spine	Seat comfort and position Entry/exit Foot pedals Awareness of traffic and pedestrians Confidence				
Cranney et al.(125)	2005	Cross-sectional survey	520 individuals with RA	Arthritis	Functional status	NA	No	NR	Disease-modifying antirheumatic drugs (DMARDs): 94.6% ≥2 DMARDs: 63.4%
Impact of a Rehabilitation Program									
Ostrow et al.(130)	1992	Randomized controlled trial (RCT)	Individuals who received and 8 week range of motion (ROM) exercise training vs. Individuals who did not receive ROM training	RA	Automobile Driving On-Road Performance Test (ADOPT): Handling time Handling direction Handling position Straight line backing Straight backing time Handling (composite score) Safe practices Observing	NA	No	NA	NA

Quality of Evidence Base

The results of our assessment of the overall quality of the evidence base for Key Question 2 are presented in Table 21. Complete details of our quality assessment can be found in the *Study Summary Tables* presented in Appendix G. Our assessment found that the quality of the included studies was in the low-to-moderate range. Five of the seven included studies were graded as being moderate quality. The remaining two studies were graded as low quality.

Table 21. Quality of Studies for Key Question 2

Reference	Year	Quality Scale Used	Quality
Crash Studies			
Koepsell et al.(126)	1994	Revised Newcastle-Ottawa Quality Assessment Scale Case Control Studies	Low
McGwin et al.(127)	2000	Revised Newcastle-Ottawa Quality Assessment Scale Case Control Studies	Moderate
Sims et al.(128)	2000	Revised Newcastle-Ottawa Quality Assessment Scale Case Control Studies	Moderate
Studies of Driving Performance/Ability			
Cranney et al.(125)	2005	Revised Newcastle-Ottawa Quality Assessment Scale Cohort Studies	Moderate
Jones et al.(40)	1991	Revised Newcastle-Ottawa Quality Assessment Scale Cohort Studies	Moderate
DiStefano et al.(129)	2003	Revised Newcastle-Ottawa Quality Assessment Scale Cohort Studies	Moderate
Studies of a Rehabilitation Program			
Ostrow et al.(130)	1992	ECRI Institute Assessment Tool for Controlled Interventional Studies that have Independent Groups	Moderate

Generalizability of Evidence to Target Population

Important characteristics of the individuals represented in the seven studies that comprise the evidence base for Key Question 2 are presented in Table 22.(131)

The generalizability of the findings of these latter studies to CMV drivers is unclear. All of the studies included private motor vehicle license holders, an unknown number of whom may have held commercial driver licenses. Exposure to risk is lower among noncommercial vehicle drivers, because their driving exposure is lower than that of CMV drivers. Women tend to be overrepresented in studies of general driver populations. In this case, the number of females included in the studies of private motor vehicle license holders ranged from 75% to 22%, meaning that gender may be an issue when considering generalizability of populations. The ages of the private motor vehicle license holders included in these studies are likely to be slightly older, on average, when compared to those of CMV drivers. It is unclear whether the ethnicity of the private motor vehicle license holders included in these studies is representative of CMV drivers due to lack of reporting.

Table 22. Individuals with Arthritis Enrolled in Studies that Address Key Question 2

Reference	Year	Number of Individuals with Arthritis Included (n =)	Diagnosis (e.g., questionnaire)	Age Distribution	% Male	% CMV Drivers	Driving Exposure	Ethnicity	Generalizability to Target Population
Crash Studies									
Koepsell et al.(126)	1994	Cases: n = 234 Controls: n = 446	Physician diagnosed (medical record)	≥65	50%	Not reported (NR)	Miles driven in previous year: Cases (%): <5,000: 44; 5,000–10,000: 25; >10,000–15,000: 20; >15,000: 12 Controls (%): <5,000: 44; 5,000–10,000: 28; >10,000–15,000: 19; >15,000: 8	NR	Unknown
McGwin et al.(127)	2000	Cases: n = 454 Controls: n = 198	Physician diagnosed	65 to 93	Cases: 49.6 Controls: 51.1	NR	Miles driven in previous year: Cases (%): <4,000: 25.8; 4,000–7,999: 26.2; 8,000–13,000: 21.3; >13,000: 26.6 Cases (%): <4,000: 32.4; 4,000–7,999: 22; 8,000–13,000: 21.4; >13,000: 24.2	Cases (%): W: 74.6; B: 23.0; O: 2.5 Controls (%): W: 74.2; B: 22.5; O: 3.3	Unknown
Sims et al.(128)	2000	n = 174	Physician diagnosed	55 to 78+	52.6%	NR	NR	Black: 14.9% White: 85.1%	Unknown
Studies of Driving Performance/Ability									
Cranney et al.(125)	2005	n = 520	Physician diagnosis	26 to 76	29.8%	NR	NR	NR	Unknown
Jones et al.(40)	1991	n = 533	Physician diagnosed	Average: 76.1 Range: 24-100	68%	NR	NR	NR	Unknown
DiStefano et al.(129)	2003	n = 94	Physician diagnosed	NR	23.4%	NR	NR	NR	Unknown
Studies of a Rehabilitation Program									
Ostrow et al.(130)	1992	n = 32	NR	60-85 years of age	Treatment: 31% Control: 25%	NR	NR	NR	Unknown

Findings

The individual findings of each of the seven studies that address Key Question 2 are presented in detail in Appendix G. Three of these studies examined whether the arthritides were associated with an increase in an individual's risk for a motor vehicle crash.(126-128) Four additional studies examined whether the arthritides were associated with the ability to carry out driving-related tasks, such as steering, use of gears, and use of the brake pedal.(40,125,129,130)

Crash Studies

Koepsell et al. Study

The Koepsell et al. study(126) examined whether having arthritis would increase an individual's risk of a motor vehicle crash. The data were collected using a matched case-control design from individuals who participated in the Group Health Cooperative of Puget Sound (GHC, Washington state). To qualify as a case (n = 234), an individual had to be aged ≥65 years and had to have experienced a motor vehicle crash that required medical care within 7 days of the index event. Controls (n = 446) were required to be GHC participants aged ≥65 years, matched by gender and county of residence, and those who had not experienced a motor vehicle crash. Each participant, or an appropriate surrogate, completed a questionnaire addressing a number of variables, including the following:

- Driving habits
- Miles driven per year
- Disease status: OA or RA

Koepsell et al. calculated ORs to determine the relative risk of motor vehicle crash associated with a number of chronic conditions, including the arthritides. Mantel-Haenszel techniques for stratified data were employed to control for differences at baseline. Further controlling for confounding factors was carried out using a conditional logistic regression approach. While these analyses may be suggestive of an association between OA, RA, and crash, neither analysis found these associations to be statistically significant (OR = 1.1 [95% CI: 0.8 – 6.0] and 1.6 [95% CI: 0.5 – 5.3], respectively). Because the study was not powered to detect the increases in crash risk observed, the findings of this study must be considered as inconclusive.

McGwin et al. Study

The McGwin et al. study(127) examined whether having arthritis would increase an individual's risk of a motor vehicle crash. (Quality Rating: Moderate) Data examined in this case-control study were obtained from the Alabama Department of Public Safety (ADPS): to be eligible, individuals had to be 65 years of age or older and have a driver's license. Cases (n = 447) were comprised of individuals who had been involved in a minimum of one motor vehicle crash between January 1 and December 31, 1996. Controls (n = 454) were comprised of individuals who had not had a motor vehicle crash during the same time period; controls were frequency matched to cases by age and gender. Telephone interviews were conducted with all cases and controls to obtain data on the following:

- Demographic data: age, gender, ethnicity, marital status, and education
- Chronic medical conditions
- Medications
- Visual function
- Cognitive status
- Driving habits (quality of driving, estimated yearly mileage, level of comfort with driving situations such as driving at night, etc.)

The data were analyzed using frequency distributions, and ORs were calculated for the demographic and driving variables. Unconditional logistic regression models were used to compare the at-fault cases to the control group and to the not at-fault cases.

The authors separated the population into three separate subgroups: 1 case group of individuals with various medical conditions who had crashed in the year 1997; and 2 control groups of individuals with various medical conditions who had not been involved in a crash and drivers with various medical conditions who had been involved in a crash but were deemed to be "not at fault." The prevalence of arthritis among cases (individuals who crashed) was compared to that observed in the two control groups while controlling for age, gender, race, and annual mileage. This analysis found that the prevalence of arthritis was slightly higher than that observed among noncrashers. However, this slight increased prevalence was not statistically significant (OR = 1.2 [95% CI 0.9 – 1.7]). Further subgroup analysis found that the prevalence of arthritis among women who had crashed was significantly increased (OR = 1.8 [95% CI: 1.1 – 2.9] females only; OR = 0.8 [95% CI: 0.5 – 1.3] males only). Consequently, the findings of McGwin suggest that arthritis is a significant risk factor for crash among women but not among men.

Sims et al. Study

The third study to attempt to determine whether arthritis is associated with an increased risk for a crash was reported on by Sims et al.(128) These investigators reported on a variety of medical and functional factors associated with crashes in a group of drivers from Alabama. Relevant data were collected via the application of an in-depth medical, functional, visual, and cognitive evaluation administered to individuals (n = 174) aged ≥55 years who lived in Jefferson County, AL in 1989. These evaluations were then repeated two years later. Information regarding the outcome of interest—crash—was obtained from ADPS.

Sims et al. used Cox proportional hazard models to determine relative risk and 95% CIs associated with a number of medical conditions, including arthritis. Tests of linear trend were performed with the Cox models, and significance was assessed with the Wald chi-square test. In addition, model fit was assessed through Martingale and deviance residuals that were plotted against the rank of person miles; influence statistics were determined, and collinearity was examined.

This analysis found no evidence to support the contention that individuals with arthritis are at increased risk for a crash (RR = 1.04 [95% CI: 0.61–1.78]).

Arthritides and Driving-related Tasks

None of the three studies above provide convincing evidence that arthritis has an impact on driver safety. Because of the small size of the included studies, and their consequent low power to detect an increase in crash risk, we cannot conclude that no association between arthritides and crash exists. Rather, it remains unclear whether drivers with arthritis are at an increased risk for a crash.

Because the findings of the only studies to have examined the risk for a crash among individuals with arthritis are inconclusive, we looked for other sources of evidence that may provide some insight into the relationship between arthritis and driver safety. The findings of these additional studies are presented below.

Cranney et al. Study

Cranney et al.(125) conducted a study to assess self-reported problems with driving experienced by individuals with RA. Five hundred twenty individuals with RA were identified using the Southeastern Ontario Academic Medical Organization database. Participants completed a questionnaire that asked about driving status (still driving or not) and several other variables.

Forty individuals were found to have abandoned driving. Reasons for discontinuation included the impact of arthritis on driving ability and a fear of becoming involved in a crash. Individuals who had discontinued driving were significantly older than those who had not (63.5 years of age versus 58.1), and they were more likely to have a higher score for the HAQ[6] than those who remained driving.

RA was identified as a factor that limited self-reported driving ability in 58% of all participants. Stiffness (51.3%) and pain (57%) were the most frequently reported limiting agents in driving, with activities performed both before (mirror adjustment) and during (shoulder checks, or turning the head to monitor other traffic) driving noted in the questionnaire responses. Individuals with foot pain reported limitation of, but not difficulty during, driving. Neck pain was associated in a 20% increase in limiting of driving, while low back pain was associated with an 18% increase in driving limitation. A total of 8% of individuals then driving reported that they had been involved in a crash that they associated with their RA.

Jones et al. Study

Jones et al.(40) examined the ability to perform a variety of driving functions (e.g., reversing, steering/cornering, use of gears and foot pedals) in a group of individuals with arthritis (n = 94; 72 females, 24 males) who were attending a hospital-based occupational therapy clinic.

[6] The Health Assessment Questionnaire (HAQ) is an instrument used to determine functional status.

The authors found that, overall, individuals with RA had the highest percentages of driving disabilities, with RA affecting driving abilities, including steering and cornering, mirror adjustment, use of the gears, and use of the handbrake. Individuals with OA had the second highest percentages of driving disabilities, with OA affecting driving abilities, including reversing (where it exceeded the RA percentages), steering/cornering, and seat comfort and position.

The authors then examined whether two methods of adaptive driving technique—the "threading" method of steering, and reversing with mirrors—would be of assistance for individuals with RA and OA. It was found that approximately 89% of individuals with RA experienced an improvement in driving ability with the threading steering method, and 80% of that population experienced improvement using the reversing with mirrors method. Of the individuals with OA, 100% experienced an improvement in driving using the threaded steering method, while approximately 82% experienced an improvement in using the reversing with mirrors method.

DiStefano et al. Study

DiStefano et al.(129) attempted to establish the types of driving errors that occurred among older drivers and examine the relationship of these errors to driving test outcomes. The data were collected from a series of "fitness to drive" assessments (n = 496) performed by the VicRoads agency of the Victoria, Australia government.

The disorders were organized into three categories – physical, cognitive, and mixed. Chi-square tests indicated that there was no significant relationship between any of these categories and whether an individual passed or failed the driver assessment test. A logistic regression analysis was performed to examine whether driver performance could predict into which category the participant was categorized: the results indicated that this was not the case.

Individuals with arthritic disorders failed the driver assessment test approximately 61% of the time: to put this into perspective, of the seven types of medical conditions listed, arthritis was the group with the highest percentage of failures. Scores for other conditions were cardiac (49%), endocrine (46%), visual (49%), musculoskeletal (48%), mental/behavioral (48%), and nil noted (43%).

Ostrow et al. Study

Ostrow et al.(130) examined the effect of an 8-week ROM exercise program on a variety of driving skills in a group of individuals with RA. The data were obtained through an RCT in which the treatment group (n = 16) received the exercise program training and weekly visits with a clinician. They were also required to record their compliance with the program, and their frequency and extent of driving. The control group (n = 16) did not participate in the exercise program or undergo weekly visits with a clinician. They did, however, keep a log of frequency and extent of driving. Individuals in both groups underwent two sets of tests at 1, 8, and 11 weeks into the study. The first set of tests examined ROM at five different joint sites, with specific tests addressing the following:

- Chin (flexion and extension)

- Neck rotation (left and right)
- Side bends (left and right)
- Trunk rotation (left and right)
- Shoulder flexion

The second set of tests utilized the Automobile Driver On-Road Performance (ADOPT) to examine the following:

- Handling time: total time to complete a parallel parking maneuver
- Handling direction: number of times the participant changed the direction of the vehicle during parallel parking maneuver
- Handling strikes: checking to see if the vehicle touched the parallel parking boundaries
- Handling position: the distance of the furthest tire from the curb at the completion of the parallel parking maneuver
- Straight-line position: did the vehicle vary from the straight-line backing boundaries in a parking situation
- Straight backing time: the amount of time taken to complete a straight-line parking maneuver
- Handling (composite score)
- Safe practices: gap selection, restricted travel, communication lane changing, maintaining speed around turns, observing to the rear, observing to the side, looking back, and observing rear quarter
- Observing: using mirrors, turning the head to the right or left, and looking over the shoulder

Ostrow et al. used ANOVAs to determine whether any improvements in the test scores were significant across the total testing sessions for each participant. It was determined that individuals in the exercise program group experienced significant improvement in trunk rotation to the right (but only for weeks one through six, with less improvement from weeks six through eight) and shoulder flexibility (throughout the testing period). In the control group, trunk rotation demonstrated a decline in the first six weeks of the study, with shoulder flexibility improving slightly during the course of the study. An examination of driving skills by group demonstrated a significant improvement in handling position (following a six-week decline at the beginning of the study) and observing in the treatment group. The control group declined in observing during the last two weeks of the study, but experienced an improvement in handling position. There was no significant difference in driving pattern changes between the treatment and control groups.

Section Summary

Whether the presence of an arthritide is associated with an increased risk for a crash among CMV drivers cannot be determined at this time.

Our searches did not identify any studies that examined crash risk (or a surrogate marker for crash risk) among individuals who drive a CMV and have an arthritide.

Although an arthritide appears to be associated with reduced driving performance and is cited as a reason for giving up driving by some individuals, it remains unclear whether those among the general driver population who choose to drive with arthritis are at an increased risk for experiencing a crash (Strength of Evidence: Minimally Acceptable).

Direct Evidence: Three included studies (Median Quality: Moderate) directly examined the relationship between the arthritides and crash risk using a case-control design. None of these studies provided evidence to support the contention that arthritis is associated with an increased risk for a motor vehicle crash. Because of the small size of the included studies, and their consequent low power to detect an increase in crash risk, we cannot conclude that no association between arthritides and crash exists. Rather, it remains unclear whether drivers with arthritis are at an increased risk for a crash.

Indirect Evidence: Because the findings of the only studies to have examined the risk for a crash among individuals with arthritis are inconclusive, we looked for other sources of evidence that may provide some insight into the relationship between arthritis and driver safety. Our searches identified four such studies. One study found that elderly individuals with arthritic disorders were more likely to fail a driving test. Another study found that many individuals with RA gave up driving as a direct consequence of their disorder, suggesting that this arthritide does impact driving ability. A third study found that RA or OA had a deleterious impact on driving ability. Individuals with RA appeared to experience the highest percentages of driving disabilities, with the disorder affecting several important driving tasks, including steering and cornering, mirror adjustment, use of the gears, and use of the handbrake. Individuals with OA experienced the second highest percentages of driving disabilities, with OA impacting driving tasks such as reversing (where it exceeded the RA percentages) and steering/cornering. In addition, the latter group experienced significant problems with attaining seat comfort. The final study demonstrated that individuals who underwent an exercise-based rehabilitation program designed to improve mobility showed improvements in range of motion and in one driving task (observing) when compared to similar individuals who did not receive rehabilitation training.

Key Question 3: Does decreased angle of rotation at the level of the spine and neck (as might be the result of ankylosis and/or other vertebral injury) increase crash risk and/or affect driving ability?

Background

Movement and function in the human body are quantified under the rubric of ROM, defined as the normal range of movement for a joint in flexion and extension. This normal distance and direction may be reduced (i.e., "limited ROM") by a number of factors, including the following:(132)

- Mechanical problems
- Joint pain
- Injury
- Disease (arthritis)

The ability to observe the general environment, accumulate important information necessary to drive a motor vehicle in specific settings, and perform the physical tasks central to operating a vehicle are all related to whether an individual has an adequate ROM. McPherson et al.(133) suggested a set of driving activities related to ROM. These activities are outlined in Table 23.

Table 23. Specific Joint Sites and ROM Affected in Driving

Joint Site	Range of Motion (ROM)
Neck (flexibility)	Fatigue prevention while driving Allows individual to look over shoulder while driving Facilitates parallel parking Facilitates reversing of vehicle Facilitates side-to-side viewing
Trunk (flexibility)	Facilitates parallel parking Facilitates reversing of vehicle Eases ability to adjust mirrors Facilitates making adjustments to instruments on dash or using controls such as lights or windshield wipers Facilitates side-to-side viewing
Spinal (flexibility)	Facilitates parallel parking Facilitates reversing of vehicle Eases ability to adjust mirrors Eases ability to pick up objects from floor or seat of vehicle
Overall (flexibility)	Braking Entering and exiting vehicle Side-to-side vision Steering Parking the vehicle Adjusting seat belts Long periods of sitting in vehicle Assists posture and prevents fatigue

Specific conditions related to compromised trunk kinematic status (a decrease in the angle of rotation at the level of the spine and neck), which are described in Table 24, include the following:

- Ankylosing spondylitis
- OA
- Spinal stenosis
- Degenerative disc disease
- Cervical spondylosis

This section of the evidence report will focus on these conditions.

It should be noted that the literature available on the potential effects of many of these conditions on driving performance is sparse. Hunter-Zaworski stated, "The transportation and human factors literature indicated that little is known about the relationship between physical limitations and driving performance." The absence of literature, as evidenced by our searches on the topic since this critique was made in 1990, indicates that little has been done to remedy the lack of evidence in the intervening years.(134)

A second item of note is recent research investigating the relationship between lumbar ROM and functional ability. Parks et al. examined this relationship and found that lumbar ROM and functional ability, as measured by factors such as walking time, sitting time, and lifting, was weak or nonexistent.(135) Sullivan et al. found similar results when examining the relationship between active spinal ROM and functional ability in individuals with low back pain.(136) As with the previous studies, Nattrass et al. found no evidence of a relationship between lumbar ROM and functional impairment. These studies serve as a reminder that reduced spinal ROM does not necessarily imply functional disability.(137)

Table 24. Rotational Disorders of the Spine

Condition	Causes	Effects	Diagnosis	Treatment	Risk Factors
Ankylosing Spondylitis (AS)	Unknown cause Linked to marker HLA-B27: 90% of individuals with AS have the genetic marker; however, <5% of individuals with the marker develop AS Infection (proposed theory: immune reaction to infection triggers AS response in those who have the genetic marker)	Sacroiliitis Stiffness Pain Stooped shoulder (with thoracic AS) Chest pain and tenderness Enthesitis Fatigue Synovitis Damage can lead to fusion of joints in spine or other areas	**Radiographs** **One of following three clinical criteria:** Low back pain / stiffness >3 months duration, improved with exercise but not with rest Functional limitation of lumbar spine on bending Limitation of ability to expand chest relative to established norms **Genetic marker testing** (HLA-B27) **Any two of the following clinical criteria:** Recurring genital sores Eye inflammation with vision loss Characteristic skin lesions Positive pathergy test	**Pharmacotherapy** Nonsteroidal anti-inflammatory drugs (NSAIDs) Corticosteroid injections Oral corticosteroid Tumor necrosis factor inhibitors (e.g., etanercept, infliximab) Miscellaneous (sulfasalazine, methotrexate) **Surgery** Hip, shoulder, or knee replacement Corrective spinal surgery **Exercise** **Posture Therapy**	Genetic predisposition: HLA-B27 <40 years of age Family member with disease
Cervical Spondylosis	Degenerative disc disease	Stiffness Pain Fatigue Radiculopathy Damage can lead to fusion of joints in cervical spine	Physical examination Radiographs Nerve function tests Myelogram	**Pharmacotherapy** NSAIDs **Surgery** Removal of bone spurs and decompression of damaged discs **Exercise** **Thermal Therapy**	Aging Wear and tear on spine Prior neck injury
Osteoporosis	Imbalance in bone deposition and resorption rates	Thin and brittle bones Fracture Kyphosis	Densitometry	**Calcium supplementation** **Increased vitamin D intake** **Exercise** **Pharmacotherapy** Biphosphonates Calcitonin Estrogens Parathyroid hormone Raloxifene	Aging Gender (female) Family history and personal history of adult fracture Ethnicity (White, Asian) Bone structure and body weight (small, low weight) Menopause/Menstrual history Lifestyle (smoking, excess alcohol consumption) Medications/Chronic diseases (ex. anticonvulsants)

Condition	Causes	Effects	Diagnosis	Treatment	Risk Factors
Spinal Stenosis	Advancing age Arthritis Scoliosis	Narrowing of spinal canal Pain Radiculopathy Weakness in legs or arms	Physical examination Radiographs Magnetic Resonance Imaging (MRI) Computed tomography (CT) Myelogram	**Physical therapy** **NSAIDs** **Steroid injections** **Surgery** **Laminectomy** **Spinal fusion**	Aging Narrow spinal canal at birth
Degenerative Disc Disease	Advancing age	Pain Compression of discs	Physical examination Radiographs	**Thermal therapy** **NSAIDs** **Physical Therapy** **Exercise** **Surgery**	Aging Acute injury Chronic/repetitive injury Heavy physical work Obesity Smoking

Ankylosing Spondylitis of the Spine

Ankylosing spondylitis of the spine is a condition in which areas of tissue that serve as attachment sites for ligaments, muscles, and joint capsules to bone associated with the vertebral joints in the body become inflamed, eroded, sclerotic, and ossified. This process fuses the vertebrae by damaging the annulus fibrosis and vertebral bone margin, causing the fibers of the annulus to become bony tissue and cementing the two structures together. Flexibility needed to function is lost.(138-140) It is this combination of fusion and pain that results in limited ROM.(141)

Prevalence and Incidence

It is currently estimated that between 0.1% and 0.2% of the population (approximately 500,000 individuals, or 129 in 100,000 individuals) have been diagnosed with ankylosing spondylitis in the United States.(142) One estimate places ankylosing spondylitis frequency at 0.5%, which is roughly equivalent to the prevalence of RA.(140) It most commonly occurs in young adults (17 to 35 years of age), particularly males, who develop the disorder 2 to 3 times more frequently than females.(140,142,143)

Treatments for Ankylosing Spondylitis of the Spine

The treatment options for ankylosing spondylitis depend on the severity of the condition, age of the individual, and projected progression of the condition. Treatments for AS are not able to cure or arrest the progression of the disorder; instead, they function to decrease pain and stiffness and improve movement to enable the individual to perform functions of daily living. Effective treatment of ankylosing spondylitis usually involves a number of therapies, including NSAIDs, DMARDs, corticosteroids, tumor necrosis factor (TNF) blockers, physical therapy, and surgery (joint replacement, etc.).(138,140,142,143)

Osteoporosis

Osteoporosis is a metabolic condition in which bone deposition and resorption rates become unbalanced, causing trabecular and cancellous bone to become thin and brittle as tissue mass is reduced. As this mechanical support diminishes even mild stresses to the bone, such as sneezing or rolling over in bed, can result in fracture and damage to the skeletal tissues, causing chronic pain and permanent changes to the body's structural support system. The primary osteoporotic conditions are Type I and Type II osteoporosis. Type I osteoporosis (postmenopausal osteoporosis), believed to be the result of increased osteoclastic resorption in the trabecular bone, is largely associated with vertebral crush fractures. Type II osteoporosis is generally associated with the aging process in which the body undergoes a normal decline in osteoblastic deposition in both trabecular and cancellous bone. Type II osteoporosis is associated with fractures of the femoral neck, vertebrae, proximal humerus, proximal tibia, and pelvis. Secondary osteoporosis is associated with endocrine diseases such as hyperthyroidism and diabetes mellitus; medications including barbiturates and heparin; conditions such as chronic renal failure, RA, and hepatic disease; and tobacco use.(144)

Prevalence and Incidence

In the United States it is currently estimated that approximately 13% to 18% of females and 3% to 6% of males over the age of 50 have osteoporosis, for a total of almost 10 million individuals. Prevalence of osteoporosis increases with age: in women 80 years and older it is approximately 44%. The incidence rate is expected to increase as the population ages, with estimates for 2010 approaching 12 million people, and 2020 estimates being almost 14 million individuals. At this rate, 1 in 2 people over 50 years of age will have, or will be at risk of developing, osteoporosis of the hip.(144,145)

Treatments for Osteoporosis

The treatment options for osteoporosis depend on the severity of the condition, age of the individual, and projected progression of the condition. Treatments for osteoporosis function to decrease bone loss and potentially increase bone mass. Effective treatment of osteoporosis usually involves a number of therapies, including adequate calcium and vitamin D intake, exercise, and medications such as biphosphonates, calcitonin, estrogens, parathyroid hormone, and raloxifene.(145)

Spinal Stenosis

Spinal stenosis occurs when the spinal cord becomes compressed, leading to pain, numbness of the lower extremities, and limited mobility. Degenerative spinal stenosis occurs with advancing age as the spinal and nerve root canals are affected by changes in the ligaments and vertebrae. These changes function to narrow and exert pressure on the spinal cord and nerve roots, leading to the symptoms outlined above. ROM may be impinged due to pain and structural changes associated with the disorder.(146)

Prevalence and Incidence

In a recent report on the treatment of degenerative lumbar spinal stenosis, ECRI Institute examined a number of studies that reported, among other back disorders, the prevalence of spinal stenosis. It was estimated that approximately 13% to 14% of individuals who see a specialist for back pain may have spinal stenosis. Other estimates state that it occurs in between 1.7% and 8% in the general U.S. population. As the symptoms of lumbar spinal stenosis are similar to many other back ailments, incidence rates are difficult to obtain.(147,148)

Treatments for Spinal Stenosis

The treatment options for spinal stenosis depend on the severity of the condition, age of the individual, and projected progression of the condition. Treatments for spinal stenosis are used to reverse the condition. Conservative treatments include rest, physical therapy, NSAIDs and other analgesics, and the use of adaptive devices such as a lumbar brace or corset. Surgical treatments considered when conservative therapy proves to be ineffective include laminectomy, laminotomy, foraminotomy, and spinal fusion.(149)

Degenerative Disc Disease

Degenerative disc disease is not an actual disease; it is a term used to describe deterioration of the spinal vertebrae accompanied by pain. Degenerative disc disease is most often associated with increasing age, but may also be related to acute or repetitive trauma, or infection.(150-152)

Age-related changes include a loss of fluid in the discs, thus reducing the ability of the spinal column to absorb mechanical pressure, diminishing the discs' flexibility, and narrowing the spaces between the vertebrae. Small defects occur in the enervated annulus fibrosis, thus creating pain. To counteract instability in the spine related to the shrinking size of the vertebral discs, the body constructs osteophytes, or bone spurs, which may impinge on the spinal cord or nerves. This encroachment on the surrounding tissues may result in pain and changes in nerve function. Pain may ultimately affect ROM, typically in the lumbar and cervical spine.(150-152)

Prevalence and Incidence

Disc degeneration has been documented in asymptomatic group's age 11 to 16 years, with 20% of people in their teens demonstrating mild disc degeneration. By age 50, some 10% of discs show degenerative pathology, and by age 70, 60% of vertebral discs are severely degenerated. Low back pain, which is often associated with degenerative disc disease, has a lifetime prevalence of 70% in industrialized nations. The annual incidence of low back pain that may be related to degenerative disc disease is 5% in the United States.(151,152)

Treatments for Degenerative Disc Disease

Treatments for degenerative disc disease depend on the severity of the disease, age of the individual, and projected progression of the condition. Treatments for degenerative disc disease are not able to cure or arrest the progression of the disorder; instead, they attempt to decrease pain and stiffness and improve movement to enable the individual to perform functions of daily living. Effective treatment of degenerative disc disease usually involves a number of therapies, including NSAIDs, reduction of lumbar lordosis, and physical therapy to strengthen the muscles of the abdomen and spine so that they provide better support. Surgical options included disc replacement, spinal implants, and spinal fusion.(151)

Cervical Spondylosis

Cervical spondylosis is a chronic condition that results from degeneration of the discs in the cervical spine accompanied by the deposition of minerals in the intervertebral discs and abnormal growth of the cervical discs.(138,153) This degeneration may lead to diminished ROM in the cervical spine, evidenced by limited ability to rotate the head from center to left or center to right, and limited ability to tilt the head toward the shoulders. In addition to the development of limited ROM, individuals with cervical spondylitis frequently experience progressive neck pain; headache; numbness and pain when compression is applied to nerve roots and nerves; grinding or popping sounds when the neck is moved; and muscle spasms.

Prevalence and Incidence

The symptoms caused by cervical spondylosis are generally the measure used to establish the prevalence of the condition: the three main symptom categories are axial neck pain, cervical radiculopathy, and cervical myelopathy. In the United States, it is estimated that approximately 66% of the population experiences axial neck pain at some point in their lifetime, with 5% experiencing axial neck pain at any given time. For cervical radiculopathy, the prevalence level is reported to be approximately 3.5 per 1,000 individuals, with an incidence level of 83 per 100,000 individuals in the United States. The prevalence and incidence rates of cervical myelopathy have proven difficult to establish due to the natural history of the disease, which begins with signs that are not readily detected in the early stages of the disease.(154)

Treatments for Cervical Spondylosis

The treatment options for cervical spondylosis depend on the severity, age, and projected progression of the condition. Treatments for cervical spondylosis are not able to cure or arrest the progression of the disorder; instead, they function to decrease pain and stiffness and improve movement with the goal of enabling the individual to perform functions of daily living. Effective treatment of cervical spondylosis usually involves a number of therapies, including: NSAIDs, cervical collar/neck brace (to lessen irritation of the nerves by limiting motion), thermal/cold therapy, physical therapy, and surgery (bone spur removal; disc decompression).(155)

Identification of Evidence Base

The evidence identification pathway for Key Question 3 is presented in Figure 7. Our searches identified a total of 358 articles that appeared relevant to Key Question 3. Twenty-two articles were retrieved and read in full. Of these 22 articles, 3 were found to meet the inclusion criteria for this question. These 3 included studies are listed in Table 25. Details of the 19 retrieved articles that did not meet our inclusion criteria are presented in Table D-3 of Appendix D, along with the reasons for their exclusion.

Figure 7. Evidence Base Development Process

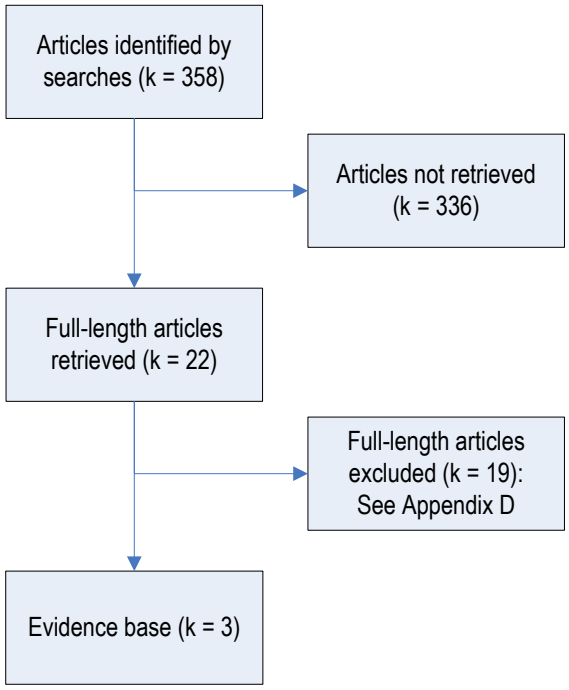


Table 25. Evidence Base

Primary Reference	Year	Study Location	Country
Disability associated with Ankylosing Spondylitis			
Dagfinrud et al.(156)	2005	Oslo	Norway
Driving Ability affected by Experimental Cervical Range of Motion (ROM) Restriction			
Barry et al.(155)	2003	Iowa	United States
Hunter-Zaworski(134)	1990	Virginia	United States

Evidence Base

The key attributes of the 3 studies that met the inclusion criteria for this key question are summarized in Table 26. A more detailed description of each of these studies can be found in the *Study Summary Tables* of Appendix G. None of the three included studies directly examined the association between reduced rotational mobility at the level of the spine or neck and crash risk in any driver population. Consequently, our assessment of the available evidence will only allow us to determine whether it is plausible that a reduced ROM at the level may have an impact on driver safety.

Of the three included studies, one study focused on the impact of ankylosing spondylitis and on several functional abilities, which included the impact of the disorder on one's ability to turn one's head when driving. The remaining two studies examined the impact of experimental cervical ROM restriction on driving ability.

Table 26. Key Study Design Characteristics of Studies that Address Key Question 3

Reference	Year	Study Design	Comparison	Risk Factors Assessed (Method)	Primary Outcome	Comorbidities	Pharmacotherapy
Disability associated with Ankylosing Spondylitis (AS)							
Dagfinrud et al.(156)	2005	Cohort	Association of AS and functional loss	AS	Turn head when driving	Not reported (NR)	NR
Driving Ability affected by AS or Cervical Range of Motion (ROM) Restriction							
Barry et al.(155)	2003	Prospective randomized crossover trial	Driver performance wearing a restrictive neck brace vs. Driver performance without a restrictive neck brace	Cervical restriction	Velocity Acceleration Cervical Axial rotation Evaluation of driver's blind spot	NR	NR
Hunter-Zaworski(134)	1990	Before/after	Effect of restricted head and neck movement on driving performance	Restricted head and neck ROM	Response time Static ROM Visual field	NR	Nonsteroidal anti-inflammatory drugs (NSAIDs)

Quality of the Evidence Base

The results of our analysis of the overall quality of the evidence base for Key Question 3 are presented in Table 27.

Table 27. Quality of Included Studies

Reference	Year	Quality Scale Used	Quality
Disability associated with Ankylosing Spondylitis (AS)			
Dagfinrud et al.(156)	2005	Revised Newcastle-Ottawa Quality Assessment Scale Cohort Studies	Low
Driving Ability affected by AS or Cervical Range of Motion (ROM) Restriction			
Barry et al.(155)	2003	ECRI Institute Assessment Tool for Controlled Studies	High
Hunter-Zaworski(134)	1990	ECRI Institute Assessment Tool for Before-After Studies	Moderate

Generalizability of Evidence Base to Target Population

Pertinent information on the characteristics of the individuals enrolled in the three studies that address Key Question 3 is summarized in Table 28.

The generalizability of the findings of these latter studies to CMV drivers is unclear. All of the studies included private motor vehicle license holders, an unknown number of whom may have held commercial driver licenses. Exposure to risk is lower among noncommercial vehicle drivers, because their driving exposure is lower than that of CMV drivers. Women tend to be over-represented in studies of general driver populations. In this case, the number of females included in the studies of private motor vehicle license holders ranged from 75% to 22%, meaning that gender may be an issue when considering generalizability of populations. The ages of the private motor vehicle license holders included in these studies are likely to be slightly older, on average, when compared to those of CMV drivers. It is unclear whether the ethnicity of the private motor vehicle license holders included in these studies is representative of CMV drivers due to lack of reporting. More complete details of the characteristics of the enrollees in these studies are presented in the *Study Summary Tables* that are to be found in Appendix G.

Table 28. Patient Characteristics

Reference	Year	N	Diagnosis (e.g., questionnaire)	Age Distribution	% Male	% CMV Drivers	Driving Exposure	Ethnicity	Generalizability to Target Population
Disability associated with Ankylosing Spondylitis									
Dagfinrud et al.(156)	2005	n = 152	Physician diagnosis	Mean: 47	58%	Not reported (NR)	NR	NR	Unknown
Driving Ability affected by Cervical Range of Motion (ROM) Restriction									
Barry et al.(155)	2003	Healthy volunteers: n = 23	NA	17 to 24 years of age	43%	NR	NR	NR	Unknown
Hunter-Zaworski(134)	1990	n = 60 30 to 50 years, impaired: 15 30 to 50 years, unimpaired: 15 60 to 80 years, impaired: 15 60 to 80 years, unimpaired: 15	ROM test	30 to 50 years of age median: 40 60 to 80 years of age median: 67	NR	NR	NR	NR	Unknown

Findings

The individual findings of each of the three studies that address Key Question 3 are presented in detail in Appendix G. The first of these studies examined whether ankylosing spondylitis was associated with functional problems in driving skills.(156) The remaining two studies examined the effect of experimental cervical ROM restriction on driving performance.(134,155)

Study of Impact of Ankylosing Spondylitis on Driving Ability

Dagfinrud et al. Study

Dagfinrud et al.(156) examined functional loss associated with ankylosing spondylitis and daily living activities, including turning the head when driving. (Quality Rating: Moderate) The data were collected from a group of 152 individuals who were recruited from the Ankylosing Spondylitis register at Diakonhjemmet Hospital, Oslo (n = 152).

Each individual underwent an evaluation, including a physical examination; an interview addressing activity limitations and participation restrictions via the Canadian Occupational Performance Measure (COPM); laboratory tests for erythmocyte sedimentation rate (ESR) and C-reactive protein; and the completion of a questionnaire requesting sociodemographic data, physical function and health status, and self-reported disease activity.

The level of physical impairment was defined according to the International Classification of Functioning, Disability, and Health rules as "problems in body structure or functions in terms of significant deviation or loss (e.g., deformity) of structures (e.g., joints) and/or functions (e.g., reduced ROM, pain, fatigue)." Measures chosen by the authors to indicate physical impairment level included: the Bath Ankylosing Spondylitis Metrology Index (BASMI), which measures spinal and hip mobility via clinical examination; and the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), which measures ankylosing spondylitis disease activity related to major symptoms such as pain, fatigue, and localized tenderness. Activity limitation (determined using the Canadian Occupational Performance Measure [COPM]) measured the patient's perception of activity performance and satisfaction with activity performance over time through structured interviews and self-rating. The COPM was used as the key measure of functional limitation and participation restriction in the statistical analysis. Function was assessed through the Bath Ankylosing Spondylitis Functional Index (BASFI), which allowed patients to self-rate ability to perform tasks such as picking up a pen from the floor or putting on articles of clothing. Subjective ratings of health as they pertained to activity limitation were obtained using the Medical Outcome Study Short Form (SF-36).

Data were processed using frequency and proportion counts; mean and standard deviations were obtained for all continuous variables; and associations were examined using Pearson correlation coefficients or linear regression. Multiple regression was employed, including block-regression analysis, to create a model that would explain the power of the independent variables on the COPM.

The authors found that the most frequently reported functional problems were “interrupted sleeping” (n = 83), “turn head when driving” (n = 57, or 37.5% of all individuals), “carry groceries” (n = 54), and “energy for social activities” (n = 53). It was concluded that the impact of functional impairment attributable to ankylosing spondylitis had an influence on activities of daily living such as driving. COPM performance (the key measure of functional limitation) was significantly correlated with the BASDAI (principal measure of disease activity; p <0.001) and BASMI (measure of spine and hip mobility; p = 0.01) scores. The BASFI score (or self-rated ability to perform tasks such as rising from a supine position) correlated significantly with all impairment variables, including the BASMI (measure of spine and hip mobility; <0.001), the erythrocyte sedimentation rate (p = 0.01), and the C-reactive protein (p = 0.003) score.

Multiple regression analysis showed that personal variables, including age, gender, duration of disease, comorbidity, and educational and occupational status, accounted for 11% of all variation in the COPM measure of performance. The impairment variables BASDAI (p <0.001) and BASMI (p = 0.03) accounted for 28% of all variation in the COPM. The inflammation markers ESR (p = 0.68) and C-reactive protein (p = 0.19) did not factor in the variation in COPM. Regression for the COPM satisfaction score with the BASFI or SF-36 as a dependent variable had a total explanatory power of 66% (p <0.001) and 55% (p <0.001).

While this study demonstrates that a common impact of ankylosing spondylitis is that it limits one’s ability to turn his/her head while driving, it does not provide evidence that this restriction in movement impacts driving. To determine this we must turn to evidence from other studies that have evaluated the impact of restricted cervical ROM on simulated driving performance.

Studies of Impact of Cervical ROM Restriction on Driving Ability

Barry et al. Study

Barry et al.(155) examined the effect of restricted cervical ROM on driving ability among a group of healthy volunteers (n = 23) who were asked to wear a restrictive neck brace. All volunteers underwent cervical spinal rotation assessment with a Cervical ROM Instrument (Performance Attainment Associates, MN, USA). The individuals were then randomly divided into two groups: the first group wore the restrictive cervical orthosis for the first on-road performance test, but did not wear it for the second performance test; while the second group went without the restrictive orthosis for the first performance test, and then used the device during the second performance test. Each volunteer then underwent blind-spot evaluation to determine whether he/she could clearly see a piece of paper at different locations around the vehicle. The paper was placed anterior to the rear bumper, lateral to the driver’s or passenger side window, posterior to the rear bumper, and posterior to the rear bumper at the vehicle midline. The cervical orthosis was applied and individuals adjusted viewing mirrors as needed. Blind-spot evaluation was reassessed, the driving route was explained, and driving with the orthosis was evaluated in a parking lot to ensure safe handling of the vehicle on the road. An evaluator accompanied each volunteer during the experiment drive to observe and use dual controls for safety. Axial rotation was

recorded using on-board digital cameras to facilitate visual scanning of intersection traffic. After the experiment, each individual was interviewed and completed a questionnaire rating the effect of wearing the orthosis on overall driving safety and ability to visualize the road, mirrors, and dashboard instruments. Wilcoxon signed-rank tests were used to evaluate the driving performance data, with separate evaluations of effect of neck brace condition, effect of on-road performance testing route, and effect of the order in which the cervical orthosis was used.

Cervical ROM was limited by the use of the orthosis: for example, mean left axial rotation without the orthosis was measured at 71.6 (±4.7) degrees; with the orthosis it was found to be 23.9 (±5.3) degrees. Mean right axial rotation with the orthosis was 24.3 (±5.5) degrees; without the orthosis it was found to be 73.4 (±3.9) degrees. The cervical ROM without the orthosis at the first 4 and last 4 intersections encountered were 50.76 (±7.32) and 50.02 (±3.99), respectively. Cervical ROM with the orthosis at the first 4 and last 4 intersections encountered were 26.67 (±4.35) and 2.75 (±2.52), respectively. The summary of the post-driving questionnaire found that the mean score of orthosis effect on driving was 6.2 (±0.4)[a]; the effect on road visualization was 5.4 (±0.5)[b]; effect on mirror visualization was 4.5 (±0.3)[b]; and the effect of visualization of dashboard instruments was 4.3 (±0.3)[b].[7]

Cervical ROM restriction was found to be associated with decreased lateral acceleration and slower driving. No difference between conditions in steering, accelerator or brake position, or lateral acceleration was observed. All of the volunteers maintained control of his/her vehicle, including making turns and appropriate stops.

Driving ability at intersections was found to be reduced by restricting cervical ROM. While rotational restriction was compensated for to some degree by an increase in eye movement, volunteers reported an increase in the size of their blind spot. The volunteers noted during post-test questioning that visualization of the road seemed suboptimal, and that in their mind, this contributed to less safe driving.

Hunter-Zaworski Study

The Hunter-Zaworski study(134) examined the effect of restricted head and neck movement on driving performance (specifically decision time) at T-intersections. The degree of restriction was assessed using a ROM test of the head and neck; what constituted "restricted" movement was not, however, defined by the author. Volunteers also underwent a visual field test. Performance data using a driving simulator was collected from a group of 60 volunteers who were divided into groups by age and disability/impairment. Four groups were created: 30 to 50 years, impaired (n = 15); 30 to 50 years, unimpaired (n = 15); 60 to 80 years, impaired (n = 15); and 60 to 80 years, unimpaired (n = 15). The simulator task required each subject to watch a video screen of intersections. Before the intersection was encountered, an announcement that an intersection was imminent was made and the volunteer was required to use the brake. When the subject determined, while watching the video, that it was safe

[7] Scores [a]: 1, driving made safer; 4, no effect; 7, made driving less safe
Scores [b]: 1, enhanced; 4, no effect; 7, hindered

to proceed through the intersection, he/she would release the brake pedal. This required the volunteers to judge when the traffic streams at both the left and right would allow for safe intersection negotiation.

The average decision time in seconds (p = 0.08, coefficient 29.66) for the 30 to 50 unimpaired group was 11.3 (standard deviation 2.97); for the 30 to 50 impaired group it was 11.4 (standard deviation 4.09); for the 60 to 80 unimpaired group it was 12.1 (standard deviation 3.08); and for the 60 to 80 impaired group it was 14.4 (standard deviation 4.35). Hunter-Zaworski found that age and average decision time shared a significant relationship. Similarly, functional level and decision time also had a significant relationship: the greater the functional impairment, the longer the decision time. When examined including age as a variable, the results suggested that the younger participants were able to compensate more readily for functional limitations. While the decision time for those aged 30 to 50 impaired group was slower than their unimpaired counterparts, it was not as slow overall when compared to the decision time results of the impaired and unimpaired 60 to 80-year-old groups.

The author concluded that younger drivers demonstrated an ability to adapt to impairments in driving more readily than older drivers, and that average decision time at T-intersections increased both with age and with age and functional impairment.

Section Summary

While it is plausible that the presence of a disorder that limits spinal/cervical ROM, including ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, or spinal stenosis, may have a deleterious impact on driving ability, one cannot determine whether these disorders are associated with an increased risk for a motor vehicle crash at this time (Strength of Evidence: Minimally Acceptable).

Three studies met the inclusion criteria for Key Question 3. No included studies directly assessed the impact of restricted spinal/cervical ROM on crash risks.

Indirect Evidence: The first included study used a cross-sectional design to establish that functional limitations introduced with spinal and/or cervical structural changes may be a factor in reduced driving performance, including a diminished ability to turn the head while driving. The second included study used a prospective crossover design to determine the relationship between cervical immobility (as imposed by the use of a cervical orthosis) and driver performance. It was found that the orthosis did alter driving performance including a decrease in lateral acceleration and slower driving speed overall. The final included study used a cohort study design to determine whether increased functional impairment to the cervical spine was associated with increased decision time at T-intersection. This study found an inverse association between the degree of functional impairment and driving performance: the greater the functional impairment reported, the longer the decision time associated with negotiating a T-intersection. The longest decision time was among impaired drivers in the older age group (age 60 to 80).

Key Question 4: Do vehicle modifications and/or appropriate limb prosthetics decrease crash risk in disabled individuals?

Background

Musculoskeletal dysfunction (depending on etiology and disease progression) can range from mild to severe, necessitating the development of a wide variety of adaptive equipment to enable individuals with such disorders to drive. The use of this equipment is generally designated "adapted driving." Determining which equipment is required to accommodate the needs of the individual and which will enable safe vehicle operation relies on a number of factors, including the individuals' activity tolerance, muscle strength, range of movement of all limbs, and ability to maintain balance in the trunk of the body. According to Sprigle et al. (1995), measurement of the physical skills in Table 29 provides a practical template for assessing functional ability.(157)

Table 29. Physical Skills to be Assessed to Determine Individual Functioning Status

Nonspecific Functional Abilities	Functional Abilities Specific to Driving
Brake reaction time	Steering reaction time
Eye-hand coordination	Brake force
Steering force	Gas force
Range of Motion (ROM)	Sensation
Manual muscle strength	Fine motor coordination
Grip strength	Pinch strength

Standards for Vehicle Modification and Assessment of Need

Very few standards currently exist regarding the design, installation, and operation of motor vehicle adaptive equipment.(158) Similarly, there are no standard systems in place to guide the team of medical personnel and the disabled individual through the process of establishing whether a person should continue to drive and to acquaint him/her with the adaptive technology available. Driver rehabilitation services are becoming an important and more visible tool in assisting in the evaluation of the disabled person's capacity to operate motor vehicles safely with adaptive equipment.(159) An integrated relationship between qualified, trained physicians and driving assessment centers in the appraisal of a disabled person's driving to determine adequate vehicle equipment adaptation has been encouraged among the medical and rehabilitation community.(160)

In the absence of standard vehicle adaptive equipment, and for the referral and assessment of the needs of people with disabilities who wish to drive, the disabled person may be required to seek out alternate transportation or cease driving. While driving cessation may be necessary in the presence of significant disabilities, the loss of driving privileges may precipitate sequelae, such as loss of independence and an increased need to rely on family or transportation services; reduced social interaction and/or opportunities; reduced quality of life, and depression.(39)

Vehicle Modifications and Functional Requirements

The type and severity of the individual's musculoskeletal disorder governs the vehicle adaptations available to that person. In addition, there are a variety of other factors, such as control and reaction time, that provide the necessary criteria to establish safe driving.(161) As concluded by Koppa, provisions (i.e., ingress and egress, primary and secondary control, occupant protection) are required for increased safe transportation independence.(158) Previous reaction time reports, at best, are vague and indicate that drivers' with disabilities times are below average and fail in the ability to conclude that they are incapable of driving.(157) Prasad, Hunter, Hanley's examination of nonstandard controls use after disability, including prevalence of crashes, revealed no difference in the overall crash rate of disabled drivers (in conducting a formal assessment of road safety) in comparison to the general population from previous studies.(162) Subsequently, Sprigle et al. have suggested that hand controls for adapted driving produce better physical skills, including brake reaction time, in comparison with normal foot-pedal use.(157)

Vehicle Modifications and Utilization

There are a wide variety of vehicle adaptations available to the disabled individual. Common adaptations include the following:(163)

- Automatic transmission
- Power steering
- Power brakes
- Conversion of the foot-operated brake and accelerator to hand controls
- Right-hand turn signals
- Foot pedal extensions
- Spinner knobs on the steering wheel
- Left foot accelerator

According to statistics provided by Verbrugge and Juarez, 1.1% of individuals with disability due to both arthritis and RA conditions had some kind of driving aid equipment installed in their vehicle. Of individuals with disabilities related solely to arthritis, 1.2% used vehicular modifications.(164) Gurgold and Harden (1978) suggested that individuals with disabilities (particularly those with severe impairments) have more opportunities for access to force-amplifying controls systems to aid in safer motor vehicle operation than were previously available.(165) The authors classified *General Driving Aid Requirements* according to residual function to provide a guideline for recommended equipment in vehicle modification for safer driving. These requirements are outlined in Table 30 below.

Table 30. General Driving Aid Requirements According to Residual Functions

Residual Function	Recommended Equipment
Minimal Impairment: Ability to use one foot and one or both hands	Minor aids involving change of interface only
Moderate impairment: deltoid, biceps, lattissimus serratus, pectoralis, radial wrist extensors, triceps finger extensors, and flexors hand intrinsic, ulnar side or wrist and fingers (2)	Substitute for all foot control functions
Maximal Impairment: deltoid, biceps, lattissimus, serratus, pectoralis, and radial wrist extensors (2)	Substitute for all foot control functions and modifications of the driving position
Severe impairment: deltoid, and biceps	Substitute for all foot control functions and modifications of hand control functions and driving position

The ability to drive is an important part of an individual's quality of life; it enables a person to perform activities such as shopping and socializing, and to work. The use of vehicle modifications can provide an important link in maintaining quality of life and independence for an individual with disabilities.(39,166,167)

Limb Prosthetics

Key Question 1 details the etiology, pathophysiology, prevalence, and incidence data for amputation. The following is a brief overview of the adaptive methods and devices in vehicle modifications available for people with amputation disabilities.

Amputation

The first aim of orthopedic and vascular medicine is to salvage the severed limb through reattachment or tissue graph wherever possible.(168) Amputations of the upper limb are largely due to trauma, whereas lower limb amputations are largely due to vascular and related secondary complications of impaired circulation (acquired amputation).(69) When the damaged or diseased limb cannot be salvaged, amputation may be deemed necessary.

Orthotic and Prosthetic Devices

An orthotic is a device to support or correct the function of movable parts of the body. For example, shoe inserts are orthotics designed to correct an irregular walking pattern. Other orthotics may include neck braces, lumbar-sacral supports, knee braces, and wrist supports. A prosthesis is an artificial replacement of a part of the body (i.e., an arm, leg, hand, joint). People who have experienced the absence or loss of a limb generally incorporate orthotic or prosthetic devices in their activities of daily living. (http://www.amputee-coalition.org/nllic_faq.html#2).

Prostheses are initially categorized as either preparatory or definitive. In the immediate postoperative period, the use of a preparatory (or temporary) prosthesis has been advocated by some medical professionals to allow rehabilitation to begin as soon as possible. Once the limb has stabilized (volume changes and healing in the limb are completed), a definitive, or permanent prostheses is used. The designs of prostheses range from one being entirely cosmetic (passive device) to one being exclusively functional (active device). The functional or active prostheses are generally categorized as body-powered and electromyographic.(169)

Body-powered Prostheses

Body-powered prostheses (cable-operated) harness the energy of muscle contractions to activate a mechanical cable or lever control. While generally considered the most durable with high-quality sensory feedback, they are considered less cosmetically pleasing than a myoelectric unit and require more muscle exertion for movement.(169)

Electromyography (EMG) Prostheses

Prostheses operated by EMG, sometimes referred to as myoelectricity, use signals generated by muscle contractions that are then streamed through electrodes placed on the residual limb stream to an electric device for movement. This type of prosthesis uses both internal and external power sources (i.e., batteries), enabling finer movement functioning, and are more cosmetically pleasing than the cable prosthesis. The two types of EMG prostheses are:(169)

- 2-site/2-function device with separate electrodes for flexion (bending) and extension (swing and reaching); and
- 1-site/2-function device with one electrode for both flexion and extension. The patient uses muscle contractions of differing strengths for prosthetic movement.

Technology in the newer-age design and manufacture of orthotic and prosthetic devices is currently aimed at reducing stress to the skeleton, increasing gait/swing/joint stability, and easing transference. Newer and lighter materials such as titanium and carbon fibers are now being used in the manufacture of prosthetic devices to take advantage of their superior strength, shock-absorption, and energy-release capacity and durability. More durable molded plastics, epoxies, and gels are increasingly used in the socket designs, replacing silicone—a much heavier material. These compounds are also more versatile for use in different climates and weather conditions.(169)

In September 1993, the first microprocessor-controlled limb was introduced: the “Intelligent Prosthesis” was the first generation of these adaptive prosthesis to incorporate the dynamics of EMG and body-powered controls.(65)

Rehabilitation Potential of the Amputee Patient

The absence or loss of a limb is a permanent disability. Determining a person’s capacity for rehabilitation and orthotic prosthetic device use is complex. Factors influencing prosthetic use and rehabilitative potential and achievement include age; gender; ethnicity; current health status and comorbidities; time interval since amputation; body location, severity, or level of amputation; and socioeconomic status.(69)

The primary aim of rehabilitation is to minimize the sensory-motor deficits and psychosocial barriers to recover and return the patient to his/her maximum level of independent functioning possible. The U.S. Centers for Medicare & Medicaid Services, part of the U.S. Department of Health & Human Services, has

published guidelines[8] regarding rehabilitation and the potential for prosthetic use for an individual with an amputation. These guidelines are listed below.

Lower Limb Amputation Prosthetic Rehabilitation Guidelines

The following are the functional classification levels to determine patient rehabilitative and prosthesis potential for lower limb amputees:

Level 0: Does not have the ability or potential to ambulate or transfer safely with or without assistance, and prosthesis does not enhance quality of life or mobility.

Level 1: Has the ability or potential to use a prosthesis for transfers or ambulation on level surfaces at fixed cadence. Typical of the limited and unlimited household ambulation.

Level 2: Has the ability or potential for ambulation with the ability to traverse low-level environmental barriers such as curbs, stairs, or uneven surfaces. Typical of the limited community ambulatory.

Level 3: Has the ability or potential for ambulation with variable cadence. Typical of the community ambulatory who has the ability to traverse most environmental barriers, and may have vocational, therapeutic, or exercise activity that demands prosthetic utilization beyond simple locomotion.

Level 4: Has the ability or potential for prosthetic ambulation that exceeds basic ambulation skills, exhibiting high impact, stress, or energy levels. Typical of the prosthetic demands of the child, active adult, or athlete.

Upper Limb Prosthetic Rehabilitation Guidelines

The patient requires the prosthesis for activities of daily living and/or rehabilitation.

The attending physician, physician assistant, or nurse practitioner must document that the patient is motivated to utilize the prosthetic.

The physician, physician assistant, or nurse practitioner must sign a written rehabilitation plan incorporating goals expected for the patient to achieve.

Adaptive Equipment for Vehicles

There is a wide variety of adaptive driving equipment available to the individual with an amputation.(170-175) The information in Table 31 is provided by the War Amps group in Canada. (http://www.waramps.ca/).

[8] http://www.cms.hhs.gov/manuals/Downloads/bp102c15.pdf

Table 31. Adaptive Equipment

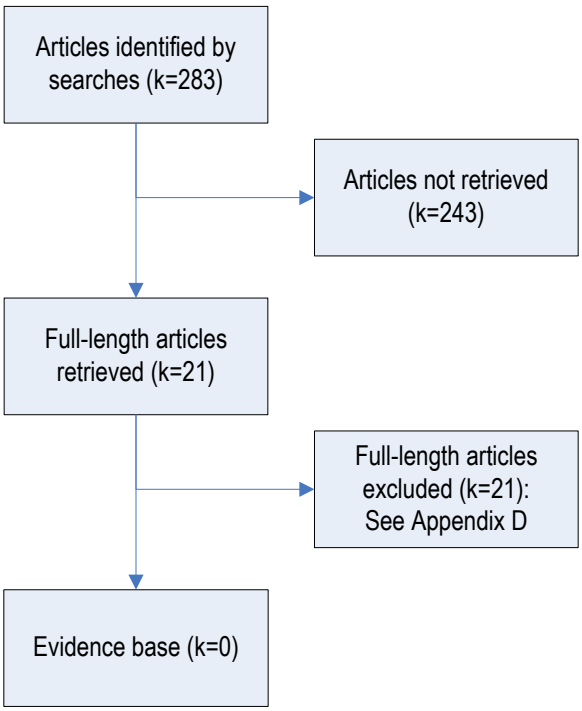
Amputation	Recommended Devices
Left leg (below-knee)	No devices/ adaptations required
Left leg (above-knee)	Parking brake extension ▪ Allows for operation of a foot-operated parking brake. ▪ *Applies to older vehicles.*
Right leg (below-knee)	Left-foot accelerator ▪ Allows for operation of the gas pedal with left leg. *Some below-knee amputees have enough control of their prosthesis to use standard pedals and will not find this necessary.*
Right leg (above-knee)	Left-foot accelerator ▪ Allows for operation of the gas pedal with left leg. *Some right-leg above-knee amputees choose to move their prosthesis out of the way and use their left leg to use standard pedals without any modifications.*
Bilateral leg amputee (below- and above-knee)	Hand controls ▪ Replace foot controls. ▪ Operate gas, brakes, horn, and dimmer. ▪ May be separate or combined into a single "joystick"-type device. **Note - some bilateral below-knee amputees have control with their prostheses and do not require any adaptations.*
Left arm	Right-hand steering knob or ring ▪ Spinner knobs for one-handed control of wheel. ▪ Rings used with a prosthetic hook (Artificial limbs should have soft pincers i.e., neoprene). Right-hand directional signal extension Crossover lever operates turn signal with right hand.
Right arm	Left-hand steering knob or ring ▪ Spinner knobs for one-handed control of wheel. ▪ Rings used with a prosthetic hook (Artificial limbs should have soft pincers i.e., neoprene). Left-hand gear shift lever extension Crossover lever operates a gear shift with left hand.
Bilateral upper limb	Check with your occupational therapist. One option is a floor-mounted steering wheel for foot control of steering.

Electronic Steering Devices Another option would be to use an electronic steering device, such as a Digipad or a Touchpad. These devices allow you to control the vehicle and vehicle accessories using digital buttons and switches. Some electronic controls resemble a joystick, which allow the steering, gas, and brake to be operated using a single device.(174) (http://www.waramps.ca/)

Identification of Evidence Base

The ideal study for addressing Key Question 4 is one that compares crash rates among individuals with musculoskeletal conditions who utilized adaptive equipment with crash rates among individuals with comparable musculoskeletal conditions who did not utilize adaptive equipment. As shown by Figure 8, no such study was identified by our searches. In summary, our searches identified a total of 283 potentially relevant articles. After an initial screen, we retrieved and examined 21 full-length articles. None of these articles met the inclusion criteria for this key question (see Appendix C). Table D-4 in Appendix D lists the articles that were excluded, along with the reason for exclusion.

Figure 8. Development of Evidence Base for Key Question 4



Section Summary

Because of a lack of pertinent evidence, one is precluded from drawing an evidence-based conclusion pertaining to the relationship between the use of vehicle modifications or appropriate limb prosthetics and a decrease in crash risk.

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Appendix A: Search Summaries

Search Summary for Key Questions 1 through 4

The search strategies employed combinations of freetext keywords as well as controlled vocabulary terms including (but not limited to) the following concepts. The strategy below is presented in OVID syntax; the search was simultaneously conducted across EMBASE, MEDLINE, and PsycINFO. A parallel strategy was used to search the databases comprising the Cochrane Library.

Medical Subject Headings (MeSH), EMTREE, PsycINFO, and Keywords

Key Question 1

Electronic Database Searches

The following databases have been searched for relevant information:

Name	Date Limits	Platform/Provider
CINAHL (Cumulative Index to Nursing and Allied Health Literature)	1982 through August 14, 2007	OVID
The Cochrane Central Register of Controlled Trials (CENTRAL)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Methodology Reviews (Methodology Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Systematic Reviews (Cochrane Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
Database of Abstracts of Reviews of Effects (DARE)	through 2007, Issue 3	http://www.thecochranelibrary.com
ECRI Institute Library Catalog	Searched July 24, 2007	ECRI Institute
EMBASE (Excerpta Medica)	1980 through August 14, 2007	OVID
Engineering Index	1970 through June 8, 2007	Dialog
Health Technology Assessment (HTA) Database	through 2007, Issue 3	http://www.thecochranelibrary.com
Healthcare Standards	1975 through August 2007	ECRI Institute
International Health Technology Assessment (IHTA)	through August 2007	ECRI Institute
MEDLINE	1950 through August 14, 2007	OVID
National Training Information Service (NTIS)	1970 through June 8, 2007	Dialog
PsycINFO	1967 through August 14, 2007	OVID
PubMed (PreMEDLINE)	PreMEDLINE[sb] Searched July 11, 2007	http://www.pubmed.gov
REHABDATA	Searched July 24, 2007	http://www.naric.com/research/rehab/default.cfm
Transportation Research Information Services (TRIS)	Searched July 24, 2007	http://ntlsearch.bts.gov/tris/index.do
U.K. National Health Service Economic Evaluation Database (NHS EED)	through 2007, Issue 3	http://www.thecochranelibrary.com
U.S. National Guideline Clearinghouse™ (NGC)	through August 2007	http://www.ngc.gov

Hand Searches of Journal and Nonjournal Literature

Journals and supplements maintained in ECRI Institute's collections were routinely reviewed. Nonjournal publications and conference proceedings from professional organizations, private agencies, and government agencies were also screened. Other mechanisms used to retrieve additional relevant information included review of bibliographies/reference lists from peer-reviewed and gray literature (gray literature consists of reports, studies, articles, and monographs produced by federal and local government agencies, private organizations, educational facilities, consulting firms, and corporations. These documents do not appear in the peer-reviewed journal literature).

Search Strategies

The search strategies employed combinations of freetext keywords as well as controlled vocabulary terms including (but not limited to) the following concepts. The strategy below is presented in OVID syntax; the search was simultaneously conducted across EMBASE, MEDLINE, and PsycINFO. A parallel strategy was used to search the databases comprising the Cochrane Library.

MeSH, EMTREE, PsycINFO, and Keywords

Conventions:

OVID

$ = truncation character (wildcard)

exp = "explodes" controlled vocabulary term (e.g., expands search to all more specific related terms in the vocabulary's hierarchy)

.de. = limit controlled vocabulary heading

.fs. = floating subheading

.hw. = limit to heading word

.md. = type of methodology (PsycINFO)

.mp. = combined search fields (default if no fields are specified)

.pt. = publication type

.ti. = limit to title

.tw. = limit to title and abstract fields

PubMed

[mh] = MeSH heading

[majr] = MeSH heading designated as major topic

[pt] = publication type

[sb] = subset of PubMed database (PreMEDLINE, Systematic, OldMEDLINE)

[sh] = MeSH subheading (qualifiers used in conjunction with MeSH headings)

[tiab] = keyword in title or abstract

[tw] = text word

Topic-specific Search Terms

Accidents

Accident$
Accidents, traffic
Collision$
Crash$
Highway safety
Motor traffic accidents
Traffic accident
Traffic safety
Wreck

Amputation

Amputation.de.
exp Amputation/
Amputees.de.
Amput$

Driving

Auto$
Automobile driving
Automobiles
Car
exp Car driving
Commercial
Driving
exp Driving behavior
Haul$
Long distance
exp Motor vehicle
exp Motor vehicles
Professional
Truck

Prosthetics

Above knee prosthesis.de.
Arm$
Arm prosthesis.de.
artificial
Artificial limbs.de.
Extremit$
Foot$
Hand$
Hand prosthesis.de.
Leg$
Limb$
Limb prosthesis.de.
Orthopedic prosthesis.de.
Prosthe$

Range of Motion

Range of motion, articular.de.
Rotation.de.
Range adj2 motion

CINAHL/EMBASE/MEDLINE/PsycINFO

Set Number	Concept	Search Statement
1	Amputation	Amputees.de. or amputation.de. or exp amputation/ or amput$
2	Prosthetics	(Artificial limbs or above knee prosthesis or limb prosthesis or arm prosthesis or hand prosthesis or orthopedic prosthesis).de.
3		(artificial or prosthe$) and (limb$ or extremit$ or hand$ or foot$ or arm$ or leg$)
4	Combine sets	or/1-3
5	Driving	4 and (automobile driving.de. or exp motor vehicles/ or automobiles.de. or exp driving behavior/ or exp car driving/ or exp motor vehicle/ or (driving or commercial or truck or car or automobil$ or long distance or haul$).ti.)
6	Accidents	4 and ((accidents, traffic or highway safety or motor traffic accidents or traffic accident or traffic safety).de. or (crash$ or wreck$ or collision$ or accident$).ti.)
7	ROM	4 and (ROM articular.de. or (range adj 2 motion))
8	Combine sets	or/5-7
9	Limit by publication type	8 not ((letter or editorial or news or comment or case reports or note or conference paper).de. or (letter or editorial or news or comment or case reports).pt.)
10	Limit by population	9 and (exp child/ or adolescent.de. or child$ or pediatr$ or paediatr$ or juvenile$ or adolescen$ or teen$ or youth$)
11		10 and adult
12		10 not 11
13		9 not 12
14	Eliminate overlap	Remove duplicates from 13
15	Limit	14 limited to English, human
16	Limit by study type	15 and ((Randomized controlled trials or random allocation or double-blind method or single-blind method or placebos or cross-over studies or crossover procedure or double blind procedure or single blind procedure or placebo or latin square design or crossover design or double-blind studies or single-blind studies or triple-blind studies or random assignment or exp controlled study/ or exp clinical trial/ or exp comparative study/ or cohort analysis or follow-up studies.de. or intermethod comparison or parallel design or control group or prospective study or retrospective study or case control study or major clinical study).de. or random$.hw. or random$.ti. or placebo$ or ((singl$ or doubl$ or tripl$ or trebl$) and (dummy or blind or sham)) or latin square or ISRCTN$ or ACTRN$)

Total Identified	Total Downloaded	Total Retrieved	Total Included
1,407	**57**	**17**	**3**

Key Question 2

Electronic Database Searches

The following databases have been searched for relevant information:

Name	Date Limits	Platform/Provider
CINAHL (Cumulative Index to Nursing and Allied Health Literature)	1982 through August 14, 2007	OVID
The Cochrane Central Register of Controlled Trials (CENTRAL)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Methodology Reviews (Methodology Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Systematic Reviews (Cochrane Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
Database of Abstracts of Reviews of Effects (DARE)	through 2007, Issue 3	http://www.thecochranelibrary.com
ECRI Institute Library Catalog	Searched July 24, 2007	ECRI Institute
EMBASE (Excerpta Medica)	1980 through August 14, 2007	OVID
Engineering Index	1970 through June 8, 2007	Dialog
Health Technology Assessment (HTA) Database	through 2007, Issue 3	http://www.thecochranelibrary.com
Healthcare Standards	1975 through August 2007	ECRI Institute
International Health Technology Assessment (IHTA)	through August 2007	ECRI Institute
MEDLINE	1950 through August 14, 2007	OVID
National Training Information Service (NTIS)	1970 through June 8, 2007	Dialog
PsycINFO	1967 through August 14, 2007	OVID
PubMed (PreMEDLINE)	PreMEDLINE[sb] Searched July 11, 2007	http://www.pubmed.gov
RehabDATA	Searched July 24, 2007	http://www.naric.com/research/rehab/default.cfm
Transportation Research Information Services (TRIS)	Searched July 24, 2007	http://ntlsearch.bts.gov/tris/index.do
U.K. National Health Service Economic Evaluation Database (NHS EED)	through 2007, Issue 3	http://www.thecochranelibrary.com
U.S. National Guideline Clearinghouse™ (NGC)	through August 2007	http://www.ngc.gov

Hand Searches of Journal and Nonjournal Literature

Journals and supplements maintained in ECRI Institute's collections were routinely reviewed. Nonjournal publications and conference proceedings from professional organizations, private agencies, and government agencies were also screened. Other mechanisms used to retrieve additional relevant information included review of bibliographies/reference lists from peer-reviewed and gray literature. (Gray literature consists of reports, studies, articles, and monographs produced by federal and local government agencies, private organizations, educational facilities, consulting firms, and corporations. These documents do not appear in the peer-reviewed journal literature.)

Search Strategies

The search strategies employed combinations of freetext keywords as well as controlled vocabulary terms including (but not limited to) the following concepts. The strategy below is presented in OVID

syntax; the search was simultaneously conducted across EMBASE, MEDLINE, and PsycINFO. A parallel strategy was used to search the databases comprising the Cochrane Library.

MeSH, EMTREE, PsycINFO, and Keywords

Conventions:

OVID

$ = truncation character (wildcard)

exp = "explodes" controlled vocabulary term (e.g., expands search to all more specific related terms in the vocabulary's hierarchy)

.de. = limit controlled vocabulary heading

.fs. = floating subheading

.hw. = limit to heading word

.md. = type of methodology (PsycINFO)

.mp. = combined search fields (default if no fields are specified)

.pt. = publication type

.ti. = limit to title

.tw. = limit to title and abstract fields

PubMed

[mh] = MeSH heading

[majr] = MeSH heading designated as major topic

[pt] = publication type

[sb] = subset of PubMed database (PreMEDLINE, Systematic, OldMEDLINE)

[sh] = MeSH subheading (qualifiers used in conjunction with MeSH headings)

[tiab] = keyword in title or abstract

[tw] = text word

Topic-specific Search Terms

Arthritis

Ankylosing
Ankylosing spondylitis
Arthrit$
Exp arthritis/
Arthritis, psoriatic.de.
Degen$
exp Infectious, arthritis/
infect$
inflamm$
Noninflamm$
Osteoarthrit$
exp Osteoarthritis/
rheumat$
exp Rheumatoid arthritis/
Spondylitis, ankylosing

Accidents

Accident$
Accidents, traffic
Collision$
Crash$
Highway safety
Motor traffic accidents
Traffic accident
Traffic safety
Wreck

Disability

Disab$
Disability evaluation.de.
Disabled persons.de.
Employment of disabled.de.
Function$
Exp functional assessment/
Physical disability.de.

Driving

Auto$
Automobile driving
Automobiles
Car
exp Car driving
Commercial
Driving
exp Driving behavior
Haul$
Long distance
exp Motor vehicle
exp Motor vehicles
Professional
Truck

Range of Motion

Range of motion, articular.de.
Rotation.de.
Range adj2 motion

CINAHL/EMBASE/MEDLINE/PsycINFO

Set Number	Concept	Search Statement
1	Arthritis	exp rheumatoid arthritis/ or exp infectious arthritis/ or (arthritis psoriatic or psoriatic arthritis).de.
2		(Spondylitis ankylosing or ankylosing spondylitis).de.
3		(Inflamm$ or Rheumat$ or ankylosing or infect$) adj3 arthrit$
4		exp osteoarthritis/ or osteoarthit$
5		Arthrit$ adj2 (degenerat$ or noninflamm$)
6	Combine sets	or/1-5
7	Driving	6 and (automobile driving.de. or exp motor vehicles/ or automobiles.de. or exp driving behavior/ or exp car driving/ or exp motor vehicle/ or (driving or commercial or truck or car or automobil$ or long distance or haul$).ti.)
8	Accidents	6 and ((accidents, traffic or highway safety or motor traffic accidents or traffic accident or traffic safety).de. or (crash$ or wreck$ or collision$ or accident$).ti.)
9	Range of motion	6 and ((ROM articular or rotation).de. or (range adj2 motion))
10	Disability	6 and (physical disability or disabled persons or disability evaluation or employment of disabled or functional assessment).de. or (disab$ or function$).ti,sh.
11	Combine sets	or/7-10
12	Limit by publication type	11 not ((letter or editorial or news or comment or case reports or note or conference paper).de. or (letter or editorial or news or comment or case reports).pt.)
13	Limit by population	12 and (exp child/ or adolescent.de. or child$ or pediatr$ or paediatr$ or juvenile$ or adolescen$ or teen$ or youth$)
14		13 and adult
15		13 not 14
16		12 not 15
17	Eliminate overlap	Remove duplicates from 16
18	Limit by study type	17 and ((Randomized controlled trials or random allocation or double-blind method or single-blind method or placebos or cross-over studies or crossover procedure or double blind procedure or single blind procedure or placebo or latin square design or crossover design or double-blind studies or single-blind studies or triple-blind studies or random assignment or exp controlled study/ or exp clinical trial/ or exp comparative study/ or cohort analysis or follow-up studies.de. or intermethod comparison or parallel design or control group or prospective study or retrospective study or case control study or major clinical study).de. or random$.hw. or random$.ti. or placebo$ or ((singl$ or doubl$ or tripl$ or trebl$) and (dummy or blind or sham)) or latin square or ISRCTN$ or ACTRN$ or (NCT$ not nctc$))
19	Remainder	17 not 18

Total Identified	Total Downloaded	Total Retrieved	Total Included
1,113	**237**	**123**	**7**

Key Question 3

Electronic Database Searches

The following databases have been searched for relevant information:

Name	Date Limits	Platform/Provider
CINAHL (Cumulative Index to Nursing and Allied Health Literature)	1982 through August 14, 2007	OVID
The Cochrane Central Register of Controlled Trials (CENTRAL)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Methodology Reviews (Methodology Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Systematic Reviews (Cochrane Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
Database of Abstracts of Reviews of Effects (DARE)	through 2007, Issue 3	http://www.thecochranelibrary.com
ECRI Institute Library Catalog	Searched July 24, 2007	ECRI Institute
EMBASE (Excerpta Medica)	1980 through August 14, 2007	OVID
Engineering Index	1970 through June 8, 2007	Dialog
Health Technology Assessment (HTA) Database	through 2007, Issue 3	http://www.thecochranelibrary.com
Healthcare Standards	1975 through August 2007	ECRI Institute
International Health Technology Assessment (IHTA)	through August 2007	ECRI Institute
MEDLINE	1950 through August 14, 2007	OVID
National Training Information Service (NTIS)	1970 through June 8, 2007	Dialog
PsycINFO	1967 through August 14, 2007	OVID
PubMed (PreMEDLINE)	PreMEDLINE[sb] Searched July 11, 2007	http://www.pubmed.gov
REHABDATA	Searched July 24, 2007	http://www.naric.com/research/rehab/default.cfm
Transportation Research Information Services (TRIS)	Searched July 24, 2007	http://ntlsearch.bts.gov/tris/index.do
U.K. National Health Service Economic Evaluation Database (NHS EED)	through 2007, Issue 3	http://www.thecochranelibrary.com
U.S. National Guideline Clearinghouse™ (NGC)	through August 2007	http://www.ngc.gov

Hand Searches of Journal and Nonjournal Literature

Journals and supplements maintained in ECRI Institute's collections were routinely reviewed. Nonjournal publications and conference proceedings from professional organizations, private agencies, and government agencies were also screened. Other mechanisms used to retrieve additional relevant information included review of bibliographies/reference lists from peer-reviewed and gray literature. (Gray literature consists of reports, studies, articles, and monographs produced by federal and local government agencies, private organizations, educational facilities, consulting firms, and corporations. These documents do not appear in the peer-reviewed journal literature.)

Search Strategies

The search strategies employed combinations of freetext keywords as well as controlled vocabulary terms including (but not limited to) the following concepts. The strategy below is presented in OVID syntax; the search was simultaneously conducted across EMBASE, MEDLINE, and PsycINFO. A parallel strategy was used to search the databases comprising the Cochrane Library.

MeSH, EMTREE, PsycINFO, and Keywords

Conventions:

OVID

$ = truncation character (wildcard)

exp = "explodes" controlled vocabulary term (e.g., expands search to all more specific related terms in the vocabulary's hierarchy)

.de. = limit controlled vocabulary heading

.fs. = floating subheading

.hw. = limit to heading word

.md. = type of methodology (PsycINFO)

.mp. = combined search fields (default if no fields are specified)

.pt. = publication type

.ti. = limit to title

.tw. = limit to title and abstract fields

PubMed

[mh] = MeSH heading

[majr] = MeSH heading designated as major topic

[pt] = publication type

[sb] = subset of PubMed database (PreMEDLINE, Systematic, OldMEDLINE)

[sh] = MeSH subheading (qualifiers used in conjunction with MeSH headings)

[tiab] = keyword in title or abstract

[tw] = text word

Topic-specific Search Terms

Accidents

Accident$
Accidents, traffic
Collision$
Crash$
Highway safety
Motor traffic accidents
Traffic accident
Traffic safety
Wreck

Driving

Auto$
Automobile driving
Automobiles
Car
exp Car driving
Commercial
Driving
exp Driving behavior
Haul$
Long distance
exp Motor vehicle
exp Motor vehicles
Professional
Truck

Range of Motion

Back$
Cervical$
Head$
Move$
Neck$
Range of motion.de.
Range of motion, articular.de.
Restrict$
Rotat$
spinal
Spine
Turn$
Vertebr$

CINAHL/EMBASE/MEDLINE/PsycINFO

Set Number	Concept	Search Statement
1	Driving	(automobile driving.de. or exp motor vehicles/ or automobiles.de. or exp driving behavior/ or exp car driving/ or exp motor vehicle/ or (driving or commercial or truck or car or automobil$ or long distance or haul$).ti.)
2	Accidents	((accidents, traffic or highway safety or motor traffic accidents or traffic accident or traffic safety).de. or (crash$ or wreck$ or collision$ or accident$).ti.)
3	Combine sets	1 or 2
4	Limit by publication type	3 not ((letter or editorial or news or comment or case reports or note or conference paper).de. or (letter or editorial or news or comment or case reports).pt.)
5	Limit by population	4 and (exp child/ or adolescent.de. or child$ or pediatr$ or paediatr$ or juvenile$ or adolescen$ or teen$ or youth$)
6		5 and adult
7		5 not 6
8		4 not 7
9	Range of Motion (ROM)	8 and (ROM or ROM articular).de.
10		8 and ((rotat$ or turn$ or move$ or restrict$) and (head$ or neck$ or back$ or cervical or spine or spinal or vertebr$))
11	Combine sets	9 or 10
12	Eliminate overlap	Remove duplicates from 11
13	Limit by study type	12 and ((Randomized controlled trials or random allocation or double-blind method or single-blind method or placebos or cross-over studies or crossover procedure or double blind procedure or single blind procedure or placebo or latin square design or crossover design or double-blind studies or single-blind studies or triple-blind studies or random assignment or exp controlled study/ or exp clinical trial/ or exp comparative study/ or cohort analysis or follow-up studies.de. or intermethod comparison or parallel design or control group or prospective study or retrospective study or case control study or major clinical study).de. or random$.hw. or random$.ti. or placebo$ or ((singl$ or doubl$ or tripl$ or trebl$) and (dummy or blind or sham)) or latin square or ISRCTN$ or ACTRN$)

Total Identified	Total Downloaded	Total Retrieved	Total Included
358	**22**	**22**	**4**

Key Question 4

Electronic Database Searches

The following databases have been searched for relevant information:

Name	Date Limits	Platform/Provider
CINAHL (Cumulative Index to Nursing and Allied Health Literature)	1982 through August 14, 2007	OVID
The Cochrane Central Register of Controlled Trials (CENTRAL)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Methodology Reviews (Methodology Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
The Cochrane Database of Systematic Reviews (Cochrane Reviews)	through 2007, Issue 3	http://www.thecochranelibrary.com
Database of Abstracts of Reviews of Effects (DARE)	through 2007, Issue 3	http://www.thecochranelibrary.com
ECRI Institute Library Catalog	Searched July 24, 2007	ECRI Institute
EMBASE (Excerpta Medica)	1980 through August 14, 2007	OVID
Engineering Index	1970 through June 8, 2007	Dialog
Health Technology Assessment (HTA) Database	through 2007, Issue 3	http://www.thecochranelibrary.com
Healthcare Standards	1975 through August 2007	ECRI Institute
International Health Technology Assessment (IHTA)	through August 2007	ECRI Institute
MEDLINE	1950 through August 14, 2007	OVID
National Training Information Service (NTIS)	1970 through June 8, 2007	Dialog
PsycINFO	1967 through August 14, 2007	OVID
PubMed (PreMEDLINE)	PreMEDLINE[sb] Searched July 11, 2007	http://www.pubmed.gov
REHABDATA	Searched July 24, 2007	http://www.naric.com/research/rehab/default.cfm
Transportation Research Information Services (TRIS)	Searched July 24, 2007	http://ntlsearch.bts.gov/tris/index.do
U.K. National Health Service Economic Evaluation Database (NHS EED)	through 2007, Issue 3	http://www.thecochranelibrary.com
U.S. National Guideline Clearinghouse™ (NGC)	through August 2007	http://www.ngc.gov

Hand Searches of Journal and Nonjournal Literature

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MeSH, EMTREE, PsycINFO, and Keywords

Conventions:

OVID

$ = truncation character (wildcard)

exp = "explodes" controlled vocabulary term (e.g., expands search to all more specific related terms in the vocabulary's hierarchy

.de. = limit controlled vocabulary heading

.fs. = floating subheading

.hw. = limit to heading word

.md. = type of methodology (PsycINFO)

.mp. = combined search fields (default if no fields are specified)

.pt. = publication type

.ti. = limit to title

.tw. = limit to title and abstract fields

PubMed

[mh] = MeSH heading

[majr] = MeSH heading designated as major topic

[pt] = publication type

[sb] = subset of PubMed database (PreMEDLINE, Systematic, OldMEDLINE)

[sh] = MeSH subheading (qualifiers used in conjunction with MeSH headings)

[tiab] = keyword in title or abstract

[tw] = text word

Topic-specific Search Terms

Accidents

Accident$

Accidents, traffic

Collision$

Crash$

Highway safety

Motor traffic accidents

Traffic accident

Traffic safety

Wreck

Adaptive Devices

exp Assistive technology devices/

Self help.de.

Self-help devices.de.

Technical aid.de.

Driving

Auto$

Automobile driving

Automobiles

Car

exp Car driving

Commercial

Driving

exp Driving behavior

Haul$

Long distance

exp Motor vehicle

exp Motor vehicles

Professional

Truck

Vehicle Modification

adapt$

assistive

device$

driving

electromechanical

hand$

mechanical

modif$

technol$

vehicle$

CINAHL/EMBASE/MEDLINE/PsycINFO

Set Number	Concept	Search Statement
1	Adaptive devices	(Self-help devices or technical aid or self help).de. or exp assistive technology devices/
2	Vehicle modification	Vehicle$ adj2 (adapt$ or modif$)
3		(adaptive or assistive or mechanical or electromechanical) adj2 (driving$ or hand$ or device$ or technol$)
4	Combine sets	or/1-3
5	Driving	4 and (automobile driving.de. or exp motor vehicles/ or automobiles.de. or exp driving behavior/ or exp car driving/ or exp motor vehicle/ or (driving or commercial or truck or car or automobil$ or long distance or haul$).ti.)
6	Accidents	4 and ((accidents, traffic or highway safety or motor traffic accidents or traffic accident or traffic safety).de. or (crash$ or wreck$ or collision$ or accident$).ti.)
7	Combine sets	5 or 6
8	Limit by publication type	7 not ((letter or editorial or news or comment or case reports or note or conference paper).de. or (letter or editorial or news or comment or case reports).pt.)
9	Limit by population	8 and (exp child/ or adolescent.de. or child$ or pediatr$ or paediatr$ or juvenile$ or adolescen$ or teen$ or youth$)
10		9 and adult
12		9 not 10
13		8 not 12
14	Eliminate overlap	Remove duplicates from 13

Total Identified	Total Downloaded	Total Retrieved	Total Included
283	**40**	**21**	**0**

Appendix B: Retrieval Criteria

Appendix B will list the retrieval criteria for each key question. An example of a small set of retrieval criteria are presented below.

Retrieval Criteria for Key Question 1

- Article must have been published in the English language.
- Article must have enrolled 10 or more subjects.
- Article must describe a study that attempted to determine the risk for a motor vehicle crash directly (risk for a fatal or nonfatal crash) associated with amputation.
- Article must describe a study that includes a comparison group comprised of comparable subjects who have not had an amputation.

Retrieval Criteria for Key Question 2

- Article must have been published in the English language.
- Article must have enrolled 10 or more subjects.
- Article must describe a study that attempted to determine the risk for a motor vehicle crash directly (risk for a fatal or nonfatal crash) associated with inflammatory arthritis.
- Article must describe a study that includes a comparison group comprised of comparable subjects who do not have inflammatory arthritis.

Retrieval Criteria for Key Question 3

- Article must have been published in the English language.
- Article must have enrolled 10 or more subjects.
- Article must describe a study that attempted to determine the risk for a motor vehicle crash directly (risk for a fatal or nonfatal crash) associated with having decreased angle of rotation at the level of the spine or neck.
- Article must describe a study that includes a comparison group comprised of comparable subjects who do not have decreased angle of rotation at the level of the spine or neck.

Retrieval Criteria for Key Question 4

- Article must have been published in the English language.
- Article must have enrolled 10 or more subjects.
- Article must describe a study that attempted to determine the risk for a motor vehicle crash directly (risk for a fatal or nonfatal crash) associated with having vehicle modifications or the use of appropriate limb prosthetics.
- Article must describe a study that includes a comparison group comprised of comparable subjects who do not use vehicle modifications or the appropriate limb prosthetics.

Appendix C: Inclusion Criteria

Appendix C will list the inclusion criteria for each of the four key questions addressed in this evidence report.

Inclusion Criteria for Key Question 1

- Article must have been published in the English language. Moher et al.(176) have demonstrated that exclusion of non-English language studies from meta-analyses has little impact on the conclusions drawn. Juni et al.(177) found that non-English studies typically were of lower methodologic quality, and that excluding them had little effect on effect-size estimates in the majority of meta-analyses they examined. Although we recognize that in some situations exclusion of non-English studies could lead to bias, we believe that the few instances in which this may occur do not justify the time and cost typically necessary for translation of studies to identify those of acceptable quality for inclusion in our reviews.(176,177)
- Article must be a full-length article. Abstracts and letters to the editor will not meet this inclusion criterion.
- Article must have enrolled 10 or more subjects.
- Article must have enrolled subjects aged ≥18 years.
- Studies were limited to individuals with amputation.
- Article must describe a study that attempted to directly determine the risk for a motor vehicle crash (risk for a fatal or nonfatal crash) associated with amputation using a direct measure of crash (no indirect measures [e.g., driving simulator data]).
- Article must describe a study that includes a comparison group comprised of comparable subjects who do not have an amputation.
- Article must describe a study that attempted to determine the disease-related factors associated with an effect on driving ability among individuals with an amputation.
- Article must present motor vehicle crash-risk data in a manner that will allow ECRI Institute to calculate (directly or through imputation) effect-size estimates and CIs.
- If the same study is reported in multiple publications, the most complete publication will be the primary reference. Data will be extracted so as to avoid double-counting individuals.

Inclusion Criteria for Key Question 2

- Article must have been published in the English language. Moher et al.(176) have demonstrated that exclusion of non-English language studies from meta-analyses has little impact on the conclusions drawn. Juni et al.(177) found that non-English studies typically were of lower methodologic quality, and that excluding them had little effect on effect-size estimates in the majority of meta-analyses they examined. Although we recognize that in some situations exclusion of non-English studies could lead to bias, we believe that the few instances in which this may occur do not justify the time

and cost typically necessary for translation of studies to identify those of acceptable quality for inclusion in our reviews.(176,177)

- Article must be a full-length article. Abstracts and letters to the editor will not meet this inclusion criterion.
- Article must have enrolled 10 or more subjects.
- Article must have enrolled subjects aged ≥18 years.
- Studies were limited to individuals with OA, RA, PsA, reactive arthritis, or metabolic arthritis.
- Article must describe a study that attempted to directly determine the risk for a motor vehicle crash (risk for a fatal or nonfatal crash) associated with amputation using a direct measure of crash (no indirect measures [e.g., driving simulator data]).
- Article must describe a study that attempted to determine the disease-related factors associated with an effect on driving ability among individuals with OA, RA, PsA, reactive arthritis, or metabolic arthritis.
- Article must describe a study that includes a comparison group comprised of comparable subjects with OA, RA, PsA, reactive arthritis, or metabolic arthritis who did not have a motor vehicle crash.
- Article must present motor vehicle crash-risk data in a manner that will allow ECRI Institute to calculate (directly or through imputation) effect-size estimates and CIs.
- If the same study is reported in multiple publications, the most complete publication will be the primary reference. Data will be extracted so as to avoid double-counting individuals.

Inclusion Criteria for Key Question 3

- Article must have been published in the English language. Moher et al.(176) have demonstrated that exclusion of non-English language studies from meta-analyses has little impact on the conclusions drawn. Juni et al.(177) found that non-English studies typically were of lower methodologic quality, and that excluding them had little effect on effect-size estimates in the majority of meta-analyses they examined. Although we recognize that in some situations exclusion of non-English studies could lead to bias, we believe that the few instances in which this may occur do not justify the time and cost typically necessary for translation of studies to identify those of acceptable quality for inclusion in our reviews.(176,177)
- Article must be a full-length article. Abstracts and letters to the editor will not meet this inclusion criterion.
- Studies were limited to individuals with ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, and spinal stenosis.
- Article must describe a study that attempted to directly determine the risk for a motor vehicle crash (risk for a fatal or nonfatal crash) associated with ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, and spinal stenosis using a direct measure of crash (no indirect measures [e.g., driving simulator data]).

- Article must describe a study that attempted to determine the disease-related factors associated with an effect on driving ability among individuals with ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, and spinal stenosis.
- Article must describe a study that includes a comparison group comprised of comparable subjects with ankylosing spondylitis, cervical spondylosis, degenerative disc disease, osteoporosis, and spinal stenosis, who did not have a motor vehicle crash.
- Article must present motor vehicle crash-risk data in a manner that will allow ECRI Institute to calculate (directly or through imputation) effect-size estimates and CIs. If the same study is reported in multiple publications, the most complete publication will be the primary reference. Data will be extracted so as to avoid double-counting individuals.

Inclusion Criteria for Key Question 4

- Article must have been published in the English language. Moher et al.(176) have demonstrated that exclusion of non-English language studies from meta-analyses has little impact on the conclusions drawn. Juni et al.(177) found that non-English studies typically were of lower methodologic quality, and that excluding them had little effect on effect-size estimates in the majority of meta-analyses they examined. Although we recognize that in some situations exclusion of non-English studies could lead to bias, we believe that the few instances in which this may occur do not justify the time and cost typically necessary for translation of studies to identify those of acceptable quality for inclusion in our reviews.(176,177)
- Article must be a full-length article. Abstracts and letters to the editor will not meet this inclusion criterion.
- Article must have enrolled 10 or more subjects.
- Article must have enrolled subjects aged ≥18 years.
- Article must have enrolled individuals who utilized vehicle modifications or appropriate prosthetic limbs.
- Article must describe a study that attempted to directly determine the risk for a motor vehicle crash (risk for a fatal or nonfatal crash) associated with vehicle modifications or appropriate prosthetic limbs using a direct measure of crash (no indirect measures [e.g., driving simulator data]).
- Article must describe a study that includes a comparison group comprised of comparable subjects who utilized vehicle modifications or appropriate prosthetic limbs who did not have a motor vehicle crash.
- Article must present motor vehicle crash-risk data in a manner that will allow ECRI Institute to calculate (directly or through imputation) effect-size estimates and CIs. If the same study is reported in multiple publications, the most complete publication will be the primary reference. Data will be extracted so as to avoid double-counting individuals.

Appendix D: Excluded Articles

Table D-1. Key Question 1

Reference	Year	Reason for Exclusion
Bardach, JL(178)	1970	Background
Burger et al.(179)	1997	Outcome not appropriate
Boulias et al.(80)	2006	Outcome not appropriate
Esquenazi, A(180)	2004	Background
Fernandez et al.(79)	2000	Outcome not appropriate
Jones et al.(181)	1993	Background
Kegel et al.(68)	1993	Outcome not appropriate
Mueller et al.(182)	1994	Background
Peimer et al.(183)	1999	Outcome not appropriate
Risk, HF(184)	1980	Review
Rotter et al.(185)	2006	Outcomes not appropriate
Sensky, TE(186)	1980	Review
Shepherd and Caine(187)	1968	Review
Stock et al.(188)	1970	Review
Taylor, JF(189)	1977	Background
Verrall and Kulkarni(190)	1995	Review
Wasiak, K(191)	2005	Outcomes not appropriate
Witso et al.(192)	2006	Review

Table D-2. Key Question 2

Reference	Year	Reason for Exclusion
Aletaha et al.(104)	2006	Background
Allaire et al.(193)	2005	Background
Allaire et al.(194)	2003	Background
Angst et al.(195)	2002	Background
Arie E(196)	1986	Background
Badley and Tennant(197)	1993	Background
Barlow et al.(198)	2001	Outcome not appropriate
Bennell et al.(199)	2004	Not on topic
Bjork et al.(200)	2006	Outcome not appropriate
Bostrom et al.(201)	1997	Not on topic
Braun et al.(153)	2005	Outcome not appropriate
Brockow et al.(202)	2004	Outcome not appropriate
Bulstrode et al.(203)	1987	Review
Bunn et al.(204)	2004	Review
Cranney et al.(205)	1999	Study not appropriate to key question
de Boer et al.(206)	1999	Outcome not appropriate
Dell et al.(207)	2001	Outcome not appropriate
Dellhag et al.(208)	1995	Outcome not appropriate
Dernis-Labous et al.(209)	2003	Outcome not appropriate
Dreinhofer et al.(210)	2004	Review
Dziedzic et al.(211)	2007	Outcome not appropriate
Edlich et al.(212)	2003	Outcome not appropriate
Esenyel et al.(213)	2004	Outcome not appropriate
Eurenius et al.(214)	2007	Review
Ewert et al.(215)	2004	Review
Falkenbach and Herold(216)	1998	Background
Finch et al.(217)	1998	Outcome not appropriate
Fowler et al.(218)	2001	Outcome not appropriate
Ganz and Harris(219)	1998	Background
Goodson et al.(220)	2007	Background
Gossec et al.(221)	2007	Outcome not appropriate
Guccione, AA(81)	1994	Background
Guillemin et al.(222)	1990	Outcome not appropriate
Hakala et al.(223)	1994	Outcome not appropriate

Reference	Year	Reason for Exclusion
Hakkinen et al.(224)	2004	Background
Hakkinen et al.(225)	2001	Outcome not appropriate
Hakkinen et al.(226)	2003	Outcome not appropriate
Haywood et al.(227)	2004	Background
Hill et al.(228)	2007	Outcome not appropriate
Hunter and Allaire(229)	2004	Outcome not appropriate
Husted et al.(230)	2005	Review
Iai et al.(231)	1994	Background
Johnson et al.(232)	2007	Review
Jordan et al.(233)	2004	Review
Kalden et al.(234)	2002	Outcome not appropriate
Kapstad et al.(235)	2007	Outcome not appropriate
Keefe et al.(236)	2000	Background
Kettlekamp, DB(237)	1974	Background
Khazzam et al.(238)	2007	Background
Larsson et al.(239)	1998	Background
Leeb et al.(240)	2005	Review
Lefevre-Colau et al.(241)	2003	Background
Leigh et al.(242)	1992	Background
Leigh and Fries(243)	1992	Background
Li et al.(244)	2005	Review
Lim et al.(245)	2005	Outcome not appropriate
Lingard et al.(217)	2001	Background
Maeda et al.(246)	2004	Outcome not appropriate
Maksymowych et al.(247)	2006	Review
Maksymowych et al.(247)	2006	Outcome not appropriate
Malcus-Johnson et al.(248)	2005	Review
Marmor, D(249)	1969	Review
Massy-Westropp et al.(250)	2005	Study not related to key question
McAlindon et al.(251)	1992	Review
Meireles et al.(252)	2002	Outcome not appropriate
Milidonis et al.(253)	2005	Outcome not appropriate
Murphy et al.(254)	1984	Review
Murray-Leslie, C(84)	1991	Review
Myllykangas-Luosujarvi et al.(255)	1998	Outcome not appropriate

Reference	Year	Reason for Exclusion
Neuberger et al.(256)	1993	Background
O'Brien, WM(257)	1986	Background
Olofsson et al.(258)	2003	Outcome not appropriate
Orces et al.(259)	2002	Background
Ozminkowski et al.(260)	2006	Background
Puolakka et al.(261)	2004	Outcome not appropriate
Rapoliene and Kriscinas(262)	2006	Outcome not appropriate
Rigby et al.(263)	1989	Review
Robon et al.(264)	2000	Background
Ruof et al.(265)	1999	Review
Sammarco et al.(266)	1973	Background
Sautner et al.(267)	2004	Background
Scott et al.(268)	2003	Systematic review
Sherrer et al.(269)	1987	Review
Shotton, MA(270)	1985	Background
Sinha et al.(271)	2006	Background
Smolen et al.(272)	2003	Background
Sokka et al.(273)	2003	Review
Sokka, T(274)	2003	Review
Sokoll et al.(275)	2001	Background
Stern et al.(276)	1996	Outcome not appropriate
Stern et al.(277)	1996	Outcome not appropriate
Steultjens et al.(278)	2002	Outcome not appropriate
Strombeck et al.(279)	2003	Outcome not appropriate
Swezey,RL(280)	1997	Background
Swinkels and Dolan(281)	2004	Background
Taccari et al.(282)	1998	Outcome not appropriate
Topp et al.(283)	2005	Outcome not appropriate
Van der Esch et al.(284)	2003	Outcome not appropriate
van der Heijde(285)	1993	Outcome not appropriate
van Lankveld et al.(286)	1998	Outcome not appropriate
Vermuelen et al.(287)	2006	Outcome not appropriate
Verstappen et al.(288)	2004	Outcome not appropriate
Verstappen et al.(289)	2003	Outcome not appropriate
Viitanen et al.(290)	2000	Review

Reference	Year	Reason for Exclusion
Viitanen et al.(291)	1995	Review
Viitanen et al.(292)	1999	Background
Viitanen et al.(293)	1998	Background
Viitanen et al.(294)	1995	Outcome not appropriate
Vliet Vlieland et al.(295)	1996	Background
Vrandenburg et al.(296)	2002	Background
Wada et al.(297)	1996	Background
Weigl et al.(298)	2007	Review
Wong et al.(299)	2004	Background
Woodburn et al.(300)	2003	Background
Yang et al.(301)	2007	Review

Table D-3. Key Question 3

Reference	Year	Reason for Exclusion
Allen et al.(302)	2004	Review
Bono, CM(303)	2005	Outcome not appropriate
Chen et al.(304)	2004	Outcome not appropriate
Cook, JB(305)	1967	Review
Deans et al.(306)	1986	Outcome not appropriate
Eklund et al.(307)	1994	Background
Hildingsson et al.(308)	1990	Outcome not appropriate
Hohl, M(309)	1974	Background
Kasch et al.(310)	2001	Outcome not appropriate
Ku et al.(311)	2002	Background
Lenoir et al.(312)	2006	Outcome not appropriate
Mazer et al.(39)	2004	Background
Nissan et al.(313)	2002	Outcome not appropriate
Posse et al.(314)	2006	Background
Richardson et al.(315)	2005	Background
Richter et al.(316)	2004	Background
Rister et al.(317)	2000	Background
Scuderi et al.(318)	2005	Outcome not appropriate
Singer, BR(319)	1995	Outcome not appropriate
Uremovic et al.(320)	2005	Background

Table D-4. Key Question 4

Reference	Year	Reason for Exclusion
Hagen et al.(321)	2002	Review
Barnes, MP(160)	1997	Review
Freeman, CC(322)	1974	Review
Henriksson et al.(323)	2004	Outcome not appropriate
Jedeloo et al.(167)	2000	Review
Koppa et al.(324)	1978	Technology obsolete
Koppa et al.(158)	1990	Technology obsolete
Lehneis et al.(325)	1969	Technology obsolete
Mapelli et al.(326)	2002	Review
Mazer et al.(39)	2004	Review
Murray-Leslie, C(327)	1990	Review
Reichenberger et al.(328)	1974	Technology obsolete
Reichenberger et al.(329)	1981	Technology obsolete
Richter and Hyman(330)	1974	Review
Risk, HF(331)	1980	Review
Roush et al.(332)	1992	Review
Sensky, TE(186)	1980	Review
Sprigle et al.(333)	1994	Review
Strano, CM(159)	1997	Review
Tachakra, SS(166)	1981	Review
Turner-Stokes et al.(334)	1996	Review

Appendix E: Determining the Stability and Strength of a Body of Evidence

As stated in the main text, ECRI Institute evidence reports differ substantially from other systematic review in that we provide two types of conclusions: qualitative and quantitative. In order to reach these conclusions, we use an algorithm developed by ECRI Institute to guide the conduct and interpretation of the analyses performed during the development of this evidence report.(41) The algorithm, which is presented in Figure E-3 through Figure E-6, formalizes the process of systematic review by breaking the process down into several discrete steps. At each step, rules are applied that determine the next step in the systematic review process and ultimately in the stability and strength-of-evidence ratings that are allocated to our conclusions. Because the application of the rules governing each step in the algorithm (henceforth called a decision point) guides the conduct of the systematic review process and how its findings are interpreted, much time and effort was spent in ensuring that the rules and underlying assumptions for each decision point were reasonable.

The algorithm is comprised of three distinct sections: a *General* section, a *Quantitative* section, and a *Qualitative* section. Each of these sections, the decision points that fall within them, and the decision rules that were applied at each step in the present evidence report are described below.

Decision Point 1: Acceptable Quality?

Decision Point 1 serves two purposes: (1) to assess the quality of each included study; and (2) to provide a means of excluding studies that are so prone to bias that their reported results cannot be considered useful. To aid in assessing the quality of each of the studies included in this evidence report, we used two study quality assessment instruments. The choice of which instrument to use was based on the design of the study used to address the key questions of interest. In this evidence report we used the ECRI Institute Quality Scale I (for randomized and nonrandomized comparative studies), the ECRI Institute Quality Scale III (for pre-post studies), and a revised version of the Newcastle-Ottawa Quality Assessment Scale (for case-control studies).(335) These instruments are presented in Appendix F.

Decision Point 2: Determine Quality of Evidence Base

We classified the overall quality of each key question's specific evidence base into one of three distinct categories: high, moderate, or low quality. Decisions about the quality of each evidence base were based on data obtained using the quality-assessment instruments described above using the criteria presented in Table E-1.

Table E-1. Criteria Used to Categorize Quality of Evidence Base

Category	Median EQS I Score	Median EQS III Score	Median NOQAS Score	Median EQS VI Score
High Quality	≥9.0			
Moderate Quality	6.0 to 8.9	≥9.0	≥8.0	≥8.0
Low Quality	≤6.0	<9.0	<8.0	<9.0

EQS – ECRI Institute Quality Scale
NOQAS – Newcastle-Ottawa Quality Assessment Scale.

Decision Point 3: Quantitative Analysis Performed?

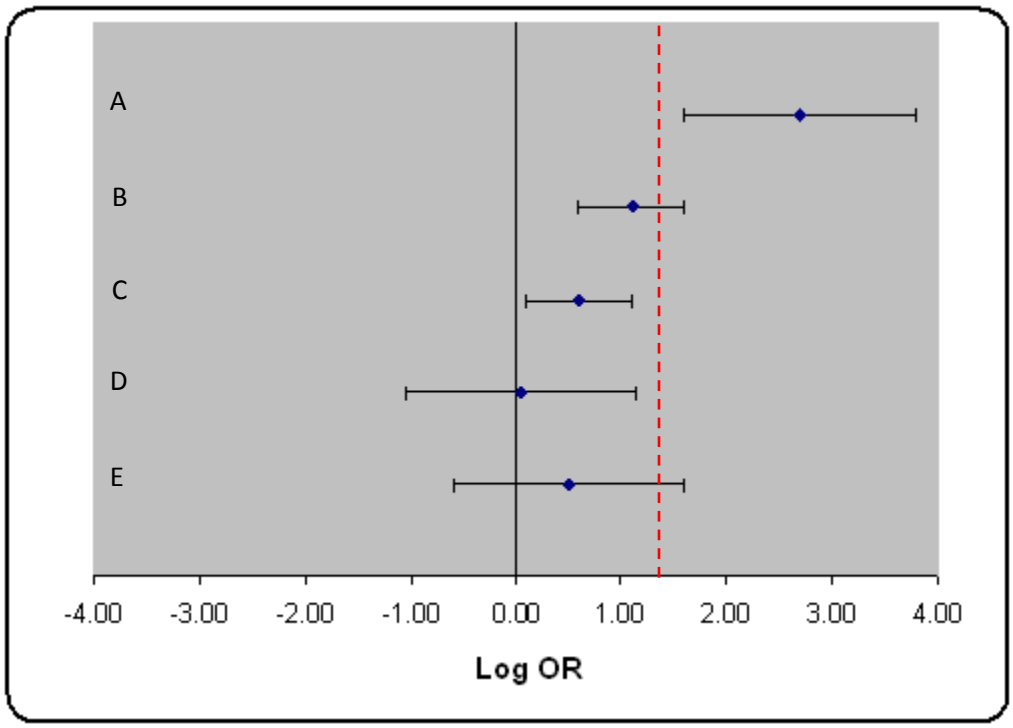
In this evidence report the answer to Decision Point 3 depended on a number of factors, including the number of available studies and the adequacy of reporting of study findings. For any given question, combinable data from at least 3 studies must be available before a quantitative analysis will be considered. If 4 or more studies were available but poor reporting precluded ECRI Institute from directly computing relevant effect-size estimates for >75% of the available studies, no quantitative analyses were performed. If no quantitative analyses were performed, we moved directly to Decision Point 8, which deals with the assessment of the available evidence with the aim of drawing a purely qualitative conclusion.

Decision Point 4: Are Data Quantitatively Consistent (Homogeneous)?

This decision point was used only when the answer to Decision Point 3 was affirmative and a quantitative analysis was performed. Quantitative consistency refers to the extent to which the quantitative results of different studies are in agreement. The more consistent the evidence, the more precise a summary estimate of treatment effect derived from an evidence base will be. Quantitative consistency refers to consistency tested in a meta-analysis using a test of homogeneity. For this evidence report we used both the Q-statistic and Higgins and Thompson's I^2 statistic.(8) By convention, we considered an evidence base as being quantitatively consistent when I^2 <50% and *P*(Q) >0.10.

If the findings of the studies included were homogeneous (I^2 <50% and *P*(Q) >0.10), we obtained a summary effect-size estimate by pooling the results of these studies using fixed-effects meta-analysis (FEMA). Having obtained a summary effect-size estimate, we then determined whether this effect-size estimate was informative. That is, we determined whether the findings of the meta-analysis allowed a conclusion to be drawn. To see what is meant by this, consider Figure E-1. Four of the findings in this figure are informative (A to D). Only finding E is noninformative.

Figure E-1. Informative Findings



Dashed Line - Threshold for a clinically significant difference.

Finding A shows that the treatment effect is statistically significant and clinically important. Finding B shows that the treatment effect is statistically significant, but it is unclear whether this treatment effect is clinically important. Finding C shows that the treatment effect is statistically significant but that the treatment effect is too small to be considered clinically important. Finding D shows that it is unclear whether there is a statistically important treatment effect, but regardless, this treatment effect is not clinically important. Finding E shows that it is unclear whether there is a statistically important treatment effect, and it is also unclear whether the treatment effect is clinically important. This latter finding is thus noninformative.

Decision Point 5: Are Findings Stable (Quantitatively Robust)?

If the findings of the FEMA were found to be informative, we next assessed the stability of the summary effect-size estimate obtained. Stability refers to the likelihood that a summary effect-size estimate will be substantially altered by changing the underlying assumptions of the analysis. Analyses that are used to test the stability of an effect-size estimate are known as sensitivity analyses. Clearly, one's confidence in the validity of a treatment effect estimate will be greater if sensitivity analyses fail to significantly alter the summary estimate of treatment effect.

For this evidence report, we utilized four different sensitivity analyses. These sensitivity analyses include the following:

1. *Random-effects meta-analysis of complete evidence base.* When the quantitative analysis is performed on a subset of available studies, a random-effects meta-analysis that includes imprecise estimates of treatment effect calculated for all available studies will be performed. For this evidence report, the summary estimate of treatment effect determined by this analysis will be compared to the summary effect-size estimate determined by the original FEMA. If the random-effects effect-size estimate differs from the original FEMA by some prespecified tolerance, the original effect-size estimate will not be considered stable.

   The prespecified tolerance levels for each of the potential effect-size estimates we could have utilized in this evidence report are presented in Table E-2.

   Table E-2. Prespecified Tolerance Levels

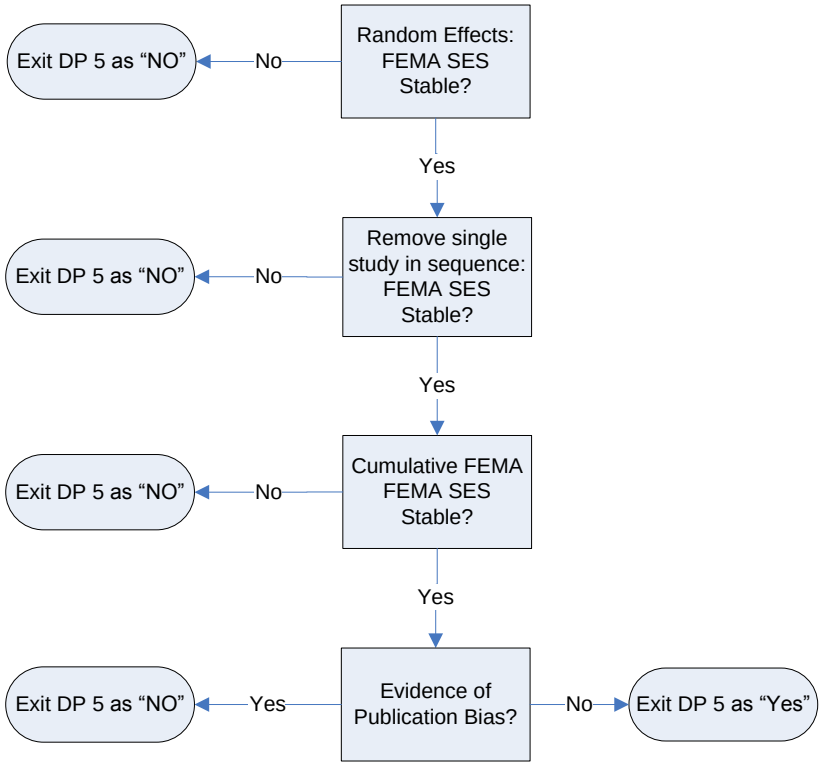
Effect-size Estimate	Weighted Mean Difference (WMD)	Standardized Mean Difference (SMD)	% of Individuals	Rate Ratio (RR)	Odds Ratio (OR)
Tolerance	+/-5%	+/-0.1	+/-5%	+/-0.05	+/-0.05

2. *Removal of one study and repeat meta-analysis.* The purpose of this sensitivity analysis is to determine whether a meta-analysis result is driven by a particular trial. For example, a large trial may have a very strong impact on the results of a meta-analysis because of its high weighting.
3. *Publication bias test.* The publication bias test used in this evidence report was that of Duval and Tweedie.(12-14,57) Based on the degree of asymmetry in a funnel plot constructed from the findings of the included studies, this test(13,14) estimates the number of unpublished studies (and their effect sizes). After addition of any "missing" data to the original meta-analysis, the overall effect size is estimated again. If evidence of publication bias was identified and the summary effect-size estimate, adjusted for missing studies, differed from the pooled estimate of treatment effect determined by the original FEMA by >±5%, then we determined that the findings of our original analysis are not robust and the effect-size estimate is not stable.
4. *Cumulative FEMA.* Cumulative meta-analysis provides a means by which one can evaluate the effect of the size of the evidence base (in terms of the number of individuals enrolled in the included studies and the number of included studies) on the stability of the calculated effect-size estimate. For this evidence report, we performed three different cumulative FEMAs:
   a. Studies were added in order of weight
   b. Studies were added cumulatively to a FEMA by date of publication—oldest study first.
   c. Studies were added cumulatively to a FEMA by date—newest study first.

   In each instance, the pooled effect-size estimate was considered unstable if any of the last three studies to be added resulted in a change in the cumulative summary effect-size estimate effect of >±5%.

Because it is possible to reach Decision Point 6 with two different types of evidence bases (100% or <100% ≥75% of total available evidence base), two slightly different sets of sensitivity analyses are needed. Figure E-2 shows the procedural algorithm that was used when dealing with these two types of evidence bases.

Figure E-2. Sensitivity Analysis Algorithm 1: Used when Original FEMA Utilized Data from All Available Studies



DP – Decision point
SES – Summary Effect Size.

Decision Points 6 and 7: Exploration of Heterogeneity

We will always attempt to determine the source of heterogeneity when the evidence base consists of 10 or more studies using meta-regression. In preparing this evidence report we did not encounter any situations where we had a heterogeneous evidence base consisting of at least 10 studies. Consequently, Decision Points 6 and 7 are irrelevant to the present report and we do not discuss them further.

Decision Point 8: Are Qualitative Findings Robust?

Decision Point 8 allows one to determine whether the qualitative findings of two or more studies can be overturned by sensitivity analysis. For this evidence report, a single sensitivity analysis was performed–a random-effects cumulative meta-analysis (cREMA). We considered our qualitative findings to be overturned only when the findings of the cREMA altered our qualitative conclusion (i.e., a statistically significant finding became nonsignificant as studies were added to the evidence base). If the qualitative

findings of the last three study additions were in agreement, then we concluded that our qualitative findings were robust.

Decision Point 9: Are Data Qualitatively Consistent?

The purpose of this decision point is to determine whether the qualitative findings of an evidence base consisting of only two studies are the same. For example, one might ask, "When compared to insulin injection, do all included studies find that inhaled insulin is a significant risk factor for a motor vehicle crash?"

Decision Point 10: Is Magnitude of Treatment Effect Large?

When considering the strength of evidence supporting a qualitative conclusion based on only one or two studies, magnitude of effect becomes very important. The more positive the findings, the more confident one can be that new evidence will not overturn one's qualitative conclusion.

The algorithm divides the magnitude of effect into two categories–large and not large. Determining the threshold above which the observed magnitude of effect can be considered to be large cannot usually be determined *a priori*. In cases where it is necessary to make judgments about whether an estimate of treatment effect is extremely large, the project director will present data from the two studies to a committee of three methodologists who will determine whether an effect-size estimate is "extremely large" using a modified Delphi technique.

Figure E-3. General Section

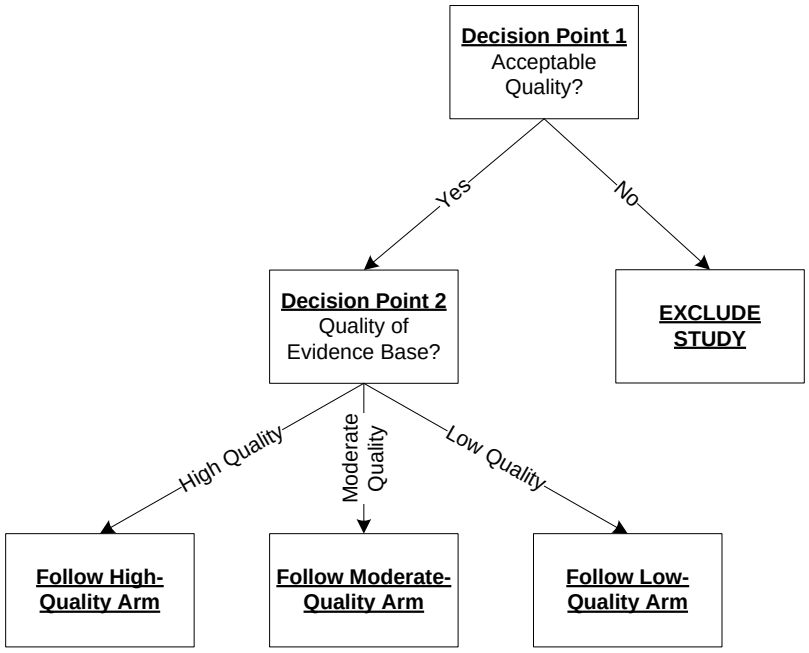


Figure E-4. High-quality Pathway

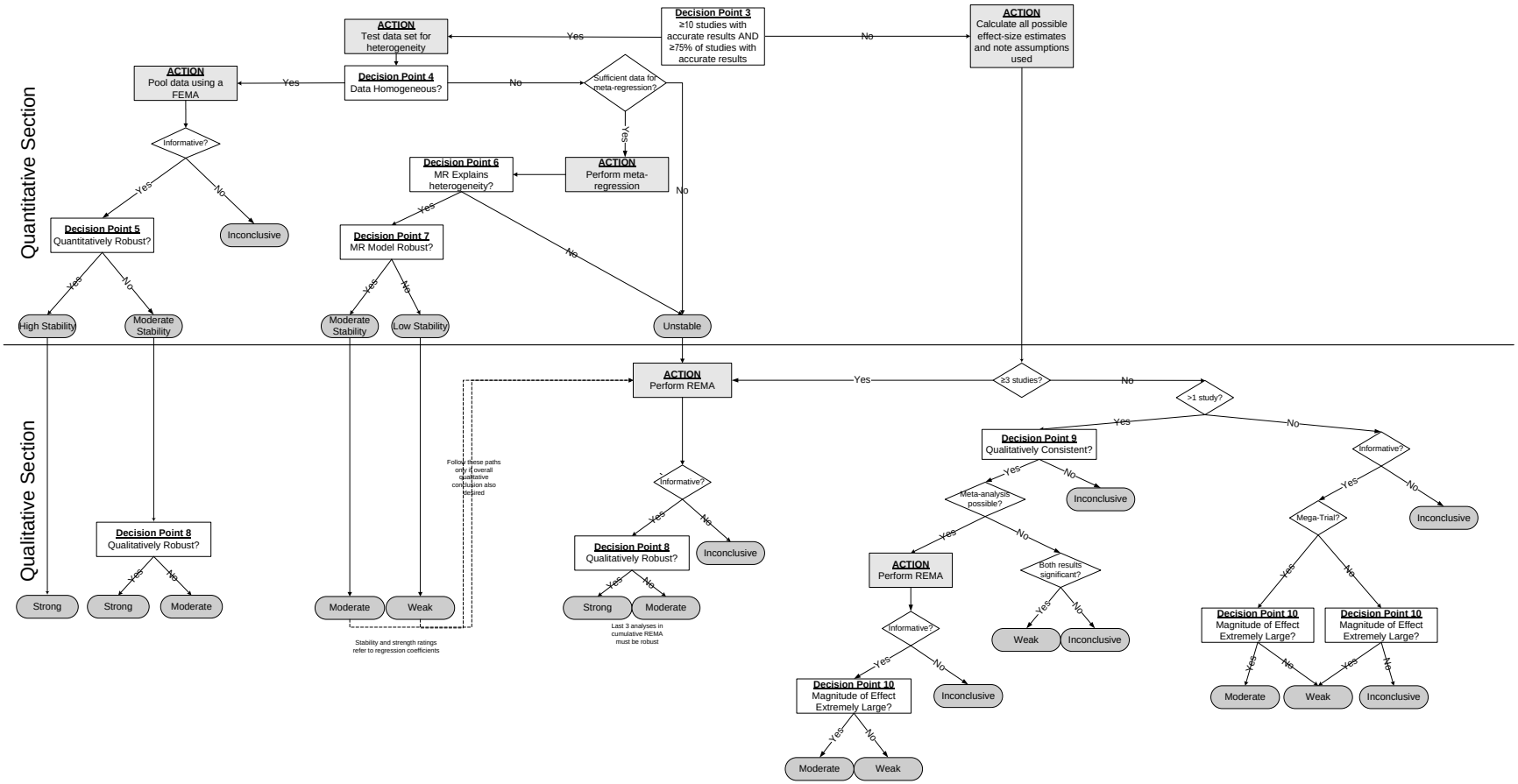


Figure E-5. Moderate-quality Pathway

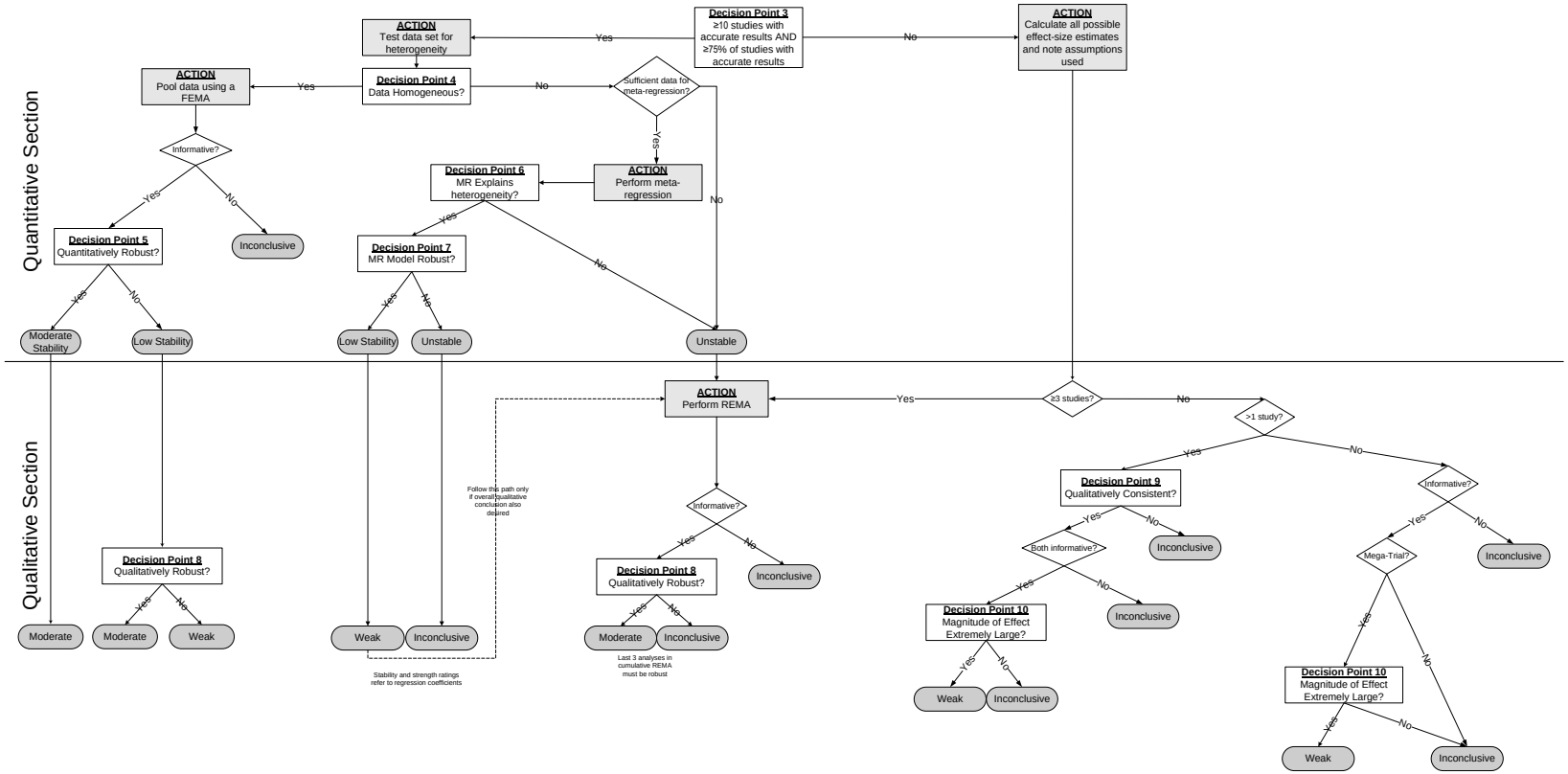
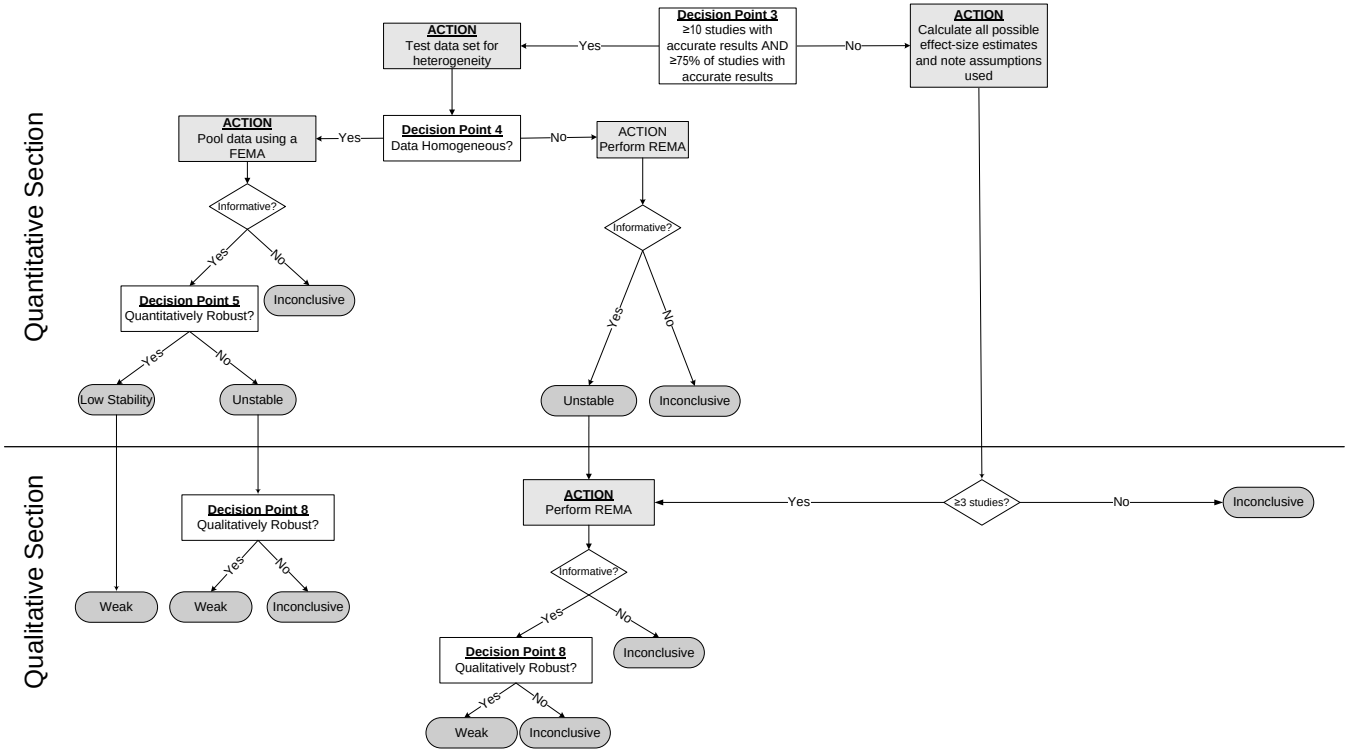


Figure E-6. Low Quality Pathway



Appendix F: Quality Assessment Instruments Used

Three different assessment instruments were used to assess the quality of the studies included in the evidence bases for the key questions addressed in this evidence report. The assessment instruments included the ECRI Institute Quality Scale I for comparative trials; the ECRI Institute Quality Checklist III for before-after studies; and a revised version of the Newcastle-Ottawa Quality Assessment Scale for Case-Control Studies.(335)

ECRI Institute Quality Scale I: Controlled Trials

Question #	Question
1	Were patients randomly assigned to the study's groups?
2	Did the study employ stochastic randomization?
3	Were any methods other than randomization used to make the patients in the study's groups comparable?
4	Were patients assigned to groups based on factors other than patient or physician preference?
5	Were the *characteristics* of patients in the different study groups comparable at the time they were assigned to groups?
6	Did patients in the different study groups have similar levels of performance on ALL of the outcome variables at the time they were assigned to groups?
7	Was the comparison of interest prospectively planned?
8	Did ≥85% of the patients complete the study?
9	Was there a ≤15% difference in completion rates in the study's groups?
10	Were all of the study's groups concurrently treated?
11	Was compliance with treatment ≥85% in both of the study's groups?
12	Were all of the study's groups treated at the same center?
13	Were subjects blinded to the treatment they received?
14	Did the authors perform any tests after completing the study to ensure that the integrity of the blinding of patients was maintained throughout the study?
15	Was the treating physician blinded to the groups to which the patients were assigned?
16	Were those who assessed the patients' outcomes blinded to the group to which the patients were assigned?
17	Was there concealment of allocation?
18	Was the outcome measure of interest objective **and** was it objectively measured?
19	Were the same laboratory tests, clinical findings, psychologic instruments, etc. used to measure the outcomes in all of the study's groups?
20	Was the instrument used to measure the outcome standard?
21	Was the same treatment given to all patients enrolled in the experimental group?
22	Was the same treatment given to all patients enrolled in the control group?
23	Were the follow-up times in all of the study's relevant groups approximately equal?
24	Was the funding for this study derived from a source that does not have a financial interest in its results?
25	Were the author's conclusions, as stated in the abstract **or** the article's discussion section, supported by the data presented in the article's results section?

ECRI Institute Quality Scale III: Pre-Post Studies

Item	Question
1	Was the study prospective?
2	Did the study enroll all patients or consecutive patients?
3	Were the criteria for including and excluding patients based on objective laboratory and/or clinical findings?
4	Were the patient inclusion/ exclusion criteria established *a priori*?
5	Was the same initial treatment given to all patients enrolled?
6	Did all patients receive the same subsequent treatment(s)?
7	Was the outcome measure objective **and** was it objectively measured?
8	Did ≥85% of patients complete the study?
9	Were the characteristics of those who did and did not complete the study compared, and were these characteristics similar?
10	Was the funding for this study derived from a source that does not have a financial interest in its results?
11	Were the author's conclusions, as stated in the abstract **or** the article's discussion section, supported by the data presented in the article's results section?

ECRI Institute Quality Scale VI: Surveys

Item	Question
1	Were the questions developed from an expert group or a focus group?
2	Was the pretest sample sufficiently large (>40 respondents)?
3	Were the characteristics of those who did not complete the study compared with those who completed the study, and were those characteristics similar?
4	Were the pretest sample respondents similar in characteristics to the study's respondents?
5	Were the respondents selected for the survey either consecutively or randomly?
6	Are the questions about crash (or other relevant outcome) not in the first 25% of the questions?
7	Does the questionnaire have reliability checks by asking the same question more than once but differently?
8	Were the respondents informed that their responses were confidential?
9	Were the conclusions as stated in the abstract and discussion consistent with the data presented in the results section?
10	Was the funding for this study derived from a source that does not have a financial interest in its results?

Revised Newcastle-Ottawa Quality Assessment Scale for Case-Control Studies

The original Newcastle-Ottawa Quality Assessment Scale for Case-Control Studies consisted of 10 questions. We adapted the instrument to better capture some sources of bias that were not considered in the original 10-item scale.

Question #	Question
1	Do the cases have independent validation?
2	Are the cases representative?
3	Are the controls derived from the community?
4	At the designated endpoint of the study, do the controls have the outcome of interest?
5	Does the study control for the most important confounder?
6	Does the study control for any additional confounders?
7	Was exposure/outcome ascertained through a secure record (surgical, etc.)?
8	Was the investigator who assessed exposure/outcome blinded to group patient assignment?
9	Was the same method of exposure/outcome ascertainment used for both groups?
10	Was the nonresponse rate of both groups the same?
11	Was the investigation time of the study the same for both groups?
12	Was the funding free of financial interest?
13	Were the conclusions supported by the data?

Appendix G: Study Summary Tables

Key Question 1

Gresset J, Meyer F. Risk of Automobile Accidents Among Elderly Drivers with Impairments or Chronic Diseases. Revue Canadienne De Sante Publique 1994; Vol 85, NO. 4; 282-5.

Key Questions Addressed	1	2	3	4	5
	✓				

Research Question: What is the influence of motor impairments on the risk of "accidents" among 70-year-old drivers?

Study Design: Case-Control

Population

Inclusion Criteria:

Cases:
- Quebec residents who held passenger vehicle permits (class 5 driver's permit)
- Drivers who were involved in crashes during their 70th year in 1988 or 1989

Controls:
- Randomly selected drivers who were not involved in crashes during their 70th year in 1988 and 1989

Exclusion Criteria:

Cases:
- Male drivers involved in fatal crashes (causing death of at least one of the individuals involved in the crash) and in crashes causing severe bodily damage (requiring hospitalization of at least one of the individuals involved

Controls:
- Individuals missing medical records

Study Population Characteristics:

Characteristics	Case	Control
Population (n)	1,400	2,636
Gender (male, %)	100%	100%
Age	70	70

Refer to Table G-1 for complete details

Generalizability to Commercial Motor Vehicle (CMV) Drivers: Unclear

Methods
- All drivers involved in crashes that involved mild bodily injury were selected for this study
- Controls were randomly selected from the 30,000± male drivers who were involved in crashes during their 70th year
- Information on subjects impairments' obtained from the Societe de l'Assurance Automobile du Québec (SAAQ)
- Information on mileage and prevailing driving conditions obtained through questionnaire mailed to study subjects
- 4 *a priori* confounding variables considered: demerit points, mileage, number of hours driven, and frequency of driving during rush hour

Statistical Methods
- Multiple logistic regression was used to obtain odds ratios (OR) while controlling for confounding factors
- 95% Confidence Interval (CI) was obtained from the standard error of the beta coefficients

Quality Assessment

Study Quality: Moderate

1	2	3	4	5	6	7	8	9	10	11	12	13
Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	NR	Y

Relevant Outcomes Assessed: Risk of road crash for drivers with chronic medical conditions and/or impairments

Results
- Prevalence of impairments including amputations and paralyses presented in Table G-1
- Among motor impairment evaluations, only motor deficits caused by paralyses associated with increase in the risk of crash (OR = 1.18, CI: 0.89-1.70)
- Response rate to questionnaire was 39.9%
- Proportion of those who responded did not differ significantly between cases and controls according to impairment or disease status
- Respondents to questionnaire, relative risk of crash increased by 12% per 10,000 km/year (OR = 1.12, CI: 1.00-1.24); driving during ≥9 hours per week was associated with relative risk of crash of 1.31 (CI: 1.06-1.62)

	• Drivers of more than 14 hours per week during rush hours had a relative risk of 1.24 (CI: 1.03-1.55) • Relationship between motor impairments and the risk of crash presented in Table G-2 • Risk of crash for individuals with amputations and paralyses presented as OR of 0.84, CI: 0.44-1.67 and OR of 1.18 (CI: 0.89-1.70), respectively
Authors' Comments	• It is possible that this study failed to identify truly increased risks of crashes associated with the various impairments and medical conditions • "Our study did not address the relationship between impairments or chronic diseases and the risk of accidents cause death or severe bodily injury" • The result from another study conducted in Quebec revealed that relative risks associated with visual impairments were similar for crashes with or without bodily injury

Table G-1. Prevalence of Chronic Impairments and Diseases among 1,400 Cases and 2,636 Controls

	Cases		Controls	
	N	%	N	%
Visual impairments	118	8.4	209	7.9
- Minimal VA	52	3.7	99	3.8
- Monocularity	5	0.4	10	0.4
- Minimal VA monocularity	61	4.4	100	3.5
Other impairments	120	8.6	228	8.7
- Hearing impairments	57	4.1	119	4.5
- Amputations	13	0.9	29	1.1
- Paralyses	50	3.6	80	3.0
Heart diseases	448	32.0	820	31.1
- Hypertension	176	12.6	346	13.1
- Heart failure	18	1.3	36	1.4
- Arrhythmias	30	2.1	35	1.3
- Ischemic heart disease	260	18.6	442	16.8
Diabetes mellitus	121	8.6	226	8.6
- Non-insulin-dependent	103	7.4	196	7.4
- Insulin-dependent	18	1.3	30	1.1

Table G-2. ORs of Accidents and Related 95% CIs for Chronic Impairments and Diseases among 70-year-old Drivers

	Odds Ratio	95% Confidence Interval	
Visual impairments	1.07	0.84	1.36
- Minimal VA	0.99	0.71	1.40
- Monocularity	0.95	0.32	2.77
- Minimal VA monocularity	1.16	0.83	1.60
Other impairments	0.99	0.78	1.26
- Hearing impairments	0.90	0.65	1.24
- Amputations	0.84	0.44	1.67
- Paralyses	1.18	0.89	1.70
Heart diseases	1.04	0.91	1.20
- Hypertension	0.95	0.78	1.16
- Heart failure	0.94	0.53	1.66
- Arrhythmias	1.63	1.00	2.65
- Ischemic heart disease	1.13	0.96	1.34
Diabetes mellitus	1.01	0.80	1.27
- Non-insulin-dependent	0.99	0.77	1.27
- Insulin-dependent	1.13	0.63	2.04

Ysander, L. The Safety of Physically Disabled Drivers. Sick and Handicapped Drivers 1970; 9: 54-61.

Key Questions Addressed	1	2	3	4
	✓			

Research Question

- To what extent is it possible, with the technical aids now available, to compensate for the disability of a handicapped driver and thereby to limit or eliminate the risk that the disability constitutes from the road-safety point of view?
- Does any particular type of disablement constitute a greater hazard than others from a road-safety point of view?

Study Design

Retrospective Case Control

Population

Inclusion Criteria

- Motor vehicle drivers with physical defects who had been granted driving licenses up to the end of 1961 in the counties of Gothenburg, Bohus, and Halland

Exclusion Criteria

Not Reported (NR)

Study Population Characteristics

Characteristics	Cases	Controls
Population (n)	494	494
Gender (male/female, %)	418 m, 85%/76 f,15%	NR
Age (range)	18 to >60	NR

Generalizability to Commercial Motor Vehicle (CMV) Drivers

Unclear

Methods

- Senior inspector of motor vehicles for the two counties keeps a record of all people who approach him about the possibility of their obtaining a driving license in spite of disablement
- List of individuals who did not pursue their request for driving license, who never obtained driving license, or who applied for and obtained license after 1961 covered by this investigation
- Material does not comprise all disabled motorists in the two counties, because the county administrative boards have no separate records of driving-license holders who are disabled
- General rule includes that all disabled individuals who wish to obtain a driving license be referred to the senior inspector of motor vehicles for consideration of their ability to drive
- Control group created to mirror cases (n = 494)
- The material is divided according to the degree of disablement:
  - Group 1: Drivers with a disability that permits only hand manipulation of the vehicle
  - Group 2: Driving made possible to disabled individuals after minor modification of controls
  - Group 3: Drivers classified as having a slight disablement such that vehicles are driven without modification of controls
- Available data pertaining to "road accidents" and traffic offenses were registered: Police records, court decisions, and other documents concerning traffic offenses kept by authorities for a limited time
- Investigation comprises of 10 period 1952-1961 for each driver only for the period disabled
- Distribution of various types of loss of function grouped to include loss of function in:
  - Left arm or hand
  - Right leg or foot
  - Left leg or foot
  - Partial loss, both legs or both feet
  - Total loss, both legs
- Other kinds of modifications to the vehicle also included
- Cause for disablement shown in Table G-3
- Questionnaire on traffic exposures sent to drivers as well as controls in the same annual driving distances

Statistical Methods

Not Reported (NR)

Quality Assessment

Study Quality:	1	2	3	4	5	6	7	8	9	10	11	12	13
Moderate	Y	Y	N	Y	Y	Y	Y	NR	Y	Y	NR	Y	Y

Relevant Outcomes Assessed

Frequency and number of disabled drivers involved in crashes reviewed

Results	• Total number of drivers in case and control groups in traffic crashes and/or involved in serious traffic offenses reported in Table G-4 • Exposure to traffic measured as the number of kilometers is greater among disabled drivers than controls. Refer to Table G-5 • 10-year period reveals an average observation period of 6.5 years; 7.1% of drivers had been involved in crashes, 12.2% of whom had been involved in crashes or serious traffic offense • Table G-6 reveals that drivers with vehicles solely operated by hand controls have a lower crash and traffic offense frequency • "Drivers suffering from the after-effects of poliomyelitis have the same accident frequency as groups 1 and 2, whereas drivers with amputations show frequency figures corresponding to group 3" • Table G-7 shows that a disproportionate number of crashes occurred among drivers without function in the right arm or leg
Authors' Comments	• "the significance of previous driving experience before disablement is difficult to evaluate" • "Investigation shows that disabled drivers do not constitute an increased risk in traffic…disabilities can be satisfactorily compensated for by applying various technical measures" • Improving compensatory technical modifications of vehicles may decrease further traffic risks associated with disabled drivers

Table G-3. Disabled Drivers: Cause of Disablement According to Age Group

Cause of Disablement	Age Group 18-20	21-25	26-30	31-40	41-50	51-60	>60	Total
After-effects of poliomyelitis	8	19	19	65	44	26	9	190
Amputations		3	11	24	22	14	2	76
Polyarthritis and arthrosis deformans	1	3	5	13	16	10	5	53
After-effects of tuberculosis of joints		2	1	11	18	8	3	43
Congenital malformations		5	7	8	4		1	25
After-effects of trauma and fractures (excluding spinal injury)		3	1	5	6	7		22
After-effects of spinal tumour and fracture		2	2	7	3	3	1	18
Organic nerve disease		1		5	9		2	17
Multiple sclerosis				7	5	4		16
Unknown or unspecified conditions		2	2	4	12	10	4	34
Total	9	40	48	149	139	82	27	494

Table G-4. Number of Drivers Involved in Road Accidents or Serious Traffic Offenses in the Investigation (I) and Control (C) Series, According to Age Group

No. of Drivers Involved in		Age Group 18-20	21-25	26-30	31-40	41-50	51-60	>60	Tot
Road accidents	I	0	5	5	7	12	4	2	35
	C	0	3	6	13	6	4	3	35
Serious traffic offences	I	0	5	2	5	8	3	2	25
	C	0	6	5	15	7	4	1	38

Table G-5. Percentage Distribution of Disabled Drivers and Drivers in the Control Series Who Supplied Information on Annual Distance Driven, Type of Driving, and Place of Driving

Stated Annual Distance Driven (km.)	Investigation Series n=316	Control Series n=333
	%	%
0	1	8
1–4,999	5	11
5,000–9,999	31	30
10,000–19,999	53	44
20,000 and above	10	7
Total	100	100
Place of driving		
Mainly urban areas	87	76
Mainly rural areas	11	16
No data given	2	8
Total	100	100
Type of driving		
Mainly for work	84	49
Mainly for pleasure	13	43
No data given	3	8
Total	100	100

Percentages are given to the nearest whole number
n=the number of drivers supplying information.

Table G-6. Percentage Distribution Involved in Road Accidents and/or Traffic Offenses in the Investigation Series, According to the Subgroups and the Most Commonly Occurring Causes of Disablement, and in the Control Series

Investigation Group or Cause of Disablement	Drivers with Road Accidents (%)	Drivers with Road Accidents and/or Serious Traffic Offences (%)
Whole investigation series m=6.5 n =494 o =63	7.1	12.2
Group 1 m=6.7 n =94 o =51	6.4	10.6
Group 2 m=5.9 n =292 o =66	6.2	11.3
Group 3 m=6.9 n =108 o =64	9.3	14.8
After-effets of poliomyelitis m=6.7 n =190 o =69	6.8	8.4
Amputations m=6.3 n =76 o =68	9.2	19.7
Control series m=6.5 n =494 o =51	7.1	14.8

m=average observation period (years)
n =number of drivers
o =percentage of drivers with more than 10,000 km/year

Table G-7. Percentage Distribution of Different Types of Loss of Function and Percentage Distribution of Road Accidents among These Types

Type of Loss of Function	Drivers (%)	Road Accidents (%)
Right arm or hand	7	14
Left arm or hand	8	11
Right leg or foot	19	32
Left leg or foot	22	3
Partial loss in both legs	14	14
Total loss in both legs	19	20
Other	11	6
Total	100	100

<table>
<tr><td colspan="12">Meikle B, Devlin M, Pauly T. Driving Pedal Reaction Times After Right Transtibial Amputations. Arch Phys Med Rehabil 2006; 87: 390-4.</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="4">4</td></tr>
<tr><td colspan="2">✓</td><td colspan="2"></td><td colspan="2"></td><td colspan="4"></td></tr>
<tr><td>Research Question</td><td colspan="11">To determine if right transtibial amputees have the potential to safely operate the foot pedals of a vehicle with their prosthetic foot, and to determine which of the 4 driving techniques is associated with the fastest reaction times</td></tr>
<tr><td>Study Design</td><td colspan="11">Repeated-measures (Single blinded)</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">• A screened sample of amputees attending an outpatient amputee for study inclusion
• Subjects who had undergone a traumatic, tumor, or vascular-related right transtibial amputation
• Licensed drivers prior to amputation
• Those who were at least 6 months post initial prosthetic fitting (to ensure adequate familiarity with prosthesis)</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">Not Reported (NR)</td></tr>
<tr><td>Study Population Characteristics</td><td colspan="10">Refer to Table G-8 for complete details</td></tr>
<tr><td>Generalizability to Commercial Motor Vehicle (CMV) Drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">• This study used an apparatus that included a set of brake an accelerator pedals used in combination with reaction timer software—the pedals were oriented in such a way as to replicate their positions relative to the seat in a conventional automobile
• The simulator was set up as such that subjects were to view shapes (circle) on a monitor similar to that of an actual traffic light; when the light in the circle turns red, the subject is to move his/her foot from the accelerator to the brake
• Each subject used his/her own prosthesis during the study; foot-pedal reaction time tested 4 different techniques
• Subjects were told to fully depress the accelerator pedal at the beginning of each trial; visual stimulus signaled the subject to depress the brake
• Different pedal layouts and techniques were tested in random order; each trial performed 15 to 30 seconds apart
• After testing, each subject ranked driving techniques in order of preference to avoid selection bias</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">• Descriptive statistics were used to summarize data
• Repeated-measures analysis of variance (ANOVA) used to test for statistically significant differences between reaction time, movement time, and total response time
• Repeated t-tests used for pedal comparisons
• Holm's sequential Bonferroni adjustment to control family-wise error rate across the 6 pairwise comparisons used
• Friedmen test to compare subject preferences for the various foot-pedal arrangements
• Wilcoxon signed-rank test used to conduct follow-up pairwise comparisons</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">Study Quality: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">• Total brake-pedal response time (in milliseconds) measured using reaction time and movement time
• Subject preference measured</td></tr>
<tr><td>Results</td><td colspan="11">• Total response times were slowest using a 2-footed driving technique ($p < 0.001$)
• Total response times were comparable using a left-sided accelerator versus the prosthesis
• Initial distances traveled prior to maximal braking shown in Table G-9
• Using the left foot to operate both the accelerator and brake led to the fastest reaction times ($p < 0.001$) and total response times ($p < 0.01$)
• See Figure G-1 for times measuring foot-pedal reaction, movement, and total response time under various pedal conditions
• Figure G-2 shows foot-pedal arrangement preference</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">Our results suggest that right transtibial amputees should be instructed not to drive with a 2-footed technique, and that they have similar pedal response times using their prosthesis when compared with a left-sided accelerator</td></tr>
</table>

Table G-8. Baseline Subject Characteristics (n = 10)

Characteristics	Values
Age (y)	53.1±9.46
Men	7 (70)
Reason for amputation	
Trauma/tumor	8 (80)
Vascular disease	2 (20)
Driving experience (preamputation), y	29.0±12.24
Currently driving	5 (50)
Current driving frequency	
Everyday	4 (40)
4–6 times/wk	
2–3 times/wk	1 (10)
Once or less per week	
Weekly kilometers	570±542.68
Car modifications	
Left-sided accelerator	1 (10)
None	4 (40)
Preamputation accelerator foot	
Right	9 (90)
Preamputation brake foot	
Right	9 (90)
Postamputation accelerator foot	
Right	3 (30)
Left	2 (20)
Postamputation brake foot	
Right	2 (20)
Left	3 (30)
Postamputation collisions	2

NOTE. Values are mean ± standard deviation or n (%).

Table G-9. Relative Distances Traveled Prior to Initiating Maximal Braking (in meters) for Various Experimental Conditions

Velocity (kph)	Right-Footed Accelerator; Left Foot Gas and Brake	Left-Footed Accelerator; Left Foot Gas and Brake	Right-Footed Accelerator; Prosthetic Foot and Brake	Right-Footed Accelerator; Prosthetic Foot Gas, Left Foot Brake
80	22.8	23.8	24.4	29.4
100	28.5	29.8	30.5	36.7
120	34.2	35.7	36.6	44.0
140	39.9	41.7	42.7	51.4

Figure G-1. Foot-pedal Reaction, Movement, and Total Response Time Under Various Pedal Conditions

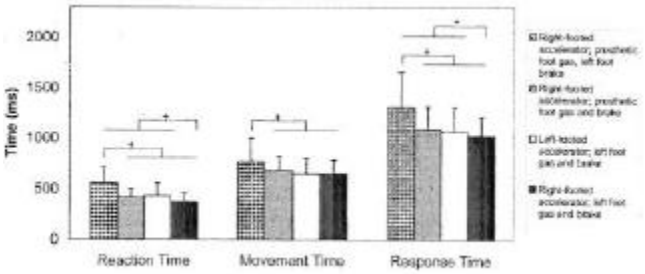
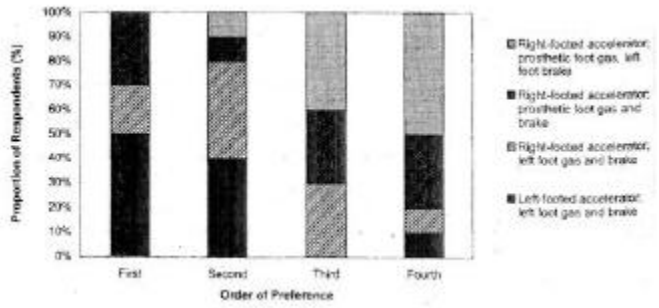


Figure G-2. Foot-pedal Arrangement Preference



Key Question 2

Koepsell T, Wolf M, McCloskey L, Buchner D, Louie D, Wagner E, Thompson R. Medical conditions and motor vehicle collision injuries in older adults. JAGS 1994; 42: 695-700

Key Questions Addressed	1	2	3	4
		✓		

Research Question: Risk of collision injury for arthritic drivers versus other medical conditions in older adults

Study Design: Case control

Population

Inclusion Criteria: Cases were licensed drivers aged 65+ years who received medical attention within one week at a Washington State HMO, Group Health Cooperative of Puget Sound (GHC), for injuries sustained in a motor vehicle crash. Controls were also members of GHC but had not been injured in a motor vehicle crash.

Exclusion Criteria:

Study Population Characteristics:

Variable	Cases	Controls
n	*235*	*448*
Age		
65–69	90	174
70-74	66	129
75-79	49	87
80+	29	56
Gender M/F	117/118	224/224
Miles driven in previous year		
<5,000	102	196
5,000-10,000	59	125
10,000-15,000	46	84
>15,000	27	39

Generalizability to Commercial Motor Vehicle (CMV) Drivers: Unclear

Methods: Potential study subjects were initially identified from police reports of car crashes in 1987 and 1988. Police records confirmed driver responsibility for crash and GHC records confirmed treatment for injury. Two matched controls for every case were selected. A reference date (collision date) was used for both cases and controls. All cases and controls were to have visited a physician through GHC one year prior to the referenced date. Data abstracted from medical records included diagnosis and treatments up to three years prior to the reference date. All participants either filled out a questionnaire or took part in a phone interview to discuss driving habits, number of miles driven/year, health habits, and sociodemographic characteristics.

Statistical Methods: Odds ratios, Mantel-Haenszel techniques, conditional logistic regression

Quality Assessment

Study Quality: Moderate

1	2	3	4	5	6	7	8	9	10	11	12	13
Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y

Relevant Outcomes Assessed: Risk of crash

Results: Risk of crash injury for arthritic drivers versus other medical conditions are shown in Table G-10. Osteoarthritis affected 53.8% of cases and 52.0% of controls, with a relative risk of injury of 1.1 (95% CI: 0.8-1.5). Rheumatoid arthritis affected 2.1% of cases and 1.3% of controls, with a slightly higher risk of motor vehicle injury at 1.6% (0.5-5.3). Drivers with diabetes posed the highest relative risk of collision injury, with an odds ratio of 2.6 (95% CI: 1.4-4.7). Depression, alcohol abuse, and a fall in the previous year were additional conditions associated with increased risk of collision injury.

Authors' Comments: Drivers with osteoarthritis and rheumatoid arthritis appear to have only a slightly increased risk of motor vehicle collision injury.

Table G-10. Risk of Collision Injury by Medical Condition

Table 4. *Relative risk of motor vehicle collision injury in relation to selected other medical conditions*

Condition	Percent Prevalence among Cases (n = 234)	Percent Prevalence among Controls (n = 446)	Odds Ratio* Est.	Odds Ratio* (95% CI)
Fall in previous year	12.4	9.2	1.4	(0.9–2.4)
Depression	9.0	5.6	1.7	(0.9–3.1)
Alcohol abuse	3.4	1.8	2.1	(0.8–6.0)
Chronic obstructive pulmonary disease	9.8	9.9	0.9	(0.5–1.6)
Asthma	5.1	4.5	1.2	(0.6–2.6)
Osteoarthritis	53.8	52.0	1.1	(0.8–1.5)
Rheumatoid arthritis	2.1	1.3	1.6	(0.5–5.3)
Cancer	18.4	17.9	1.0	(0.6–1.5)
Diabetes mellitus	11.1	4.5	2.6	(1.4–4.7)

*from matched analysis

McGwin Jr. G, Sims R, Pulley L, and Roseman J. Relations among chronic medical conditions, medications, and automobile crashes in the elderly: a population-based case-control study. Am J Epidemiol 2000; 152: 424-31

Key Questions Addressed	1	2	3	4
		✓		

Research Question: Association of arthritis with increased crash risk

Study Design: Case control

Population

Inclusion Criteria: Licensed drivers of Mobile County, Alabama aged 65+ years involved in at least one automobile crash between January 1 and December 31, 1996

Exclusion Criteria: Individuals who possessed licenses for identification purposes only

Study Population Characteristics

	At-fault drivers involved in crashes	Drivers not involved in crashes	Not-at-fault drivers involved in crashes
n	249	454	198
Age (year)	**%**	**%**	**%**
65-68	21.3	25.7	39.6
69-72	25.4	24.4	23.6
73-77	25.8	25.7	23.6
78-93	27.5	24.2	13.2
Gender	**%**	**%**	**%**
Male	49.6	49.1	51.1
Female	50.4	51.0	48.9
Prior crash involvement	**%**	**%**	**%**
No	63.9	79.0	66.5
Yes	36.1	21.1	33.5

Generalizability to Commercial Motor Vehicle (CMV) Drivers: Unclear

Methods: Drivers aged 65 years and older were selected from Alabama Department of Public Safety (ADPS) driving records. Of the 39,687 eligible individuals, 1,906 had been involved in at least one automobile crash during 1996. 560 individuals were contacted by phone and asked to participate in the study. In addition to the 447 who agreed to participate, a random sample of 1,900 possible controls was selected from similar driving records. Phone interviews took place between June–December 1997 by interviewers blind to case status. Information collected included demographics, chronic medical conditions, medications, and driving habits. A focal reference date of January 1, 1996 was used. Subjects were asked if they had been diagnosed with arthritis and the medications they were currently taking for this condition or any others. Crash involvement from 1991 – 1995 was researched via ADPS records.

Statistical Methods: Frequency distributions, odds ratios (ORs), 95% confidence interval (CI), logistic regression

Quality Assessment

Study Quality: Moderate	1	2	3	4	5	6	7	8	9	10	11	12	13
	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y

Relevant Outcomes Assessed: Crash risk

Results: The at-fault crash rate was 20% (95% CI: 0.9, 1.7) (Table G-11) greater in drivers who reported that they had arthritis than in drivers who did not report this; however, the increased risk was only apparent among females (OR = 1.8, 95% CI: 1.1, 2.9), not males (OR = 0.8, 95% CI: 0.5, 1.3). Not-at-fault drivers involved in crashes were also more likely to have heart disease, stroke, and arthritis compared with drivers not involved in crashes.

Authors' Comments: Drivers diagnosed with arthritis had an increased risk of crash involvements; however, risk was found mostly in the female population.

Table G-11. Medical Characteristics of At-fault and Not-at-fault Drivers Involved in Crashes versus Drivers Not Involved in Crashes in Mobile County, Alabama, January through December 1997

	% at-fault drivers involved in crashes (*n* = 249)	Drivers not involved in crashes (*n* = 454)					Not-at-fault drivers involved in crashes (*n* = 198)				
		%	OR*,†	95% CI*	OR‡	95% CI	%	OR†	95% CI	OR†,‡	95% CI
High blood pressure	42.9	45.7	0.9	0.6, 1.2	0.9	0.6, 1.3	45.7	0.9	0.6, 1.3	0.9	0.6, 1.4
Heart disease	26.0	20.2	1.4	0.9, 2.0	1.5	1.0, 2.2	24.3	1.1	0.7, 1.7	1.0	0.7, 1.7
Stroke	7.3	4.1	1.8	0.9, 3.7	1.9	1.0, 3.9	6.9	1.1	0.5, 2.3	1.1	0.5, 2.4
Cancer	15.3	13.7	1.1	0.7, 1.8	1.2	0.7, 1.9	13.9	1.1	0.6, 2.0	1.0	0.5, 1.8
Arthritis	48.6	43.3	1.2	0.9, 1.7	1.2	0.9, 1.7	47.4	1.1	0.7, 1.6	1.0	0.7, 1.5
Cataracts	44.6	42.8	1.1	0.8, 1.5	1.0	0.7, 1.5	35.1	1.5	1.0, 2.2	1.1	0.7, 1.8
Glaucoma	6.9	8.9	0.8	0.4, 1.4	0.7	0.4, 1.3	5.2	1.4	0.6, 3.2	1.0	0.4, 2.5
Diabetes	13.6	14.0	1.0	0.6, 1.5	0.9	0.6, 1.5	16.0	0.8	0.5, 1.4	0.9	0.5, 1.5
Kidney disease	3.2	4.7	0.7	0.3, 1.6	0.7	0.3, 1.6	6.4	0.5	0.2, 1.2	0.4	0.2, 1.2
Diabetic retinopathy	1.6	1.5	1.1	0.3, 3.8	1.4	0.3, 4.0	1.1	1.5	0.3, 8.2	1.9	0.3, 10.9
Diabetic neuropathy	1.2	0.6	2.0	0.4, 9.8	2.6	0.5, 13.1	0.5	2.3	0.2, 21.8	2.8	0.3, 28.3

OR - Odds ratio
CI - Confidence interval
† - Reference is those without condition
‡ - Adjusted for age, gender, race, and annual mileage.

<table>
<tr><td colspan="15">Sims R, McGwin G, Allman R, Ball K, Owsley C. Exploratory study of incident vehicle crashes among older drivers. Journal of Gerontology 2000; 55: M22-27</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td>1</td><td colspan="4">2</td><td colspan="4">3</td><td colspan="4">4</td></tr>
<tr><td></td><td colspan="4">✓</td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td>Research Question</td><td colspan="14">Risk of arthritis and crash involvement</td></tr>
<tr><td>Study Design</td><td colspan="14">Prospective cohort</td></tr>
<tr><td rowspan="3">Population</td><td>Inclusion Criteria</td><td colspan="13">Licensed drivers aged 55+ years and living in Jefferson County, Alabama in 1989</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="13">Individuals with Driving-Under-the-Influence convictions</td></tr>
<tr><td>Study Population Characteristics</td><td colspan="13">Variable — Values
N — 174
Age (year) — %
55-63 — 22.3
64-69 — 24.6
70-77 — 26.3
78+ — 26.9
Gender
Female (%) — 47.4
Male (%) — 52.6</td></tr>
<tr><td>Methods</td><td colspan="14">Individuals for this study were previous participants in a 1990 crash frequency study. Crash data were obtained from the Alabama Department of Public Safety (ADPS). Patient data (including medical diagnoses) were collected in 1991, while crash data were obtained from ADPS for a 5-year period from 1991 to 1996.</td></tr>
<tr><td>Statistical Methods</td><td colspan="14">Cox proportional-hazards models to calculate relative risk and 95% confidence intervals (CI), Breslow method, Wald chi-square test, Martingale and deviance residuals, influence statistics, stability of estimates, inflated standard errors, and convergence difficulties</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">Study Quality: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="14">Crash risk</td></tr>
<tr><td>Results</td><td colspan="14">Most individuals (80.3%) experienced a single crash, with remaining drivers experiencing up to 4 crashes. Individuals diagnosed with arthritis had a crash rate of 9.5 per million miles driven with a 1.04 relative risk (95% CI 0.61, 1.78) (Table G-12) of crash. The highest crash rate was measured in individuals with a diagnosis of stroke/transient ischemic attack at 21.1 crashes/million miles driven and a relative risk of 2.71 (95% CI 1.11, 6.61).</td></tr>
<tr><td>Authors' Comments</td><td colspan="14">Over a 5-year period, drivers diagnosed with arthritis demonstrated a one-fold risk of crash.</td></tr>
</table>

Table G-12. Relation of Medical Diagnoses to Vehicle Crashes

Medical Diagnoses	Percentage with Characteristic	Crash Rate*	RR†	95% CI	*p*
Arthritis	61.1	9.5	1.04	0.61, 1.78	.89
Prior fracture	53.7	10.5	1.27	0.75, 2.16	.37
Hypertension	47.5	11.5	1.36	0.81, 2.28	.25
Cataract	45.1	10.4	1.10	0.62, 1.97	.74
Pulmonary disease‡	25.7	11.0	1.29	0.73, 2.31	.38
Gastrointestinal diseases	36.6	9.3	1.02	0.60, 1.73	.94
Heart disease§	21.3	11.9	1.53	0.81, 2.89	.19
Peptic ulcer	17.7	11.4	1.10	0.54, 2.24	.80
Diabetes mellitus	15.4	6.3	0.67	0.28, 1.56	.35
Cancer history	14.9	7.7	0.83	0.37, 1.85	.65
Stroke/transient ischemic attack	9.8	21.1	2.71	1.11, 6.61	.03
Other eye disease	9.7	6.7	0.81	0.29, 2.28	.69
Macular degeneration	7.4	6.4	0.60	0.14, 2.55	.49
Glaucoma	6.9	6.4	0.84	0.30, 2.36	.74
Renal disease	6.3	6.9	0.82	0.29, 2.30	.71
Seizures	3.3	7.4	0.68	0.16, 2.90	.60
Liver disease	2.9	4.6	0.52	0.07, 3.77	.52
Diabetic retinopathy	2.3	8.6	1.37	0.19, 10.11	.76
No medical diagnoses	4.0	22.0	REF		
1–3 Medical diagnoses	60.0	10.1	0.46	0.16, 1.32	.15
≥4 Medical diagnoses	36.0	14.1	0.63	0.22, 1.86	.41
P for trend					.58

Notes: RR = relative risk, CI = confidence interval, REF = reference value for the odds ratio, which equals 1.0.

*Per million miles driven.

†Adjusted for age, gender, race, and days driving per week.

‡Includes diagnoses of asthma, emphysema, and chronic bronchitis.

§Includes diagnoses of prior myocardial infarction, congestive heart failure, and angina.

<table>
<tr><td colspan="12">Cranney A, Harrison A, Ruhland L, Vaidyanath C, Graham I, Man-son-hing M, Jaffey J, Towheed T, Anastassiades T, Dwosh I. Driving problems in patients with rheumatoid arthritis. J Rheumatol 2005; 32: 2337-42</td></tr>
<tr><td rowspan="2">Key Questions Addressed</td><td colspan="2">1</td><td colspan="3">2</td><td colspan="2">3</td><td colspan="4">4</td></tr>
<tr><td colspan="2"></td><td colspan="3">✓</td><td colspan="2"></td><td colspan="4"></td></tr>
<tr><td>Research Question</td><td colspan="11">Assess driving difficulties faced by drivers with rheumatoid arthritis (RA)</td></tr>
<tr><td>Study Design</td><td colspan="11">Survey</td></tr>
<tr><td rowspan="4">Population</td><td>Inclusion Criteria</td><td colspan="10">Individuals aged 25-76 years who had RA for 1+ years identified in the Southeastern Ontario Academic Medical Organization (SEAMO) database</td></tr>
<tr><td>Exclusion Criteria</td><td colspan="10">Not applicable (NA)</td></tr>
<tr><td>Study Population Characteristics</td><td colspan="10"><table><tr><td><u>Variable</u></td><td><u>Total</u></td><td><u>Drivers</u></td><td><u>Nondrivers</u></td></tr><tr><td>n</td><td>520</td><td>480</td><td>40</td></tr><tr><td>Age (years) mean ±Standard deviation (SD)</td><td>58.5 (11.2)</td><td>58.1 (11.0)</td><td>63.5 (12.4)</td></tr><tr><td>Mean years since diagnosis</td><td>15.5(12.8)</td><td>15.3 (12.9)</td><td>18 (12.5)</td></tr><tr><td>Female, % (n)</td><td>70.2 (365)</td><td>68.8 (330)</td><td>87.5 (35)</td></tr><tr><td>Mean duration of RA (years)</td><td>15.5 (12.8)</td><td></td><td></td></tr></table></td></tr>
<tr><td>Generalizability to Commercial Motor Vehicle (CMV) Drivers</td><td colspan="10">Unclear</td></tr>
<tr><td>Methods</td><td colspan="11">Individuals were surveyed between March and July 2004. 721 surveys were mailed to potential subjects. Survey contents included demographics, RA characteristics, current driving habits, difficulty with driving tasks, use of aids, and vehicle adaptations.</td></tr>
<tr><td>Statistical Methods</td><td colspan="11">Chi-square test, Mann-Whitney test, bivariate analysis, Categorical and Regression Tree (CART), multivariate logistic regression</td></tr>
<tr><td rowspan="2">Quality Assessment</td><td rowspan="2">Study Quality: Moderate</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>Y</td><td>Y</td><td>Y</td><td>N</td><td>Y</td><td>N</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>Relevant Outcomes Assessed</td><td colspan="11">Driving difficulty</td></tr>
<tr><td>Results</td><td colspan="11">Only 8% of drivers reported having an accident due to their RA during the past 5 years. 58% stated that RA limits their driving in some manner with the 2 most frequently reported limitations being stiffness (51.3%) and pain (57%). 19.9% of drivers reported avoiding driving due to RA in the last 6 months. Difficulties faced when driving by patients with RA are shown in Table G-13. Those individuals who reported neck pain were 20% more likely to experience limitation of driving due to RA (p <0.001). However, neck pain was not related to limitation of highway driving. There was also no correlation found between neck pain and accidents reported. Individuals with lower back pain also showed a greater chance of reporting driving limitation due to RA (chi-square test, p <0.001). Again, there was no correlation found between back pain and limitation of highway driving or accident occurrence.</td></tr>
<tr><td>Authors' Comments</td><td colspan="11">While RA limited driving in over 50% of the study population, only a small percentage stated any major driving difficulties. With less than 10% of subjects reporting an accident in the last 5 years, no predictors of crash were determined.</td></tr>
</table>

Table G-13. Activities that Cause Difficulty Driving for RA Patients

Activities	% (n)
Prior (n = 478)	
Turning the key/ignition	41.6 (199)
Opening/closing vehicle doors	40.2 (192)
Fastening or unfastening seatbelt	38.3 (183)
Reaching for the seatbelt	38.1 (182)
Getting into the driver's seat	36.6 (175)
Adjusting the seat position	19.2 (92)
Reaching to adjust mirrors	14.4 (69)
Releasing handbrake	12.3 (59)
During (n = 472)	
Sitting for any length of time	53.9 (253)
Making shoulder checks	34.3 (161)
Gripping wheel	27.9 (131)
Reversing vehicle	27.2 (128)
Turning corners	22.0 (105)
Shifting gears	14.7 (69)
Steering	14.7 (69)
Merging with traffic	14.0 (66)
Reaching to operate turn signal or dashboard	9.9 (47)
Controlling brake pedal or accelerator	8.3 (39)

Jones J, McCann J, Lassere M. Driving and arthritis. British Journal of Rheumatology 1991; 30: 361-64										
Key Questions Addressed	**1**		**2**		**3**		**4**			
			✓							
Research Question	Assess driving disabilities faced by patients with rheumatoid arthritis (RA) and osteoarthritis (OA)									
Study Design	Case Series									
Population	**Inclusion Criteria**	Patients with driving difficulties due to musculoskeletal disorders referred by a medical practitioner to Queen Elizabeth Hospital, Rotorua, New Zealand for driving assessment from January 1986 – December 1988								
	Exclusion Criteria	Not applicable (NA)								
	Study Population Characteristics	Variable n Gender M/F	Value 94 22/7							
	Generalizability to Commercial Motor Vehicle (CMV) Drivers	Unclear								
Methods	Patients were categorized into six disease categories: RA (rheumatoid arthritis, n = 37), OA (osteoarthritis, n = 23), LBP (low back pain, n = 16), FM (fibromyalgia, n = 6), AS (ankylosing spondylitis, n = 4), and miscellaneous (including juvenile chronic arthritis, systemic lupus erythematosus, polymyalgia rheumatica, and generalized osteoporosis, n = 8). 37 patients with RA had "long-standing disabling disease." Driving assessment was grouped into 14 composite parts and patients were assessed by driving ability and safeness. Once the difficulties were identified, recommendations to driving technique or vehicle were made. A four-point scale was used to assess patient's ability to carry out different parts of the driving process. Grading included: 0, no difficulty; 1, some difficulty; 2, serious difficulty; 3, impossible. A grade of 2 or 3 indicated a "presence of disability." Functional ability was categorized into: hand function, upper limb function, upper spinal function, lower spinal function, lower limb function, and supratentorial function.									
Statistical Methods	NA									
Quality Assessment	**Study Quality: Moderate**	1	2	3	4	5	6	7	8	9	10
		Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Relevant Outcomes Assessed	Driving disabilities									
Results	Driving disabilities assessed by disease category are shown in Table G-14. Drivers with RA demonstrated problems in all areas of function, but with greatest difficulty being demonstrated with *hand function* (use of hand brake - 51%) and *upper limb function* (steering/cornering -51%). *Upper spine function* (reversing) was also found difficult by 38% of RA drivers. Drivers with OA experienced the most difficulty with *upper spine function* (reversing - 65%), followed by similar difficulty in *upper limb function* (steering/cornering -30%) and *lower spine function* (seat comfort and position - 30%). Solutions to these driving disabilities are shown in Table G-15. After being taught minor modifications to vehicle and/or driving technique, seven RA drivers and five OA drivers continued to have "unsatisfactory" driving ability. In addition, two RA drivers were categorized "unsafe" drivers due to disease status while one RA patient, with severe long-standing ankylosing RA, had to be provided with a specially designed car.									
Authors' Comments	Both RA and OA drivers had primary driving difficulty with upper limb and upper/lower spine function, while the RA group alone had difficulty with hand function. Most disabilities were handled by vehicle modifications or new driving technique.									

Table G-14. Number (%) Individuals with Driving Disabilities Classified by Disease Category

	RA	OA	LBP	FM	AS	Misc	Total
n	37	23	16	6	4	8	94
Hand/upper limb							
Seat belt manipulation	5 (14)	1 (4)	0	0	1 (25)	0	7 (7)
Key manipulation	7 (19)	1 (4)	0	1 (16)	0	0	9 (10)
Hand brake	19 (51)	2 (9)	0	2 (33)	0	1 (12)	24 (26)
Upper limb/hand							
Open/close door	5 (14)	0	0	0	0	0	5 (5)
Mirror adjustment	3 (8)	0	0	0	0	0	3 (3)
Use of gears	8 (22)	1 (4)	0	0	0	0	9 (10)
Upper limb/upper spine							
Reaching seat belt	12 (32)	2 (9)	0	1 (16)	0	1 (12)	16 (17)
Steering/cornering	19 (51)	7 (30)	2 (12)	3 (50)	2 (50)	1 (12)	34 (36)
Upper spine/upper limb							
Reversing	14 (38)	15 (65)	3 (19)	2 (33)	4 (100)	0	38 (40)
Lower spine/lower limb							
Seat comfort and position	12 (32)	7 (30)	7 (44)	2 (33)	1 (25)	3 (37)	32 (34)
Lower limb/lower spine							
Entry/exit	5 (14)	4 (17)	0	2 (33)	1 (25)	1 (12)	13 (14)
Footpedals	4 (11)	4 (17)	6 (37)	1 (16)	1 (25)	2 (25)	18 (19)
Supratentorial							
Awareness of traffic and pedestrians	3 (8)	3 (13)	0	0	0	0	6 (6)
Confidence	7 (19)	6 (26)	1 (6)	1 (16)	2 (50)	0	17 (18)
Mean number of disabilities per individual	3.3	2.3	1.2	2.5	3	1.2	2.5

AS – Ankylosing spondylitis
FM – Fibromyalgia
LBP – Low back pain with or without sciatica
Misc – Miscellaneous
OA – Osteoarthritis
RA – Rheumatoid arthritis

Table G-15. Driving Disabilities and Their Solutions

Disability	Solution
Securing/undoing seatbelt	Non-inertia reel. Extend stem of seat belt attachment. Modify seat belt clip
Manipulation of key	Build up key
Use of hand brake	Convert to vertical lever for knock on/off action. Keep car in gear when parked. Use accelerator/clutch for hill start. Buy automatic car
Open and close door	Keep door hinges and handles oiled. Modify buttons. Enlarge door handles
Adjustment of mirror	Ask other car drivers to reposition mirror
Use of gearstick	Increase length of gearstick. Modify hand piece. Buy automatic car. Modify automatic gear stick to 'push down' type
Reaching seat belt	Hook belt around seat lever. Prevent full recoil of seat belt
Steering/cornering	Steering wheel cover to increase bulk of wheel. 'Threading' steering technique.* Increase front tyre pressure. Power steering
Reversing	Undo seat belt when reversing. Instal wide rear view mirror. Instal near and off side mirrors. 'Reversing with mirrors'*
Seat comfort and position	Extend seat runners. Alter seat back position. Wedge cushion. Lumbar cushion
Vehicle entry and exit	Enter buttocks rather than legs first. Extend seat runners
Use of foot pedals	Pedal modification. Automatic car
Traffic sense and confidence	Practise with experienced driver in quiet streets. Limit driving to familiar streets. Take lessons with qualified driving instructor
Pain and fatigue on long drives	Frequent stops on long trips. Judicious use of NSAIDs and analgesics. Establish a relaxed driving position

NSAIDS - Nonsteroidal anti-inflammatory drugs.

DiStefano M, Macdonald W. Assessment of older drivers: Relationships among on-road errors, medical conditions and test outcome. Journal of Safety Research 2003; 34: 415-29										
Key Questions Addressed	**1**		**2**		**3**		**4**			
			✓							
Research Question	Driving test performance of drivers with arthritis									
Study Design	Retrospective case review									
Population	**Inclusion Criteria**	Individuals referred for questionable driving competence in the state of Victoria, Australia								
	Exclusion Criteria	Individuals with major physical or specific cognitive impairments								
	Study Population Characteristics	Variable	Value							
		n	496							
		Age (average)	76.1 (range 24 – 100)							
		Gender M/F	68% M							
	Generalizability to Commercial Motor Vehicle (CMV) Drivers	Unclear								
Methods	Data were obtained from files at VicRoads, a local state driver licensing authority. 533 on-road license review test records from a 1 year period (2000) were analyzed with some individuals being tested on more than one occasion. Road tests were overseen by a VicRoads License Testing Officer (LTO) who specializes in older driver testing. The test lasts approximately 30-45 minutes with the test route commencing at the driver's home and including routine driving destinations. Driver errors are scored in six main performance categories: lane changing/diverging, speed and position on road, safety margin, car control, and low speed maneuver.									
Statistical Methods	Logistic regression analysis									
Quality Assessment	**Study Quality: Moderate**	1	2	3	4	5	6	7	8	9	10
		Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Relevant Outcomes Assessed	Driving test performance									
Results	The 49 arthritic drivers had the highest fail rate at 61% coinciding with the highest interventions by the licensing officer at 4.0. The 3 medical conditions with the highest fail rates (arthritis, cardiac, and visual) also included the oldest drivers with a mean age of 80 years. Driver performance scores are shown in Table G-16. 80% of arthritic drivers had difficulty maintaining safety margins (parked car, following distance, stop too close, and too close to object), and 78% had difficulty maintaining car control (steering, braking, accelerator, and gear choice).									
Authors' Comments	This study demonstrated the driving difficulty that a more physically impaired driver (arthritic) has versus drivers diagnosed with other medical conditions.									

Table G-16. Performance Scores by Medical Condition

Condition	*n* (%)	Mean age	% fail	Mean # of DI assists	Driver performance scores (%)					
					IN	LC[a]	PS	LSM	SM	CC
Cardiac	216 (53)	80	49	3.8	59	31	59	57	89	86
Endocrine	68 (17)	77	46	3.2	62	38	62	59	93	88
M/skeletal	66 (16)	74	48	3.1	62	33	58	59	85	83
Visual[b]	61 (15)	80	49	3.8	61	42	63	54	89	86
Arthritis	49 (12)	80	61	4.0	49	23	54	49	80	78
Mental/behavioral	44 (11)	67	48	3.5	59	35	60	51	85	80
Nil noted	44	75	43	4	66	40	66	52	89	85

CC - Car control.
IN - Intersection negotiation
LC - Lane changing
LSM - Low-speed maneuver
PS - Position and speed
SM - Safety margin

[a] For a proportion of drivers there were no recorded behavioral observations—particularly in the case of lane changing—for some performance categories. In such cases, no performance score could be calculated. For example, only 140 of the 216 drivers with a reported cardiac condition had a performance score in this category.

[b] This category included drivers with only one eye and cataracts.

Ostrow A, Shaffron P, McPherson K. The effects of a joint range-of-motion physical fitness training program on the automobile driving skills of older adults. Journal of Safety Research 1992; 23:207-19

Key Questions Addressed	**1**	**2**	**3**	**4**
		✓		

Research Question: Benefit of a fitness program on driving performance of older adults

Study Design: Randomized controlled trial (RCT)

Population

Inclusion Criteria: Drivers aged 60-85 were recruited from the Morgantown, WV area

Exclusion Criteria:

Study Population Characteristics

Variable	Experimental Group	Control Group
n	16	16
Gender M/F	5/11	4/12
Age (years) mean ±Standard Deviation (SD)	69.01 ±4.79	70.67 ±6.87

Generalizability to Commercial Motor Vehicle (CMV) Drivers: Unclear

Methods: 32 individuals were recruited by public service announcements and contacts through Rotary clubs, Kiwanis clubs, and AARP. 16 subjects participated in an 8-week range-of-motion exercise regimen to improve upper body movement. Exercises were designed so that they could be practiced at home. The control group did not participate in the exercise regimen. All study subjects were tested at weeks 1, 8, and 11 on range-of-motion tests and an Automobile Driving On-Road Performance Test (ADOPT). Logs were kept by all participants, which included number of miles driven and frequency of driving. A licensed physical therapist supervised the training program and developed the flexibility measures carried out. ADOPT consisted of a 6.8 mile road test that took approximately 45 minutes to complete.

Statistical Methods: Analysis of Variance (ANOVA)

Quality Assessment

Study Quality: Moderate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Y	NR	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	NR	Y

Relevant Outcomes Assessed: Driving performance

Results: Results of the range-of-motion measurements are shown in Table G-17. Additional analysis was undertaken on five joint sites to determine statistical significance over three sessions. Results shown in Table G-19 demonstrate a statistical significance in *trunk rotation* to the right, $F(2,60) = 3.31$, $p < 0.05$ and *shoulder flexibility*, $F(2,60) = 3.23$, $p < 0.05$. Further examination showed improvement in *trunk rotation* by the experimental group during the first six weeks, with a smaller improvement during the last two weeks of the program. At the same time, the control group was measuring deterioration in trunk rotation. Results for *shoulder flexibility* demonstrated a significant improvement for the experimental group and a slight improvement for controls. Results for ADOPT are shown in Table G-19. Again, additional analysis was undertaken to determine statistical significance in performance improvements across the three sessions. Statistical significant interactions were determined for handling position, $F(2,59) = 3.35$, $p < 0.05$, and for observing, $F(2,59) = 3.62$, $p < 0.05$ (Table G-20). Further examination of results for handling showed a surprising decline in experimental subjects' performance coinciding with an improvement in control subjects' performance. For observing, experimental subjects improved and control subjects declined on this skill during the last two weeks. Data obtained from study participants' log books showed no statistical significance differences between cases vs. controls for average number of days driven per week or average number of miles driven per week.

Authors' Comments: The benefits of an eight-week range-of-motion exercise program may carry over to the driving performance of older adults.

NR = Not reported.

Table G-17. Results of Joint Flexibility Measurements (mean and standard deviation)

	Testing Sessions					
	1		2		3	
	M	*SD*	*M*	*SD*	*M*	*SD*
Chin Flexion						
Experimental	1.29	(1.24)	1.58	(1.05)	1.38	(1.21)
Control	1.92	(1.35)	2.01	(1.11)	1.68	(1.36)
Chin Extension						
Experimental	16.74	(1.76)	17.98	(1.09)	18.20	(1.54)
Control	17.36	(2.54)	17.83	(1.68)	18.16	(1.23)
***Neck Rotation (Left)**						
Experimental	65.25	(13.38)	64.81	(12.36)	67.88	(13.19)
Control	72.19	(17.32)	71.06	(15.56)	68.50	(14.69)
***Neck Rotation (Right)**						
Experimental	73.50	(17.41)	76.69	(14.95)	76.50	(16.83)
Control	79.44	(14.83)	77.50	(14.80)	75.31	(15.08)
Side Bends (Left)						
Experimental	4.25	(2.08)	3.81	(2.04)	3.61	(1.82)
Control	3.17	(2.01)	3.32	(1.53)	2.99	(1.58)
Side Bends (Right)						
Experimental	4.45	(2.19)	3.90	(2.02)	3.60	(1.90)
Control	3.28	(2.14)	3.43	(1.65)	3.05	(1.61)
***Trunk Rotation (Left)**						
Experimental	82.00	(16.00)	89.38	(18.93)	91.56	(18.45)
Control	96.44	(24.47)	91.94	(18.55)	92.25	(15.14)
***Trunk Rotation (Right)**						
Experimental	98.00	(18.94)	101.38	(21.34)	102.00	(15.54)
Control	105.69	(21.54)	98.56	(19.55)	99.88	(18.59)
Shoulder Back						
Experimental	6.37	(2.57)	7.70	(2.83)	9.17	(2.98)
Control	4.90	(2.95)	5.51	(3.19)	5.82	(3.23)

* Trunk and neck rotation were measured as degrees in rotation. Other joint sites were measured as distance in centimeters from anatomical standard.

Table G-18. *F*-ratios for Change in Flexibility across Three Sessions

	Group	Session	Group × Session
Chin			
Flexion	1.50	1.00	0.37
Extension	0.08	9.98**	1.24
Neck Rotation			
Left	0.95	0.10	1.96
Right	0.13	0.20	1.90
Side Bends			
Left	1.40	2.21	1.28
Right	1.29	3.55*	1.81
Trunk Rotation			
Left	1.09	0.38	2.95
Right	0.01	0.42	3.31*
Shoulder	5.62*	12.96**	3.23*

* $p < 0.05$
** $p < 0.01$

Table G-19. ADOPT Driver Performance (mean and SD) across Three Test Sessions

	Testing Sessions					
	1		2		3	
	M	*SD*	*M*	*SD*	*M*	*SD*
Handling Time (HT)						
Experimental	83.33	(12.20)	87.50	(12.91)	85.94	(15.73)
Control	79.69	(16.38)	87.50	(15.81)	73.44	(23.22)
Handling Direction (HD)						
Experimental	85.00	(35.10)	100.00	(0.00)	96.88	(8.54)
Control	75.00	(41.83)	96.88	(8.54)	87.50	(20.41)
Handling Strikes (HS)						
Experimental	93.33	(25.82)	93.75	(25.00)	87.50	(34.16)
Control	93.75	(25.00)	100.00	(0.00)	81.25	(40.31)
Handling Position (HP)						
Experimental	78.33	(20.85)	68.75	(23.27)	67.19	(31.25)
Control	62.50	(36.51)	81.25	(26.61)	82.81	(31.25)
Straight Backing Lane (SBL)						
Experimental	100.00	(0.00)	81.25	(40.31)	81.25	(40.31)
Control	81.25	(40.31)	68.75	(47.87)	68.75	(47.87)
Straight Backing Time (SBT)						
Experimental	63.33	(18.58)	68.75	(17.08)	60.94	(20.35)
Control	62.50	(18.26)	65.63	(17.97)	60.94	(32.87)
Handling (HANDL)						
Experimental	83.93	(7.18)	83.69	(13.56)	80.13	(15.93)
Control	75.81	(11.46)	83.50	(14.16)	75.94	(21.50)
Safe Practices						
Experimental	74.13	(12.91)	74.56	(10.15)	76.75	(15.64)
Control	70.68	(10.46)	72.75	(7.43)	66.88	(13.70)
Observing						
Experimental	54.07	(21.02)	54.94	(22.42)	62.13	(26.22)
Control	51.00	(16.64)	53.63	(15.20)	43.88	(22.08)

Mean and standard deviation are expressed in % appropriate response.

Table G-20. *F*-Ratios for ADOPT Driver Performance

	Group	Session	Group x Session
Handling Time (HT)	2.22	2.11	1.31
Handling Direction (HD)	2.28	4.68*	0.20
Handling Strikes (HS)	0.01	2.14	0.57
Handling Position (HP)	0.36	0.28	3.35*
Straight Backing Line (SBL)	1.49	1.80	0.00
Straight Backing Time (SBT)	0.04	1.14	0.09
Handling (HANDL)	0.95	2.00	0.61
Safe Practices	2.08	0.40	1.96
Observing	1.36	0.27	3.62*

Key Question 3

Barry C, Smith D, Lennarson P, Jermeland J, Darling W, Stierman L, Rizzo M, Traynelis V. The effect of wearing a restrictive neck brace on driver performance. Neurosurgery 2003; 53: 98-102																														
Key Questions Addressed	**1**			**2**			**3**			**4**																				
							✓																							
Research Question	Relationship between neck restriction and driver performance																													
Study Design	Randomized controlled trial (RCT)																													
Population	**Inclusion Criteria**	Licensed drivers in the state of Iowa 18+ years who volunteered for the study																												
	Exclusion Criteria	Drivers with prior cervical spine problems																												
	Study Population Characteristics	Variable	Total study population	Group A	Group B																									
		n	23	11	12																									
		Gender M/F	10/13	4/7	6/6																									
		Age (years) mean ±Standard deviation (SD)		20.8 ±2.97	20.5 ±2.85																									
	Generalizability to Commercial Motor Vehicle (CMV) Drivers	Unclear																												
Methods	23 healthy volunteers participated in the study at the Neurosurgery and Neurology Departments at The University of Iowa Hospitals and Clinics. Patient evaluations were two-fold. First, an assessment of cervical spinal rotation was measured using goniometry. Study subjects were then fit with a Philadelphia cervical orthosis, a commonly used device to restrict cervical motion. Secondly, on-road performance testing took place in a state-of-the-art lab utilizing the Automobile for Research in Ergonomics and Safety-instrumented vehicle. Subjects were randomly assigned to Group A (wearing a cervical orthosis during drive 1 and not drive 2) or Group B (wearing a cervical orthosis only in drive 2) with drivers performing on two similar routes. Road tests lasted 20 minutes each with a 10-minute break in between. Each driver's blind spot was identified for additional performance evaluation. Upon completion of assessments, subjects filled out a questionnaire discussing views on overall driving safety and visualization factors while driving.																													
Statistical Methods	Wilcoxon signed-rank tests																													
Quality Assessment	**Study Quality: High**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Relevant Outcomes Assessed	Driver performance																													
Results	Results for cervical range of motion (ROM) are shown in Table G-21. Use of the orthosis was associated with a statistically significant reduction (p <0.05) in all measurements of cervical motion (flexion, extension, and axial rotation). Results for driving performance demonstrated a decreased lateral acceleration and slower driving by subjects wearing the orthosis. Both groups were able to make turns, stop appropriately, and maintain vehicle control at all times. Video images of drivers documented suboptimal assessment of intersection traffic in volunteers while wearing the orthosis. Further analysis revealed a statistically significant decrease in cervical axial rotation when volunteers approached intersections while wearing the orthosis. A significant decrease in cervical ROM was demonstrated by orthosis wearers at evaluations at "first four and last four intersections" (Table G-22). During the first four intersections orthosis wearers attempted a wide range of torso movement, but they only utilized eye movements to scan the last four intersections. Blind-spot evaluations resulted in a statistically significant increase in the blind spot at Positions 1 and 5 in subjects wearing the cervical orthosis (p <0.05)(Figure G-3). A summary of questionnaire responses are shown inTable G-23. Although visualization of the car instruments was not impeded, most drivers felt that their visualization was hindered with use of cervical orthosis and made their driving less safe.																													
Authors' Comments	Drivers who wear a cervical orthosis may be at an increased risk for crash. Additional studies conducted with a larger study population of ankylosing spondylitis (AS) patients are recommended.																													

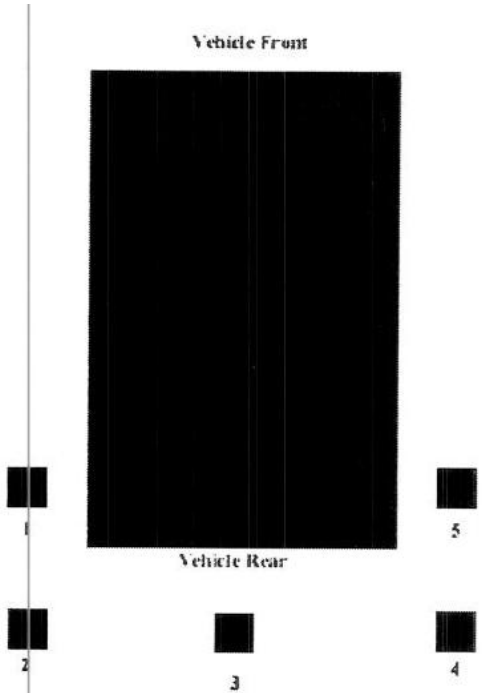
Table G-21. Cervical ROM (with and without orthosis)

Measurements	With orthosis (degrees)	Without orthosis (degrees)
Mean flexion	15.5 ± 3.8	58.8 ± 1.9
Mean extension	25.9 ± 3.8	76.9 ± 5.3
Mean right axial rotation	24.3 ± 5.5	73.4 ± 3.9
Mean left axial rotation	23.9 ± 5.3	71.6 ± 4.7

Table G-22. Cervical ROM (first four and last four intersections)

Mean cervical range of motion	Without orthosis (degrees)	With orthosis (degrees)
First four intersections encountered	50.76 ± 7.32	26.67 ± 4.35
Last four intersections encountered	50.02 ± 3.99	2.75 ± 2.52

Figure G-3. Blind Spot Testing Diagram



Testing diagram in top-down view showing the positions used in assessment of the blind spot. The five locations tested are labeled 1-5.

Table G-23. Summary of Questionnaire Responses

Evaluation	Mean score
Effect on driving[a]	6.2 ± 0.4
Effect on visualization of road[b]	5.4 ± 0.5
Effect on visualization of mirrors[b]	4.5 ± 0.3
Effect on visualization of instruments[b]	4.3 ± 0.3

[a] 1, made driving safer; 4, no effect; 7, made driving less safe.
[b] 1, enhanced; 4, no effect; 7, hindered.

Hunter-Zaworski K. T-Intersection simulator performance of drivers with physical limitations. Transportation Research Record 1990; 1281: 11-5											
Key Questions Addressed	**1**		**2**		**3**		**4**				
					✓						
Research Question	Relationship between limited head and neck mobility and driver performance										
Study Design	Before After										
Population	**Inclusion Criteria**	Individuals with a valid license who drive a minimum average of 10 miles/week									
	Exclusion Criteria										
	Study Population Characteristics	Variable n Median age 30–50 year age group Median age 60–80 year age group	Value 60 40 67								
	Generalizability to Commercial Motor Vehicle (CMV) Drivers	Unclear									
Methods	Subjects were recruited through local ads and contacts with local agencies, including AARP. Half of the study participants had some degree of physical limitation restricting head and neck movements. Nearly all subjects aged 60–80 years showed limited neck mobility. Many subjects with arthritis were taking anti-inflammatory medications and were regular participants in exercise programs sponsored by the Arthritis Foundation. Assessment of participants included range of head and neck movement and visual field. Driving performance was tested on a simulator in a lab setting. Performance times of drivers at 18 simulated T-intersections were collected. Each intersection had varying traffic volume and sight distance. Drivers were allowed two trial sessions before testing. Subjects were instructed to watch video presentations of the intersection, depress the brake pedal, watch the scene, and remove their foot from the brake once they felt it was safe to turn left across the intersection. Each presentation ended once the pedal was released. A two-minute break was incorporated between presentations. A data acquisition system recorded the response time and the degree of head movement.										
Statistical Methods	Analysis of Variance (ANOVA)										
Quality Assessment	**STUDY QUALITY: MODERATE**	1	2	3	4	5	6	7	8	9	10
		Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Relevant Outcomes Assessed	Driver performance										
Results	Total results only included correct intersections driven by each subject due to several older subjects not following instructions plus misjudging several intersections. Results for average decision time are shown in Table G-24. Relationship of average decision time versus age was significant at the 4% level. Age group 30–50 (impaired and unimpaired) took two seconds less to decide to turn at T-intersections versus age group 60–80 (impaired and unimpaired). In addition, standard deviations for the older drivers were 0.43 seconds higher, indicating greater inconsistency in this age group. Correlation between functional level and average decision time was also addressed. See Table G-25 for definition of functional levels (combination of age and impairment level). Results for correlation of functional levels are shown in Table G-26. Mean decision time increases with functional level, and the increase in decision time between the younger and older age groups is approximately two seconds. Results demonstrated that the younger impaired drivers were able to compensate for their impairment in their driving behavior, but the older drivers (impaired or unimpaired) were not.										
Authors' Comments	Skewed intersections present a significant problem to drivers with limited neck mobility. While younger drivers are able to compensate for their impairments while driving, older drivers are not.										

Table G-24. Average Decision Time in Seconds versus Age

AGE	MEAN	STD.DEV
30-50	11.3	3.45
60-80	13.3	3.88

p = 0.04; Coefficient of Variation = 29.88.

Table G-25. Description of Functional Level

Functional level	Description
1	30–50 years old with no impairment
2	30–50 years old with impairment
3	60–80 years old with no impairment
4	60–80 years old with impairment

Table G-26. Average Decision Time (seconds) versus Functional Level

FUNCTIONAL LEVEL	MEAN	STD. DEV.
1 30-50, UNIMPAIRED	11.3	2.97
2 30-50, IMPAIRED	11.4	4.09
3 60-80, UNIMPAIRED	12.1	3.08
4 60-80, IMPAIRED	14.4	4.35

p = 0.08; Coefficient of Variation = 29.66.

Dagfinrud H, Kjeken I, Mowinckel P, Hagen K, Kvien T. Impact of functional impairment in ankylosing spondylitis: impairment, activity limitation, and participation restrictions. J Rheumatol 2005; 32: 516-23											
Key Questions Addressed	**1**		**2**		**3**		**4**		**5**		
					✓						
Research Question	Assess functional difficulties faced daily by ankylosing spondylitis (AS) patients										
Study Design	Prospective cohort										
Population	**Inclusion Criteria**	Individuals were identified through AS records at the Department of Rheumatology, Diakonhjemmet Hospital, Oslo, Norway.									
	Exclusion Criteria										
	Study Population Characteristics	Variable		Value							
		n		152							
		Age (years) mean ±Standard deviation (SD)		47 ±13							
		Gender M/F		58%M, 42%F							
		Disease duration (years) mean ±SD		15 ±12							
	Generalizability to Commercial Motor Vehicle (CMV) Drivers	Unclear									
Methods	In 2002, 465 patients were invited by questionnaire to participate in the study. In 2003, 283 individuals still living in Oslo were invited to participate, and 152 accepted. Patients were asked to respond to a comprehensive questionnaire that included information on physical function and disease activity. Measures of the spinal column and hip and shoulder joints were obtained by a physical therapist. An occupational therapist obtained patients' perceptions of their activity limitations and participation restrictions utilizing the Canadian Occupational Performance Measure (COPM). Study variables were categorized according to the dimensions of the International Classification of Functionality (ICF) model, which included personal variables (age, sex, disease-related factors, education, and occupation) and impairment variables (problems in body structure or function). Impairment level was assessed by the Bath AS Metrology Index (BASMI) and Bath AS Disease Activity Index (BASDAI).The BASMI score is calculated by adding the scores for 5 clinical exams of the spinal column and hip joint—scale of 0–2 with 0 being normal mobility. The BASDAI is a self-reported assessment of disease activity covering major symptoms of AS. Inflammation was evaluated by erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP).										
Statistical Methods	Independent sample t tests, Pearson correlation coefficient, linear regression, block-regression analysis										
Quality Assessment	**Study Quality: Moderate**	1	2	3	4	5	6	7	8	9	10
		Y	Y	Y	N	Y	Y	Y	Y	NR	Y
Relevant Outcomes Assessed	Driving limitations										
Results	Women reported more disease activity than men (BASDAI score 53.1 ±23.6 vs. 38.0 ±21.0) (Table G-27) and more severe physical limitations (BASFI score 39.0 ±24.2 vs. 27.7 ±23.4) (Table G-28). The most frequently reported problems in the COPM interviews were "interrupted sleeping" (n = 83) and "turn head when driving" (n = 57) (Table G-29), with no significant differences in responses by gender. Significant correlations were demonstrated between the COPM Performance and BASDAI and BASMI, and between Bath AS Functional Index (BASFI) and all impairment variables (Table G-30).										
Authors' Comments	Only 37% of AS patients reported impaired physical limitations while driving, with women reporting more severe overall physical limitations than men.										

Table G-27. Impairment Variables

Measure	Total Sample, n = 152	Male, n = 88	Female, n = 64	95% Confidence Interval of Difference	p
BASDAI	44.3 (23.2)	38.0 (21.0)	53.1 (23.6)	−22.3, −8.0	< 0.001
BASMI	2.7 (2.6)	3.0 (3.0)	2.2 (1.9)	−0.2, 1.7	0.06
ESR	17.7 (16.5)	16.9 (16.8)	18.8 (16.2)	−7.4, 3.6	0.49
CRP	9.2 (11.7)	10.8 (16.8)	8.9 (11.7)	−3.0, 6.9	0.44

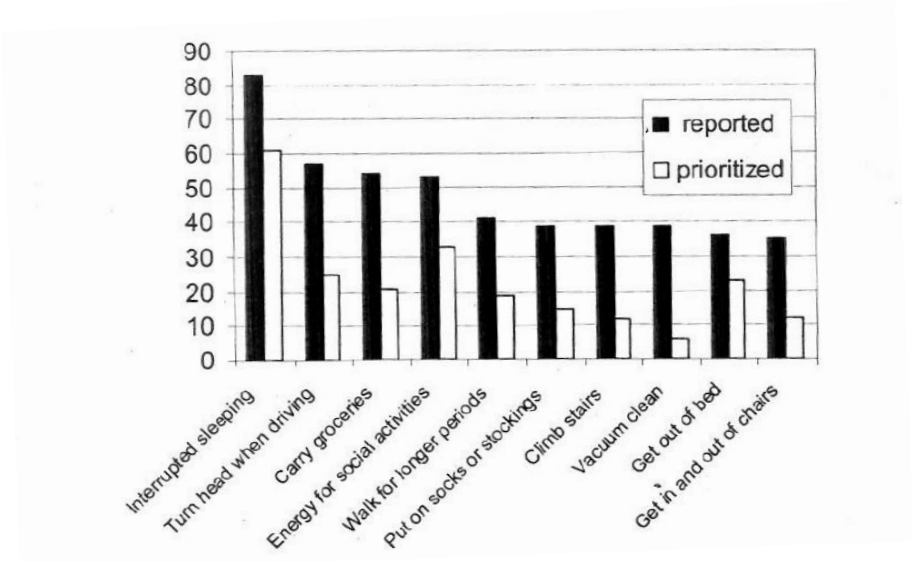
* Gender comparison: independent sample t test (continuous variables) or chi-square (counts).

Table G-28. Variables of Activity Limitation and Participation Restrictions

Measure	Total Sample, n = 152	Male, n = 88	Female, n = 64	95% Confidence Interval of Difference	p
BASFI*	32.4 (24.3)	27.7 (23.4)	39.0 (24.2)	−19.0, −3.6	0.004
SF-36 physical function**	71.8 (21.4)	77.2 (20.0)	64.3 (21.2)	6.1, 19.5	< 0.001
COPM performance***	5.9 (2.5)	6.3 (2.5)	5.4 (2.4)	0.2, 1.8	0.02
COPM satisfaction***	5.2 (3.0)	5.6 (3.0)	4.5 (2.9)	0.2, 2.1	0.02

* 0–100, 100 = worst score
** 0–100, 100 = best score
*** 0–10, 0 = no problems
Gender differences: independent sample t test; BASFI: Bath Ankylosing Spondylitis Functional Index; COPM: Canadian Occupational Performance Measure.

Table G-29. Responses to COPM Interviews



The 10 most frequently described and prioritized problems reported by patients with AS in COPM interviews (n = 152).

Table G-30. Pearson Correlation Coefficients between Measures of Impairment and Activity/Participation Level

Impairment Variables	COPM Performance Pearson Correlation	p	BASFI Pearson Correlation	p
BASDAI	–0.60	< 0.001	0.68	< 0.001
BASMI	–0.22	0.01	0.51	< 0.001
ESR	–0.09	0.29	0.21	0.01
CRP	–0.07	0.40	0.25	0.003

BASDAI - Bath Ankylosing Spondylitis Disease Activity Index
BASFI - Bath Ankylosing Spondylitis Functional Index
BASMI - Bath Ankylosing Spondylitis Metrology Index
COPM - Canadian Occupational Performance Measure
CRP - C-reactive protein
ESR - Erythrocyte Sedimentation Rate