PHYSICAL ACTIVITY IN THE SPINAL CORD INJURED POPULATION: EXERCISE RECOMMENDATIONS FOR INCREASING CARDIOVASCULAR AND STRENGTH PARAMETERS BASED ON CURRENT LITERATURE

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1. INTRODUCTION

a) Literature Review

The purpose of this summer studentship was to review the literature on cardiovascular (CV) and strength exercise for people with spinal cord injury (SCI). At the completion of this review recommendations are proposed for a home-based exercise programme.

The exercise programme will be designed for people with SCI who are long-term wheelchair users and will specifically target the older individual. Considerations will also be given to the maintenance and prevention of shoulder injuries. The aim of the exercise programme is to provide patients with a resource that can be used in their own homes, with limited equipment, to maintain cardiovascular fitness and strength. In addition the exercise recommendations may be used as a resource for physiotherapists or other health professionals, especially those in remote areas where exposure to patients with SCI is limited.

Physiotherapy in the acute stage following SCI is aimed at maximising function and regaining independence. During this phase the maximal work capacity may only be half that of controls (Hoffman, 1986). At some point in the rehabilitation, the patient reaches a plateau in functional gains and is released from initial hospitalization (Klose, Schmidt, Needham, Brucker, Green & Ayyar, 1990). After discharge the patient is expected to continue a self-supervised maintenance programme, this requires an enormous amount of self-discipline (Cowell, Squires & Raven, 1986). Patients must adapt to a life that is the very different to the one they left behind. As well as the physical limitations imposed by their injury there are many other issues that occupy their attention such as returning to family life, concerns surrounding employment and psychological issues that develop post-SCI. It is not unexpected that exercise may not be a priority during this early stage.

b) Life expectancy following spinal cord injury

Recent advances in the medical management of SCI have meant that patients are living longer (Ballinger, Rintala & Hart, 2000) and now have a life expectancy that approaches that of the general population (Finley, Rodgers & Keyser, 2002). The goal of rehabilitation has shifted from 'extension of life expectancy to enhancement of independence and quality of life' (Hicks et al, 2003, p.34).

b) The Debilitative Cycle

A reduction in physical activity and changes in metabolism have been noted following SCI (Grange, Bougenot, Groslambert, Tordi & Rouillon, 2002). About 25% of individuals with paraplegia have a VO2max of 15ml/kg/min (normal range for males is 34-61ml/kg/min and females 30-42ml/kg/min), which is barely sufficient to meet the demands of independent living (Noreau & Shephard, 1995). It has been noted by

Hoffman (1986) that this decreased functional work capacity may limit independence, and increase the risk of CV disease. DiCarlo (1988) postulates that it is because of this reduced physical work capacity, that many individuals with SCI tend to fatigue during activities of daily living (ADLs) before positive training effects can occur. Many authors (Ellenberg, MacRitchie, Franklin, Johnson & Wrisley, 1989; Hoffman, 1986) have stated that the performance of ADLs is insufficient to elicit a heart rate (HR) within the appropriate range to obtain a training effect. Therefore performance of these on their own is inadequate to maintain CV fitness. Without a training regime after discharge from hospital, SCI patients will not be able to maintain or improve their CV fitness (Cowell et al, 1986). Further, the independence of persons with SCI within the community depends on their ability to transfer, propel a wheelchair, and perform ADLs. These activities require upper body strength and CV endurance (Cooney & Walker, 1986). 'A lack of physical fitness for specific tasks can be a serious obstacle to autonomy following SCI' (Noreau & Shephard, 1995, p.227). It can be therefore summarised that gains in CV fitness are likely to have a direct effect on the performance of ADLs in people with SCI. This impact may be greater in individuals with tetraplegia, as they often begin an exercise programme with less than the minimum strength and VO2max needed for self-care and independent mobility (Noreau & Shephard, 1995).

2. COMPLICATIONS FOLLOWING SPINAL CORD INJURY THAT MAY INFLUENCE THE ABILITY TO EXERCISE

Although the occurrence of secondary complications following SCI is being reduced, other long-term complications are becoming more common (Finley et al, 2002). In addition as people with SCI are living longer, a new set of problems have appeared as ageing is superimposed on pre-existing disability (Pentland & Twomey, 1994). Besides impairing the rehabilitation process and increasing hospital stay, these complications further contribute to the debilitative cycle (Hoffman, 1986).

a) Common complications

The most common secondary complications following SCI are:

- Pressure sores
- Metabolic changes: the resting metabolic rate of a person with SCI is 10-30% lower than that of a non-disabled person of comparable age (Noreau & Shephard, 1995).
- Muscle atrophy
- Urinary tract infections
- Lowered aerobic capacity
- Respiratory disorders
- Osteoporosis
- Renal dysfunction
- Musculoskeletal disorders
- Coronary heart disease and associated cardiovascular diseases

(Finley et al, 2002; Grange et al, 2002; Cowell et al, 1986)

b) Musculoskeletal complications

Some of the musculoskeletal secondary complications that arise following SCI are:

- Heterotrophic ossification
- Joint degeneration
- Overuse injuries (e.g. carpal tunnel syndrome and shoulder impingement)
- Osteoporosis
- Osteoarthritis
- Tendonitis
- Bursitis
- Contractures
  (Finley et al, 2002).

c) Musculoskeletal Complications of the shoulder

Because the prevention of shoulder injuries is an important component of this review, complications affecting the shoulder are specifically discussed.

i. The weight bearing shoulder

Awareness of the complications of the weight-bearing shoulder is necessary as the long-term survival of SCI patients continues to improve (Gellman, Sie & Waters, 1988). Usually the shoulder is used for mobility and prehension, this transforms to a weight bearing function following SCI (Lal, 1998). Gellman et al (1988), state that heightened awareness of the complication of the weight-bearing upper extremity is necessary to keep patients functioning in society.

It has been propounded by Capodaglio, Grilli and Bazzini (1996) the physical stress and discomfort during functional tasks e.g. wheelchair mobility or transferring, may be due to the recruitment of a smaller muscle mass. Additionally the loss of muscle control in the upper limb and paralysis of the trunk muscles in persons with tetraplegia causes an unstable base for the arm which may contribute to shoulder pain following SCI. (Gronley, Newsam, Mulroy, Rao, Perry & Helm, 2000).

ii. Do patients with spinal cord injury suffer from shoulder pain?

A literature review found that the reported incidence of shoulder pain varied between authors (see table 1).

Table 1: Reported prevalence of shoulder pain in subjects with SCI

KEY: P= persons with paraplegia, T=persons with tetraplegia
FIM = Functional independence Measure
CHART = Craig Handicap Assessment and Reporting Technique

Authors	**Sample**	**Number of subjects**	**Prevalence**	**Outcome measure used**
Ballinger et al (2000)	P and T	89	30%	FIM, CHART
Bayley et al (1987)	P and T	94	30%	Self-report
Curtis et al (1999b)	P and T	42	75%	Self-report, WUSPI
Curtis et al (1999a)	P and T	195	T=59%, P=42%	WUSPI
Dalyan, Cardenas and Gerard (1999)	P and T	130	58.5% (upper limb pain; 71% in shoulder)	Self-report
Gellman, Sie and Waters (1988)	P	84	34.5%	Self-report
MacKay-Lyons	T	19	68%	Patient notes

(1994)				
Pentland and Twomey (1994)	P	52	60% (upper limb pain)	Self-report
Salisbury et al (2003)	T	40	85%	101-point Numerical Rating Scale
Sie et al (1992)	P and T	239	41 %	Self-report
Silverskiold, Robert and Waters (1991)	P and T	60	Acute P=35% T=78% 18mth P=35% T=33%	Self-report
Waring and Maynard (1991)	P and T	52	60%	Patient notes

In summary the occurrence of shoulder pain ranged from 26 – 85 % of patients following SCI. In addition shoulder pathology tended to be more prevalent in the tetraplegic population compared to paraplegic population. This could be due to the musculoskeletal insufficiencies discussed previously.

iii. Two patterns of pathology: acute and chronic

There may be two patterns of shoulder pain (Mackay-Lyons, 1994). One occurring in the acute SCI population, the other in chronic SCI survivors. Campbell and Koris (1995) investigated shoulder pain in 24 patients who were both acute and chronic. Causes of shoulder pain in the acute group were capsulitis/ capsular contracture (most common), rotator cuff tears, anterior instability rotator cuff impingement, osteoarthritis. Causes of shoulder pain in chronic group were anterior instability (most common), multidirectional instability, capsulitis/ capsular contracture, Charot arthropathy, rotator cuff tear/impingement, scapular pain. If there are two patterns of shoulder pain, this may have implications for the treatment and management. Clinical diagnosis and appropriate treatment is of paramount importance for diagnosed of shoulder pain prior to commencement of any exercise programme.

iv. Does shoulder pain affect quality of life?

A painful shoulder is not only an inconvenience in persons with SCI, it can make the difference between dependence and independence (Campbell & Koris, 1995). It has been stated by MacKay-Lyons (1994) any complication involving the upper extremities should be viewed as a potential barrier to independence and, as such, should be seriously considered in terms of preventative and therapeutic strategies.' (p.225) Functionally shoulder pain tends to limit a persons access to the wider world, decreasing community integration (Ballinger et al, 2000).

Sie, Waters, Adkins and Gellman (1992) have postulated that there is a two-fold effect of upper extremity pain in SCI persons.

1) Their upper limbs are subject to demanding use that may result in overuse and pain.

2) The consequences of pain on functional use are severe.

Ballinger et al (2000) reiterated that shoulder problems were related to functional limitations, disability and perceived health. Specifically they found that shoulder pain was related to a lower measure of disability (CHART), whereas decreased shoulder ROM related to greater functional limitations (FIM) and affected the individuals self-care ability.

Tasks most likely to elicit pain in patients with SCI are those which allow interaction in the community and are associated with roles important to independence and self-esteem (Pentland & Twomey, 1994).

Shoulder pain poses a serious problem for both clinicians and the individual with SCI, for the following reasons (MacKay-Lyons, 1994):

- It is relatively common.
- Pain appears to be unmanageable with conventional treatment modalities.
- Time dedicated to functional rehabilitation is compromised by time taken to treat pain.
- Pain interferes with certain rehabilitation activities.
- The development of shoulder pain can create additional stress for a person who is already psychologically traumatized.

v. The aetiology of shoulder pain

A number of theories have been proposed to account for the high prevalence of shoulder pain in the SCI population. The following is a summary of these theories:

- Loading in extreme ranges: (Gellman et al, 1988; Bayley, Cochran & Sledge, 1987; Veeger, Rozendaal & van der Helm, 2002; Dalyan, Cardenas & Gerard, 1999).

- Postural changes:
    - The passive pull of gravity on the arm, places stress on the supraspinatus tendon (Salisbury, Choy & Nitz, 2003).

- High compressive forces: (Bayley et al, 1987).

- Weight bearing during transfers:
    - This skill demands repetitive axial loading and joint compression (Gellman et al, 1988).

- Fatigue:
    - This especially occurs in overhead positions (Burnham, May, Nelson, Steadward & Reid, 1993).

- Referred pain from the cervical spine:
    - Especially in C5-6 level injuries (Salisbury et al, 2003).

- Abnormal distribution of force :(Bayley et al, 1987).

- Repetitive movement patterns
    - This movement pattern encourages protraction and elevation of the scapula and internal rotation of the humerus (Curtis et al, 1999b).

- Trunk flexion: (Finley et al, 2002)

- Degeneration**:**
    - Ballinger et al (2000) state that ageing factors which exacerbate existing bone and joint problems may appear earlier in the SCI population than in the non-disabled population. Often wheelchair use exceeds 20 years.

    - In the SCI population there is an increase in the prevalence of degenerative conditions associated with ageing and overuse of the upper extremities (Curtis et al, 1999a).

    - Bayley et al (1987) found that 23 out of 31 patients had shoulder impingement syndrome with acromial bursitis, and after closer observation found that 65% of rotator cuff tears were caused by degeneration rather than trauma. The onset of the three most common shoulder pathologies occurred on average between 12 and 19 years post-SCI. This delayed onset suggests that rotator cuff problems were related to stress on the shoulder rather than occurring at the time of the initial SCI.

    - Lal (1998) reported that individuals with a higher level of wheelchair activity, higher age, and female gender are more prone to developing degenerative changes in the shoulder. On X-ray the acromioclavicular joint was found to be most susceptible.

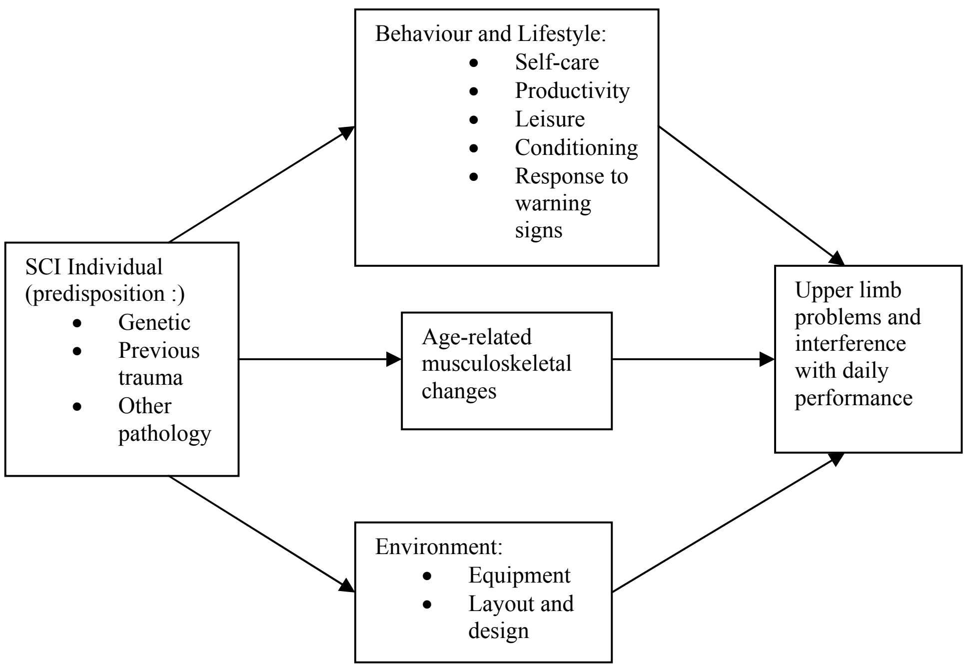
- Intra articular pressure:
    - Bayley et al (1987) measured the intra-articular pressure within the shoulder during functional tasks, and found that it exceeded the arterial blood pressure by 1.5-2 times. The authors conclude that 'the high pressure in conjunction with abnormal distribution of stress transmitted across the subacromial area during transfer or propulsion of a wheelchair, contributes to the high rate of problems about the shoulder in paraplegics.' (p.676). However they found that increased stress, while contributing to soft tissue damage, did not necessarily lead to degenerative arthritis.

- Veeger et al (2002) found low contact forces within the glenohumeral joint during wheelchair propulsion. Despite this, peak force and stresses in the rotator cuff were high. This stress should be considered a cause of overuse injuries.

- Orthopaedic problems:
  - Sie et al (1992) reported that most diagnoses of shoulder pain in tetraplegic patients were orthopaedically related (45%), including tendonitis, bursitis, capsulitis and osteoarthritis. In paraplegic patients carpal tunnel syndrome was most common (66%) followed by shoulder pain (36%).

- Overuse:
  - Pentland and Twomey (1994) suggest that overuse of the shoulder following SCI can be attributed to a number of factors including an already existing predisposition, behaviour / lifestyle factors, age-related changes (see figure 1 below).

Figure 1: The development of overuse related upper limb problems in individuals with SCI (Pentland & Twomey, 1994).



These authors state that the main factors involved in overuse in the shoulder appear to be:

- rotator cuff compression and muscle fatigue resulting from repetitive or static shoulder elevation

- work posture
- chronological age
- compression and ischaemia within the shoulder joint region due to weight-bearing on the shoulder.

- Muscle imbalance leading to impingement:
  - Contraction of the deltoid causes an upward translation of the humerus. This is counterbalanced by the downward pull of the rotator cuff and some of the shoulder adductors (latissimus dorsi, teres major and the lower fibres of the pectoralis major). The rotator cuff muscles control the upward thrust of the humerus during axial loading of wheelchair propulsion and upper extremity weight bearing activities. A weakness in these muscles may result in superior translation of the humeral head, resulting in impingement of soft tissues (Burnham et al, 1993).

  - Burnham et al (1993) showed that paraplegic athletes were stronger in all directions than able-bodied controls however those athletes with impingement syndrome were weaker in adduction and internal/external rotation.

  - Powers, Newsam, Gronley, Fontaine and Perry (1994) tested the strength of the shoulder musculature in subjects with SCI and compared them to abled-bodied controls. It was found that persons with tetraplegia were significantly weaker than either persons with paraplegia or control subjects. No differences were found between persons with paraplegia and the controls. The authors concluded that due to this strength deficit, patients with tetraplegia may be at greater risk of shoulder pathology because of both 'muscular limitation and increased functional demand.'

  - In the tetraplegic population shoulder pain may be due to impaired muscle innervation and altered movement patterns (Salisbury et al, 2003). Paralysis of the rotator cuff may result in impingement as the pull of the deltoid is not countered. Weakness of serratus anterior will decrease acromial elevation and in conjunction with weak rhomboids, which may result in excessive scapula protraction, may predispose the patient to shoulder impingement (Salisbury et al, 2003). In the case of shoulder girdle weakness the trapezius muscle may be overused as it may be the only functioning shoulder muscle providing scapular elevation and retraction. Weakness of the muscles about the shoulder contributes to reduced active shoulder movement, and results in the shortening of muscles and capsular tightening.

vi. The influence of time since injury on shoulder pain

Sie et al (1992) found that there was an increase in shoulder pain in paraplegic persons as the time since injury increase. Curtis et al (1999a) and Gellman et al (1988) reported a similar result in both paraplegic and tetraplegic populations.

vii. Summary

Shoulder pain is highly prevalent in the SCI population and appears to be compounded by changes that occur with normal ageing. Pain interferes with an individual's independence, and there is a need for the implementation of upper limb pain prevention and management programmes both in acute care and in ongoing, long-term care.

It has been suggested that there may be at least two different patterns of shoulder pain following SCI– one of acute onset and limited duration, the other of delayed onset and prolonged duration.

The aetiology of shoulder pain following SCI has been attributed to a number of factors with the prevalence increasing with the time since injury. Impingement seems to be the commonly sited diagnosis, with muscle imbalance thought to be a contributing factor. Weakness of the rotator cuff, shoulder adductors and serratus anterior in conjunction with tight anterior musculature may predispose a patient to impingement syndrome.

d) Cardiovascular Complications

Cardiovascular disease is common in the SCI population, and is the leading cause of death following SCI (Le & Price, 1982). It occurs earlier in the abled -bodied population and is the most frequent cause of death among person surviving more than 30 year after SCI, accounting for 46% of all deaths (Whiteneck, 1992 cited in Bauman et al, 1999).

i. Sympathetic nervous system

Any lesion at T4 or above is capable of disturbing the sympathetic drive to the cardiovascular system, resulting in a low maximum heart rate (HR) and a low stroke volume (Cowell et al, 1986). This lower stroke volume is due to a loss of vasomotor tone and peripheral pooling of blood caused by a reduced venous return.

ii. Lipid profile

Bauman et al (1999) stated that low high-density lipoprotein (HDL) cholesterol is associated with increased risk for coronary heart disease (CHD). These authors also showed that immobilization following SCI resulted in a reduction in HDL in men, Caucasians and the Latin American population compared to controls. This was supported by Hoffman (1986).

Dearwater et al (1986) found HDL was not only lower in person's with SCI, it was lower in sedentary SCI subjects when compare to active SCI subjects or control. This implies that reduced HDL is a result of reduced activity. The logical inference can be drawn that increased activity may be associated with a reduced risk of coronary heart disease by alterations in an individual's lipid profile.

iii. Glucose tolerance

Dearwater et al (1986) found significantly lower resting glucose levels in subjects with SCI compared with abled-bodied controls.

e) Summary

An inactive lifestyle has been shown to increase the risk of CV disease in all populations. In general the SCI population are less active and are at increased risk of developing secondary complications following their injury, than the able-bodied population. CV complications and musculoskeletal pathology (especially involving the shoulder girdle) are common. These issues are exacerbated by age-related changes that are increasingly problematic as the life expectancy of the SCI reaches that of the abled-bodied population. It has been shown that higher levels of activity can improve overall health and well-being in SCI individuals. Of significance to this study, exercise interventions have the potential to reduce the complications of SCI and aid in improving independence and quality of life.

3. THE EFFECTS OF PHYSICAL ACTIVITY

It appears that regular physical activity throughout life offers protection in terms of health and longevity (McArdle, Katch & Katch, 1991).

a) The effects of physical activity in the non-disabled population

In the non-disabled population exercise has been shown to:

- Reduce the risk of CHD by improving blood lipid profiles, reducing blood pressure and improving glucose and insulin sensitivity.
- Increases bone density.
- Enhance the immune function.
- Improve psychological well-being.
- Increase oxygen uptake, cardiac output and stroke volume.

(Hoffman, 1986; Finley et al, 2002)

b) The effects of physical activity in the SCI population

A mass of information exist on the health benefits of exercise in the abled-bodied population. It is not however known whether these recommendations are suitable for producing optimal training responses in the SCI population (Hooker & Wells, 1989). Both strength (ability to develop tension) and endurance (aerobic capacity) contribute to overall functional capacity in persons with SCI (Ellenburg et al, 1989). These authors found a significant deficit in arm aerobic capacity during the first 2 to 12 weeks following the onset of paraplegia. They recommend that rehabilitation professionals should emphasise continued participation in endurance activities both for psychological and cardiovascular health.

In general people with SCI are often less active and have lower work capacities than the nondisabled population (Finley et al, 2002). This inactivity is reported to limit functional ability due to poor endurance and strength, and can increase the risk of secondary complications (Finley et al, 2002).

Drory, Ohry, Brooks, Dolphin and Kellermann (1990) showed that there is a decreased CV adaptation to exercise performance in high level SCI subjects. These authors suggest that this is a result of the disruption of the sympathetic control in addition to decreased plasma catecholamine levels and decreased pulmonary function. They postulated that this is caused by impaired respiratory muscles in individuals with high level SCI. In these patients an elevation of HR during exercise is dependent upon vagal withdrawal (Drory et al, 1990) and circulating catecholamines (Hoffman, 1986).

Other factors affecting exercise tolerance in SCI individuals are a decreased venous return, small muscle mass and loss of adrenal response to exercise. Loss of adrenal response reduces lipolysis and muscle glycogenolysis (Duran, Lugo, Ramirez & Eusse, 2001).

Grange et al (2002) conducted an exercise programme on both healthy and paraplegic patients. Although both groups showed significant improvement the training effect was less in the subjects with paraplegia. The authors attributed this difference to thermal regulation disorders which may limit metabolism and sweating responses. The authors also note that the regulation of cellular and extracellular hydration was disturbed causing an alteration in exercise capacity.

Ventilatory responses of paraplegic persons may also be affected by decreased efficiency of the inspiratory muscles, limiting CV gains when compared to healthy subjects (Grange et al, 2002).

Hoffman (1986) states that central circulatory changes occur when subjects train large muscle groups, while peripheral changes occur following training of smaller muscle groups. As the SCI population have a reduced amount of muscle mass to recruit, CV adaptation is likely to occur peripherally. For example when an individual is training using an arm ergometer it may be concluded that peripheral changes will occur, while central changes are possible but less pronounced. This author also states that 'exercise performance is limited by reduced cardiac output and impaired regional blood flow to exercising muscle because of loss of sympathetic regulation of vasculature.' (p.317)

c) Summary

Exercise appears to have both physical and psychological benefits. In general, it seems that persons with SCI can also receive benefits from exercise, but their response and adaptation may be blunted by cardiovascular and respiratory complications.

The more specific aspect of the effects of exercise on the shoulder and on the cardiovascular system will now be addressed.

d) The effects of physical activity on the shoulder

i. Can musculoskeletal problems of the shoulder be addressed and treated as part of an exercise programme?

Altered stress within the shoulder in conjunction with altered postural control in paraplegics may lead to acute and chronic complaints of the shoulder. Therapy is aimed at correcting these imbalances by appropriate strengthening (Mayer et al, 1999).

Ballinger et al (2000) believe that 'keeping the shoulder strong and flexible will help prevent the wear and tear that people with SCI routinely place on their shoulder joints during ADLs' (p.1581). These authors suggest that shoulder problems may be alleviated by exercise programmes designed for older persons to increase shoulder flexibility and strength.

The shoulder abductors and flexors are often strong in individuals with SCI as these movements are frequently performed because the wheelchair bound person is lower to the ground. Reaching is therefore a common activity. Weakness of the humeral head depressor (rotator cuff and adductors) may be a factor in the development of rotator cuff impingement syndrome in wheelchair athletes. It is possible that adductor and rotator cuff strengthening could be an effective prophylactic and active treatment modality (Burnham et al, 1993).

'Tightness of the anterior shoulder muscles in addition to weakness of the posterior muscle seems to contribute to the development of shoulder pain in wheelchair users' (Curtis et al, 1999a). In their study of 42 wheelchair users, subjects performed strengthening and stretching exercises in the form of a home exercise programme for 6 months. The authors noted that there was an initial increase in shoulder pain when beginning the programme for the first 2 months. However during months 4 and 6 pain was reduced to below baseline measures. These authors recommend that strengthening scapular retraction combined with humeral extension, shoulder external rotation and adduction can significantly reduce subjects shoulder pain.

ii. Does activity protect joints?

Shoulder impingement and tendonitis have been attributed to overuse (Bayley et al, 1987) however moderate physical activity has been shown to be beneficial and may protect the shoulder from degeneration. Wylie and Chakera (1988) found that 18% of active paraplegic persons developed degenerative changes while 45% of inactive patients developed shoulder changes. Also Wing and Treadwell (1983) examined 20 shoulders involved in a 'swing-through' gait where the shoulder joint was stressed, and found no evidence of degeneration.

An exercise programme targeting muscles that are weak around the shoulder girdle may be beneficial in reducing shoulder pain. Participants and health professionals should be aware that initially pain may worsen but should improve after 2 months of training. Exercise compliance may therefore be an issue that needs to be addressed.

e) The effects of physical activity on the cardiovascular system

Fitness is defined by the ACSM guidelines (1990) as 'the ability to perform moderate to vigorous level of physical activity without undue fatigue and the capability of maintaining such ability throughout life'. (p.265)

CV exercise training for SCI individuals may reduce their risk of coronary artery disease through increasing physical activity, aiding in reduction of stress levels, controlling body weight and controlling blood pressure (Cooney & Walker 1986).

The role of endurance training in cardiopulmonary health and function is well documented. Adaptations following training should result in improvements in functional endurance, thereby reducing fatigue (DiCarlo, 1988).

Vincent, Braith, Feldman, Kallas and Lowenthal (2002) prescribed resistance exercise for the older adult. The authors state that 'improvements in aerobic capacity and endurance would be greater in people who are more deconditioned, such as frail elderly people or patients rehabilitating from illness.' (p.678) It is therefore plausible that the effects of exercise training in the SCI population may be similar to those that occur in elderly individuals. Significant improvement in aerobic capacity was found following resistance exercise (which was thought to produce only gain in muscular strength).

Measurement of the effect of exercise on CV variables following SCI is commonly by measurement of maximal power output and VO2max.

Maximal power output (MPO)

Bougenot et al (2003), Cooney and Walker (1986), Duran et al (2001), Grange et al (2002), Hicks et al (2003), Tordi et al (2001) all found increases in maximal power output following CV training in SCI subjects. The improvements ranged from 19.6% to 81%. These results indicate a significant increase in work capacity and suggest a beneficial adaptation response to training. The large variation in improvement may have been due to the fact that persons with paraplegia were used by four of these researchers, while both paraplegic and tetraplegic subjects were used by the remaining two. Additionally the frequency, intensity and length of programme varied between authors and may have influenced results.

VO2 max

CV training studies by Bougenot et al (2003), Cooney and Walker (1986), DiCarlo (1988), Grange et al (2002), Vincent et al (2002), Pollock et al (1974), Tordi et al (2001) found improvements in VO2max ranging from 16%-99 % . Again the large variation in improvements may have resulted from subjects and protocol differences.

Improvements after CV training have also been recorded in:

- time to exhaustion
- heart rate
- peak minute ventilation
- blood pressure
- lipid profile
- Glucose tolerance.

f) The effects of circuit and strength training

i. Resistance Training

Strength is trainable until very late in life, and activity and conditioning can help offset age-related strength losses (Pentland & Twomey 1994).

Duran et al (2001) found that persons with paraplegia who performed a 16 week exercise programme that included resistance training, significantly increased that amount of weight lifted and the number of repetitions performed. Improvements were also found in FIM score and time to complete a wheelchair skill test. Hicks et al (2003) found that twice weekly training in paraplegic and tetraplegic subjects produced a significant increase in strength, ranging from 19%-34 % . Participants also displayed significant increases in ergometry power output. They reported less pain, stress and depression in conjunction with higher indices of satisfaction with physical function, level of perceived health and overall quality of life.

ii. Circuit Training

Arm cranking and wheelchair propulsion have been shown to increase CV fitness in persons with SCI but are limited in their ability to produce strength gains. Traditional weight training exercises (low repetition / high resistance) has been shown to increase strength but does not produce large gains in CV fitness (Cooney & Walker, 1986).

Circuit resistance training has been shown to increase both cardiorespiratory changes and muscle strength in the non-disabled population (Gettmen et al, 1978). This type of exercise consists of one set of resistance exercises performed in a series. A prescribed number of circuits are completed for each training session (Jacobs, Nash and Rusinowski, 2000). This type of intermittent exercise intensity may be more beneficial since they mimic the discontinuous nature of daily activity patterns (Bougenot et al, 2003).

Very few studies exist that have investigated the effects of circuit resistance training in SCI persons. Cooney and Walker (1986) conducted a controlled study on the use of circuit resistance training in persons with paraplegia, over a 9 week period. Results showed a significant increase in cardiovascular endurance unfortunately strength outcomes were not investigated. One of the problems with the equipment used in the above study was that the hydraulic equipment requires concentric contraction only. In addition the subjects were required to make multiple transfers from wheelchair to exercise equipment, prolonging rest time between stations. Jacobs et al (2001) recommend that for circuit training rest times should be minimized.

Jacobs et al (2001) examined the use of circuit resistance training on 10 complete paraplegic subjects with long-standing SCI. The muscles selected to strengthen were 'the upper trunk and shoulder complex, with an emphasis on the deltoid, posterior shoulder muscles, scapular stabilizers and upper back. These are the areas of defined muscle weakness for persons with paraplegia.'(p.712) The exercise programme also involved stretching of the chest (pectorals) and back (scapular stabilizers and shoulder girdle depressors). Justification was given that these were the muscles that were commonly thought to be tight and were seldom stretched during the ADLs (Jacobs et al, 2001). It was found that 12 weeks of circuit resistance training significantly increased both cardiorespiratory endurance and muscular strength in persons with chronic paraplegia.

g) The psychological effects of physical activity following SCI

Hicks et al (2003) showed that 9 months of exercise training in subjects with SCI resulted in CV, strength and psychological improvements. Subjects reported less pain, stress and depression. They also scored higher in their satisfaction of physical functional, perceived health and quality of life ratings.

It was noted by Midha, Schmitt and Sclater (1999) that ‘mild endurance exercise performed by wheelchair-bound subjects, 2-3 times per week can produce significant benefits to subjective feelings of well-being, body habitus, conditioning and serum cholesterol’ (p.259).

h) Conclusions

Following SCI, patients reduce their physical activity. A debilitative cycle of decreased activity and declining work capacity is set in place.

A number of secondary complications result after SCI, having physical, psychological and social consequences. Often independence and quality of life is compromised and community participation reduced.

Activity has the potential to improve physical and psychological variables. As life expectancy is improving after SCI, exercise can contribute to enhancing independence and quality of life in the long-term.

4. EXERCISE RECOMMENDATIONS IN THE LITERATURE

Specific recommendations about the type, intensity, duration and frequency of exercise for SCI persons have not been established (Tordi et al, 2001). Despite the benefits of exercise following SCI, few studies have attempted to define the exact guidelines for training (Bougenot et al, 2003).

There are obviously large inter-individual discrepancies in the SCI population (Tordi et al 2001) as there are in many populations. It is therefore recommended that training programmes be individualized according to the individual's characteristics.

a) Cardiovascular Training

The following recommendations and protocols have been used in the literature for improving CV fitness in persons with SCI.

i. Mode

The American College of Sports Medicine (ACSM) guidelines (1990) recommend any activity that uses large muscle groups will improve CV fitness. Various forms of exercise and exercise equipment have been used to improve fitness in the SCI population.

Arm cranking has been show to improved fitness levels and endurance in SCI persons (Capodaglio, Grilli and Bazzini (1996); DiCarlo (1988); Drory et al (1990); Hicks et al (2003); Pollock et al (1974)). Wheelchair ergometry has also been successfully used by Grange et al (2002) and Bougenot et al (2003) with significant increases in fitness and endurance capacity.

The above two methods are currently the most reliable and valid exercise modes for evaluation of exercise performance and prescription of training programmes in the SCI population (Drory et al 1990). While Tordi et al (2001) claim that arm-cranking is disadvantageous as it does not reproduce the movement required for wheelchair propulsion, it may have the advantage of improving fitness and endurance , which may translate into improvements in other areas of function or participation.

Resistance exercise is traditionally thought to improve only strength measures. However Vincent et al (2002) prescribed resistance training 3 times per week over a 24 week period and found significant increases in both strength and cardiorespiratory endurance. Cooney and Walker (1986) prescribed subjects hydraulic resistance exercise in the form of circuit training and also found strength and CV improvements in both subjects with paraplegia and tetraplegia.

The use of functional electrical stimulation (FES) has resulted large gains in CV fitness. The advantage of FES is that increase stress can be placed upon the CV system by recruiting a larger muscle mass and reactivating the ‘muscle pump’ of the legs (Noreau & Shephard 1995). Recently hybrid exercise has also show to have dramatic improvements in CV fitness. Hybrid exercise involves subjects performing voluntary upper body exercise (e.g. arm cranking) combined with FES leg cycling exercise. Wheeler et al (2002) state that the rationale for using this hybrid exercise include:

- activation of a larger muscle mass,
- increased autonomic sympathetic outflow to provoke appropriate cardiopulmonary responses,
- reduced venous pooling in the lower limb thereby improving venous return, stroke volume and cardiac output,
- higher cardiac volume load to promote central training effects,
- training at a higher oxygen uptake for more efficient aerobic conditioning,
- training benefits for both upper and lower body musculature, and

Both FES and hybrid exercise have be shown to be advantageous however the limitations are the high cost, long preparation time and the need for technical assistance (Noreau & Shephard 1995).

Exercising in the supine position

McLean, Jones and Skinner (1995) postulate that the supine position may enhance venous return, thereby increasing central blood volume and stroke volume and reducing HR at any given submaximal workload via the Frank-Starling mechanism. Higher peak VO2 has been recorded in the supine position compared to sitting and these authors propose three mechanisms, which support this finding:

1) increased ventilation,
2) greater venous return, and
3) enhanced stability of the trunk.

They conclude that subjects with upper thoracic or cervical level SCI may benefit from exercising in supine as this position minimizes the pull of gravity on the abdomen and allows the diaphragm to rest in a more elevated position, reducing the work of ventilation. This position may also assist in stabilizing the scapular and thus reduce the prevalence of shoulder pain.

ii. Frequency

Exercising three times per week has been recommended by the following authors: Bougenot et al (2003), Cooney and Walker (1986), DiCarlo (1988), Hooker and Wells (1989), Grange et al (2002), Duran et al (2001), Vincent et al (2002), Pollock et al (1974). In contrast, Davis, Plyley and Shephard (1991) have suggested that three exercise sessions per week is too rigid and results in poor compliance. With this in mind, Hicks et al (2003) found significant improvements in physical and psychological variables after training SCI twice per week for nine months. Of significance to this discussion the ACSM guidelines (1990) recommend exercising at a frequency of 3-5 days per week in the non-disabled population, however as discussed previously, any exercise programme needs to be individually tailored.

iii. Intensity/ Duration

In the healthy adult the ACSM guidelines (1990) recommend exercising at an intensity of 60-90% HRmax or 50-85% VO2max or heart rate reserve (HRR) for 20-60 minutes. Due to the potential hazards and compliance issues with high intensity activity, lower to moderate intensity activity is recommended for the nonathletic adult.

Vincent et al (2002) assigned 62 elderly subjects to either a high-intensity or low-intensity group. Subjects performed resistance training three times per week over a 24 week period. Significant increases cardiorespiratory endurance was found, regardless of group allocation. It was concluded that significant improvements in aerobic capacity can be obtained in older adults as a consequence of either high or low-intensity resistance training.

Does this apply to persons with SCI?

Davis et al (1991) investigated the cardiorespiratory response of persons with paraplegia to four patterns of arm cranking training three times per week:

1. high-intensity long-duration: 40min at 70% peak oxygen intake
2. high-intensity short-duration: 20min at 70% peak oxygen intake
3. low-intensity long-duration: 40min at 50% peak oxygen intake
4. low-intensity short-duration: 20min at 50% peak oxygen intake

All groups show a significant increase in peak oxygen intake except group four (low-intensity short-duration training). The authors concluded that ‘as in elderly populations the low initial fitness levels of the typical wheelchair population apparently allows a response to quite low (but unaccustomed) levels of exertion’ (p.70). These authors concluded that regular training (three x 40mins per week) can enhance the endurance performance of inactive spinally-injured individuals even if they exercise at 50% of their peak oxygen intake.

The Square Wave Endurance Exercise Test (SWEET) has been used by a number of authors (Bougenot et al, 2003; Grange et al, 2002; Tordi et al, 2001). This consists of an interval training programme divided into bouts of exercise, five minutes in duration. Each five minute bout consists of four minutes of moderate exercise (base) and one minute of intense exercise (peak). Bougenot et al (2003) utilized this protocol on seven subjects with paraplegia. The exercising intensity was varied so that at the completion of nine bouts of exercise an 80% HRmax was obtained. The intensity of the base was set at ventilatory threshold (VT assessed from respiratory variables) and the peak at maximal tolerated power (MTP the highest load that could be maintained at a constant speed for 1 minute). Results showed significant increases in CV variables and power output. Additionally Grange et al (2002) and Tordi et al (2001) used the SWEET protocol training programme and found significant increases in peak oxygen uptake and maximum tolerated power. Tordi et al (2001) suggest that the advantage of using the SWEET protocol is the ability to adjust intensity. They state that constant high load exercise results in metabolic acidosis due to the formation of lactate. During the SWEET protocol however, hyperventilation produces ventilatory alkalosis during and after the peak and the four minute 'base' stimulates neoglycogenesis. The net result is that lactate levels are decreased and lactate acidosis is reduced.

Monitoring Intensity

Muscular strength and endurance are developed by the overload principle (ACSM guidelines, 1990). Grange et al (2002) stipulates that it is important to have a measure of the strain a given exercise imposes on the individual to be sure the stimulus is sufficient to induce an adaptive response. The optimal work intensity for endurance training in healthy subjects should be within the range of the anaerobic threshold. At this point oxidative metabolism is being used with minor lactate being produced (McArdle et al, 1991).

A number of methods for monitoring exercise intensity in the SCI population and recommendations from the literature are discussed below:

- **% of HRmax: (220-age)**

Various percentages of HRmax have been prescribed in exercise programmes for SCI persons, ranging from 60% to 90% HRmax. Hoffman (1986) selected a training intensity of 60-70% HRmax while Cooney and Walker (1986) selected 60-90% HRmax. Pollock et al (1974) trained subjects at 80-85% HRmax and Hicks et al (2003) recommend 70% HRmax. All of the previously mentioned studies found improvements in CV parameters.

Due to the autonomic dysfunction experienced by persons with tetraplegia, heart rate (HR) has been shown to be an unreliable indicator of exercise intensity (Finely et al, 2002). Maximal HR for individuals with SCI range from about 100-130 bpm (DiCarlo, 1988; Hoffman, 1986; Cowell, 1986). This is due to the small muscle mass available to perform exercise and to the reduced sympathetic nerve innervation.

McLean, Jones and Skinner (1995) state that the low-peak HR found in persons with SCI limit the usefulness of the percent maximal HR method for prescribing exercise. They found a poor correlation between HR and VO2max and suggest that exercise intensity should not be based on HR for those with high-level tetraplegia exercising in the sitting position.

In contrast to this Cooney and Walker (1986) found that both paraplegic and tetraplegic subjects were able to achieve HRmax of 60-90% when performing hydraulic resistance exercises. This was within the range recommended for by the American College of Sports Medicine to increase CV fitness in able-bodied populations (ACSM 1990). Hicks et al (2003) exercise regime produced similar HR changes to submaximal exercise in both paraplegic and tetraplegic subjects. The authors state that they 'did not have strong evidence of sympathetic dysfunction limiting exercise performance' (p.41). However all tetraplegic subjects in this study had incomplete lesions so might have been able to activate their sympathetic nervous system.

- **Heart rate reserve (HRR)**

HRR = HRmax –HRrest

Training HR = (HHR x % of desirable intensity) + HRrest (Duran et al, 2001)

50-60% HRR has been shown to improve fitness in the SCI population (DiCarlo, 1988). Duran et al (2001) gradually increased target HR from 40% to 80% training HR and found CV improvements.

Hooker and Wells (1989) divided subjects into a low-intensity and moderate-intensity group working at 50-60% and 70-80% HRR. Submaximal testing revealed that only the moderate-intensity group showed a significant training effect (decreased rated perceived exertion, post exercise HR, and lipid profile). The authors conclude that 70% HHR was the minimal intensity needed to elicit a training effect.

- **Rated perceived exertion (RPE)**

These scales permit individuals to accurately control the exercise intensity without the use of technical instrumentation (Grange et al, 2002). One of the most common RPE scales used is the Borg Scale. This scale has been shown to correlate positively with workload and heart rate. Ratings of perceived exertion during exercise 'may be a simple yet valuable means of evaluating effective exercise intensity' (Capodaglio, Grilli and Bazzini, 1996 p.689). The ACSM guidelines (1990) recommend a RPE of 12 to 16 (20-point Scale) for CV training in the non-disabled population.

Studies that have used the Borg Scale include a study by Capodaglio, Grilli and Bazzini (1996) on eight acute paraplegic patients. Subjects performed 20-30 minutes of arm cranking at moderate intensity (score 3 on Borg's 10-point scale), five days per week for 6 week and showed improved fitness levels. Grange et al (2002) compared healthy and paraplegic patients during wheelchair ergometry task following a rehabilitation programme. Results showed that both groups improved in maximum tolerated power and peak oxygen uptake, and that there was no significant difference in perceived exertion between groups. They conclude that perceived exertion could be used to control exercise intensity during a rehabilitation programme for paraplegics, similar to healthy subjects. However McLean et al (1995) found that tetraplegic subjects consistently tended to underrate their RPE. They found that neither %HRmax, %HRR, %VO2max nor RPE were completely applicable to the tetraplegic population. Their preliminary trials indicate that 50-60% of peak power output or alternatively a RPE of 10-12 (20 point Borg Scale), may provide an appropriate level of exercise intensity for arm ergometry in tetraplegic patients.

Table 2 is a useful resource that displays corresponding values for the various methods of monitoring exercise intensity.

Table 2: (from Pollock and Wilmore cited in ACSM guideline 1990)

Relative intensity (%)			
HRmax	**HRR or VO2max**	**RPE**	**Description of intensity**
< 35%	< 30%	< 10	Very light
35-59%	30-49%	10-11	Light
60-79%	50-74%	12-13	Moderate
80-89%	75-84%	14-16	Heavy
> 90%	>85%	>16	Very heavy

iv. Length of programme

In the reviewed literature the length of exercise programme varied from four to twenty four weeks, with the ACSM (1990) recommending 15-20 weeks in the able-bodied population.

b) Strength Training

The aim of strength training in the SCI population is to selectively strengthening those muscles used in ADLs and those in which persons with SCI experience the most weakness and pain. Therefore an understanding of the movements, the musculature, the intensity and type of contraction involved is essential.

i. Which muscle should be targeted in persons with SCI?

Research can be useful in identifying weak muscle in the SCI population. In a study on 10 paraplegic men, Jacobs et al (2001) showed that specific attention needs to be directed at strengthening the shoulder external rotators, as weakness in these muscles has been associated with instability and activity-limiting pain in persons with paraplegia. Further Burnham et al (1993) reported muscle imbalance in SCI subjects. They found weakness in the shoulder adductor and rotators. These authors noted that this weakness may contribute to impingement syndrome in paraplegic athletes. They therefore recommend that these muscles should be targeted in any strength training regime. In addition the authors suggest that posture training to encourage scapular retraction may help in limiting shoulder impingement.

Of significance to this discussion, an exercise programme that stretches the anterior shoulder muscles (including pectoralis and biceps) and strengthening the posterior muscles (especially the muscles that control external rotation, adduction and scapular retraction) has been suggested by Curtis et al (1999a) to prevent the onset of shoulder pain in wheelchair users. Therefore this important factor should be taken into account when designing a specific, individualized training programme.

ii. EMG studies

By investigating the muscles active during functional movement (e.g. weight relief manoeuvre) it is possible for the therapist to refine strengthening programmes to specifically target the appropriate muscles. EMG has been a useful tool in identifying these active muscles, and has added to the knowledge base. For example it was previously thought that C5 and C6 tetraplegics elevated their trunk in a weight-shift manoeuvre by depressing their shoulder while using gravity to 'lock' their elbows into extension. The EMG studies below are refuting this theory.

In a study by Gefen, Gelmann, Herbison, Cohen and Schmidt (1997) on six male subjects with SCI lesions at C6, EMG showed that the anterior deltoid is active in extension of the elbow in a closed kinetic chain. They found that with the hand in a fixed position the shoulder muscles cannot move the arm instead the humerus moves forward, resulting in extension of the elbow joint. In support of this Marciello, Herbison, Cohen and Schmidt (1995) showed that both the upper pectoral and anterior deltoid were active in elbow extension and that they were able to exert increasing forces. Additionally, EMG studies have shown that persons with tetraplegia who have paralysis of their triceps brachii can lift themselves by generating shoulder flexor and adductor moments (Harvey & Crosbie 2000). Interestingly an increase in flexor moment about the elbow was not associated with an increase in EMG activity in the bicep muscle. They suggest that the elbow flexor moment was attributed to passive stretch of soft tissue on the anterior surface. A similar phenomenon was attributed to the wrist flexor moment. Elbow flexor moments are critical to lifting because as the hand is fixed shoulder flexors moment cannot increase without concurrent increases in elbow flexor moments. Generation of flexor rather than extensor moments enabled individuals with paralysed triceps to extend their elbows and weight-bear through them. These authors found that only 70% of the subject's weight was lifted at the time of full elbow extension. The remaining weight was lifted by continuing activity in the upper pectorals and anterior deltoid increasing shoulder flexion. In addition shoulder girdle depression enhances the subject's ability to lift their weight. Of significance to this study Harvey and Crosbie (2000) suggest that therapist should pay attention to strengthening the latissimus dorsi which is responsible for this action.

Perry, Gronley, Newsam, Reyes and Mulroy (1996) suggest that it is important to strengthen the sternal pectoralis and latissimus dorsi without causing impingement at the glenohumeral joint. Both of these muscles adduct and depress the humerus, and they suggest that resisted adduction should be used in place of exercises that rely on axial loading of the arm. As such open chain exercises using Theraband may be more appropriate than closed chain exercises that rely on body weight for resistance. Further to this discussion, when prescribing exercise, Burnham et al (1993) recommend that shoulder adduction strengthening exercises should be performed below shoulder level to minimize the risk of impingement and that rotation exercises should begin with the shoulder in neutral.

iii. Strength Recommendations

In summary the recommendations from the literature for strength training after SCI are:

Muscles to be targeted

EMG has identified groups of muscles that are important in functional movement including:

iv. Shoulder rotators
v. Shoulder adductors
vi. Scapular retractors
vii. Shoulder flexors (especially the anterior deltoid and upper pectorals)
viii. Shoulder girdle depressors (namely latissimus dorsi)

Mode

Various types of equipment have been used to increase the strength on SCI subjects including free weights, wrist cuffs, machines, pulleys, tubing or body weight (Finley et al 2002). Theraband was also used for shoulder strengthening by Curtis et al (1999). It has been suggested in literature that a wrist strap can be used for tetraplegic patients to accommodate for weak or absent grasp.

Frequency

2 days per week is recommended in the ACSM guidelines (1990) to increase strength in the non-disabled population. Hicks et al (2003) trained subjects at this frequency with positive results. Curtis et al (1999) on the other hand instructed subjects to perform resistance exercises daily. They found regular resistance exercise resulted in an improvement in shoulder strength.

Repetitions and Sets

There are many conflicting views on the number of repetitions and sets within the literature. One set of 8-12 repetitions consisting of 8-10 exercises that target the major muscle groups are recommended by the ACSM guidelines (1990) for the abled-bodied population. Studies by Hicks et al (2003) varied this prescription in the SCI population. These authors began their resistance programme with two sets of each exercise and progressed to three sets after the first four weeks, while Curtis et al (1999) utilized three sets of fifteen repetitions for their programme.

Intensity

Exercise intensity for resistance exercise was not stipulated in every study. Hicks et al (2003) began with 2 sets at 50% 1RM then progressed to 3 sets of 70-80% 1RM. The authors reassessed the load every 6 weeks to ensure a constant training intensity. Of significance to this study the ACSM recommends resistance exercise be performed 'to near fatigue' (ACSM guidelines 1990) in the abled-bodied population.

Type of contraction

Wheelchair propulsion is characterised by short-term exercise with alternating concentric and eccentric components (Mayer et al, 1999). These authors found that eccentric exercises of the shoulder region produced less fatigue than concentric exercise in a group of paraplegic subjects. They conclude that eccentric exercises offer the advantage of lower muscular fatigue, and higher maximal strength. It was noted however that due to the structural damage and subjective pain reported by subjects while performing these movements, eccentric exercise should be recommended with reservations.

c) Circuit Training

There is limited research available on circuit training in persons with SCI. Cooney and Walker (1986) showed that hydraulic resistance exercise performed in a circuit, three times per week for nine weeks showed significant CV gain in SCI subjects. In contrast, Gettman et al (1978) reported that twenty weeks of circuit weight training improved strength in adult men, but produced only small aerobic effects. It should be noted however that subjects were able-bodied, rest period ranged between 20 and 30 seconds and the intensity was set at 50% 1RM for each subject.

i. Recommendations for Circuit training

Mode

Cooney and Walker (1986) used hydraulic resistance exercises for the shoulder and chest with positive results. Resistance, repetitions and rest was prescribed according to a predetermined formula. Jacobs et al (2001) circuit consisted of arm cranking and resistance exercises performed on a multi-station exercise machine, with improvements in both fitness and strength.

Frequency

Both Cooney and Walker (1986) and Jacobs et al (2001) prescribed their circuit to patients 3 times per week with favourable results at the end of nine weeks and 12 weeks respectively.

ii. Repetitions and Rest

The ACSM guidelines (1990) recommend that 10-15 repetitions should be performed per station and that rest between stations should be limited to 15-30 seconds. N.B. one set per exercise is performed before progressing to the next exercise.

A study by Jacobs et al (2001) had subjects perform one set of ten repetitions on exercise one followed immediately by another set of ten repetitions on exercise two then two minutes arm cranking without rest. This routine was repeated for exercises three and four, and again for exercises five and six. This comprised or one 'circuit' which was repeated three times in an exercise session. (NB rest was limited to 15 sec between exercise stations). This study produced positive result and it should be noted that the recommended number of repetitions and rest is similar to that suggested by the ACSM guidelines (1990).

Intensity

Cooney and Walker (1986) had subjects perform at 60-90% HRmax. In contrast Jacobs, et al (2001) began with 50% 1RM by week eight training at 60% 1RM Low resistance / high intensity.

Duration

Cooney and Walker (1986) progressed the duration of their circuit from eight minutes in stage one to 30-40 minutes in stage three. Jacobs, et al (2001) circuit was 40-45minutes in duration, consisting of resistance exercises, endurance exercise (arm cranking). During the rest periods subjects HR was not allowed to drop below baseline measurements.

Length of programme

Cooney and Walker (1986) circuit exercise programme was conducted over 9 weeks, while Jacobs et al (2001) performed theirs over 12 weeks.

d) Stretching

Curtis et al (1999a) performed static stretching of the anterior shoulder muscles (pectorals and biceps). Subjects stretched twice daily for five sets, holding each stretch for 20-30 seconds.

5. PRECAUTIONS WHEN PRESCRIBING AN EXERCISE PROGRAMME TO AN INDIVIDUAL WITH SCI

Before commencing or prescribing an exercise programme to individuals with SCI, Finley et al (2002) state:

- Medical clearance should be sought from a physician
- To prevent exercise-induced hypotension, caused a redistribution of blood and abdominal binder and/or compressive stockings should be worn
- A security strap should be used to ensure trunk support if abdominal and trunk control is reduced.
- Monitor for thermoregulatory distress. This is due to the loss of autonomic vasomotor control and the absence of sweating and vasoconstriction/ vasodilation below the level of the lesion.

6. LIMITATIONS IN THE LITERATURE

Common limitations exist in the literature regarding exercise prescription and training in persons with SCI. In general there is a lack of standardisation of testing protocols and procedures, of methodology and experimental design and of a preciseness in the documentation and reporting of the quantity and quality of training (Finley et al 2002).

Little research has been conducted using home programmes. Most of the reviewed articles have been conducted either as part of inpatient rehabilitation or in clinic outpatient exercise programme. The shoulder programme by Curtis et al (1999a) was the exception and was conducted as a home exercise programme.

Design limitations include the use of prospective or cross-sectional rather than longitudinal studies. This limits the ability to investigate long-term changes that occur with SCI or changes that are related to pre-existing conditions (Finley et al 2002).

Few studies have been conducted on women or minorities. This limits the ability to extrapolate results to other populations. Although as the majority of SCI occurs within the male population, this is less of a problem.

In addition confounding variables are often not controlled. Factors such as pre-existing conditions, smoking, medications, and alcohol intake are frequently not considered.

7. EXERCISE RECOMMENDATIONS BASED ON THE FINDINGS OF THE LITERATURE REVIEW

a) Cardiovascular Training:

Positive results recorded in SCI individuals after training using the ACSM guidelines suggest that these general guidelines may be suitable for this population as well.

ACSM Guidelines: **Mode:** continuous exercise using large muscle groups **Frequency:** 3-5days per week **Intensity:** 60-90% HRmax or 50-85% VO2max **Duration:** 20-60 minutes

However a number of points should be clarified when prescribing exercise for the SCI population.

i. Mode

It is acknowledged that electrical stimulation of the leg muscles of SCI patients while on a bicycle ergometer is sufficient to produce central CV adaptation. Although hybrid training has been shown to produce the greatest increase in VO2max it is extremely expensive, requires assistance and is limiting for persons with contractures, fractures or lower limb problems. It may therefore be unsuitable for the average SCI person wish to maintaining fitness in the long-term.

As a home-based fitness programme, arm cranking or wheelchair ergometers are less expensive. These methods are a reliable and valid mode for evaluation of exercise performance and prescription of training programmes in the SCI population. Wheelchair and arm ergometers are commercially available however a more cost effective option is to modify a second-hand Exercycle into an arm crank.

<u>Supine position</u>

The supine position has cardiovascular benefits, such as increased venous return. In addition this position may also stabilize the scapular during resistance exercise. The position may be appropriate for those people suffering from shoulder pain. However it is acknowledged that this position:

a) limits the numbers of exercises that can be performed, especially in persons with tetraplegia

b) limits the ease with which patients can transfer from one exercise to the next in a circuit programme (this may result in extended rest periods which may detract from the CV benefits).

ii. Frequency

In concurrence with the ACSM guidelines (1990) it is recommend that exercise be performed 3-5 days per week, with four being the optimal.

iii. Intensity/ Duration

In the healthy adult the ACSM guidelines (1990) recommend exercising at an intensity of 60-90% HRmax or 50-85% VO2max or heart rate reserve (HRR).

However as the HR response to exercise is lower in persons with tetraplegia due to their autonomic dysfunction, it is suggested that a lower training HR be selected. 60-70% HR max, will provide a sound basis for an endurance exercise programme for individuals with SCI. Alternatively if HR monitors are unavailable or if recording of HR is difficult, a rated perceived exertion scale may be used.

Table 1

Relative intensity (%)			
HRmax	**HRR or VO2max**	**RPE**	**Description of intensity**
< 35%	< 30%	< 10	Very light
35-59%	30-49%	10-11	Light
60-79%	**50-74%**	**12-13**	**Moderate**
80-89%	75-84%	14-16	Heavy
> 90%	>85%	>16	Very heavy

It is recommended that exercise intensity be set at an RPE of 12-13 (moderate) on the 20-point Borg Scale.

Square Wave Endurance Exercise Test (SWEET) consisting of an interval training programme divided into bouts of exercise may also be useful for training in the SCI population, as alternating intensity is this way may more accurately mimic activity in daily living.

iv. Length of programme

The ACSM (1990) recommends 15-20 weeks for an exercise programme, however as the benefits of exercise are experience throughout life, it is suggested that exercise becomes part of the patients lifestyle. The programme should be varied every 6-8 weeks with weights, resistance and type of exercise being reassessed during this time.

b) Strength Training

i. Muscles groups

The following muscle groups should be targeted in an attempt to strengthen those muscles that are weak and those that are necessary for functional movement.

- shoulder internal rotators (subscapularis, and pectoralis major, latissimus dorsi and teres major) and external rotators (infraspinatus and teres minor)
- shoulder adductor (sternal pectoralis and latissimus dorsi)
- scapular retractors (rhomboids)
- anterior deltoid
- upper pectoralis
- serratus anterior

Rotator cuff strengthening exercise should begin with the shoulder in neutral to minimize any mechanical impingement.

Shoulder adduction exercises should be performed below shoulder level to minimize the risk of impingement. Resisted adduction should be used in place of exercises that rely on axial loading of the arm.

ii. Mode

Any mechanism that adds resistance e.g. machine / free weights, wrist cuffs, pulleys, Theraband or body weight.

i. Frequency

2 days per week

ii. Repetitions and Sets

1-2 sets of 8-15 repetitions

iii. Intensity

70-80% 1RM

iv. Type of contraction

Both concentric and eccentric exercise can be recommended. However due to the possibility of muscle damage and pain that may occur with eccentric training, it should be prescribed with care and under supervision.

c) Circuit training

Circuit training can be recommended to increase both CV and strength in the SCI population. The circuit should consist of 8-10 strength exercises and have a CV component. Rest periods between 'stations' should be kept to between 15 – 30 seconds (HR should not fall below baseline during this time).

i. **Frequency**
ii. 3 times per week

iii. Reps and Rest
10-15 reps per station

iv. Intensity
Low resistance / high intensity:

60-80% HRmax, 50-70% HRR, RPE 12-13 (moderate), 50-60% 1RM

v. Duration
30-40minutes

d) Flexibility

Stretches for the shoulder, back and chest muscles (including pectorals and biceps). 5 sets should be performed, holding each stretch for 20-30seconds.

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