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Chapter

Role of Biokinetics Rehabilitation among Spinal Cord Injured (SCI) Patients

Adelle Jordaan, Terry Jeremy Ellapen, Mariette Swanepoel and Yvonne Paul

Abstract

Spinal cord rehabilitation is a complex and consuming pathology, requiring the skillsets of numerous experts to ensure optimal treatment. To this end, the expertise of an exercise therapist (biokineticist) can play a significant role in health maintenance, as well as in the prevention of the co-morbidities often experienced by this population (elevated risk for metabolic syndrome and coronary heart disease associated with SCI), positively improving patients’ overall quality of life. Biokinetics can furthermore help to lower cardiometabolic risks through the prescription of individualized exercise programs and by working in conjunction with other members of the patients’ health team. Physically active spinal cord injured individuals who use their wheelchairs as an exercise machine can benefit from the expertise of a biokineticist as far as these physically active spinal cord injured individuals often experience upper limb neuro-musculoskeletal overuse injuries. In so far as biokineticists are final-phase rehabilitation exercise therapists who prescribe structured physical activity to improve the physical and physiological conditioning of the patient, they are similar to other exercise therapists, such kinesiotherapists, physical therapists, or physiotherapists, and function within a multi-disciplinary rehabilitation team to improve the quality of life of a spinal cord injured individual.

Keywords: biokineticist, cardiometabolic risk, injury, spinal cord injury

1. Introduction

The unfortunate consequences of spinal injury often include paralysis, inability to stand and walk, increased cardiometabolic risks leading to metabolic syndrome, a loss of independence, social isolation, and decreased quality of life [1–3]. Spinal cord injured patients require a comprehensive multi-disciplinary team, especially during post-hospitalization [1, 2, 4]. The medical fraternity has observed that post-hospitalization, many spinal cord injured patients adopt a physically inactive lifestyle that facilitates various sedentary lifestyle pathologies commonly referred to as non-communicable diseases [5, 6]. Martin Ginis et al. and Hicks et al. encourage spinal cord injured patients to participate in habitual physical activities to combat the onset
of non-communicable diseases [7, 8]. Gorgey et al. contended that prolonged sitting is a foremost risk facilitating the early onset of non-communicable diseases and premature death among those with spinal cord injuries [5]. The purpose of this chapter is to describe the role of one therapeutic profession (Biokinetics) involved with the physical and exercise rehabilitation of spinal cord injured patients in a South African context.

2. The genesis of the medical and therapeutic experts that intervene during the pathogenic and fortogenic healthcare paradigms of spinal cord injury

Medical treatment begins once the spinal cord injury has been identified by the medical doctors (trauma unit neuro and orthopedic surgeons), when the patient is admitted to an acute care center [9]. At the acute care center, the patient may undergo surgery, if necessary, and in-hospital stay rehabilitation. The acute stage of spinal cord injury falls with the pathogenic paradigm, which involves the illness-care dimension (treatment of the spinal cord injury which has been sustained) and/or illness-prevention dimension (the increased intrinsic risk of other prospective pathologies such as non-communicable diseases) [10]. The medical specialists managing the spinal cord injured patient during the pathogenic paradigm include trauma unit medical practitioners and nurses, neuro-surgeons, and orthopedic surgeons. Post-surgical rehabilitation therapy is offered by physiotherapists in the course of the patient's hospital stay [10, 11]. The in-hospital physiotherapy of spinal cord injured patients concentrates on regaining motor tasks, such as optimal use of upper limbs, standing (with and without crutches), walking (if possible, with prosthetic devices), the patient being able to transfer him/herself from the bed to the wheelchair and vice versa, selecting the appropriate wheelchair based on the severity of the injury (motorized versus manual wheelchair), and gaining mobility with the wheelchair [2, 12]. The physiotherapist teaches the spinal cord injured patient both bed-bound and non-bed bound exercises to strengthen muscles and regain balance, proprioception, and kinesthesia [13]. The physiotherapy rehabilitation phase can vary from a few days to several weeks [2].

Successful recovery from a spinal cord injury depends on the severity of the injury and the treatment a patient receives in the course of each stage of the management spectrum [9]. The treatment of spinal cord injuries spans from hospitalization to surgical care, and rehabilitation (in-hospital stay and post-hospitalization) strategies [9]. A multidisciplinary medical team for spinal cord injuries usually consists of therapists, such as a physiotherapist (also known as physical therapist), occupational therapist, rehabilitation nurse, medical specialist physician, a dietician, psychologist, and biokineticist [14]. Physicians or general practitioners (GP’s) are recognized as the principal source for referral of spinal cord injured patients for participation in structured physical activity and/or leisure-time physical activity [6]. Gorgey and colleagues stated that the multi-disciplinary team that engages in the care and rehabilitation of spinal cord injured patients needs to comprehend the various benefits of physical activity as an integral part of the rehabilitation strategy [15]. Acute stage medical management of spinal cord injured patients focuses on decreasing additional neurological impairment to the spinal cord, and enhancing recovery and rehabilitation after an injury, commencing as soon as the individual is medically stable [2]. Spinal cord injury is considered to be a long-term neurological impairment, which requires the expertise of multiple healthcare professionals over a prolonged period of time to manage aspects related to this neurological condition [12, 16].
Once the acute and sub-acute treatment (which resides in the pathogenic healthcare paradigm) of spinal cord injury has been completed, the patient then enters the fortogenic healthcare paradigm. In the fortogenic healthcare paradigm, the spinal cord injured individual is considered apparently healthy, without increased risk of pathology, but is attentive to assume a physically active lifestyle to prevent the risk of illness (non-communicable diseases) and prevent a decrease in their quality of life. At this stage, the spinal cord injured patient requires the expertise of an occupational therapist and a biokineticist. The focus of the occupational therapist during spinal cord rehabilitation involves the adaption of the individual to their physical and social environments by reclaiming the abilities that help them to create a significant life \([17]\). Occupational therapy principally concentrates on the fundamental activities of daily living, home-based activities, and sensory, perceptual, and cognitive exercises \([13]\). The role of a biokineticist during spinal cord injury rehabilitation will be discussed in the subsequent sections.

3. What is the profession of Biokinetics?

The Health Profession Council of South Africa defines Biokinetics as a final-phase functional therapeutic health and wellness profession, concerned with improving the physical and physiological health and wellbeing of patients and apparently healthy individuals through the scientific prescription of personalized physical activity and exercise in the framework of chronic clinical and neuromusculoskeletal pathologies and performance enhancement in both the pathogenic and fortogenic healthcare paradigms (Figure 1) \([18]\). Ellapen and Swanepoel contend that Biokinetics has been intermittently involved with health and wellness.
campaigns aimed at preventing and rehabilitating neuro-musculoskeletal injuries and non-communicable diseases. Biokinetics is an ambassador of the philosophy that *exercise is medicine* [10, 19, 20] and operates within the pathogenic health paradigm (illness and illness prevention healthcare dimensions) when rehabilitating patients who have sustained non-communicable diseases, as well as within the fortogenic paradigm when encouraging a physically active lifestyle as a physiological defensive mechanism to prevent the occurrence of non-communicable diseases among healthy individuals. The neuro-musculoskeletal focus of Biokinetics concentrates on final-phase functional rehabilitation involving muscle strengthening, increasing muscle endurance, cardiorespiratory conditioning, muscle extensibility, joint flexibility, proprioception, kinesthesis, and patient education [21].

4. How can Biokinetics improve the quality of life of a spinal cord injured person?

To appreciate the value of a biokineticist as a prominent member of the rehabilitation strategy for a spinal cord injured person, one needs to understand the consequence that physical inactivity has on their lives. It is important for health care professionals, governing bodies, rehabilitation centers, and community organizations to understand what factors constrain and promote physical activity in the SCI population, to be in a better position to support people with SCI in being physically active for life. This sub-section will describe the perils that physically inactive spinal cord injured persons may succumb too.

It is an accepted reality that spinal cord injured persons lead a limited physically active lifestyle as compared to their able-bodied counterparts and are more susceptible to the onset of non-communicable diseases [22–24]. Approximately 85% of spinal cord injured persons are physically inactive and the additional 15% reported participation in physical activity that is below the threshold where it has meaningful health benefits [25]. The objectives for incorporating a physically active lifestyle into the spinal cord injured person's rehabilitation strategy is to avert and/or manage the onset of non-communicable diseases and improve the person's quality of life [1]. Habitual compliance to a structured physical activity and exercise program as part of a spinal cord injured person's rehabilitation strategy offers the following benefits: reducing the risk of cardiovascular diseases, metabolic syndrome, arthritis, osteoporosis, osteoarthritis, and urinary tract infections [26, 27].

i. Physical activity has been identified as improving or inhibiting many of the health and well-being complications associated with SCI. For example, physical activity has been proven to reduce levels of perceived musculoskeletal and neuropathic pain [28].

ii. The upsurge of cardiovascular diseases and related co-morbidities such as diabetes mellitus, obesity, and dyslipidemia are significant concerns that are consequences of a physically inactive lifestyle and which many spinal cord injured persons contract [1]. Myers and colleagues have reported that autonomic dysfunction among physically inactive spinal cord injured individuals contributes to fluctuating blood pressure, arrhythmia, and a blunted cardiorespiratory response to physical activity and exercise, which hinders cardiorespiratory fitness [27].
iii. Many physically inactive spinal cord injured persons have compromised metabolic systems, resulting in a slow basal metabolic rate leading to increased body fat and obesity, increased risk lipid profiles resulting in hypertriglyceridemia, insulin resistance, and impaired glucose tolerance resulting in diabetes mellitus [29].

iv. Both strength and endurance activities contribute to improving overall functional capacity. Moreover, expiratory muscle training exercises help in improving inspiratory muscle function [30].

v. Prolonged bed rest after a spinal cord injury facilitates muscle fiber atrophy and causes spinal cord injured persons to replace their muscle mass with fat [15]. Jiang and colleagues reported that a sedentary lifestyle is associated with osteoporosis, which increases the risk of fractures, a risk that spinal cord injured persons must safeguard against [31].

vi. Aerobic exercise helps to improve energy levels, decrease fatigue, and manage body weight. It also enhances heart and lung function and improves the body’s ability to use oxygen. Early rehabilitation improves cardiac efficiency [32].

vii. In line with the biopsychosocial model of the International Classification of Functioning Disability and Health (ICF-DH), the objective of rehabilitation is to restore “the individual to the highest level of participation, and returning individuals to the life they want as far as their disability will permit” [33].

viii. Physical activity has shown improved psychological wellbeing through enabling experiences such as personal control, responsibility, and risk taking that further post-traumatic progress [34].

ix. A small portion of spinal cord injured individuals forgo a physically inactive lifestyle and are instead physically active, using their wheelchairs as an exercise apparatus [19]. These individuals experience upper limb overuse injuries, which may also curtail physical activity [19, 35]. Common overuse injuries include rotator cuff tendinitis, shoulder impingement, biceps tendinitis, ulnar neuropathy, lateral epicondylitis, carpal tunnel syndrome, and De Quervain’s tenosynovitis [36]. Will and colleagues contend that inefficient wheelchair propulsion biomechanics is the primary culprit of the aforementioned overuse injuries [37]. Van der Scheer and colleagues reported that spinal cord injured wheelchair sports activists who have poor aerobic capacities, tend to adopt inefficient wheelchair propulsion biomechanics when engaged in prolonged endurance activities causing overuse injuries [38]. Sprigle and Will et al. stated that the contributors to poor biomechanical posture among spinal cord injured wheelchair users are drooping/angled shoulders and forward leaning [37, 39]. The dorsal coronal plane kinematic analyses of the angulated shoulder girdle posture are associated with rotator cuff tendinitis and shoulder impingement [40]. Ellapen and colleagues reported that the angulated shoulder girdle posture is associated with an ineffective static passive locking mechanism of the glenohumeral joint [40]. This ineffective static locking mechanism is a result of scapular depression and downward rotation because of the eccentrically lengthened trapezius and rhomboid muscles, together with a laxed
superior glenohumeral capsule [41]. The inefficient kinematic angulated shoulder girdle posture creates an abnormal force-couple relationship asymmetrically elongating the trapezius and the condensing pectoralis minor in the coronal plane [41]. The concentrically contracted pectoralis minor muscles pull in the chest, producing a sunken appearance and posteriorly hyper-flexing the thoracic vertebrae, causing kyphosis. The sagittal plane kinematic analyses indicate a rounded shoulder appearance, reminiscent of pectoralis minor and serratus anterior contractures, and elongated rhomboids. The caudally orientated humeral head is medially rotated, indicating subscapularis and pectoral minor contractures [40, 41]. Collectively, the angulated shoulder appearance diminishes the impingement interval space between the coracoacromial-arch and the humeral head, diminishing the impingement interval spacing, compressing the supraspinatus, sub-acromial bursa, and biceps brachii [40, 41]. The collective biomechanic cascades of these kinematic events describe the pathomechanics of rotator cuff tendinitis, shoulder impingement, sub-acromial bursitis, and biceps tendinopathy [40, 41].

Jordaan describes a biokineticist as a specialized exercise therapist who functions in professional association with other health and medical specialists registered with the Health Professions Council of South Africa [12]. The scientifically based physical-activity prescribed rehabilitation program denotes an explicit and individual-oriented physical-training program based on the individuals’ physical condition status [19]. Final-phase rehabilitation is the point in the rehabilitation process when structured exercise and physical activity constitute the primary therapeutic modality [12]. The collaborative relationships among therapeutic practitioners and medical staff in South Africa are strained due to competition over patients and a lack of understanding and appreciation of each other’s scope of the profession. Physiotherapists have claimed that chiropractors and biokineticists encroach on their scope of the profession [42]. Booysen and colleagues have reported that despite attempts to foster interdisciplinary collaboration among South African medical staff and therapists, there is resistance [43, 44]. Ellapen and colleagues proposed that a better understanding of the scope of expertise of each of the aforementioned professions should be taught at South African universities, which will lead to an appreciation for the specific skill set that each profession offers [42, 44]. Jordaan and colleagues have advocated that medical practitioners, including nurses, physiotherapists, occupational therapists, biokineticists, nutritionists, psychologists, neurologists, or orthopedic surgeons, need to work collaboratively to provide better quality management of spinal injured patients [1]. A multi-disciplinary collaborative clinical team provides the most efficacious healthcare of spinal cord injured patients [1, 45].

i. A typical biokinetic rehabilitation program will include a general warm-up, progressing into a specific warm-up. Thereafter the patient will perform stretching, moving into a series of strengthening and/or aerobic exercises. The cool-down phase involves stretching of muscles and a gentle aerobic activity to return the heart rate to normal levels.

ii. The biokinetic rehabilitation program will include aerobic exercises to improve cardiorespiratory conditioning. The structured aerobic program will help to effectively mediate glucose metabolism, increase insulin sensitivity, reduce insulin resistance, and collectively prevent the onset of diabetes mellitus.
Habitual aerobic exercises also reduce low-density lipoprotein cholesterol (LDL-cholesterol) and triglycerides, which collectively reduce the spinal cord injured person’s cardiometabolic risk for metabolic syndrome and coronary artery diseases.

<table>
<thead>
<tr>
<th>Modes of physical activity</th>
<th>Intensity, frequency, and duration</th>
<th>Clinical rehabilitation objectives</th>
<th>Time to achieve goal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aerobic exercise</strong></td>
<td>Duration: ranging from 20 to 60 minutes depending on person’s fitness status. Intensity: ranging from 50 to 80% of the person’s maximum heart rate (HR\text{max}) Frequency: 3-5 days per week</td>
<td>• Increase aerobic capacity • Increase active muscle strength and endurance • Increase active muscle hypertrophy • Decrease body fat • Reduce the person's cardiometabolic risk by reducing excessive LDL cholesterol, glucose, and triglycerides • Improve person’s overall functional muscle strength, endurance, and aerobic capacity for independent functionality</td>
<td>6 months</td>
</tr>
<tr>
<td>Arm ergometer</td>
<td></td>
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<tr>
<td>Wheelchair ergometer</td>
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<tr>
<td>Wheelchair treadmill</td>
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<tr>
<td>Arm cycling</td>
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<td>Swimming</td>
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</tbody>
</table>

| **Muscle flexibility**     | PNF stretching: contract-relax, hold-relax, and/or slow reversal hold-relax performed by biokineticist Static stretching: hold stretch for 20 seconds × 2 repetitions Dynamic stretching: Stretch major muscles depending on applicability to person | • Increase muscle extensibility • Increase joint range of motion • Avoid onset of muscle contractures | 6 months |
| PNF stretching facilitated by biokineticist | | | |
| Static stretching          | | | |
| Dynamic stretching         | | | |

| **Strength**               | Intensity: 10–20 repetitions × 2 sets Frequency: 2-4 days per week | • Increase muscle strength and endurance • Recreate symmetrical force couple relationships between agonist and antagonist muscle pairings • Promote muscle hypertrophy • Increase muscle strength and endurance to promote independent functionality • Improve body posture • Improve wheelchair propulsion biomechanics | 6 months |
| Resistance bands           | | | |
| Dumbbells and barbells     | | | |
| Resistance equipment if applicable to person | | | |

All pictures were sourced from the internet.

Table 1. Comprehensive overview of a spinal cord injured patient’s rehabilitation plan for a six-month mesocycle [46].
### Warm-up
- **Duration:** 5–10 minutes for arm ergometer and/or wheelchair cycling
- **Swimming:** 10–20 minutes
- **Intensity:** approximately 60% of HR_max

### Stretching: static stretching (hold all stretches for 20 seconds and repeat twice)

<table>
<thead>
<tr>
<th>Muscle and/or muscle group</th>
<th>Picture</th>
<th>Muscle and/or muscle group</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalenae, levator scapulae and trapezius</td>
<td><img src="image1" alt="Scalenae Stretch" /></td>
<td>Scalenae and sternocleidomastoid</td>
<td><img src="image2" alt="Scalenae Stretch" /></td>
</tr>
<tr>
<td>Deltoids</td>
<td><img src="image3" alt="Deltoids Stretch" /></td>
<td>Biceps brachii</td>
<td><img src="image4" alt="Biceps Brachii Stretch" /></td>
</tr>
<tr>
<td>Triceps brachii</td>
<td><img src="image5" alt="Triceps Brachii Stretch" /></td>
<td>Shoulder external and internal rotators</td>
<td><img src="image6" alt="Shoulder Rotators Stretch" /></td>
</tr>
<tr>
<td>Pectoral major and minor and scalenes</td>
<td><img src="image7" alt="Pectoral Major and Minor Stretch" /></td>
<td>Latissimus dorsi, teres major, abdominal obliques and intercostal muscles</td>
<td><img src="image8" alt="Latissimus Stretch" /></td>
</tr>
</tbody>
</table>
### Stretching: static stretching (hold all stretches for 20 seconds and repeat twice)

<table>
<thead>
<tr>
<th>Muscle and/or muscle group</th>
<th>Picture</th>
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<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip flexors</td>
<td><img src="image" alt="Hip flexors" /></td>
<td>Hip extensors</td>
<td><img src="image" alt="Hip extensors" /></td>
</tr>
</tbody>
</table>

### Strengthening of major muscles (repetitions: 10–20, sets: 2)

- **Deltoids**
  - ![Deltoids](image)
- **Biceps brachii**
  - ![Biceps brachii](image)
- **Triceps brachii**
  - ![Triceps brachii](image)
- **Shoulder external rotators**
  - ![Shoulder external rotators](image)
- **Shoulder internal rotators**
  - ![Shoulder internal rotators](image)
- **Latissimus dorsi and teres major**
  - ![Latissimus dorsi and teres major](image)
- **Hip flexors**
  - ![Hip flexors](image)
- **Hip extensors**
  - ![Hip extensors](image)
iii. The stretching component of the biokinetic rehabilitation program will elongate shortened muscles and prevent muscle contractures. The patient will start with static stretching, moving into proprioceptive neuromuscular facilitation (PNF), and finally, dynamic stretching.

iv. Subsequently, the strengthening component of the biokinetic program will strengthen weak muscles. Collectively, the stretching and strengthening exercises will symmetrically ensure a synergistic force-couple relationship that will prevail among all active agonist-antagonist muscles.

v. Physical rehabilitation programs should incorporate treatments designed to prevent certain complications such as frozen joints, contractures, or bedsores.

Table 1 illustrates a comprehensive rehabilitation plan for a spinal cord injured person for a six-month mesocycle as recommended by Durstine and Moore [46]. Table 2 is a general biokinetic rehabilitation program targeting muscle strength and endurance and extensibility.

### 5. Conclusion

Spinal cord injury requires a multidisciplinary team of medical and paramedical experts to ensure that the person maintains the quality of life post-injury. To this end, biokineticists, as final-phase rehabilitation exercise therapists who can help the spinal cord injured patient prevent the onset of various non-communicable diseases, are fundamental to ensuring success in the strategic approach of the team. A small proportion of spinal cord injured patients continue to live a physically active life but unfortunately succumb to various neuro-musculoskeletal overuse injuries. The intervention of a biokineticist through the prescription of preventative exercise can aid in eliminating these overuse injuries and ensuring the individual enjoys an active and healthy life.
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Conflict of interest

None.

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