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Abstract

In this research, the residual walking potential for people with severe spinal injury was studied. The **primary questions** addressed by the research were as follows:

(a) What aspects of personal and interpersonal functioning would be greatly affected by severe spinal cord injury (SCI)?

(b) What factors may be strongly associated with negative change in the exercise behaviour of SCI people?

(c) Is pre-injury normal walking knowledge still available after SCI?

(d) If it is, how can it be accessed?

The goal of the research was to clarify whether the rehabilitation approach involving normal gait exercise would lead to better outcomes and bring more benefit to SCI people in terms of their physical, emotional, social and vocational well-being.

Three independent studies were conducted. In **Study 1**, a survey questionnaire was used to identify and investigate the beliefs that 219 wheelchair-dependent SCI people had about their post-traumatic physical, psychological and social-vocational life, and to identify the factors that they perceived as being critical influences on their exercise behavior.

In **Study 2**, gait analysis was performed. This compared two walking patterns performed by 20 healthy participants: walking with no aids, or normal gait (NG); and walking with braces, or brace gait (BG). Furthermore, this study investigated the nature of the experience that the participants reported while walking with braces.

In **Study 3**, a comparison was conducted between two walking patterns of a single male participant who experienced an incomplete cervical SCI and was unable to regain his pre-morbid (normal) gait over the five-year post-traumatic period. The participant's gait pattern was measured and analysed prior to and after introducing guided NG exercise intervention.

Study 1 data supported the hypothesis that SCI people do wish to walk again and practice walking exercises, but the nature of this desire changes over time and is influenced by the severity of other impairments (especially bowel and bladder control), the passive nature of the rehabilitation provided and changes in their marital and employment status.

In **Study 2**, the difference between NG and BG was found to be significant. This supported the view that they are two distinctive walking skills. The participant's perception of low safety and high exertion was closely related to their experience of great discomfort reported during brace walking. The data highlighted several cognitive, emotional and physical factors that could be strongly involved in functional improvements of the current brace aids.

Study 3 supported the view that NG walking knowledge was available and accessible after a severe spinal cord injury. Although direct voluntary access to this implicit knowledge remained unavailable, indirect access was gained by means of a client-focused memory reprocessing integrative metalearning approach. This approach involved a collaborative therapist–client relationship, six consecutive rehabilitation stages and consistent support in exercising normal locomotion.

The **findings of this research** enhanced the understanding of changes that SCI people might experience in their personal, emotional, physical and social-vocational functioning. The importance of a holistic rehabilitation approach that strongly integrates normal gait exercises with comprehensive psycho-social rehabilitation was emphasised. The need for early holistic intervention, involving NG exercises and functional electrostimulation, as well as social and vocational rehabilitation, was also emphasised. Overall, the research called for a holistic approach and further integrative study, aiming for better understanding of the critical factors associated with improved rehabilitation, in order to maximise the residual potentials of SCI people.

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Acknowledgements

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Integrative Metalearning Approach could Facilitate Improved Rehabilitation Outcomes for People with Severe Spinal Cord Injury

Introduction

As at 2000, the estimated average number of people sustaining a spinal cord injury (SCI) per year was 18 per million in New Zealand, 15 per million in Australia and 40 per million in America (Hirst, Anderson, Clarke, & Wells, 2000). From a purely numerical perspective, this might not sound a large amount. However, these numbers represent real people and the proportions would indicate that, on average, every year 12,000 people sustained an SCI across America, Australia and New Zealand. Of those people, 75 per cent were under 45 years of age. When healthy, this age group usually represents the most productive members of society.

A severe SCI is often followed by dramatic changes to people's physical and physiological voluntary abilities (Hauser, 2001). Many of them become wheelchair-bound and more dependent on others. Nene, Hermens, and Zilvold (1996, p. 507) emphasised that 'the sudden conversion of a vigorously active person into a helpless physical entity leads to severe psychological shock'. Their professional career often suffers as well. Robertson (1999) emphasised that, in New Zealand, an average of 60% of SCI people do not return to employment. Furthermore, due to natural ageing, as well as the longitudinal disability, people were found to be prone to acquiring greater health problems and dependency.

In the Spinal Injuries Association guide (1995), SCI people often expressed their dissatisfaction with the rehabilitation that was commonly provided. Many abandoned their orthoses, reporting that they could not see any sense in using these aids while, at the same time, energy consumption was extremely high and walking itself felt awkward, unstable and dangerous (Maddox, 1994). The majority of SCI people were found to be willing to participate in rehabilitation that would facilitate greater ambulatory independence.

Current rehabilitation approach

Typical rehabilitation for SCI people focuses mainly on the extent of the paralysis, the level of lesion, and exercise of the healthy muscles. Other aspects of the SCI seem to be vaguely assessed or not assessed at all.

Over the last six decades, rehabilitation practice has relied mainly on proprioceptive neuromuscular facilitation methods, emphasising that all human beings have untapped existing potential that has to be identified and then facilitated to the best of each person's ability (Kabat, Knott & Voss, cited in Adler, Beckers, & Buck, 1993). This principle, however, seems to be applied selectively. In the case of SCI people, their unique potential often remains ignored, while current rehabilitation relies on assumptions about their incapacity, based on a general medical idea that people with SCI involving complete lesion above certain vertebrae (for instance, Th_{10}, Th_{12}) are unsuitable for normal gait (NG) and that independent NG is achievable only when the SCI lesion is below the L_4 vertebra (Braunwald et al., 2001). As Adler, Beckers and Buck (1993) emphasised, following stabilisation of fractured vertebrae the SCI rehabilitation is mainly concerned with strengthening of a patient's healthy extremities, whole body stretching and training regimes aiming to facilitate basic daily functioning, such as wheelchair use, showering and servicing physiological needs (for example, use of urinary catheters and laxatives). People with an SCI are usually provided with wheelchairs and different types of orthotic aids (for example, braces and standing frames).

The procedure that is currently used for defining the nature of a walking disorder is based on criteria developed by Sounders and colleagues in 1953 (Whittle, 1996). First of all, the properties of pathological gait should be defined in comparison to NG. Achieving NG to its best possible degree has been set as a goal, and therefore the therapists are expected to understand gait properties and take them into account when assisting a client. According to Adler, Beckers and Buck (1993), as well as the Spinal Injuries Association (1995), in those cases where walking ability is already present, and therefore considered as possible, therapists are applying their gait knowledge. However, it was not used in the rehabilitation of SCI people whose voluntary movements were identified as absent. Why was this important knowledge selectively applied? The current rehabilitation approach is likely to reflect the widely accepted medical opinion that after severe SCI people would not be able to walk again, and therefore NG exercise would be useless and consequently it should not be provided. In those cases where the diagnosis defined the complete neurological damage of the spinal cord, a person's disability status is often considered as final (Asbury, 2001; Braunwald et al., 2001; Maddox, 1994).

From a scientific perspective, it is important to emphasise that NG exercise for wheelchair-dependent SCI people has not been tried in clinical practice. Neither has it been investigated through scientific research. Therefore, the opinion that NG cannot be achieved should not be given scientific or clinical credence.

Social perception and exercise behaviour

The belief that NG exercise is useless, and therefore a waste of time, could have a great negative impact on SCI people. It has already resulted in the common rehabilitation tendency of not trying NG exercise. Two decades ago, Bandura (1986) emphasised that social support could have an important influence on self-efficacy, which, in return, could act as a mediator between social support and exercise behaviour. When applied to walking disability, this could mean that if NG was widely accepted as useful exercise, people doing it would be encouraged to undertake further training and their achievements would facilitate improved self-efficacy beliefs that would further support their intention and commitment to NG exercise. The theory of planned behaviour (TpB) (Ajzen, 1991) emphasised three conceptually independent variables that have determining influence on intention: subjective perception of how difficult or possible the planned action may be (perceived behavioural control), attitude and subjective norm. Even if a person has a very positive attitude and a willingness to walk again, the belief that they have no voluntary control of their walking ability, and that this is considered a final state, would strongly influence their exercise behaviour. As Farr and Moscovici (1984) have suggested, the social presentation of a category (in this case, permanent NG disability) would not be an individual construction, but rather a product of many discussions and opinions disseminated through different media.

At present, the hope of SCI people seems to be undermined by a biased social advocacy based solely on a physiological perspective of SCI. Taking into account that SCI people have a strong desire and hope to walk again, even after being informed about the final status of their disability, an important question arises — what happened to this person's wish? Why has the important human need for the recovery of normal functioning remained largely ignored by current rehabilitation practice?

The aim of this research was to identify what the critical factors associated with improved rehabilitation for SCI people are, and whether the rehabilitation approach that includes assisted NG exercises would better aid SCI people in maximising their residual potentials.

Three hypotheses were investigated:

(1) SCI people wish to walk again and do walking exercises, but the nature of this desire changes over time, influenced by the severity of other impairments, as well as expert opinion, lack of rehabilitation support and changes in their social status.

(2) Brace gait (BG) is significantly different from NG: they are two distinctive walking skills.

(3) NG walking knowledge is available and accessible after a severe spinal cord injury.

Study 1

Study 1 was designed to investigate the first hypothesis.

Method

Participants

The criteria for research participation included random assignment of 219 volunteers who were wheelchair-dependent after experiencing a severe SCI. In respect of the level of their SCI impairment, participants were divided into two groups: 203 people whose SCI impairment was at the thoracic level (SCI-Th), and 16 people whose SCI impairment was at the cervical level (SCI-Ce). There were no specific requirements regarding participants' age, gender or cultural background. The final assignment consisted of 124 male and 95 female participants. For SCI-Th participants, ages ranged between 19 and 45 years ($M = 28.8$), while the age of their spinal injuries ranged between 2 and 24 years ($M = 5.51$). Within the SCI-Ce group, ages ranged between 22 and 34 years ($M = 27.1$), while the age of their spinal injuries ranged between 1 and 15 years ($M = 4.75$). Two-tailed t-tests for independent sample validation revealed that these differences (mean age of participants and injury duration) were not statistically significant. Therefore, they played no part in the later analyses.

Procedure

After a brief explanation of the research procedure, the participants were given the opportunity to contact the researcher if they chose to volunteer. Information sheets were provided and it was emphasised that name and contact details would remain confidential and be destroyed after the research was completed. The interviews were conducted using phone or face-to-face structured interviews. Retrospective reports and reports related to the participants' current status were collected using questionnaires, in which open-ended and closed questions were used, as well as questions requiring a seven-point or five-point Likert scale response (Isakovic, 2005).

The levels of intensity for willingness to walk (*WW*) and willingness to do currently provided walking exercises (*WWexer*) were measured over four post-injury time periods, where: *Time 1* = immediately after the injury occurred; *Time 2* = within the two post-injury weeks; *Time 3* = from 2 weeks to 6 months post-injury; and *Time 4* = the present (at the time of the research interview). Data were analysed using a 2 (Group) x 4 (Time) ANOVA with repeated measures on the last factor.

To analyse the change in importance levels (priority) for each of five inabilities that both participant groups rated as the most important, the importance levels were coded as numerical scores from 1–5 (a five-point Likert scale), where: 5 = highest importance; 4 = high importance; 3 = average importance; 2 = minor importance; 1 = least importance. Further analysis was conducted using a 2 (Group) x 4 (Time) ANOVA with repeated measures on the last factor.

The influence that social opinion (*Socop*) and the rehabilitation nature might have on the SCI participant's exercise behaviour was analysed. For *Socop*, focus was on three social groups (medical experts, family and other SCI people) and their reported beliefs about the likelihood of the SCI participant's future recovery in terms of NG, BG usage, and ability to independently use a wheelchair. The likelihood was rated using a five-point Likert scale, where: 5 = certain recovery and ability to use wheelchair; 4 = high chance; 3 = 50 per cent chance; 2 = low chance; 1 = no chance of recovery/no ability to use wheelchair. In regard to the rehabilitation nature, the participants emphasised three basic factors commonly defining rehabilitation nature: NG non-presence; BG presence; and passive nature of rehabilitation (*PassiveRhb*), which included exercising passive movements (stretching and motion facilitated by therapist), as well as exercising healthy muscles. To understand how often NG, BG and *PassiveRhb* were provided for the participants, the frequency of their usage was measured using a five-point Likert scale where: 5 = regularly (every day and sufficiently); 4 = pretty regularly (very often); 3 = irregularly (not often); 2 = just a few trials; 1 = not exercised at all. Given the complexity of real-life factors, standard multiple regression was used to explore the relationship between *WWexer*, being the continuous dependent variable, and independent variables or outcome predictors, being factors from two factor groups: *Socop* and rehabilitation nature.

One-way ANOVA was conducted to investigate the participants' perception of the current BG exercise efficacy. Relevant factors that were reported by all participants, and therefore measured, were their perception of the usefulness of BG and their feelings of comfort and safety during BG. All factors were rated on a seven-point Likert scale, where 7 indicated extremely and 1 indicated not at all (comfortable, useful, safe). The data for perceived BG-usefulness were calculated over four post-injury time periods using a 1 (Group) x 4 (Time) ANOVA with repeated measures on the last factor. Given that BG was present only within *Time 3*, participants' perceptions of the comfort and safety of BG were measured only within that period.

The participants frequently reported their marital (*Marit*) and employment (*Empl*) status as being of great importance to them. Therefore, the changes in participants' social status was focused on analysing these two variables. Simple descriptive statistics were obtained for both SCI-Th and SCI-Ce in relation to the time before and after the SCI. Mixed between-within subjects 2 (Group) x 2 (Time) ANOVA was used to investigate the relationship between SCI occurrence and change in *Marit* and *Empl* respectively.

With respect to the complexity of real life dynamics, a complex analysis of this study aimed to highlight the nature of the influence that multiple undesirable factors had on the feelings, beliefs, life quality and exercise behaviour of SCI people.

Results

Two-tailed t-tests revealed that the differences in the age of participants [t (217) = 0.99, $p > .05$] and the difference in the age of their injuries [t (217) = 0.60, $p > .05$] were not statistically significant.

A 2 (Group) x 4 (Time) ANOVA with repeated measures on the last factor revealed a main effect of Group, F (1, 217) = 81.74, $p < .001$. This reflects the overall higher mean for the SCI-Th group (M = 6.47) than for the SCI-Ce group (M = 5.34). These main effects have to be interpreted in the light of a significant Group x Time interaction, F (3, 651) = 29.57, $p < .001$. There was a significant effect of post-injury time (*Time*), F (3, 651) = 151.61, $p < .001$.

Post hoc testing revealed that while the two groups did not differ immediately after SCI (*Time 1*), over the longer period (Fig. 1) *WW* in SCI-Th was significantly greater than for SCI-Ce on *Time 2*, t (217) =10.67, $p < .001$; *Time 3*, t (217) = 6.24, $p < .001$; and *Time 4*, t (217) = 7.51, $p < .001$. However, overall *WW* intensity remained high for both groups (M = 5.91).

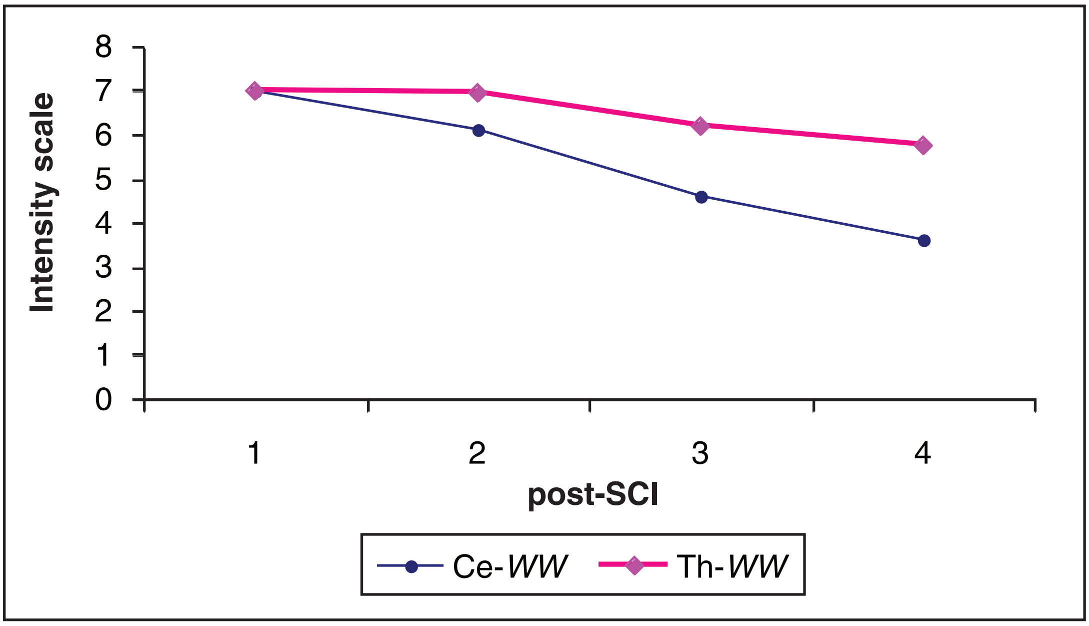


Fig. 1 *Mean values of* WW *intensity change over post-SCI time*

Willingness to do current WWexer

A 2 (Group) x 4 (Time) ANOVA with repeated measures on the last factor revealed a main effect of Group, F (1, 217) = 285.72, p < .001. This reflects the overall higher mean for the SCI-Th group (M = 4.87) than for the SCI-Ce group (M = 2.85). There was a significant effect of post-injury Time, F (3, 651) = 444.98, p<.001. These main effects have to be interpreted in the light of a significant Group x Time interaction, F (3, 651) = 36.92, p < .001. Post hoc testing revealed that the two groups significantly differed on *Time 1*, t (217) = 19.81, p < .001; *Time 2*, t (217) = 23.72, p < .001; *Time 3*, t (217) = 7.62, p < .001; and *Time 4*, t (217) = 2.59, p < .01. While *WWexer* was high on *Time 1* for both SCI-Th (6.94, 0.28) and SCI-Ce (5.31, 0.60), it dramatically decreased for SCI-Th (1.7, 0.79) and SCI-Ce (1.19, 0.40) to the level of 'not at all'. This indicated that 6 months after SCI willingness to participate in currently provided ambulatory exercise programmes ceased (Fig. 2).

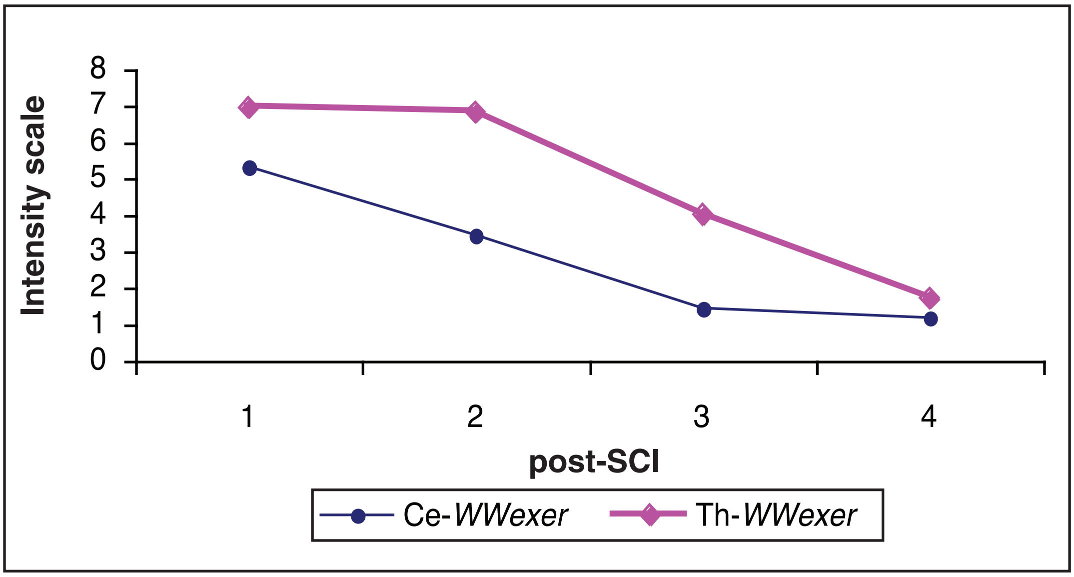


Fig. 2 WWexer *intensity change over post-SCI time*

Priority of the impaired abilities

A 2 (Group) x 4 (Time) ANOVA with repeated measures on the last factor revealed a main effect of Group for: walking ability (*Walkab*), F (1, 217) = 206.82, $p < .001$; ability to control bladder and bowel functions (*Bbab*), F (1, 217) = 264.53, $p < .001$; and working ability (*Wrkab*), F (1, 217) = 6.61, $p < .01$. This reflects the overall higher mean for the SCI-Th group than for the SCI-Ce group. There was a significant effect of Time found for *Walkab*, F (3, 651) = 102.92, $p < 0.001$; *BBab*, F (3, 651) = 22.65, $p < 0.001$; and *Wrkab*, F (3, 651) = 35.41, $p < 0.01$. These main effects have to be interpreted in the light of a significant Group x Time interaction for each: *Walkab*, F (3, 651) = 19.37, $p < .001$; *BBab*, F (3, 651) = 4.80, $p < .001$ and *Wrkab*, F (3, 651) = 4.98, $p < .01$. The participants' ability to use their hands remained rated at the highest priority level (5) for the SCI-Ce group, and therefore was not included in analysis.

Descriptive statistics (Fig. 3), showed change in *Walkab*, *BBab* and *Wrkab* importance. By *Time 4*, they where at the same high level (4) for the SCI-Th group, while for the SCI-Ce group the *Walkab* importance decreased, whereas it increased for *BBab* and *Wrkab*.

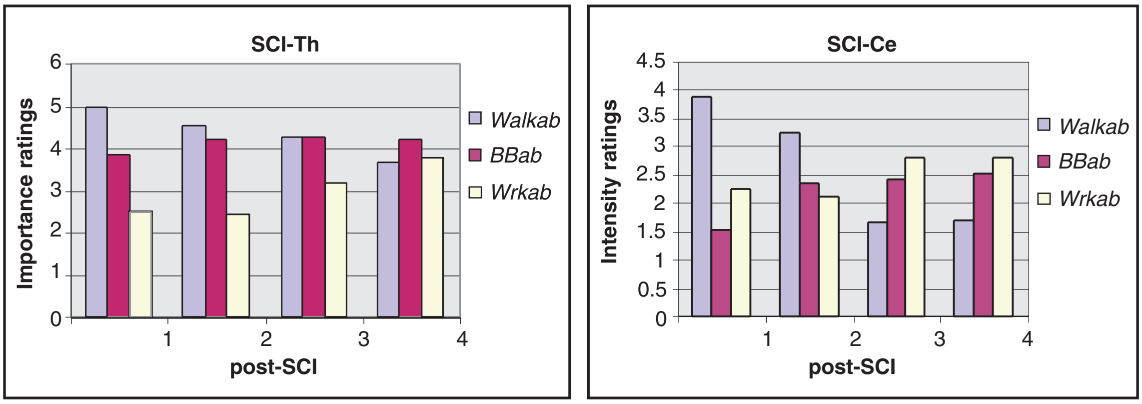


Fig. 3 Priority levels of inabilities over post-SCI time for: (a) SCI-Th; and (b) SCI-Ce

Social opinion reported by SCI-Ce participants

Four fundamental influential factors reported were: personal opinion (*Persop*); medical/expert opinion presented as a statement or diagnosis (*Medop*); family opinion (*Famop*); and other SCI people opinion (*SCIop*). Each was further specified in relation to: perceived rehabilitation nature (active or passive); availability of NG and/or BG exercises; and probability of achieving NG or BG, or being wheelchair-dependent but independent from others.

All SCI-Ce participants reported that NG and BG exercises were 'not at all' provided and that *Medop* was always perceived as 'NG not at all possible'. Therefore, these constant variables were excluded from analysis. For the SCI-Ce group the standard multiple regression therefore included control of 10 factors as independent variables. It explained 78.4% of the variance in perceived willingness for *WWexer*. Given the small number of participants ($N = 16$), both R Square (0.61) and Adjusted R Square (0.55) values were observed and they indicated a good estimate of the true population value.

A strong negative correlation was found between passive rehabilitation (*PassiveRhb*) and *WWexer* ($r = -0.75$, $p < 0.01$), indicating that greater predominance of *PassiveRhb* coincides with the decrease of *WWexer*. Among remaining independent variables, only *Famop* presented with moderate statistically significant positive correlation with *WWexer* ($r = 0.32$, $p < 0.01$). *Medop* showed no significant impact on *WWexer*. Given the nature of the correlational analysis, these findings did not indicate a causal relationship between variables.

The passive nature of rehabilitation showed the only significant unique contribution to the prediction of *WWexer* (B= -0.95, $\beta = -0.70$, $p < 0.01$).

Perceived efficacy of BG exercise

Three factors were observed with respect to the perceived efficacy of BG exercise (*BGexer*): usefulness (*BGusful*), comfort (*BGcomf*) and safety (*BGsafe*). Actual participation in BG exercise was provided only for the SCI-Th group and it happened during *Time 3* only (within the 6-month period). As illustrated in Fig. 4, before their participation in BG exercise (*Time 1* and *Time 2*) participants rated *Bgusful* as 'extremely useful' ($M = 6.6$), showing favourable guessing and high expectations.

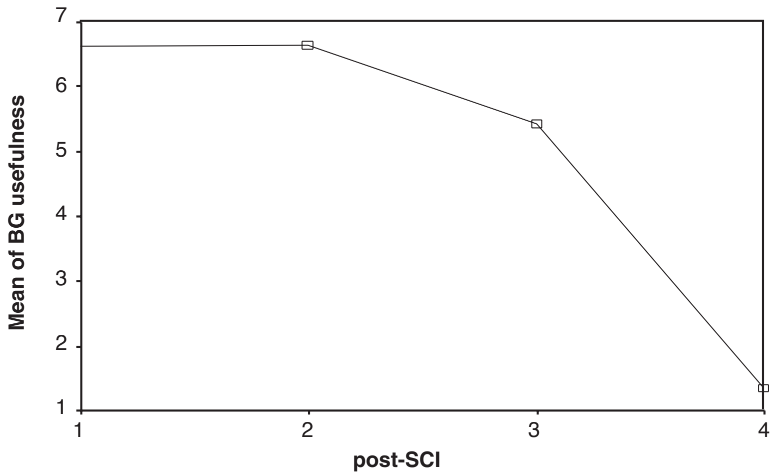


Fig. 4 *Mean trend of* BGusful *for SCI-Th*

After the actual participation in BG, the mean values indicated that *BGexer* was perceived as 'almost not at all' useful (1.34, 0.51), and neither comfortable (2.23, 0.9) nor safe (1.99, 0.6). One-way ANOVA revealed a main effect for *BGusful*, F (6, 805) = 53.37, $p < 0.01$; *BGcomf*, F (3, 199) = 21.60, $p < 0.01$; and *BGsafe*, F (2, 200) = 17.47, $p < 0.01$. These findings indicated that all three factors had a significant effect on people's willingness to exercise BG walking.

Change in Empl *and* Marit *with respect to SCI occurrence*

There was a significant effect of Time (pre-injury and post-injury), F (1, 217) = 33.43, $p < .001$, indicating a significant relationship between SCI occurrence and negative change in *Empl*.

There was no significant Group x Time interaction, indicating that difference in *Empl* change between SCI-Th and SCI-Ce was not statistically significant. Data showed that dramatic negative change of *Empl* occurred in 63% of SCI-Th, 29% remained in the same *Empl*, and 8% experienced some positive change of *Empl* (from unemployed to employed part time). For SCI-Ce, 69% of people experienced negative changes in their *Empl* and 31% reported no change.

There was a main effect of Time, F (1, 217) = 14.55, $p < .001$, indicating a significant relationship between SCI occurrence and negative change in *Marit*. There was no significant Group x Time interaction, showing that difference between the two participant groups was not statistically significant. In 65% of SCI-Th *Marit* remained the same, while negative changes occurred in 29% and positive changes occurred in 6% of participants. For SCI-Ce, the change proportions were similar (64% with no changes, 30% with negative changes and 6% with positive changes).

Conclusion

The findings of this study showed that SCI people wish to walk again and do walking exercises, but the nature of this desire changes over time, influenced by the severity of other impairments, as well as expert opinion, lack of rehabilitation support and change in the participants' social status. These findings were consistent with the view that dramatic changes occur in people's lives due to SCI (Maddox, 1994; SIA, 1995; Nene et al., 1996; Rossignol, 2000). In addition to significant changes in their physical functioning, SCI people often experienced changes in their personal life, where most of them have lost their pre-injury employment and many of them their primary relationship too.

The findings also emphasised that SCI people perceived common rehabilitation practice as passive and lacking NG exercises. While their willingness to be able to walk normally remained very strong throughout their post-injury life, their willingness to participate in currently provided walking exercises dramatically decreased, and became almost non-existent by the time of their participation in this study. The data showed that SCI people's willingness to exercise might not change solely on the advice of medical experts. However, their exercise behaviour could change in respect of the type of rehabilitation offered. This suggests a need to explore whether SCI people might be more willing to actively engage if a more active exercise programme, which might facilitate improved walking and greater overall physical independence, was available.

When the wishes and beliefs of SCI people were not taken into account, and when the therapy was assigned to everyone as a uniform model, this could be seen as poor social support. Looking from Bandura's (1986) perspective, which emphasised the importance of social support, the client-beneficial rehabilitation programme would benefit from following the modern psychotherapy approach, whereby the therapist respects the client and is empathically attuned to help the client to identify their feelings, beliefs and the nature of their problems, and then help them to set the desired goals and work towards them. In order to help the client achieve their greatest improvement, the therapeutic intervention (rehabilitation programme) should be tailored to suit each particular client (SCI person). When achieved, a better therapist–client relationship could facilitate the improved rehabilitation outcome. When the therapist is empathically attuned to the client, respectful to the client's beliefs and hopes, and when they genuinely work together with the client and for the client's best interests, the likelihood of achieving a better therapy outcome would be greater (Rogers, 1957; Beck, 1983; Elliot, Watson, Goldman & Greenberg, 2004).

Study 2

This study was designed to explore the idea that BG is significantly different from NG: they are two distinctive walking skills.

Method

Participants

Twenty healthy participants volunteered for this study. They had no history of spinal or back injury, had never experienced walking difficulties, and had never experienced walking with braces where hip, knee and ankle joints (HKA) were rigid. All 20 participants were able to fit into the available HKA braces. There were no specific requirements regarding participants' gender, age, or social or cultural background. The group consisted of 3 males and 17 females, with ages ranging between 19 and 49 years. The participants' height and weight were within the normal range and they reported being healthy.

Research design

In order to investigate the difference in walking patterns between NG and BG, a within-group design was used and quantitative statistical data obtained using a systematic analysis of gait. The kinematic data were collected for each participant, using two-dimensional gait analysis procedure. Participants' walking performance was examined under two conditions: walking normally with no aids (NG condition), and walking with HKA braces, where hip, knee and ankle joints were immobilised and rigid (BG condition). Participants' subjective reports were used for qualitative and quantitative (seven-point Likert Scale) analysis, to investigate their perception of the BG walking experience.

Procedure

After presenting the letter of consent and the ethical approval form, any concerns regarding the experimental procedure and the participants' right of voluntary involvement were discussed. After this, the participant was invited to dress in long black leggings or biking pants and a T-shirt. For the purpose of gait analysis, white markers were attached on the participant's anatomical landmarks: skeletal locations of wrists, elbows, shoulders, hips, knees, ankles, heels and toes (Fig. 5).

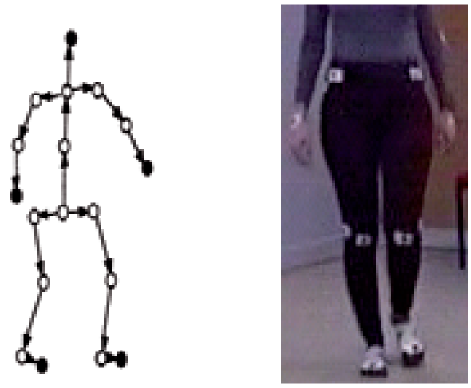
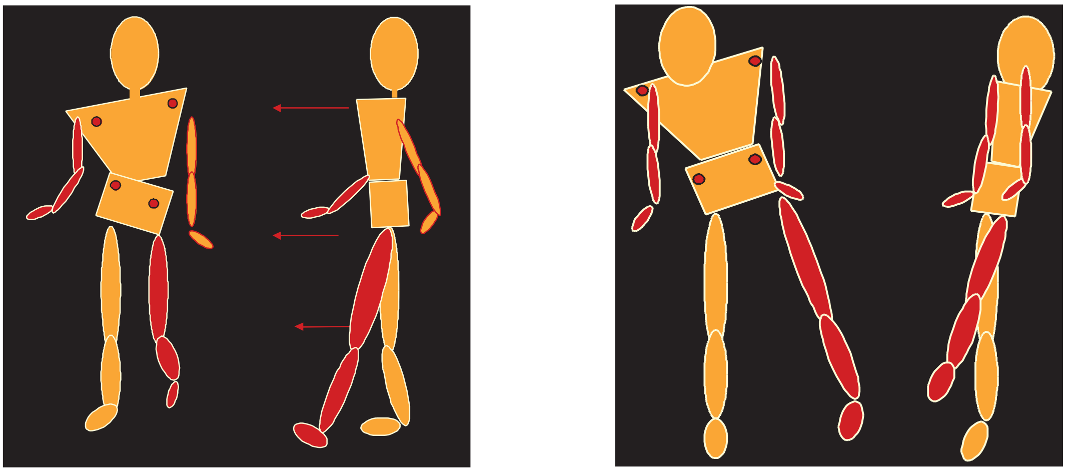


Fig. 5 *Two-dimensional body markers — application on a stick figure and on the participant's body*

Participants were tested individually in a small and quiet gait laboratory room. Each trial consisted of a 60 m walking exercise. Walking trials were recorded from anterior-posterior and saggital planes by two cameras. Before the participants started walking (while in the resting state), as well as after NG and BG walking trials, their heart rate was measured, as well as blood pressure, subjective feelings of fatigue/exertion and bodily discomfort.

For each participant, data under NG conditions were collected first. After a five-minute break and braces application, the BG data were collected. During the BG trials, participants were asked to report about their feelings of comfort, safety, ability/freedom to control leg movements, confidence, fatigue, similarity with NG, willingness to do BG again, and the perceived impact that rigid joints may have on their perception of BG exercise.

The data obtained through BG exercise were compared with the NG data and the differences were analysed. The focus of the kinetic analysis was on investigating five basic gait properties (gait factors): hip vertical excursion (vertical hip motion), trunk lateral displacement (trunk swaying in lateral directions), trunk tilt (trunk anterior-posterior movement), stride width (base size), and stride length (successive positions of the same foot).



(a) *(b)*

Fig. 6 *Simple observational comparison between: (a) NG; and (b) BG walking patterns, focusing on hip motion, lateral displacement, stride width (base size), stride length and trunk tilt*

The occurring circumduction was notified as well, as illustrated in Fig. 6.

Statistical analysis structure

For comparison between the NG and BG patterns, the two-dimensional kinematic analysis provided descriptive statistical data. To identify the factors related to the participants' experience of BG, as well as to estimate the nature of their contribution to participants' perception of BG experience, qualitative and quantitative analyses were performed using a self-perception questionnaire.

Standard multiple regression was conducted, with dependent variables being perceived exertion, based on Borg's ratings of perceived exertion (RPE) scale (Borg, 1998), and perceived safety. The independent variables were: level of voluntary legs-muscles control; familiarity with BG; level of confidence; level of fatigue; perceived impact of rigid joints on feelings of safety, discomfort and confidence; negative automatic thoughts of falling backward; BG being 'odd'; and 'lack of freedom'. Reported negative feelings of being 'stuffed' and 'awkward' were also reported.

After the BG exercise was completed, participants rated their willingness to undertake BG exercise again (when not needed for the research).

To gain more insight into the nature of their BG experience, all the estimated participants' reports were classified according to five basic life experiences (Table 1), following the five-part model of Padesky and Greenberger (1995), and with respect to the interactive nature of their relationship, emphasised by Aaron Beck (1983).

Table 1: *Five life experiences reported by participants, in three particular contexts*

Context (environmental factor)	Thoughts Frequency of occurrence (1–7 rating)	Feelings Intensity (1–7 rating)	Bodily sensations Intensity (1–7 rating) (6–20 for Borg's RPE)	Behaviour Frequency of occurrence (1–7 rating)
While exercising BG	'I will fall backward' 5 'If I fall, I can injure myself' 'This is odd' 5 'It's a sort of imprisonment' or 'lacking freedom and safety' 3.5	Unsafe 1.9 Not confident 2.4 Awkward 5 'Framed', 'captured' and 'stuffed' 4 Unfamiliar 6	Very tiring 4.9 Bodily discomfort 4.1 Great exertion (Borg's RPE) 15.8	Unwilling to do BG (if not for research purposes) 7
Social stereotype in respect of perceived disability (participants estimated)	Are generally disabled Highly dependent Are a liability Are depowered Low life value	Feel pity for those who present with disability	Low voluntary control Low ability Pain Hard to move around and do usual things	Underestimate 'disabled person' Patronise Expect little Give little opportunity Ignoring 'disabled person' by addressing another person with them
Participants imagined their response to the context of 'being disabled and perceived a victim'	Can't take their life in their hands 3.5 Lacking opportunity 5 Others will underestimate and patronise me 4.5 . . . and expect nothing from me 3.5	Terrible 6 Depowered and weak 5 Dependent 5 Uncertain 5 Low self-esteem 3.5 'Imprisoned' or 'stuffed' 3 Inferior 3 Anxious 5	Awkward 6 Unable to do independently the usual things 5	Avoid those who stereotype and pity me (withdraw) 6 Unwilling to quit hope 6.7 Try my best to recover 6 If recovery not possible, then try to reorganise my life, to gain control and make it work 7

Results

Stride width

The stride width was measured as a side-to-side distance between the line of the two feet, from the point below the centre of the right ankle joint to the left. During the NG gait cycle, the stride width was much smaller (M = 6.1 cm, SD = 1.1) than during the BG gait cycle (M = 20.8 cm, SD = 2.6 cm).

Hip vertical excursion

Simple statistical analysis revealed that the vertical excursion of the hip (hip obliquity) was within a greater range during NG (min. = -0.4 cm; max. = 4.3 cm), than during BG (min. = -1.8 cm; max. = 1.0 cm). The data illustrated in Fig. 7 showed a reduced range of motion during BG. The HKA braces disallowed normal ankle and knee movements and triggered circumduction of the swing-leg in all participants.

The path of the hip motion during BG was found to follow almost the opposite direction from NG pattern (Fig. 6). Through right-stance phase, the BG hip motions were at the most antagonistic positions (in respect to the NG) at the mid-stance (with NG hip = 4.3 cm; BG = -1.7 cm) and about the end of the terminal stance of the gait cycle (NG hip = 1.9 cm; BG = -1.8 cm). About the beginning of the BG initial swing, and after reaching more balanced static vertical posture, the hip continued with its irregular motion (BG hip = -0.3 cm), in the opposite direction to NG (NG hip = 1.8 cm).

Although the graph (Fig. 7) illustrated 100% of a gait cycle (single stride), the image of the graph does not represent the length of an actual stride, but solely its proportions.

While during the single stride 60% should be a stance phase and 40% a swing phase of the same leg, the length of the right and left steps should be equal (Whittle, 1996).

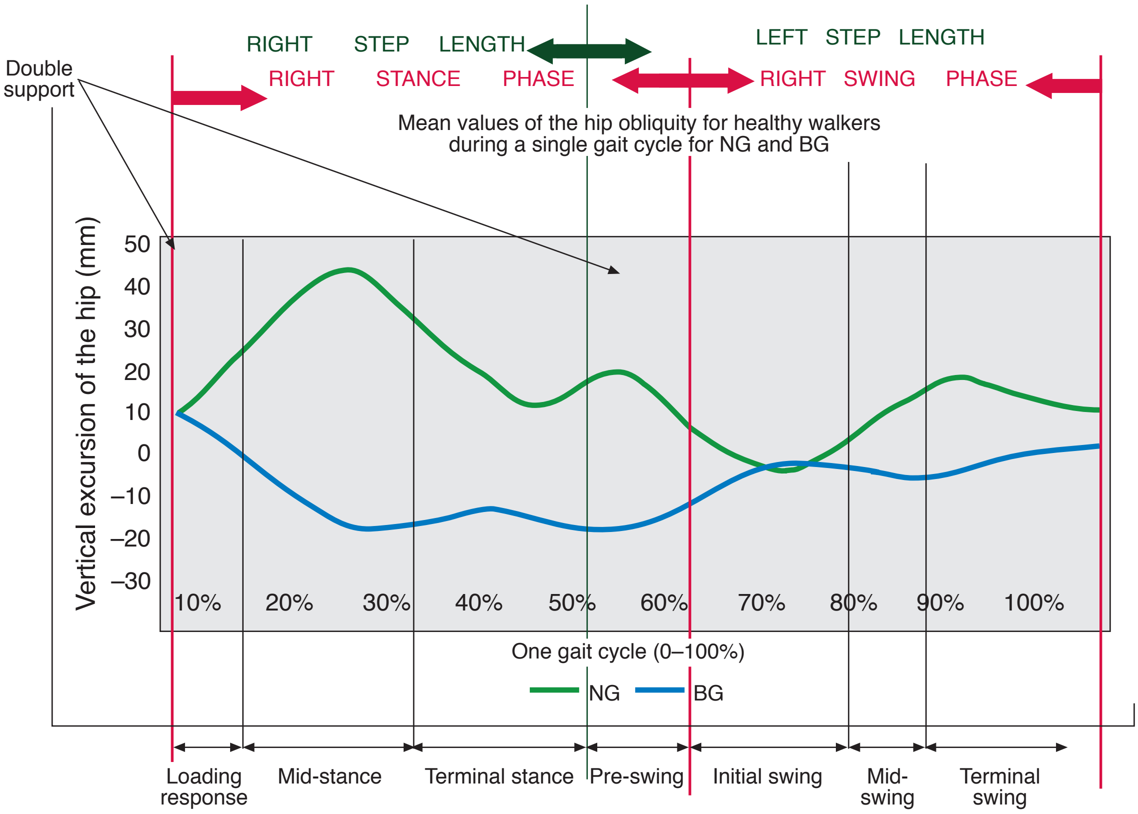
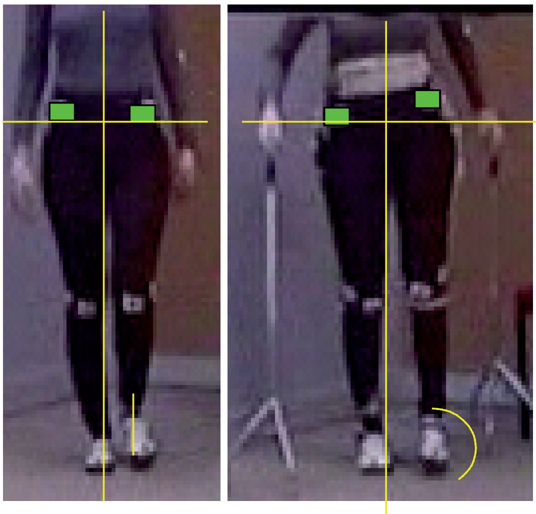


Fig. 7 *Hip vertical excursion for healthy participants during NG and BG single gait cycle*

Note: All the phases (structural properties of one stride or a single gait cycle) are named and marked with lines and arrows.

While these stride proportions were preserved in both walking patterns, the directions of the hip motions appeared to be greatly irregular during the BG, presenting with emphasised hip-hiking and circumduction (illustrated in Fig. 8).



(a) *(b)*

Fig. 8 *Hip and foot motions in swing during: (a) NG walking (hip drop; narrow base; no circumduction); and (b) BG walking (hip hiking; circumduction of the swinging leg; wider base)*

Stride length

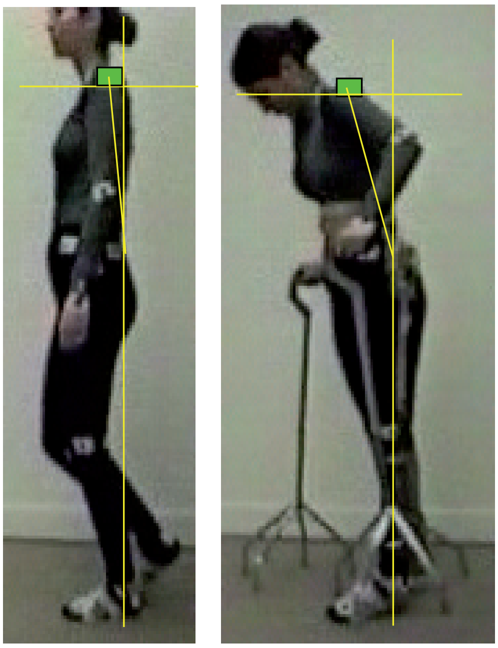
For both NG and BG, the stride length was measured between successive positions of the right foot. During NG (M = 154.2 cm, SD = 8.9 cm) it was within the average range (144 cm–173 cm) that is commonly considered to be a normal stride length (Whittle, 1996). The stride was much shorter during BG (M = 66 cm, SD = 19.6 cm).

Trunk lateral displacement

The trunk normally moves from side to side, once in stance and once in the swing phase of a gait cycle (Whittle, 1996). This type of lateral displacement is commonly known as waddling. During the NG cycle, its lateral displacement (angular kinematics) is much smaller ($M = 3^{\circ}$, $SD = 0.95^{\circ}$) than during the BG cycle ($M = 11.9^{\circ}$, $SD = 3.5^{\circ}$).

Trunk tilt

Early in the stance phase, when people usually move their centre of gravity forward, their trunk bends forward and around the time of opposite-leg initial contact it straightens again. As presented in Fig. 9, to compensate for rigid knee extensions during BG walking, the participants presented (angular kinematics) with much greater trunk tilt ($M = 18.1^{o}$, $SD = 3.4^{o}$) than during NG ($M = 4.4^{o}$, $SD = 0.5^{o}$).



(a) *(b)*

Fig. 9 *Trunk tilt during: (a) NG; and (b) BG*

Subjective experiences

The participants' heart rate and blood pressure remained within the normal range during BG and were not significantly different from NG values.

Descriptive statistical data indicated that before starting the BG exercise the participants' ideas about how they should walk with braces were extremely unclear, showing a low level of BG understanding ($M = 2.6$, $SD = 1.1$). During BG exercise participants reported that BG was not familiar with respect to their NG experience ($M = 1.6$, $SD = 0.7$). They perceived BG walking as being very unsafe ($M = 1.9$, $SD = 0.6$), very tiring ($M = 4.9$, $SD = 1.4$), and tiring with great energy expenditure (Borg's RPE: $M = 15.8$, $SD = 3.7$). They reported low confidence (*M* = 2.4, *SD* = 0.8), and believed that having rigid joints during brace walking had an extreme impact on their feelings of being unsafe (*M* = 6.4, *SD* = 0.6), uncomfortable (*M* = 6, *SD* = 1.1) and not confident with BG (*M* = 5.9, *SD* = 0.9). During BG exercise, all the participants reported experiencing the highest level of discomfort with their rigid knees (*M* = 4.5, *SD* = 0.95).

The standard multiple regression model was found to be significant in explaining 93.2% variance in perceived BG exertion (F (14, 5) = 19.6; $p < .05$). Seven experiential factors showed statistically significant individual contributions to the participants' feelings of exertion during BG: feeling awkward (B = 4.4, *ß* = 0.98); thought of falling backward (B = 2.2, *ß* = 0.66); perceived safety (B = -3.5, *ß* = -0.6); feeling framed, captured and stuffed (B =-1.7, *ß* = -0.41); low confidence in BG (B = -1.9, *ß* = -0.38); bodily discomfort (B = - 0.94, *ß* = -0.27) and the particular discomfort of rigid joints (B = 2.1, *ß* = 0.6).

The standard multiple regression model was also found to be significant in explaining 93.2% variance in perceived BG-safety (F (14, 5) = 10.15; $p < .05$). Seven experiential factors showed statistically significant individual contributions to perceived low safety during BG: feeling awkward (B = 1.06, *ß* = 1.36); perceived exertion (B = -0.2, *ß* = -1.14); thought of falling backward (B = 0.54, *ß* = 0.95); particular discomfort of rigid joints (B = 0.4, *ß* = 0.68); feeling framed, captured and stuffed (B = -0.46, *ß* = -0.63); low confidence in BG (B = -0.44, *ß* = -0.52); and bodily discomfort (B = - 0.25, *ß* = -0.41).

Subjective beliefs

The healthy participants reported the belief that there was a high level of social stereotyping with respect to disability (*M* = 6.0, *SD* = 0.73). They described this by saying that 'disabled people' were commonly underestimated, depowered, patronised and subject to low expectations.

The participants reported that disability would have extreme impact (*M* = 6.35, *SD* = 0.67) on people's lives. When imagining the situation where other people perceived them as victims, they believed that it would have a great impact on their life (*M* = 5.95, *SD* = 1.23) and that they would feel very bad or 'terrible' (*M* = 5.9, *SD* = 0.72), greatly depowered and weak (*M* = 4.9, *SD* = 1.0), dependent (*M* = 4.8, *SD* = 0.95) and uncertain (*M* = 4.8, *SD* = 1.1). The participants believed that their self-esteem would be much lower (*M* = 3.5, *SD* = 0.69) and that they would feel moderately inferior (*M* = 3.1, *SD* = 0.76) and 'somewhat imprisoned' or 'stuffed' (*M* = 3.2, *SD* = 0.7). They reported that this would make them feel extremely awkward (*M* = 6.2, *SD* = 0.77) and possibly very anxious (*M* = 5.3, *SD* = 1.2).

When the participants tried to rationalise how disability would impact upon their life, they reported that negative thoughts were instantly coming to their mind. They believed that they would be greatly lacking in opportunities (M = 4.9, SD = 0.88), others would expect nothing from them most of the time (M = 5.0, SD = 0.77), and the disability and being perceived as a victim would make them greatly unable (M = 5.3, SD = 1.1) to perform their usual actions independently. They believed that they would be less able (M = 3.5, SD = 0.8) to 'take their life in their hands'. If this was the case, they reported that they would greatly dislike those who stereotyped or pitied them (M = 6.1, SD = 0.76), would be extremely unwilling to give up hope (M = 6.7, SD = 0.49), and would be extremely determined to try their best to recover (M = 6.3, SD = 0.72).

The participants reported that if recovery of their pre-injury status was not possible they would be very determined (M = 5.9, SD = 0.9) to try to reorganise their life, regain control and 'make it work'.

Conclusion

The findings of this study supported the hypothesis that BG is significantly different from NG and that they are two distinctive walking styles.

In normal walking, the pattern of movement must be able to support at least four basic needs, without any apparent difficulty (Whittle, 1996, p. 108): (1) each leg in turn must be able to support the body weight without collapsing; (2) balance must be maintained, either statically or dynamically, during single-leg stance; (3) the swing-leg must be able to advance to a position where it can take over the supporting role; and (4) sufficient power must be provided to make the necessary limb movements and to advance the trunk.

Looking at the BG performed by healthy participants, they had rigid joints and therefore a swing-leg could not compensate for the leg length by normal knee flexion. In order to detach the leg from the ground and initiate a swing the hip had to be elevated (hip-hiking), which, in return, triggered excessive ipsilateral lean of their trunk and circumduction of the rigid swing-leg. This dramatically affected their body balance. In order to regain some stability, the walking base increased. Rigid joints also triggered a feeling of falling backward. In order to avoid this, the trunk leaned forward. This additional ambulatory compensation further disturbed the vertical body balance, and participants had to lean forward on their arms and walking sticks, which contributed to greater energy expenditure.

Having been found to create great difficulty for healthy walkers, the question of how helpful and useful HKA braces would really be for people who have a variety of gait abnormalities arises. Should they be considered as the main walking aids and the only rehabilitation goal for SCI people?

The goal of this research was not to disregard the use of HKA braces in rehabilitation of SCI people, but to clarify the potential for their improvement and to call for further research. This may help in clarifying what rehabilitation approaches would be of greater benefit and lead towards an improved life and safer walking practice.

If assisted NG exercises were available, the alternative BG walking might be used as comparative walking training, in order to sharpen the participants' criteria in differentiating NG properties. At this stage, while feeling BG to be unsafe and useless (SIA, 1995; Maddox, 1994), people would be less likely to use it. On the other hand, current rehabilitation practice often assumes that NG is impossible and offers no alternative walking exercises. At the same time, much research has shown that Functional Electrical Stimulation (FES) and its NG pattern could bring greater ambulatory independence (Marsolais, 2001).

The findings of **Study 2** emphasised a great similarity, or mirroring effect, involved in transference between personal and societal beliefs in relation to the concept of disability. As illustrated by the five-part cognitive model in Fig. 10 (based on Padesky & Greenberger, 1995), the social stereotype seemed to be radiating through the emotional, cognitive and physical experiences of people (highlighted in Fig. 10), further affecting their behaviour.

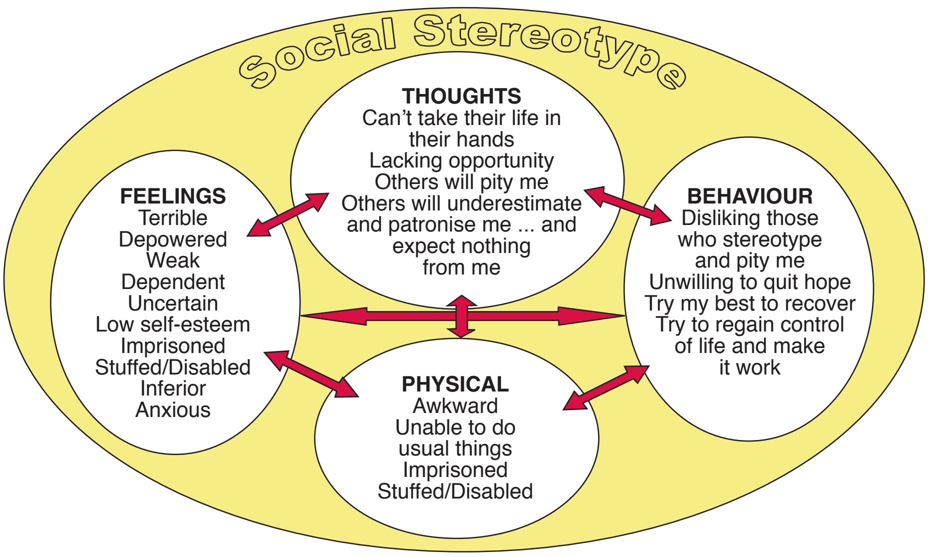


Fig. 10 *The effect of the social stereotype*

Further research is needed to investigate the mirroring process that could be involved in triggering the transference of biased beliefs into negative attitudes of current rehabilitation professionals with regard to NG (for example, ‘NG is impossible, and therefore NG exercise is unnecessary’).

Study 3

This third study was designed to investigate the third hypothesis — that NG walking knowledge is available and accessible after a severe spinal cord injury. The general aim was to examine if NG reacquisition was achievable for those SCI people who had been unable to perform NG since the injury occurred.

Walking knowledge is a procedural skill and therefore it is stored through implicit memory processing. It is known that implicit knowledge cannot be accessed voluntarily. However, indirect access may be possible through relearning or assisted performance of the target skill (Stadler & Frensch, 1998). This would imply that if the walking knowledge has been preserved it will be available. However, the way to indirectly access it would be through assisted performance of pre-injury NG. In this case the speed of NG occurrence and the quality of the NG properties should be analysed.

Method

Participants

One 32-year-old Caucasian male, JM, volunteered for this study. He reported having an incomplete SCI of five years' duration at the cervical level C4. JM was able to voluntarily control movements of all extremities and was able to walk independently (no aids). However, he walked very slowly, with great lateral displacement, low stability, poor balance and high spasticity. While standing upright his knees were always slightly bent. While walking, however, his knees stayed rigidly in almost the same position. JM felt dangerously unstable when walking down stairs and needed greater care or extra help. He was unemployed, living off social welfare (Invalid's Benefit).

JM regularly attended all recommended rehabilitation programmes and physiotherapy assessments. However, he had only achieved a pathological walking pattern that was very similar to BG.

JM reported that over the 5-year post-injury period he had frequently asked physiotherapists if he could try to walk 'normally', and that he was given the explanation that he 'wouldn't be able to achieve it, due to his SCI and muscular problems' (JM, personal communication during 5-year post-injury period). After this, JM watched healthy people walking and tried 'to do the same'. However, he never achieved NG.

Research design

A within-subject design was used in a single case study, to investigate whether the introduction of NG exercise would trigger any degree of NG reacquisition in the SCI person (JM), where voluntary control of all movements was present, but an NG walking pattern was never achieved.

To obtain the objective statistics in kinematic analysis, the same kind of two-dimensional gait analysis procedure was used as in **Study 2**, focusing on five basic NG factors.

At the baseline phase, as well as at the first, fourth and last NG trial, the participant's kinematics were compared with the BG and NG data obtained from healthy walkers who participated in **Study 2**.

To identify the nature of JM's walking experience over all walking trials, qualitative and quantitative analyses were performed using the same self-perception questionnaire that was used in **Study 2**.

Procedure

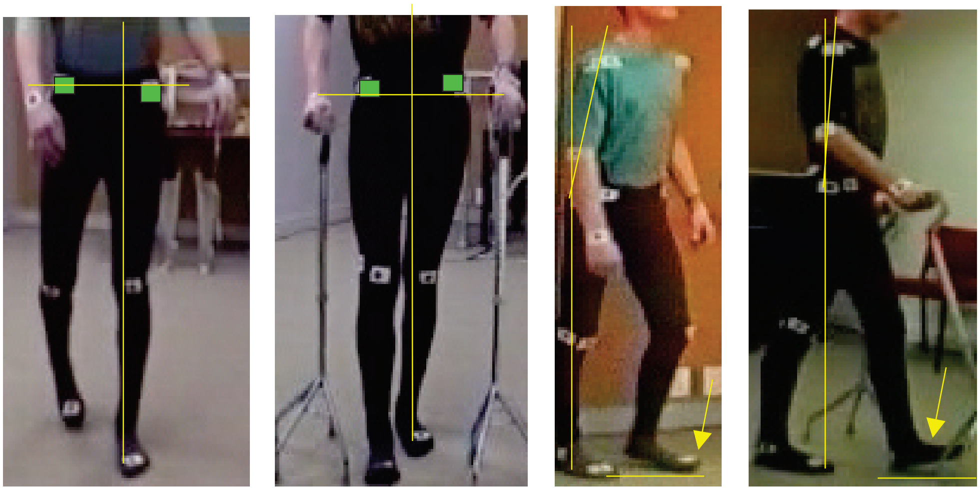
JM's gait was analysed under two conditions: (a) prior to NG intervention (baseline phase); and (b) after the NG intervention was introduced (NG intervention phase). The further effects of NG intervention were investigated by observing and analysing gait changes over 10 consecutive NG walking trials.

JM's NG mastery developed through six stages. Stage 1 consisted of the baseline condition when JM was *lacking an understanding of targeted NG skill* and its properties (L stage). At the L stage, JM's problematic walking was recorded. The following five stages represented the integrative part of NG intervention.

During Stage 2, JM was supported in gaining an *understanding* of NG (U stage). During the U stage, video footage was presented to JM and he was invited to compare his gait with the NG and BG walking patterns performed by the healthy participants in **Study 2**. The researcher helped JM to identify all noticeable anomalies in his post-injury gait by asking him to compare and discuss particular gait factors. For example: 'Would you, please, look at the motion of your hip. Where does your hip go while that leg is going to swing? . . . Well done, yes, it goes up. Look at the healthy walker now. Where is his hip moving during his NG? Correct, it goes down'.

At this cognitive stage of learning, a carefully guided discussion enabled JM to understand the NG pattern and to distinguish it from pathological BG-like walking. He noticed that his gait presented with pathological hip-hiking and inappropriate foot placement at the end of the swing: touching the ground with a flat foot or tiptoes (Fig. 11(a)).

After this cognitive task, the physical part of NG intervention was introduced at Stage 3 by asking JM to exclusively *devote his NG performance* to two simple and achievable NG tasks: (1) his hip must go down while the hip-leg was going to swing; and (2) at the end of the swing the heel must touch the ground first (heel strike) (D stage).



(a) *(b)* *(a)* *(b)*

Fig. 11 *JM's walking trials with focus on hip motion and foot placement: (a) at baseline phase (pathological gait); and (b) at initial NG intervention phase (first NG trial)*

Within the D stage it was important to provide JM with *consistent support in exercising normal locomotion (NG)*. The goal was for him to achieve reprocessing of normal walking memory through re-experiencing his pre-injury NG locomotion. Therefore, true NG properties were exercised. The physical properties of NG are multiple and extremely complex in their functioning. This meant a simplified performance of NG was required. Given that JM and the researcher both identified hip-hiking and inappropriate foot placement as the most profound gait abnormalities, two simple tasks were chosen to address these particular issues: hip down and heel strike.

When JM reported 'feeling odd and unstable' while trying to initiate normal hip and foot motions, he was offered the use of two walking quad-sticks or two light walking sticks for supporting his balance. At this stage, JM chose the two quad-sticks (Fig. 11).

Once NG was achieved, JM was asked to make sure that his NG hip motion and heel strike were retained during his everyday walking (between the NG trial sessions). This was Stage 4, where JM exercised *voluntary* control of NG pattern (V stage).

To assure greater safety when walking in a crowd, JM used two light walking sticks.

The principle of *consistent support in exercising normal locomotion (NG)* was aimed at facilitating integrative metalearning by focusing on consistent normal and natural locomotion, and this involved both cognitive and physical exercising. The researcher further investigated whether this would enable JM to gain the following Stage 5, where he might be capable of spontaneous gait evaluation (self-correcting) and *independent* NG within his everyday living regime (I stage). The researcher introduced JM to slow-motion exercising accompanied by deep, slow breathing, relying on the basic Wu style Tai Chi Chuan exercises (Ma & Zee, 1990).

After his daily walking maintained consistency with NG pattern and remained stable over a couple of weeks, JM concluded his NG-exercise intervention. He named this last stage, Stage 6, as 'Go for it' or 'Go stage'. Two 6-month follow-up sessions were made available to JM for evaluation of his NG performance.

During and after each walking trial, JM responded to the research questionnaires and analysed his feelings and beliefs related to his walking experience. In this way JM provided his intrinsic feedback (Shumway-Coog & Woollacott, 2001). The researcher provided extrinsic, verbal feedback during each NG trial (concurrently) and after they were completed (terminal feedback). After each NG trial, the video footage was observed (visual feedback) and discussed by the researcher and JM together.

JM's walking pattern was further compared with his baseline walking and his last achieved NG. After this, his NG was compared with the NG performed by the healthy participants in **Study 2**. The aim was to help JM acquire a clear understanding of the achieved NG pattern (knowledge of results).

When JM presented with consistent independent NG (after 10 NG sessions), the NG intervention was concluded.

Results

Through the baseline L stage, JM presented with emphasised hip-hiking, circumduction, flat-foot and tiptoe strike (as illustrated in Fig. 11(a)), as well as rigid and spastic posture. He reported (using the seven-point Likert Scale) very low confidence (2), and low safety (3) and comfort (3.5), as well as experiencing no pleasure (1) while walking. JM experienced high spasticity (5) and great fatigue (5). He also reported extreme energy expenditure (Borg's RPE = 19), while his stride width (M = 25.7; SD = 3.6) and trunk lateral displacement (M = 19.20°; SD = 2.68°) were large, and extreme values of trunk tilts (anterior = 16.5°; posterior = 9.5°) were recorded.

At the U stage, clear understanding of basic NG properties was achieved. At the beginning of the D stage, at his first NG attempt, JM was able to voluntarily correct both attended gait abnormalities and achieve normal hip obliquity and heel strike. This triggered the immediate spontaneous NG pattern (Fig. 11(b)). Although JM's walking was slow, other gait abnormalities were corrected.

The following V and I stages were successfully achieved: hip-hiking and disbalance disappeared; and heel strike (Fig. 12) and stride width became regular (M = 5.8; SD = 1.5). Trunk lateral displacement (M = 4.6; SD = 1.0), anterior tilt (4.7), low energy expenditure (6), low fatigue (1), and great feelings of safety (6.5), confidence (6), comfort (6.5) and pleasure (7) were also achieved. JM reached his Go stage having minimal single spasm (1.5) and no noticeable posterior tilt. He presented with stable, confident and self-reliant NG while walking on flat surfaces and up and down the stairs, as well as while walking backwards, forwards and sideways. He has also enrolled in a computer course and started a part-time job.

(a) (b)

Fig. 12 *JM's walking pattern achieved by the last NG trial (session 10), showing typical NG hip motion and foot contact in: (a) anterior; and (b) posterior planes*

Conclusion

The fact that the NG walking pattern was achieved instantly, at the first attempt, strongly supported the hypothesis that, after severe SCI, JM's walking knowledge remained available and accessible.

The fact that JM could not voluntarily access his pre-injury walking knowledge could be explained by at least two factors: (1) walking is a procedural skill and knowledge of the skill is therefore not voluntarily accessible; and (2) JM was not provided with adequate assistance to indirectly access procedural knowledge (simple tasks that simulate the NG target skill). The history of JM's unsuccessful trials to imitate the gait of healthy walkers further supported the idea that walking knowledge, being a procedural skill, cannot be accessed voluntarily.

During this research, JM's ability to improve his gait triggered greater motivation for future exercising and was closely related to the overall improvement in his quality of life. This supported the findings of previous research, which emphasised that the ability of SCI people to adapt and control their gait would be of great benefit to them, and would increase their motivation for exercising (Jezernik, Scharer, Colombo & Morari, 2003).

As noted at baseline (L stage), JM's spasms were debilitating his balance and he reported that these had continually increased since the injury. He was offered the surgical intervention of implanting a baclofen pump intrathecally (within the meninges of the spinal cord), where baclofen infusion would reduce high spasticity. He had experienced a one-off injection trial some time before and reported remembering that as an undesirable experience where 'Yes, the spasms decreased, but the whole body was . . . sort of flaccid. I felt like a sausage'.

As JM reported, his gait deterioration was likely to progress and his spasms would increase further. The baclofen pump would probably then become necessary. JM reported being afraid that he would 'end up in a wheelchair'. In this respect, the assistance given to JM during **Study 3** was invaluable.

General discussion

This integrative research programme emphasised the importance of several critical factors closely associated with improved rehabilitation for people with severe SCI.

The data clearly indicated that after experiencing severe SCI people maintained a great willingness to regain normal walking ability. However, their willingness to participate in the rehabilitation, which is currently BG-focused and otherwise passive, markedly decreased soon after they tried BG.

The following question emerged: If SCI people prefer active gait training, why do current rehabilitation practices not include NG exercises? This is an especially important question, given that previous research supported the idea that through active participation an SCI person could change their gait pattern (Jezernik et al., 2003). In general, medical practice aims to follow the ethical principle emphasising that the patient's best interests and specific wishes should be highly respected (Blackmer, 2002; Sullivan, 2004). However, the current rehabilitation focus was found to be unattuned to the real world of SCI people and their unique goals and wishes and, therefore, to this ethical principle. Medical opinion is usually based on significant research findings and clinical experience. However, no research was found that investigated what impact NG exercise may have on rehabilitation following SCI. Rehabilitation currently provided for SCI people does not include NG exercise. Therefore, there is no opportunity to rely on clinical experience. Opinions that are not empirically and clinically supported are not scientifically sound. In this respect, the current belief that NG exercise is unnecessary and NG reacquisition impossible should be recognised as an untested assumption that requires scientific investigation.

What could be the consequence of never trying NG again? Recent research findings by Tran, Boord, Middleton and Craig (2004) indicated that brainwave activity may be associated with overall sensory input. Lower brain activities in SCI people were found to be related to deafferentation that occurs following SCI (decrease in impulses that should be conveyed from receptors to the brain or spinal cord). When walking knowledge is available, but within minimal ambulatory ability, the person may need to maximise their residual potentials in order to make it usable. If walking was never tried again, the lack of demand and non-exercising would likely trigger further deterioration of residual potentials. Previous research concerned with the survival of motor neurons emphasised that greater use of muscles that are related to a target skill increased reproduction of related neurons and therefore survival of the relevant skill (Jessell, 1991). From this perspective, a person's decision to never walk again might have a fatal impact on the survival of walking skill.

Professor Leonid Dmitrievich Potehin (personal communications, March–December 1982) advocated the idea that the human brain is not only an ingenious and inventive mechanism, but is also selective and able to reorganise itself. If there is no demand for a skill, an impaired skill might be taken from the brain's busy schedule. Potehin emphasised that the properties of normal gait should be performed in order to regain normal gait. Therefore, he introduced exercises involving consistent support of NG locomotion and they became a fundamental part of the rehabilitation trial programme in the Burdenko rehabilitation centre (Saki, Ukraine).

The present research focused on the investigation of the same principle, naming it *consistent support in exercising normal locomotion (NG)*.

Potehin (2002) noted that, while neurophysiological complexity of sensory-motor impairments represents a clinical picture that highlights what structures may be completely or partially damaged, the optimal rehabilitation outcome is best achieved when all ambulatory (physical), psychological (emotional, motivational), social and neurophysiological interventions are interlaced. When the spinal cord is severely damaged, the key issues are what is actually lost, and what abilities still reside, and to what degree. It is obvious that the impact of a severe SCI is far beyond pure physiology.

Current rehabilitation practices often seem to ignore or overlook the implicit nature of walking knowledge, while insisting on mainly passive rehabilitation and voluntary-retrieval strategies — for example, asking people to move or to remember pre-injury movements (participants' reports). If the person is wheelchair-dependent and unable to voluntarily control their muscles, the prospective NG intervention would need to rely on the residual abilities of a particular SCI person. For SCI people, a carefully designed programme, consistent with a target skill (for example, normal locomotion) and tailored to match the unique needs of a person, would facilitate optimal achievement and successful progress through the L-U-D-V-I-Go rehabilitation stages. This is likely to be a very slow process for the SCI person with severe spinal impairment and high dependency, but it could provide them with greater potential for their optimal recovery.

Future research should be conducted integrating biomechanics with psychology. The vertical posture and ambulatory improvement may bring additional benefit for SCI people through lessening many ‘secondary’ problems — for example, reducing their osteoporosis, improving blood circulation, and a decrease in bedsores, excess weight, and feelings of being ‘disabled’, ‘unable’ and ‘useless’.

This study has highlighted the need for an integrative approach, if an optimal rehabilitation outcome and greater benefits for SCI people are to be achieved. The importance of accurate kinetic analysis of a target skill, as well as understanding of its implicit or explicit nature, is required if the most efficient physiotherapy intervention is to be realised.

In order to successfully tailor the rehabilitation therapy to match the unique needs of and gain the greatest benefit for the SCI person, knowledge about their unique neuropsychological, biomechanical and psychosocial functioning must be integrated. This holistic memory reprocessing integrative metalearning approach may lead to improved ambulatory independency, overall health and motivation, and therefore greater benefit for the SCI person. Similarily, as the t’ai chi master Ma Yueh-liang (Ma & Zee, 1999) emphasised, in order to facilitate quality growth in their disciples (or clients), the teacher (or therapist) must have experience in their practice and aim for perfect balance between their physical, emotional, mental, psychological and philosophical concepts.

Healthy human walking, with its vertical posture, does not seem to be a purely physical activity. Looking from a holistic perspective, this sophisticated human skill is more likely to be a refined product of body–mind harmony. The beliefs, feelings and hopes of SCI people should be seriously taken into account. It must be recognised that the major goal for most SCI people is ‘walking again’ and ‘being able’ (Adler et al., 1993; Maddox, 1994; Rossignol, 2000).

The Russian saying ‘*ходящый человек*’ (the walking man) does not imply only its direct, literal meaning, but rather the thought that the man is a unique being who lives consistently breathing his whole-life dynamics through each step, which further leads to his unique growth and discovery.

References

Adler, S.S., Beckers, D., & Buck, M. (1993). *PNF in practice: An illustrated guide*. Berlin, Germany: Springer-Verlag.

Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behavior and Human Decision Processes*, *50*, 179–211.

Asbury, A. K. (2001). Numbness, tingling and sensory loss. In E. Braunwald, A. S. Fauci, K. J. Isselbacher, D. L. Kasper, S. L. Hauser, D. L. Longo, & J. L. Jameson (Eds.), *Harrison's principles of internal medicine* (17th ed., Chapter 368). New York, NY: McGraw-Hill. [CD-Rom, version 1.0.]

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood, NJ: Prentice-Hall.

Beck, A. T. (1983). Cognitive therapy of depression: New perspectives. In P. J. Clayton & J. E. Barrett (Eds.), *Treatment of depression: Old controversies and new approaches* (pp. 265–290). New York, NY: Raven.

Blackmer, J. (2002). Awareness and use of advance directives in the spinal cord injured population. *Spinal Cord. The Official Journal of The International Spinal Cord Society*, *40*, 581–594.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics. Retrieved January 11, 2005, from http://ahsmail.uwaterloo.ca/kin356/rpe/rpe/Borg%20RPE%20Scale.html

Braunwald, E., Fauci, A. S., Isselbacher, K. J., Kasper, D. L., Hauser, S. L., Longo, D. L., & Jameson, J. L. (Eds.). (2001). *Harrison's principles of internal medicine* (17th ed.). New York, NY: McGraw-Hill. [CD-Rom, version 1.0.]

Elliot, R., Watson, J. C., Goldman, R. N., & Greenberg, L. S. (2004). *Learning emotion-focused therapy: The process-experiential approach to change*. Washington, DC: American Psychological Association.

Farr, R. M., & Moscovici, S. (Eds.). (1984) *Social representations*. Cambridge, England: Cambridge University Press.

Hauser, S. L. (2001). Diseases of the spinal cord. In E. Braunwald, A. S. Fauci, K. J. Isselbacher, D. L. Kasper, S. L. Hauser, D. L. Longo, & J. L. Jameson (Eds.), *Harrison's principles of internal medicine* (17th ed., Chapter 368). New York, NY: McGraw-Hill. [CD-Rom, version 1.0.]

Hirst, K., Anderson, M., Clarke, A., & Wells, E. (2000). Review of the admissions to the two New Zealand spinal units. *Spinal Network News*, *3*(2), 12–13.

Isakovic, M. (2005). *Critical factors associated with improved rehabilitation for people with severe spinal cord injury: Looking towards maximising their residual potential*. Unpublished doctoral dissertation, Victoria University of Wellington, New Zealand.

Jessel, T. M. (1991). Cell migration and axon guidance. In E. R. Kandel, J. H. Schwartz, & T. M. Jessell (Eds.), *Principles of neural science* (3rd ed., pp. 283–295). Amsterland, Netherlands: Elsevier.

Jezernik, S., Scharer, R., Colombo, G., & Morari, M. (2003). Adaptive robotic rehabilitation of locomotion: A clinical study in spinally injured individuals. *Spinal Cord. The Official Journal of The International Spinal Cord Society*, *41*, 657–666.

Ma, Y., & Zee, W. (1990). *Wu style Taichichuan: Push-hands (Tuishou)* (2nd ed.). Hong Kong: Shanghai Book Co. Ltd.

Maddox, S. (1994). *Spinal Network*. Malibu, CA: Spinal Network and Miramar Communications, Inc.

Marsolais, B. (2001). *Paraplegic Walking Made Practical with FNS & Orthoses*. Retrieved January 11, 2005, from http://feswww.fes.cwru.edu/projects/research/ebmnih1.php

Nene, A. V., Hermens, H. J., & Zilvold, G. (1996). Paraplegic locomotion: A review. *Spinal Cord. The Journal of The International Medical Society of Paraplegia*, *34*, 507–524.

Padesky, C. & Greenberger, D. (1995). *Clinician's guide to mind over mood*. New York, NY: The Guilford Press.

Potehin, L. D. (2002). *Кинезитерапия больных со спинальной параплегией.* Novokuzneck, Russia: Мануальная Терапия. Retrieved January 11, 2005, from the Russian website: Kineziterapia:\PhD\Potehin\Kineziterapija.htm

Robertson, J. (1999). Employment research. *Spinal Network News*, *3*(2).

Rogers, C. R. (1957). The necessary and sufficient conditions of therapeutic personality change. *Journal of Consulting Psychology*, *21*, 95–103.

Rossignol, S. (2000). Locomotion and its recovery after spinal injury. *Current Opinion in Neurobiology*. Amsterdam, Netherlands: Elsevier Science Ltd.

Shumway-Coog, A., & Woollacott, M. H. (2001). *Motor control: Theory and practice*. Baltimore, MD: Lippincott Williams & Wilkins.

Spinal Injuries Association. (1995). *Moving forward. The guide to living with spinal cord injury*. London, England: Author.

Stadler, M. A., & Frensch, P. A. (Eds.). (1998). *Handbook of implicit learning*. Thousand Oaks, CA: Sage Publications Ltd.

Sullivan, W. J. (2004). Letter to the editor. *Spinal Cord. The Official Journal of The International Spinal Cord Society*, *42*, 132.

Tran Y., Boord P., Middleton J., & Craig A. (2004). Levels of brain wave activity (8–13 Hz) in persons with spinal cord injury. *Spinal Cord. The Official Journal of The International Spinal Cord Society*, *42*, 73–79.

Whittle, M. W. (1996). *Gait analysis: An introduction* (2nd ed.). Oxford, England: Reed Educational and Professional Publishing Ltd.