ORIGINAL ARTICLE

Comparison of Single Bout Effects of Bicycle Training Versus Locomotor Training on Paired Reflex Depression of the Soleus H-Reflex After Motor Incomplete Spinal Cord Injury

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ABSTRACT. Phadke CP, Flynn SM, Thompson FJ, Behrman AL, Trimble MH, Kukulka CG. Comparison of single bout effects of bicycle training versus locomotor training on paired reflex depression of the soleus H-reflex after motor incomplete spinal cord injury. Arch Phys Med Rehabil 2009; 90:1218-28.

Objective: To examine paired reflex depression changes post 20-minute bout each of 2 training environments: stationary bicycle ergometer training (bicycle training) and treadmill with body weight support and manual assistance (locomotor training).

Design: Pretest-posttest repeated-measures.

Setting: Locomotor laboratory.

Participants: Motor incomplete SCI (n=12; mean, 44±16y); noninjured subjects (n=11; mean, 30.8±8.3y).

Intervention: All subjects received each type of training on 2 separate days.

Main Outcome Measure: Paired reflex depression at different interstimulus intervals (10s, 1s, 500ms, 200ms, and 100ms) was measured before and after both types of training.

Results: (1) Depression was significantly less post-SCI compared with noninjured subjects at all interstimulus intervals and (2) post-SCI at 100-millisecond interstimulus interval: reflex depression significantly increased postbicycle training in all SCI subjects and in the chronic and spastic subgroups ($P<.05$).

Conclusions: Phase-dependent regulation of reflex excitability, essential to normal locomotion, coordinated by pre- and postsynaptic inhibitory processes (convergent action of descending and segmental inputs onto spinal circuits) is impaired post-SCI. Paired reflex depression provides a quantitative assay of inhibitory processes contributing to phase-dependent changes in reflex excitability. Because bicycle training normalized reflex depression, we propose that bicycling may have a potential role in walking rehabilitation, and future studies should examine the long-term effects on subclinical measures of reflex activity and its relationship to functional outcomes.

Key Words: Bicycling; H-reflex; Rehabilitation; Spinal cord injuries.

AFTER SCI, SEGMENTAL REFLEX excitability is initially reduced during spinal shock and then becomes progressively enhanced.[1-4] The loss of descending control and enhanced synaptic effectiveness of peripheral afferents results in a reduced ability to modulate the stretch reflex[5] and H-reflex[6-8] during gait. This loss of modulation can result in unwanted interference contractions of lower-limb muscles during locomotor phases that require rapid lengthening of muscles.[9,10] One of the ways in which the impaired spinal modulation manifests post-SCI is a change in the transmission of successive volleys from Ia afferents to motoneurons.[4,11-16] In noninjured subjects, 2 successive stimuli result in the second H-reflex being smaller in amplitude compared with the first, which is termed paired reflex depression.[17] This depression is an indirect measure of the probability of neurotransmitter release at the Ia afferent synapse.[18] The degree of depression of the second reflex amplitude is dependent on the interstimulus interval: the shorter the interval, the greater the depression.[19-22] This depression is also termed homosynaptic depression, postactivation depression,[18,23-25] or paired reflex depression.[26]

Post-SCI, however, paired reflex depression in both the H-reflex and stretch reflex pathways is significantly impaired (lower).[25,27] Accordingly, when a series of volleys of electrical stimulation are carried via Ia afferents, the depression of H-reflex that is normally seen is impaired or lost after SCI.[2] The firing of muscle spindles in response to stretch of soleus muscle (eg, swing phase of walking) post-SCI has a much higher probability of producing reflex muscle activity in the soleus muscle when it is normally inactive.[5,28] Results from others[7,29] and from our own previous work[8,30] have shown that H-reflex modulation during serial lengthening of the soleus muscle (as occurs in stance and swing phases of walking) post-SCI is impaired and reflex amplitudes are significantly greater com-

List of Abbreviations

AIS	American Spinal Injury Association Impairment Scale
BWS	body weight support
EMG	electromyography
GABA	gamma-aminobutyric acid
MAS	Modified Ashworth Scale
SCI	spinal cord injury
5-HT	5-hydroxytryptamine

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Table 1: Demographic Information for Subjects With Incomplete SCI

Subject	Age (y)	Duration of Injury (mo)	Level of Injury	Sex	ASIA Grade	Ashworth Scale (Ankle)				Motor Score	Medication	Dose	Assistive Device
						Sitting		Supine					
						R	L	R	L				
1	50	4	C7	M	D	1	1	1	1	83	Clonipen	4×/wk	Cane
2	48	26	C5	M	D	NA	NA	NA	NA	87	None	NA	W
3	76	35	C3–4	M	D	0	0	0	0	NA	Zanaflex	2×/d	None
4	48	5	C6–7	M	D	1	0	0	0	87	Gabapentin	1000mg; 4×/d	PW
5	42	88	C5–6	M	D	1	1	1	1	88	None	NA	None
6	55	3	C5–6	M	D	NA	3	NA	3	73	Baclofen	5mg; 2×/d	W+R-AFO
7	23	84	C5–6–7	M	D	NA	NA	NA	NA	NA	NA	NA	B/L LC
8	44	33	C6	M	D	2	2	3	3	64	NA	NA	PW
9	51	21	C5–6	F	D	2	2	0	2	70	None	NA	None
10	50	6	C8, T1	F	D	0	1	1	2	87	None	NA	None
11	22	12	C5	M	D	3	3	3	3	87	N/A	NA	None
12	22	19	C5–6	F	C	3	2	3	2	47	None	NA	PW+B/L AFO

NOTE. MAS scores of 2 indicates a slight increase in muscle tone in less than half the range of ankle dorsiflexion. Scores of 2 or higher indicate greater increase in muscle tone and through the complete range of motion and scores less than 2 indicate lower tone.
Abbreviations: AFO, ankle foot orthosis; ASIA, American Spinal Injury Association; B/L, bilateral; C, cervical; L, left; LC, loftstrand crutches; NA, not available; PW, platform walker; R, right; SCI, spinal cord injury; T, thoracic; W, walker.

pared with noninjured subjects. Thus, one of the problems during walking post-SCI appears to be an impaired modulation of reflex activity during task-specific lengthening of lower extremity muscles. Hence, a task-specific therapeutic strategy consisting of alternating stretch-shortening cycles may improve H-reflex modulation during muscle lengthening. Walking on a treadmill with body weight support and manual trainers (locomotor training) and training on a stationary assisted bicycle ergometer (bicycle training) both feature rhythmic shortening and lengthening of lower-extremity muscles.

Locomotor training that induces task-specific patterns of sensory and motor activity may enhance the recovery of walking by optimizing the activity-dependent neuroplasticity of the nervous system.[31,32] Neuronal circuits may reorganize by strengthening existing and previously inactive connections.[32-34] It is hypothesized that such reorganization could improve the sequencing of spinal inhibitory mechanisms such as reciprocal inhibition[9,35] and presynaptic inhibition[6,7,36] and increase the modulation of reflex excitability during walking (eg, lengthening of the soleus muscle).

Although research indicates that recovery of walking can be obtained with task-specific training such as locomotor training on a treadmill, thus providing load-bearing and sensorimotor practice of walking,[33,37] others have suggested that the coordinated coupling of the legs, the alternative phasing of the flexors and extensors of the limbs, and cyclical feedback from peripheral afferents are important task-relevant components of locomotion.[38,39] Therefore, a task such as pedaling a bicycle ergometer may induce neuroplastic changes that are beneficial to improving modulatory neural processes (reciprocal inhibition, presynaptic inhibition).

The nature of the relationship between paired reflex depression and neurologic injury is not clearly understood.[40] The purpose of this experiment was to compare, in noninjured and subjects with motor incomplete SCI, paired reflex depression before and after a single bout of training on a bicycle ergometer and locomotor training on a treadmill (with partial BWS and trainer assistance). On the basis of previous research,[25,27] we hypothesized that reflex depression post-SCI will be significantly lower than recorded in noninjured subjects. In noninjured subjects, we hypothesized that reflex depression would not change after both forms of training. Stationary bicycling and walking on a treadmill involve repetitive stretching and shortening of the soleus muscle; hence, we hypothesized that paired reflex depression would increase after both forms of training in subjects with incomplete SCI.

METHODS

Subjects

Data were obtained from 12 subjects with incomplete SCI (mean age, 44±16y) (table 1) and 11 noninjured subjects (mean age, 30.8±8.3y). Inclusion criteria for the subjects with incomplete SCI were: (1) adults more than 18 years old, (2) a diagnosis of first-time SCI including etiology from trauma, vascular, or orthopedic pathology at cervical or thoracic levels, (3) a range of 3 months to 3 years post-SCI, AIS class C or D, (5) a medically stable condition, (6) no other degenerative spinal disorders, (7) the ability to walk independently a minimum of ~18 meters continuously with or without an assistive device, (8) the ability to walk at least ~90 meters total per day, and (9) the ability to give informed consent. The above criteria, specifically AIS class C or D and ability to walk a minimum of 60 feet continuously, were set to ensure that SCI subjects would be able to participate in the complete protocol and minimize subject dropout. In addition, we wanted to recruit subjects who could actively participate in both the training protocols rather than training passively. Able-bodied subjects served as noninjured controls and had no history of neurologic or orthopedic problems that could impair walking function. All subjects signed written consent as approved by the institutional review board at the University of Florida.

Initial Testing

The initial subject evaluation (1wk before testing) began with a clinical evaluation of the subjects with incomplete SCI to identify levels of impairment and initial levels of function by the AIS and bilateral upper- and lower-extremity motor and sensory scores.[41] Bilateral ankle plantar flexor spasticity was evaluated by the modified Ashworth scale.[42]

Experimental Protocol

Each subject returned 1 week later to undergo their initial experiment. All persons with incomplete SCI first walked with