An Intensive Programme of Passive Stretch and Motor Training to Manage Severe Knee Contractures after Traumatic Brain Injury: A Case Report

Joan Leung, MAH, PhD (Candidate);^{*†} Lisa A. Harvey, PhD;^{*‡} Anne M. Moseley, PhD^{†§}

ABSTRACT

Purpose: While contemporary management of contractures (a common secondary problem of acquired brain injury that can be difficult to treat) includes passive stretch, recent evidence indicates that this intervention may not be effective. This may be because clinical trials have not provided a sufficient dose or have not combined passive stretch with other treatments. The purpose of this case report is to describe a programme of intensive passive stretch combined with motor training administered over a 1.5-year period to treat severe knee contractures. **Method:** Five months after traumatic brain injury, an adolescent client with severe contractures in multiple joints underwent an intensive stretch programme for his knee contractures, including serial casting and splinting, which was administered for 10 months in conjunction with a motor training programme administered for 1.5 years. **Results:** The client regained full extension range in his knees and progressed from being totally dependent to walking short distances with assistance; these effects were maintained at follow-up 5.5 years after injury. **Conclusion:** The use of a high dose of passive stretch in conjunction with motor training may be an option to consider for correcting severe contractures following acquired brain injury.

Key Words: brain injuries; contracture; exercise therapy; muscle stretching exercises.

RÉSUMÉ

Objectif : Bien que le contrôle des contractures (un problème secondaire fréquent propre aux lésions cérébrales acquises et pouvant être difficile à traiter) comprenne des étirements passifs, des preuves récentes indiquent que cette intervention pourrait être inefficace. Cela pourrait s'expliquer par le fait que les essais cliniques n'ont pas utilisé des dosages suffisants ou qu'ils n'ont pas jumelé les étirements passifs à d'autres traitements. L'objectif de ce rapport de cas consiste à décrire un programme d'étirements passifs intensifs allié à un entraînement moteur administré durant une période d'un an et demi pour le traitement de contractures sévères au genou. **Méthodologie :** Cinq mois après un traumatisme cérébral, un client adolescent aux prises avec des contractures sévères à de multiples articulations a été soumis à un programme intensif d'étirements pour ses contractures au genou, y compris l'application successive de plâtres et d'attelles. Le programme a été administré pendant 10 mois, en même temps qu'un programme d'entraînement moteur qui a duré un an et demi. **Résultats :** Le client a retrouvé la pleine extension de son genou et ses progrès se sont étendus d'une dépendance totale à la capacité de marcher sur de courtes distances sans aide; ces effets se sont prolongés pendant un suivi de cinq ans et demi après le traumatisme. **Conclusion :** L'utilisation des étirements passifs à dosage élevé en même temps qu'un entraînement moteur pourrait être une avenue à considérer pour corriger les contractures sévères résultant d'un traumatisme cérébral.

Contractures—a reduction in passive joint range due to shortening and stiffening of soft tissues spanning joints—are commonly observed after acquired brain injury (e.g., stroke, traumatic brain injury); incidence ranges from 23% to 85%.^{1,2} Contractures are a problem because they limit function, reduce mobility, and are linked to pain.¹ Not surprisingly, contractures contribute to poor motor recovery, prolonged length of hospital stay, and poor rehabilitation outcomes.^{3,4}

Contractures develop in the early weeks after acquired brain injury,^{5–12} worsen over time,^{6,7,10–12} and can persist for protracted periods after brain injury,^{5,9} often despite interventions to treat and prevent them. To date, passive stretch and motor training have been the most widely used physical therapy interventions for this purpose. Several randomized controlled studies have reported that passive stretch alone does not produce clinically worthwhile or sustained effects in people with brain

From the: *Royal Rehabilitation Centre Sydney; †Sydney Medical School and ‡Rehabilitation Studies Unit, Sydney Medical School/Northern, University of Sydney; §George Institute for Global Health, Australia.

Correspondence to: Joan Leung, Senior Physiotherapist, Brain Injury Unit, Royal Rehabilitation Centre Sydney, 59 Charles St., Ryde, NSW 2112 Australia; joan.leung@royalrehab.com.au.

Contributors: All authors designed the study; collected, analyzed, and interpreted the data; and drafted or critically revised the article.

Competing Interests: None declared.

Physiotherapy Canada 2013; 65(3);223–228; doi:10.3138/ptc.2012-29

Figure 1 Resting position in bed on first admission (5 months post injury).

injury.^{6,8,12–21} These findings were confirmed by a recent Cochrane review that provided high-quality evidence that passive stretch produces negligible short-term (mean between-group difference 1°, 95% CI, 0–3) or long-term (mean between-group difference 0°, 95% CI, –2 to 2) changes in joint range of motion (ROM) when administered to people with a variety of neurological conditions. The typical dose of passive stretch applied in the reported trials was 30 minutes to 12 hours per day over 4–12 weeks (median duration 30 days);²² this dosage of passive stretch may be insufficient. In addition, contracture is a complex problem; passive stretch focuses predominantly on reversing soft-tissue shortening and does not address the underlying causes of contracture, such as poor motor control and spasticity.⁹ Combining passive stretch with interventions that address the contributors to contracture is likely to offer a better prospect to effectively manage contracture than passive stretch alone. Importantly, passive stretch may need to continue until the underlying causes are addressed if treatment is to achieve a sustained effect.

This report describes the case of an adolescent with severe traumatic brain injury (TBI) and severe contractures. His knee contractures were managed with programmes involving months of prolonged passive stretch, including serial casting and splinting, combined with 1.5 years of motor training. Ethical approval was granted by the Human Research Ethics Committee of the Royal Rehabilitation Centre Sydney.

METHODS

Case description

A 16-year-old boy was involved in a motorcycle accident and sustained a TBI. His first documented Glasgow Coma Scale score (2 weeks after the injury) was 5/15. He had post-traumatic amnesia for more than 6 months,

which indicates the extremely severe nature of his injury. He did not receive rehabilitation and was discharged to a nursing home directly from the acute-care facility 3.5 months after injury. At 5 months post injury, he was admitted to a brain-injury unit for a trial of rehabilitation and to review his nursing-home programme.

On admission, the client was minimally responsive and unable to verbalize. He was confined to a bed with his arms and legs fully flexed and his lower body rotated to the left (see Figure 1). Physical examination revealed multiple contractures. Maximum passive knee extension was –50° on the right and –45° on the left, measured with a goniometer, a common and reliable method for measuring physiologic knee ROM ($\kappa = 0.88$).²³ (All measurements were rounded to the nearest 5°.) He also had severe contractures in his hips, ankles, shoulders, elbows, wrists, fingers, and trunk. He was able to follow verbal instructions to blink his eyes, open his mouth, turn his head, and, inconsistently, abduct his right shoulder to 30°. Manual muscle testing showed no voluntary control or strength in his lower limbs.²⁴ He had strong flexor spasticity in all limbs (4/4 on the Modified Ashworth Scale).²⁵ Functionally, he was fully dependent and required a high level of care; he scored 18/126 on the Functional Independence Measure (FIM),²⁶ the lowest possible score on this scale (see Table 1).

Intervention

This case report focuses on the management of the client's knee contractures from admission to the brain-injury unit through to 5 years later. Initially, passive stretch was applied to his knees for approximately 12 hours/day, using ready-made knee orthoses (see Figure 2). Two months after his admission (7 months post-injury), the left knee showed a 10° improvement in extension ROM, but the right knee showed a 5° deterioration (see Table 1). The slow progress and the deterioration in right-knee ROM in the first 2 months after admission prompted the move to a more aggressive stretch programme. Serial casting^{27–30} for the right knee therefore began. A series of five casts was applied over 5 weeks. At the same time, the duration of splinting for the left knee was increased to 24 hours/day. The client gained nearly full passive extension in both knees after 5 weeks. Adjustable custom-made knee orthoses were then applied to both knees 24 hours/day to maintain the gain in range. The orthoses were removed only for hygiene and therapy; the client's skin condition was closely monitored.

Motor training and lower-limb strength training were initiated following the correction of the client's knee contractures. He attended the gymnasium for 1 hour/day. Physical therapy followed the principles of motor relearning,³¹ with an emphasis on muscle strengthening in functional positions and repetitive training augmented with appropriate encouragement and feedback. Initial training involved exercises to elicit muscle activity and

Table 1 Timeline of Progress in Knee Extension Range of Motion, Knee Extensor Muscle Strength, Spasticity, and Dependence (FIM)

	Time since injury				
	5 mo	12 mo	14 mo	25 mo	5.5 y
Stage of rehabilitation	1st admission	1st discharge	2nd admission	2nd discharge	Follow-up
Stretch interventions	Knee splinting 12 h/d	Serial casting followed by 24 h/d knee splinting	Gradual reduction of knee splinting time	Cessation of knee splinting	
Knee extension ROM					
Right	−50°	Full	Full	Full	Full
Left	−45°	Full	Full	Full	Full
Knee extensor strength, /5					
Right	0	3	3	4	4
Left	0	3	3	4	4
MAS score, /4	4	2	2	1	1
FIM score, /126	18	28	28	32	54

ROM = range of motion; MAS = Modified Ashworth Scale; FIM = Functional Independence Measure.

Figure 2 Knee orthosis used to apply 12 hours of passive stretch per day at the beginning of the client's first admission (5 months post injury).

strengthen the leg muscles, first with the orthoses applied and then without. Over time, the client progressed to assisted cycling, concentric and eccentric exercises, and repetitive sit-to-stand practice. The duration of practice and complexity of tasks were increased gradually; treatment targets were set and progressed as he improved. Progress was slow, as the client exhibited behavioural problems that affected his ability to participate in training. A reward system designed by the team psychologist was used to increase adherence to therapy.

Eight months after admission (13 months post injury), the client had full passive bilateral knee extension and showed improved strength in both lower limbs. The hip flexion contractures also resolved as knee ROM improved. He was able to stand with moderate support from two assistants and bilateral knee orthoses. Although it seemed an appropriate time to start weaning him off the orthoses,

this step was postponed because he was discharged prematurely to secure a nursing-home placement. One month after discharge (14 months post injury), he was readmitted to the brain-injury unit for further rehabilitation as planned. He participated in in-patient rehabilitation for another 11 months, during which he began gait training, first with and later without the support of the knee orthoses. He stopped wearing the knee orthoses 2 months into this second admission (16 months post injury). At the beginning of the gait training, a forearm support frame (Pacer Gait Trainer, Wonderland Rehab & Child Care, Lidcombe, NSW) was used for walking, which provided support to the client's pelvis and had straps to stop his left leg from crossing the midline (see Figure 3). He subsequently progressed to walking with an ordinary forearm support frame. He never developed skin or other problems from the orthoses, and the orthoses had to be modified only once to accommodate changes in weight and muscle bulk. Anti-spasticity medication (dantrolene) was used throughout his in-patient rehabilitation. He also received botulinum toxin injections for his wrists, fingers, elbows, and ankles, but not for his knees. The effect of the injections was mixed: while both elbows and the right wrist and fingers responded well to the injections, the ankles, left wrist, and left fingers did not. The ankle contractures were subsequently corrected with serial casting, and ROM was maintained using customized ankle-foot orthoses (the same approach used for his knees).

RESULTS

The client was discharged back to a nursing home at 25 months post injury, with a plan for him to eventually move to a group home designed to reintegrate young people with disabilities into the community. At this time, he had anti-gravity strength (grade 3/5) in the knee extensor

Figure 3 Walking with a walking frame (Pacer Gait Trainer) and the assistance of one person (22 months post injury). Note: At the time this photo was taken, the client was wearing an ankle-foot orthosis for his right ankle and receiving serial casting for his left ankle. He later progressed to using an ordinary forearm support frame.

Figure 4 Standing without knee orthoses but with bilateral ankle-foot orthoses, the support of parallel bars, and supervision from one person (24 months post injury). Note: a ball was used to keep the feet separated and he was wearing customized ankle-foot orthoses.

muscles and full passive extension in the knees. He was able to stand with supervision and the support of a rail (see Figure 4) and could walk 140 m with one assistant and a forearm support frame. His FIM score was 32/126 (see Table 1).

The client was reviewed 5.5 years post injury. He was still living in a nursing home and receiving a maintenance programme prescribed by the nursing-home physiotherapist. He maintained full passive knee extension bilaterally and had grade 4/5 strength in the knee extensor muscles (see Table 1). He could perform standing transfers with one person. He used an electrical wheelchair as his primary form of mobility but was learning to walk using a wall-mounted handrail with assistance of one person. His FIM score was 54/126 (see Table 1). He received surgical interventions to correct the deformities of his left wrist and fingers, and was subsequently transferred to a community group home.

DISCUSSION

Contractures are a common problem after acquired brain injury and can be difficult to manage. High-quality evidence indicates that passive stretch, as typically administered by physical therapists to people with neu-

rological conditions, is ineffective.²² This case report describes an adolescent with TBI whose severe knee contractures did not respond to usual care but resolved following a high dose of passive stretch combined with intensive motor training and anti-spasticity medication. Long-term follow-up indicated that these effects were sustained.

Severe contractures have significant deleterious effects on mobility and function. Poor mobility and function may also precipitate contracture, thereby setting up a vicious cycle. The client presented in this case report had an extremely severe TBI, multiple joint contractures, severe and generalized spasticity, and very poor motor control. These severe impairments, together with protracted post-traumatic amnesia, suggested a poor prognosis. Yet by the time he was discharged 25 months post injury, the knee contractures had resolved and he could perform standing transfers and walk short distances with assistance. This outcome was better than anticipated.

While it is impossible to rule out the possibility that the observed improvements were due to spontaneous recovery, bias, or other factors, we propose that the resolution of knee contractures enabled the client to participate in motor training and that this, in turn, led to

improvements in strength and control that helped maintain knee ROM. The lack of progress in the first 7 months before the interventions began lends support to our argument.

The approach described here has three strong features. First, a high dose of passive stretch was used. The knee contractures resolved only after an increase in the dose of passive stretch (from 12 to 24 hours/day); this highlights the importance of applying an adequate dose of passive stretch to achieve a therapeutic effect. Second, concomitant intervention (in this case, the individualized motor training programme) was implemented to treat the underlying contributors to contracture; the motor training, a key component of the programme, could not begin until after the correction of the knee contractures. Third, passive stretch was continued until the client had gained adequate strength to maintain the knee ROM. Perhaps these are the keys to successful management of contractures. The use of anti-spasticity medication may also have contributed to the successful outcome.

There is currently controversy about the effectiveness of passive stretch.²² However, no trial has examined the use of intensive passive stretch administered over extended periods (e.g., 24 hours/day over a few months) and in conjunction with other interventions (in this case, motor training). This could well be the key to successful contracture management and an option to consider for correcting contractures following acquired brain injury. It may be premature to abandon stretch altogether on the basis of the recent Cochrane review.²² This case study suggests the need for further research. It may be appropriate to consider a clinical trial, but conducting a study involving an intensive programme such as the one reported here will pose challenges for future researchers.

CONCLUSION

This case study illustrates the resolution of severe and chronic contractures following an intensive programme of passive stretch provided in conjunction with a motor training programme. This approach may provide the answer to contracture management, but it requires further scrutiny within a clinical trial. Until such trials have been conducted, however, this approach may be an option to consider for the correction of severe contractures following acquired brain injury.

REFERENCES

- Fergusson D, Hutton B, Drodge A. The epidemiology of major joint contractures: a systematic review of the literature. *Clin Orthop Relat Res.* 2007;456(456):22–9. <http://dx.doi.org/10.1097/BLO.0b013e3180308456>. Medline:17179779
- Kwah LK, Harvey LA, Diong JH, et al. Half of the adults who present to hospital with stroke develop at least one contracture within six months: an observational study. *J Physiother.* 2012;58(1):41–7. [http://dx.doi.org/10.1016/S1836-9553\(12\)70071-1](http://dx.doi.org/10.1016/S1836-9553(12)70071-1). Medline:22341381
- Turner-Stokes L, ed. *Rehabilitation following acquired brain injury: national clinical guidelines.* London: RCP, BSRM; 2003.
- Dénes Z. A másodlagos károsodások jelentősége a súlyos agykárosodást szenvedett betegek rehabilitációja során [Consequence of secondary complications during the rehabilitation of patients with severe brain injury]. *Orv Hetil.* 2009;150(4):165–9. Medline:19144601
- Singer BJ, Jegasothy GM, Singer KP, et al. Incidence of ankle contracture after moderate to severe acquired brain injury. *Arch Phys Med Rehabil.* 2004;85(9):1465–9. <http://dx.doi.org/10.1016/j.apmr.2003.08.103>. Medline:15375817
- Turton AJ, Britton E. A pilot randomized controlled trial of a daily muscle stretch regime to prevent contractures in the arm after stroke. *Clin Rehabil.* 2005;19(6):600–12. <http://dx.doi.org/10.1191/0269215505cr8910a>. Medline:16180595
- Pandyan AD, Cameron M, Powell J, et al. Contractures in the post-stroke wrist: a pilot study of its time course of development and its association with upper limb recovery. *Clin Rehabil.* 2003;17(1):88–95. <http://dx.doi.org/10.1191/0269215503cr5870a>. Medline:12617383
- Lannin NA, Cusick A, McCluskey A, et al. Effects of splinting on wrist contracture after stroke: a randomized controlled trial. *Stroke.* 2007;38(1):111–6. <http://dx.doi.org/10.1161/01.STR.0000251722.77088.12>. Medline:17122432
- Ada L, O'Dwyer N, O'Neill E. Relation between spasticity, weakness and contracture of the elbow flexors and upper limb activity after stroke: an observational study. *Disabil Rehabil.* 2006;28(13–14):891–7. <http://dx.doi.org/10.1080/09638280500535165>. Medline:16777777
- Ada L, Goddard E, McCully J, et al. Thirty minutes of positioning reduces the development of shoulder external rotation contracture after stroke: a randomized controlled trial. *Arch Phys Med Rehabil.* 2005;86(2):230–4. <http://dx.doi.org/10.1016/j.apmr.2004.02.031>. Medline:15706548
- O'Dwyer NJ, Ada L, Neilson PD. Spasticity and muscle contracture following stroke. *Brain.* 1996;119(5):1737–49. <http://dx.doi.org/10.1093/brain/119.5.1737>. Medline:8931594
- Lannin NA, Horsley SA, Herbert R, et al. Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. *Arch Phys Med Rehabil.* 2003;84(2):297–302. <http://dx.doi.org/10.1053/apmr.2003.50031>. Medline:12601664
- Harvey LA, Batty J, Crosbie J, et al. A randomized trial assessing the effects of 4 weeks of daily stretching on ankle mobility in patients with spinal cord injuries. *Arch Phys Med Rehabil.* 2000;81(10):1340–7. <http://dx.doi.org/10.1053/apmr.2000.9168>. Medline:11030499
- Harvey L, de Jong I, Goehl G, et al. Twelve weeks of nightly stretch does not reduce thumb web-space contractures in people with a neurological condition: a randomised controlled trial. *Aust J Physiother.* 2006;52(4):251–8. [http://dx.doi.org/10.1016/S0004-9514\(06\)70004-6](http://dx.doi.org/10.1016/S0004-9514(06)70004-6). Medline:17132119
- Moseley AM, Hassett LM, Leung J, et al. Serial casting versus positioning for the treatment of elbow contractures in adults with traumatic brain injury: a randomized controlled trial. *Clin Rehabil.* 2008;22(5):406–17. <http://dx.doi.org/10.1177/0269215507083795>. Medline:18441037
- Horsley SA, Herbert RD, Ada L. Four weeks of daily stretch has little or no effect on wrist contracture after stroke: a randomised controlled trial. *Aust J Physiother.* 2007;53(4):239–45. [http://dx.doi.org/10.1016/S0004-9514\(07\)70004-1](http://dx.doi.org/10.1016/S0004-9514(07)70004-1). Medline:18047458
- Dean CM, Mackey FH, Katrak P. Examination of shoulder positioning after stroke: a randomised controlled pilot trial. *Aust J Physiother.* 2000;46(1):35–40. Medline:11676788
- Gustafsson L, McKenna K. A programme of static positional stretches does not reduce hemiplegic shoulder pain or maintain shoulder range of motion—a randomized controlled trial. *Clin Rehabil.* 2006;20(4):277–86. <http://dx.doi.org/10.1191/0269215506cr9440a>. Medline:16719026
- Ben M, Harvey L, Denis S, et al. Does 12 weeks of regular standing prevent loss of ankle mobility and bone mineral density in people with recent spinal cord injuries? *Aust J Physiother.* 2005;51(4):251–6. [http://dx.doi.org/10.1016/S0004-9514\(05\)70006-4](http://dx.doi.org/10.1016/S0004-9514(05)70006-4). Medline:16321132

20. Harvey LA, Byak AJ, Ostrovskaya M, et al. Randomised trial of the effects of four weeks of daily stretch on extensibility of hamstring muscles in people with spinal cord injuries. *Aust J Physiother.* 2003;49(3):176–81. Medline:12952517
21. Harvey LA, Herbert RD, Glinsky J, et al. Effects of 6 months of regular passive movements on ankle joint mobility in people with spinal cord injury: a randomized controlled trial. *Spinal Cord.* 2009;47(1):62–6. <http://dx.doi.org/10.1038/sc.2008.71>. Medline:18574489
22. Katalinic OM, Harvey LA, Herbert RD, et al. Stretch for the treatment and prevention of contractures. *Cochrane Database Syst Rev.* 2010;9(9):CD007455. Medline:20824861
23. Cibere J, Bellamy N, Thorne A, et al. Reliability of the knee examination in osteoarthritis: effect of standardization. *Arthritis Rheum.* 2004;50(2):458–68. <http://dx.doi.org/10.1002/art.20025>. Medline:14872488
24. Hislop HJ, Montgomery J. Daniels and Worthingham's muscle testing: techniques of manual examination. 8th ed. New York: W.B. Saunders; 2007.
25. Waninge A, Rook RA, Dijkhuizen A, et al. Feasibility, test-retest reliability, and interrater reliability of the Modified Ashworth Scale and Modified Tardieu Scale in persons with profound intellectual and multiple disabilities. *Res Dev Disabil.* 2011;32(2):613–20. <http://dx.doi.org/10.1016/j.ridd.2010.12.013>. Medline:21232915
26. Hamilton BB, Laughlin JA, Fiedler RC, et al. Interrater reliability of the 7-level Functional Independence Measure (FIM). *Scand J Rehabil Med.* 1994;26(3):115–9. Medline:7801060
27. Verplancke D, Snape S, Salisbury CF, et al. A randomized controlled trial of botulinum toxin on lower limb spasticity following acute acquired severe brain injury. *Clin Rehabil.* 2005;19(2):117–25. <http://dx.doi.org/10.1191/0269215505scr827oa>. Medline:15759526
28. Mortenson PA, Eng JJ. The use of casts in the management of joint mobility and hypertonia following brain injury in adults: a systematic review. *Phys Ther.* 2003;83(7):648–58. Medline:12837126
29. Zablotny C, Andric MF, Gowland C. Serial casting: clinical applications for the adult head injured patient. *J Head Trauma Rehabil.* 1987;2(2):46–52. <http://dx.doi.org/10.1097/00001199-198706000-00007>.
30. Booth BJ, Doyle M, Montgomery J. Serial casting for the management of spasticity in the head-injured adult. *Phys Ther.* 1983;63(12):1960–6. Medline:6647551
31. Carr JH, Shepherd RB, editors. *Neurological rehabilitation.* 2nd ed. New York: Churchill Livingstone; 2010.