'Wii-habilitation' and robotic exoskeletons: technology in physiotherapy

The Lokomat® – a robotic gait exoskeleton, body weight support system, treadmill, and screen mounted at eye level to provide patient with motivation. (Picture courtesy of Hocoma.)

Aideen Henry[1],
Aileen Barrett[2]
[1]RCSI physiotherapy student
[2]Practice Education Co-ordinator,
School of Physiotherapy, RCSI

Abstract

For mobility-impaired patients, gait retraining is an integral part of the rehabilitation programme. Manual assisted body weight support treadmill training (BWSTT) has been a major focus of research and is considered one of the primary methods of gait retraining. In recent years the focus of research has shifted to robotic assisted treadmill training, which is as efficacious as manual assisted BWSTT but is considered more cost-effective with respect to personnel and labour. The Lokomat® is a machine that provides robotic assisted treadmill training by means of a robotic gait orthosis, body weight support system and treadmill. Manufactured by Hocoma in Switzerland, it has been the subject of intense media attention since it was introduced to the US in 2001. Similar attention has been given to the Nintendo Wii™ gaming system for its potential role in rehabilitation. Although not specifically designed for use in the medical arena, the Nintendo Wii™ has been linked with functional rehabilitation benefits in a variety of patient groups. The aim of this paper is to review the clinical applications of the Lokomat® and Nintendo Wii™, and to provide an analysis of the advantages and disadvantages associated with each as a physiotherapy modality in rehabilitation.

Keywords: Physiotherapy, treadmill training, Lokomat®, virtual reality, Nintendo Wii™, gait re-education.

Royal College of Surgeons in Ireland Student Medical Journal 2010; 3: 70-74.

Introduction

Almost 650 million people around the world live with a disability, most of whom require ongoing and intensive physiotherapy and rehabilitation.[1] The most common neurological causes of debilitation include stroke, Parkinson's disease, cerebral palsy, multiple sclerosis and spinal cord injury. The figures for each of these diseases are striking. In the United States there are 5.5 million stroke survivors, the majority of whom suffer with a stroke-related permanent disability.[2] This can cost up to $140,000 in healthcare per patient over the course of their lifetime.[3] Parkinson's disease affects more than one million people in the US, at least four million people worldwide, and approximately 7,000 people in Ireland.[4] An estimated 8,000 babies will be affected by cerebral palsy this year, and approximately 800,000 people have the condition in the US.[5] Multiple sclerosis is one of the most common causes of neurological debilitation, affecting more than 30 per 100,000 of the population in the US.[6] Finally, the incidence of spinal cord injury in the US is estimated at 40 per million, with approximately 12,000 new cases annually.[7]

Patients suffering from these neurological conditions generally experience impairments with balance and proprioception,[8] cardiovascular fitness,[9] co-ordination, motor control,[10] sensation and muscle strength.[11] All of these compromise an independent lifestyle and limit self efficacy, mobility and participation in an active social life.[12] Therefore, rehabilitation that optimises functional capabilities and can return some ambulatory independence is of the utmost importance. Studies have shown that rehabilitation that is intensive, repetitive and task specific can enhance neuro-plasticity[13] and improve motor performance in patients with neurological or orthopaedic lesions.[14] Unfortunately, the high costs of rehabilitation limit its application in the clinical setting.[14] However, many of these techniques can become automated due to their repetitive and mechanical nature, which would make them ideal candidates for technological innovations that play an ever increasing role in rehabilitation.[15]

The restoration of gait is often one of the primary goals in rehabilitation of patients with injury to their neurological system.[16] Gait retraining is based on activating the plasticity of the nervous system. The afferent receptors of the lower limbs are stimulated, which then generates the necessary sensory feedback to train the central pattern receptors in the spinal cord that seem to regulate locomotion.[17] Exercise such as BWSTT involves the gait rehabilitation of the patient on a moving treadmill, while strapped into a harness suspended over the machine, providing support to their trunk. It is vital to the production of neurotrophin 3 (NT3) and BDNF (brain derived neurotrophic factor), which are believed to play an integral role in synaptic plasticity.[18] The exercise of practising a gait cycle on the treadmill results in the generation of sensory feedback and production of the aforementioned factors.

Manual assisted BWSTT has also proven to be beneficial to a patient's progress.[16,19] This technique is similar to BWSTT, with the added component of at least two therapists, who assist in manually moving the patient's limbs in a physiologically correct gait pattern, as the treadmill is in operation. A primary advantage of this method is that little or no ambulatory function is required by the patient to begin gait retraining, leading to improvements in overground gait such as symmetry, endurance and speed post stroke, and an increase in motor impairment and balance scores.[19,20] These improvements have also been maintained at six months following locomotor rehabilitation.[21] Unfortunately, manual assist BWSTT is limited by high operating costs and a risk of injury to therapists, and is not consistent in delivering a repetitive gait pattern.[22]

Lokomat®

The introduction of the Lokomat® has been greeted with widespread enthusiasm since this operating system is expected to overcome the shortcomings of BWSTT. Manufactured in Switzerland by Hocoma AG, the Lokomat® consists of a robotic gait orthosis, a body weight support system and a treadmill.[23]

The patient's legs are strapped into a motorised exoskeleton, which then simulates walking by generating passively guided and symmetrical lower extremity trajectories that are consistent with a typical physiological gait pattern.[15] The reproduced movements include inter-limb co-ordination and gait cycle timing (stance versus swing phase).[23] The software incorporated into the Lokomat® is the distinguishing feature of this machine as it allows precise adjustments of gait pattern as required by the patient. It also maintains constant supervision of the interaction between the patient and the treadmill by means of force transducers placed at each hip and knee. Patient motivation is provided by both the physiotherapist and a screen mounted at eye level that provides an estimate of performance and encourages a reduction in performance error. The body weight support system used by the Lokomat® is called the 'Levi', which is influenced by various fluctuations in order to encourage a more physiological and vertical gait.[23] This weight support allows the patient to train at higher speeds, which may accelerate recovery.[24]

The Lokomat® differs from other gait retraining technologies in that it provides the level of support necessary to begin training at the earliest possible stage. This is particularly important for recovery in stroke patients.[25]

The Lokomat® increases the duration of the gait retraining session, minimises the labour-intensive assistance provided by the physiotherapists and reduces the number of personnel required. Depending on how often it is used, it also has the capacity to allow the patient to be as active as possible throughout the therapy session, which can maximise the activity-dependant plasticity of the spinal cord.[26] Improvements have also been recorded in patients' cardiorespiratory function, bone density, and even bowel motility and tissue health.[27]

There are currently two Lokomats® in operation in Ireland, one at the National Rehabilitation Hospital in Dublin and the second at the First Steps Rehabilitation Clinic in Limerick. Although the settings are different, the physiotherapists using these machines have unanimously supported the use of Lokomat® as a vital component in their neuro-rehabilitation programme.

Disadvantages of the Lokomat® include limitations placed on the upper extremities, pelvis and trunk, which may alter the muscular work required for propulsion and, in turn, lead to a reduced metabolic cost of the exercise.[28,29] The reduction in the metabolic cost of the exercise

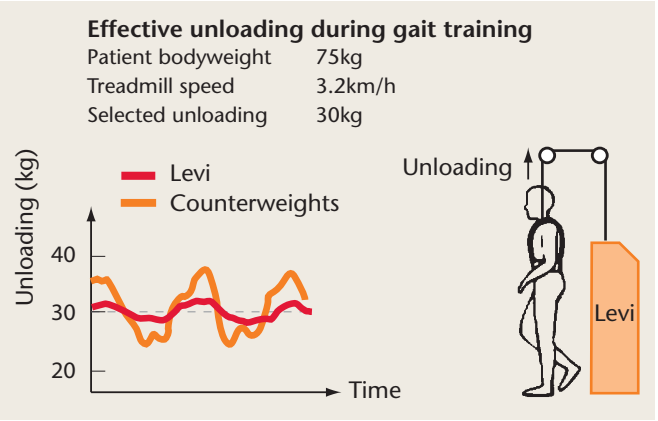

FIGURE 2 (above): Unloading of body weight during training by the Lokomat® body weight support system – the Levi. (Picture courtesy of Hocoma.)
FIGURE 3 (left): A paediatric Lokomat®. (Picture courtesy of Hocoma.)

limits the aerobic benefits that the patient may gain from it. The passive guidance provided by the Lokomat® is a vital component in the initial stages of gait retraining. The patient's limbs are controlled by the robotic exoskeletons, which 'passively guide' the limbs through a physiological gait pattern. However, this assistance may compromise motor learning due to the lack of 'error signals' experienced throughout the gait cycle, thus leading to excessive hip abduction.[25] In other words, the patient does not experience the feeling of mistakes during their training session, and their learning may therefore be limited.

Despite these limitations, the feedback from researchers, physiotherapists and patients has been positive. Patients have reported that the functional gains achieved over the course of their treatment have made a dramatic difference to their daily lives.[27] The official launch of the Lokomat® at the First Steps Rehabilitation Clinic took place on September 14, 2009. Already, the positive effects, both physical and psychological, can be seen in the patients who have used it. In the future, the Lokomat® could potentially be used in conjunction with other therapies to assist in the recovery of a variety of dysfunctions.

Nintendo Wii™

Virtual reality (VR) technology has been used for several years for psychosocial purposes,[30] but interest has now increased in the role that VR technology and gaming may play in the treatment of people with physical disabilities.[31] The interactive rehabilitation exercise programme (IREX), which uses motion capture technology, illustrates the application of a VR system designed specifically for rehabilitation. Unfortunately, this and other VR systems designed for this purpose are either expensive or not commercially available.[32] Focus has therefore shifted to the use of low cost gaming systems as a method of performing task-specific and repetitive exercises in a physiotherapy programme.[33] Of emerging interest is a system that bears no resemblance to the Lokomat® but has found a role as a rehabilitation platform. The Nintendo Wii™ gaming system has been shown to encourage a task-specific, repetitive exercise programme and has already been trialled in many rehabilitation clinics since it was introduced in November 2006. The Wii™ offers a low cost, commercially available alternative to VR and its application may prove to be useful across a variety of medical disciplines. The Wii™ is unique among other gaming systems in that it is based on motion and a spatially sensitive wireless controller, which uses accelerometers in three axes and an infrared sensor bar to recognise and interpret gestures in the environment.[34] The system provides rich multi-sensory feedback such as auditory, haptic and visual components that are often lacking in other VR systems.[32] The Wii Sports™ programme incorporates five different sports activities: tennis; bowling; baseball; golf; and, boxing. In order to play each game, the player needs to respond with specific physical movements that are translated to the movements of the player on screen. These movements are similar to those prescribed in physiotherapy exercises and have a beneficial effect on balance, arm movement, hand–eye co-ordination and posture.[36] This was confirmed by a study at Longwood University that investigated the use of Wii™ in the rehabilitation of arthritis patients. They found that the Wii™ can be a beneficial part of exercise since it employs similar movements to conventional rehabilitation exercises.[37] Physiotherapists in England are also using the Wii™ in the treatment of burns patients to improve flexibility during recovery.

The Wii Fit Balance Board™ has also been used in the treatment of patients with neurological disorders and lower limb amputations. This system incorporates a touch sensitive board into the original console and controller version. The player stands on the board, which detects slight changes in movement and pressure, and allows for the participation of the player in games such as yoga and skiing. Studies are currently underway to assess the role of the Wii Fit Balance Board™ in the reduction of falls and increased confidence in the elderly. Wii Fit™ games are also physically strenuous, which may have a positive impact on a patient's aerobic health, and levels of obesity and inactivity in children.[38] They also allow the patient to play the game in either the sitting or standing positions, which encourages the participation of wheelchair users. A Nintendo Wii™ is now regularly being used in Hospital 2, St James's Hospital in Dublin. It is used primarily in the rehabilitation of stroke patients, the majority of whom seem to enjoy the games while simultaneously receiving rehabilitation benefits. According to Sinead Coleman, Senior Physiotherapist in Care of the Elderly,

Rehabilitation Unit at St James's Hospital, the boxing and bowling games are the most popular, and also the most efficacious in improving balance, trunk control and general upper extremity movements. Scope for the Wii™ to gain a permanent position in conventional rehabilitation programmes remains unclear. In its favour, many studies conclude that the majority of long-term rehabilitation patients spend a significant amount of time in inactive situations without directed or self-directed exercise.[39,40,41] Therefore, the Wii™ may be a useful method of optimising the visual perception, postural control and functional mobility of certain patients. As a means of therapy it is considerably cost-effective, requiring only one physiotherapist to supervise, which depends on the patient, and has a multi-player option.[32] The Wii™ appeals to a broad demographic of people and patients generally report that they enjoy playing the games, which may increase compliance with their programmes and encourage continued use in their homes. Despite its emerging popularity, current research suggests that the Wii™ is not a suitable replacement for more conventional therapies. The movements incorporated by patients while playing the Wii™ are generally more complex than those in a conventional physiotherapy programme. This can complicate attempts to standardise a treatment regimen since patients would perform different motions using different amounts of force.[36] Wii™ Fit games include a number of built-in levels of difficulty. It is not possible to adjust these levels, which may rule out the participation of certain patients.[42] There have also been reports of injuries received while playing the Wii™, such as patellar dislocation, which indicates the need for proper safety precautions.[43] Although the Wii™ certainly allows for more diversity and variety within therapy, further research needs to be done to fully assess its effects with specific patient groups and to standardise a method of playing.

Conclusion

Physiotherapy practices are constantly evolving in conjunction with advances in technology, ultimately producing new ideas and equipment that enhance the effectiveness of therapeutic interventions such as the Lokomat® and the Nintendo Wii™. There are many benefits attributed to the Lokomat®, although the long-term effects of its use remain unclear.[16] Despite limitations such as restriction of movement and alteration of muscle work patterns, the Lokomat® allows patients to execute practised movements in a consistent manner,[17] reduces staffing demands and may prevent injury to therapists.

The use of the Nintendo Wii™ in physiotherapy adds excitement and a unique stimulus to rehabilitation. It is capable of providing similar benefits to VR rehabilitation but without the associated cost and complications.[35] Although not suitable for every patient, the Wii™ has the potential to assist in the rehabilitation of patients with physical and possibly cognitive impairments.

Overall, these new modalities offer a promising new direction for rehabilitation and will hopefully promote the continued integration of technology into physiotherapy. Further research is necessary to better understand the long-term efficacy of the Lokomat® and the Nintendo Wii™, but the field of rehabilitation technology is likely to expand in the near future and maybe even make rehabilitation fun.

Acknowledgements

I would like to thank Aileen Barrett, RCSI, the staff of the National Rehabilitation Hospital, Dublin, Sinead Coleman, Senior Physiotherapist, St James's Hospital, and Jane Evans for their assistance and advice in the writing of this paper.

References

1. **Howard G, Howard VJ, Katholo C, Oli MK, Huston S.** Decline in US stroke mortality: an analysis of temporal patterns by sex, race and geographic region. *Stroke* 2001; 32: 2214-20.
2. **Rosamund W, Flegal K, Furie K *et al.*** Heart disease and stroke statistics 2008 update: a report from the American Heart Association statistics subcommittee. *Circulation* 2008; 117: e25-e146.
3. *Parkinson's Disease Stages and Symptoms.* Cited July 21, 2009. Available from: http://www.stagesofparkinsonsdisease.com/understanding-parkinsons-disease-statistics.php.
4. 4 my child – Cerebral palsy facts and statistics. Cited July 21, 2009. Available from: http://www.cerebralpalsy.org/what-is-cerebral-palsy/statistics/.
5. The Neurology Channel – Multiple Sclerosis. Cited July 21, 2009. Available from: http://www.neurologychannel.com /multiplesclerosis/index.shtml.
6. **The Spinal Cord Injury Information Network.** Spinal Cord Injury Facts and Stats page. Cited July 21, 2009. Available from: http://www.spinalcord.uab.edu/show.asp?durki=119513.
7. **Tyson S, Selley A.** A content analysis of physiotherapy for postural control in people with stroke: an observational study. *Disabil Rehabil* 2006; 28: 865-72.
8. **Potempa K, Lopez M, Braun LT, Szidon JP, Fogg L, Tincknell T.** Physiological outcomes of aerobic exercise training in hemiparetic stroke patients. *Stroke* 1995; 26: 101-5.
9. **Duncan P, Studenski S, Richards L *et al.*** Randomised clinical trial of therapeutic exercise in subacute stroke. *Stroke* 2003; 34: 2173-80.
10. **Duncan P, Richards L, Wallace D *et al.*** A randomised, controlled pilot study of a home based exercise program for individuals with mild and moderate stroke. *Stroke* 1998; 29: 2055-60.
11. **Rimmer JH, Riley BB.** A new measure for assessing the physical activity behaviours of persons with disabilities and chronic health conditions: the physical activity and disability survey. *Am J Health Promot* 2001; 16: 34-42.

12. **Meyer-Heim A, Ammann-Reiffer C, Schmartz A *et al.*** Improvement of walking abilities after robotic-assisted locomotion training in children with cerebral palsy. *Arch Dis Child* 2009; 94: 615-20.
13. **Riener R, Lunenburger L, Jezernik S, Anderschitz M, Columbo G, Dietz V.** Patient-co-operative strategies for robot-aided treadmill training: first experimental results. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 2005; 13: 380-94.
14. **Hornby GT, Zemon DH, Campbell D.** Robotic assisted body-weight supported treadmill training in individuals following motor incomplete spinal cord injury. *Phys Ther* 2005; 85: 52-66.
15. **Danielsson A, Stribrant Sunnerhagen K.** Oxygen consumption during treadmill walking with and without body weight support in patients with hemiparesis after stroke and in healthy subjects. *Arch Phys Med Rehabil* 2000; 81: 953-7.
16. **Hidler JM, Wall AE.** Alterations in muscle activation patterns during robotic-assisted walking. *Clinical Biomechanics* 2005; 20: 184-93.
17. **Hutchinson KJ, Gomez-Pinilla F, Crowe MJ, Ying Z, Basso M.** Three exercise paradigms differentially improve sensory recovery after spinal cord contusion in rats. *Brain* 2004; 127: 1403-14.
18. **McCain KJ, Pollo FE, Baum BS, Coleman SC, Baker S, Smith PS.** Locomotor treadmill training with partial body weight support before overground gait in adults with acute stroke: a pilot study. *Arch Phys Med Rehabil* 2008; 89: 684-91.
19. **Visintin M, Barbeau H, Korner-Bittensky N, Mayo NE.** A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. *Stroke* 1998; 29: 1122-8.
20. **Sullivan KJ, Knowlton BJ, Dobkin BH.** Step training with body weight support: effect of treadmill speed and practice paradigms on poststroke locomotor recovery. *Arch Phys Med Rehabil* 2002; 83: 683-91.
21. **Westlake KP, Patten C.** Pilot study of Lokomat versus manual-assisted treadmill training for locomotor recovery post stroke. *Journal of Neuroengineering and Rehabilitation* 2009; 6: 18.
22. **The Hocoma Website.** Hocoma Features and functions of the Lokomat page. Cited July 10, 2009. Available from: http://www.hocoma.ch/en/products/lokomat/features-functions/.
23. **Pohl M, Mehrholz J, Ritschel C, Ruckriem S.** Speed-dependant treadmill training in ambulatory hemiparetic stroke patients: a randomised control trial. *Stroke* 2002; 33: 553-8.
24. **Horn SD, DeJong G, Smout RJ, Gassaway J, James R, Conroy B.** Stroke rehabilitation patients, practice and outcomes: is earlier and more aggressive therapy better? *Arch Phys Med Rehabil* 2005; 85: s101-s14.
25. **Huang H, Ferris DP.** Neural coupling between upper and lower limbs during recumbent stepping. *J Appl Physiol* 2004; 97: 1299-1308.
26. **Edgerton VR, Roy RR.** Paralysis recovery in humans and model systems. *Current Opin Neurobiol* 2002; 12: 658-67.
27. **Gottschall JS, Kram R.** Energy cost and muscular activity required for propulsion during walking. *J Appl Physiol* 2003; 94: 1766-72.
28. **Macko RF, Ivey FM, Forrester LW.** Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke. *Stroke* 2005; 36: 2206-11.
29. **Keshner EA.** Virtual reality and physical rehabilitation: a new toy or a new research and rehabilitation tool? *Journal of Neuroengineering and Rehabilitation* 2004; 1: 13.
30. **Cobb SVG, Sharkey PM.** A decade of research and development in disability, virtual reality and associated technologies: review of ICDVRAT 1996-2006. *The International Journal of Virtual Reality* 2007; 6: 51-68.
31. **Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P.** Use of a low cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. *Phys Ther* 2008; 88: 1196-207.
32. **Flynn S, Palma P, Bender A.** Feasibility of using the Sony Playstation 2 gaming platform for an individual post stroke: a case report. *Journal of Neurologic Physical Therapy* 2007; 31: 180-9.
33. **Halton J.** Virtual rehabilitation with video games: a new frontier for occupational therapy. *Occupational Therapy Now* 2008. Cited August 5, 2009. Available from: http://www.caot.ca/otnow/jan%2008/virtual.pdf.
34. **Crosbie J, Lennon S, Basford JR, McDonough SM.** Virtual reality in stroke rehabilitation: still more virtual than real. *Disabil and Rehabil* 2007; 29: 1139-46.
35. **Peltier M.** Wii can work it out. *Nursing Homes: Long Term Care Management* 2007; 56: 72-3.
36. **Sutton MA.** New technologies gain popularity with older adults. *Adult Development and Aging News* 2008.
37. **Daley A.** Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics* 2009; 124: 763-71.
38. **Tinson DJ.** How stroke patients spend their days, an observational study of the treatment regime offered to patients with movement disorders in hospitals following stroke. *Int Disabil Studies* 1989; 11: 45-9.
39. **Lincoln NB, Gamlen R, Thomason H.** Behavioural mapping of patients on a stroke unit. *Int Disabil Studies* 1989; 11: 149-54.
40. **Esmonde T, McGinley J, Goldie P *et al.*** Stroke rehabilitation: patient activity during non-therapy time. *Austral J Physio-ther* 1997; 43: 43-51.
41. **Flynn SM, Lange BS, Yeh SC, Rizzo AA.** Virtual reality rehabilitation – what do users with disabilities want? Cited August 5, 2009. Available from: http://playpen.icomtek.csir.co.za/~acdc/assistive%20devices/Artabilitation2008/archive/2008/papers/ICDVRAT2008_S03_N03_Flynn_Lange_Yeh_Rizzo.pdf.
42. **Hirpara KM, Abouazza OA.** The "Wii Knee": a case of patellar dislocation secondary to computer video games. *Injury Extra* 2008; 39: 86-7.