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Evaluation of a specific balance and coordination programme for individuals with a traumatic brain injury

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The purpose of this study was to evaluate the effectiveness of an aerobic dancing training, designed to reduce postural imbalance and coordination deficits for individuals who had sustained a traumatic brain injury (TBI). A two group experimental design was conducted. A control group participated in a traditional muscular training (TMT) programme while participants in the experimental group were assigned to an aerobic dancing, Slide™ and Step™ training programme (specific training group (ST)). Participants were evaluated pre- and post-training. Balance was quantified using a force platform and coordination using a Peak Performance system to compare the velocity profiles of a modified Jumping jack test. Results showed that temporal variables were significantly different pre- and post-training for the ST group, but no changes were found in the TMT group. The results of the balance test indicated a significant reduction of postural sway area in the ST group but not in the TMT group. Overall, the combination workout with Step™ and Slide™ is more effective in reducing balance and coordination deficits when compared to muscular based training.

Introduction

Following traumatic brain injury (TBI), individuals experience cognitive, behavioural, and emotional sequela. In 33% of cases, people with severe TBI have post-traumatic postural control and coordination deficits [1, 2]. This reduced ability to control posture can be reflected by modifications in gait patterns and in functional activities, such as stair climbing [3]. Since postural control implies complex interactions between the musculoskeletal and neural systems, a lesion in one of these systems can disrupt normal postural control [4]. Subsequent to a TBI, postural control impairment is often related to a deficit of neuronal pathways that process visual, vestibular, and proprioceptive information involved in maintaining stability [1]. Several studies have shown that participants with TBI have augmented postural sway in quiet stance, reflected by increased movement of the centre of pressure when compared to healthy participants. Dault and Dugas [5] found that participants with TBI showed more than double the amount

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of sway in anterio-posterior direction when compared to healthy age matched controls. The postural imbalance can also persist many years after trauma and the rehabilitation process [6]. In addition to balance deficits, individuals with TBI often experience motor coordination deficits in daily activities, such as dressing or tying shoelaces [7].

Balance and coordination deficits present a major barrier to the return to professional life following a TBI. Vanier [8] notes that only 35% of individuals with severe TBI return to work in 2 years following the accident and those that do often have to modify their professional or job ranking. Since the majority of TBI individuals are young (between 15–24 years old), training programmes that may improve the probability of return to vocational activities must be considered [9].

A longitudinal study [6] showed that participants with TBI remain with deficits in postural control and coordination, even after their rehabilitation was completed. This problem could reflect insufficient stimulation in motor rehabilitation of posture and balance. In designing a rehabilitation programme, therapists need to take into account all the deficits related to the TBI and prescribe a programme that stimulates the different systems related to the nature of the deficit [10]. Recently, balance rehabilitation that challenges body stability has been advocated for cerebellar patients [11] and the elderly [12]. Berrol and Katz [13] proposed dance therapy to help TBI participants find autonomy in various domains of human life. Dance therapy can stimulate physical, psychomotor, cognitive, and emotional components. This stimulation is essential to cortical reorganization in the aftermath of TBI. Berrol [14] reported a case study of a 35-year-old man who sustained post-traumatic coma lasting 1 month and was hospitalized for 3 months. After his discharge, he entered a dance and movement therapy programme for 4 months. The results indicated substantial improvements in coordination, balance, and range of movement. Two years after training, the man was living by himself and attending a community college. This case study highlights the potential benefits of dance therapy in this population to reduce deficits relating to postural control and motor coordination.

Aerobic dancing has been shown to improve cardiovascular endurance, flexibility, muscular endurance, and static balance in young and elderly women [15, 16]. Reese and Lavery [17] proposed a training programme involving Slide™ to improve proprioception. This type of training consists of participants sliding from one stopper to the other on a slippery surface while maintaining their balance. Participants must control movement of the trunk in order to maintain balance and prevent falls from occurring due to the slippery surface [18]. Step training consists of stepping up onto and down from a bench with alternate legs. Since upper and lower limbs are necessarily coordinated in this movement, such training could help to improve multijoint coordination. A combined aerobic dancing, Step™ and Slide™ training programme seems to provide an excellent rehabilitation programme since it stimulates all the different sensory systems involved in balance control and requires multi-limb coordination. Therefore, the purpose of this preliminary study was to evaluate the effectiveness of a training programme that combined aerobic dancing, Slide™ and Step™ training, to reduce postural imbalance and coordination deficits in TBI participants compared to normally-prescribed muscular training.

Method

Participants

Ten TBI participants were recruited from the InterVal Rehabilitation Centre in Trois-Rivières, Québec. They were selected by physical educators and a therapist at the Centre. The selection criteria were (a) the ability to walk without external help, (b) no orthopaedic problems that could be aggravated by training, and (c) their availability and motivation to participate in the programme. Ten individuals demonstrated an interest for the study and were aged between 18–54 years old (mean age 29.6 ± 11.3). The sample was mostly composed of men (75%), which is representative of the TBI population [19]. Informed consent was obtained from all participants, and the project was approved by the Ethics Committee of the Rehabilitation Centre. Five participants were assigned to the specific training group (ST) based on their reported availability to participate in the 12-week programme. Two participants (#4 and #5) from this group were still involved in the rehabilitation treatment on a daily basis during the study. The remaining five participants were assigned to the traditional muscular training (TMT) programme prescribed at the centre. Two participants of the TMT group did not complete the study therefore only three participants from the TMT were included in the analysis. The participants' medical files were consulted to determine if there were any contraindications to physical activity. Diagnoses and severity of lesions are stated in table 1.

Coordination assessment

Coordination was evaluated by using a jumping jack movement. This task requires coordinated movements of the upper and lower extremities in a rhythmic fashion [20]. Since some of the participants could not jump easily, the jumping jack test was modified. Thus, the participants were asked to lie in a supine position, on a low-friction surface (3 Slides™), and execute eight jumping jack movements at a

Table 1. Participant demographics

P[a]	Sex	Age (years)	Group	IBIBT[b] (months)	General medical information
1	M	35	ST	104	Severe HI, L frontal contusion, L temporal craniotomy
2	F	27	ST	84	Severe HI, $2\frac{1}{2}$ months PTC[c]
3	M	25	ST	106	Severe HI, polytraumatism, L hemiplegia
4	M	18	ST	6	Severe HI, marked cerebral oedema
5	F	54	ST	10	Severe HI, 11-days PTA, 1-month PTC, R occipital haematoma
6	M	27	TMT	7	Mild HI, less than 24 h PTA, L frontal skull fracture, Severe HI,
7	M	20	TMT	13	Severe HI, 2-month coma, 3-months PTC, poor coordination
8	M	31	TMT	25	L subarachnoid haematoma, R hemiplegia

[a] P: Participant number.
[b] IBIBT: Interval between injury and the beginning of training.
[c] PTC: post traumatic coma.
L = left; R = right.

self-chosen pace (see figure 1). Reflective markers were placed on the wrists, knees and umbilical point. The knee joint was chosen rather than the ankle joint as a reference point, since the recording area was restricted due to ceiling height, where the digital camera was placed. Reflective marker displacement was tracked by a video camera (Panasonic WV-3990, 60 Hz) installed above the participant. Calibration was performed using a standard metre stick. The video recordings were digitized with a Peak Performance Technologies Inc. system, and were filtered with a second order low pass Butterworth filter. Cut-off frequencies were between 5–6 Hz for each curve; these were determined and filtering was done by using the Peak 5 filtering package. To quantify coordination, the temporal difference between the time to reach peak velocity for each limb in every cycle was used. Peak velocity was determined by visually inspecting velocity values for each cycle. This temporal difference was defined as the temporal delay, and analysis was done by comparing the right and left side for both wrists and knees. A paired *t*-test was conducted to compare the differences between pre- and post-training because of the small sample size and also because the data was not normally distributed.

Balance assessment

The Clinical Test for Sensory Interaction in Balance (CTSIB) was chosen to quantify postural control [21]. The CTSIB consists of six conditions in which visual

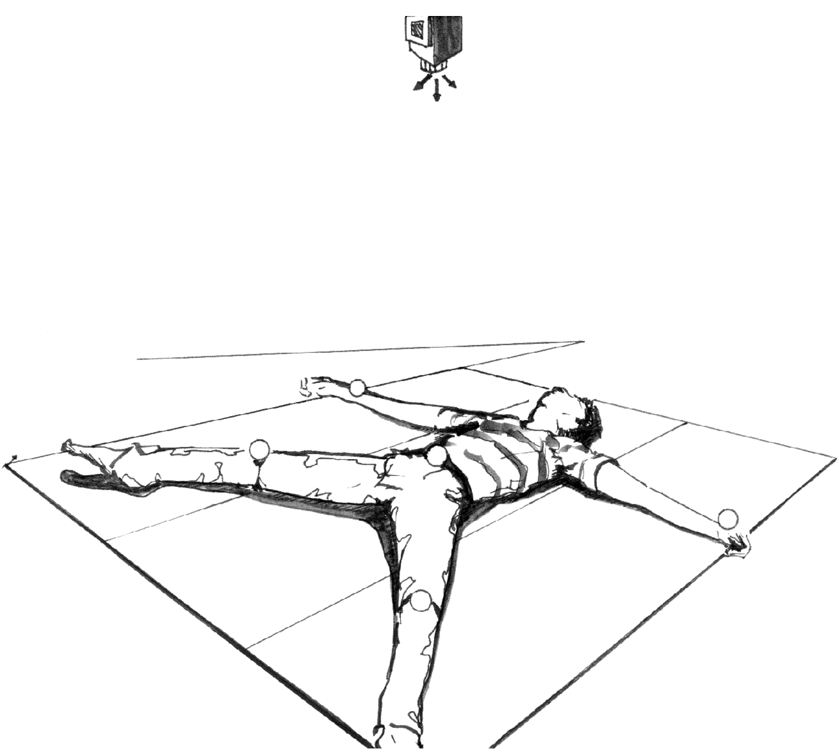

Figure 1. Illustration of modified Jumping Jack and camera placement. The participant is lying on three Slides™ to facilitate execution of movement.

and proprioceptive information is modified. The participants were asked to stand with feet shoulder width apart and both arms at their sides on a force platform for two consecutive trials of 20 seconds for each condition. The order of conditions was randomly presented. For the first three conditions, they stood on a flat surface, and for conditions 4, 5 and 6, participants stood on a piece of foam 15-cm thick. The foam was used to minimize proprioceptive input. To manipulate visual input, three different visual conditions were used: normal vision, no vision, and modified vision with a conflict dome similar to the one used by Shumway-Cook and Horak [21]. The conflict dome, constructed from a baseball batter's hat, altered the visual reference points generally used to maintain posture. A hard plastic visor was added and placed 6 cm from the eyes before attaching a black and white vertically striped-pattern. To ensure that participants couldn't use visual reference points for balance, a white material was placed under and on top of the visor to obstruct vision. The participants were asked to look at an X placed in the middle of the visor to prevent dizziness. The six conditions were completely randomized for each participant. Conditions 1 and 6 from this protocol are illustrated in figure 2.

Postural sway was monitored using a force platform (AMTI OR6-S200) with strain gauges in all four corners connected to an A/D converter and a computer. The strain gauges registered forces and moments in the x, y, z-planes. Peak Performance Technologies Inc. Software was used to calculate centre of pressure (COP) displacements from these values. These signals were sampled at 100 Hz. The perimeter of the sway area (COP displacement) over 20 seconds was measured, using a digitizing tablet (Wacom) with an interactive computer program. Patterns were traced manually three times, and the average was calculated to determine the sway area for each trial. Statistical analysis was performed on the mean of both trials

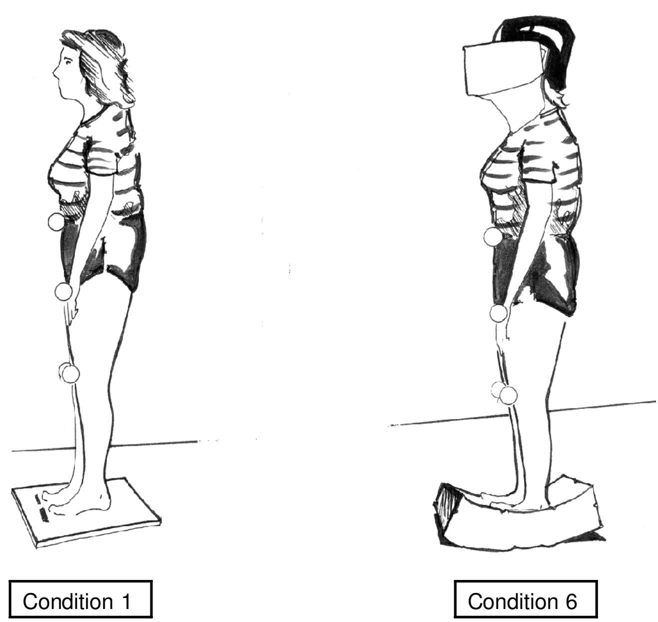

Figure 2. Illustration of conditions 1 and 6 of CTSIB. For description, see text.

for each condition. A Friedman Test was first conducted to determine if the pre- and post-training effect was different across balance test conditions. The results of this analysis showed no significant postural sway differences across the six conditions. Therefore, a paired *t*-test was conducted on the average of all conditions for each group separately to compare the differences in sway area between pre- and post-training. Results were considered significant when $p < 0.05$.

Training

The TMT group continued the usually prescribed muscular training by the physical educators of the Centre, using weight-training equipment (Nautilus^{TM}). This standardized programme was commonly used at the Centre to improve muscular strength and endurance. Training sessions lasted 60 minutes twice a week for 12 weeks. Mean training time was 900 ± 330 minutes. The ST group trained with a combined aerobic dancing, Step^{TM} and Slide^{TM} programme. Training sessions lasted 30 minutes twice a week for 12 weeks. Mean training time was 500 ± 81 minutes. Before allowing participants to perform on the Slide^{TM}, the instructor observed each participant for the first 2 weeks in order to have a better understanding of their balance deficits: the Slide^{TM} component was included at the end of the second week.

After a general warm-up, the first part of the ST group training session consisted of a combination of various movements performed in aerobic dance classes. However, the level of difficulty was adapted to meet the motor ability of each individual. The speed of execution was reduced and most movements were repeated many times. In the second part, the participants followed different Step^{TM} movements indicated by the experimenter. For example, they walked up and down the Step^{TM} for eight counts and then did a knee lift by alternating the leading leg on every count. The Slide^{TM} portion of training took place in the last part of each session. The participants were asked to move from one end of the slide to the other and execute various movements when they approached the stopper. With training, the complexity and difficulty of movements were intensified, by adding arm motions and increasing speed. By the end of training, the goal was to execute four aerobic dancing movements, eight Step^{TM} movements and eight Slide^{TM} movements without any help from the instructor. A daily record was kept to monitor the progression of each participant in the ST group.

Results

Progress in training programme

The results from this restricted group of participants revealed that all participants exhibited rapid improvements in their ability to perform the workout movements. Indeed, at the end of the second week, most participants could perform all four workout movements. By the 8th week, all participants were capable of executing all the basic movements for each component of the programme. In subsequent weeks, training was devoted to increasing speed of execution and following the imposed rhythm.

Kinematic analysis of jumping jack movements

Participant 5 demonstrated the largest improvement. The velocity patterns of the wrists and knees for participant 5 of the ST group are presented in figure 3. This subject exhibited a major coordination deficit before training, revealed by large variability of the opening and closing movements of the arms and legs between cycles. The first two cycles of wrist movements were executed very rapidly (0.53 m/s and 0.51 m/s) and the last three were done much slower (mean speed of 0.37 ± 0.06 m/s) on the left side. A similar pattern was observed on the right side, although with much slower peak speeds in all five cycles (mean speed 0.27 ± 0.07 m/s). Moreover, peak speeds for the wrists and knees were not reached at the same time, indicating a clear asynchrony in execution of the movement. Figure 4 illustrates the movement patterns of the same participant after training. The patterns were more synchronous and the peak speeds higher and quite stable over the cycles (mean speed 0.69 ± 0.06 m/s). Movements were executed much slower before training (42.4 s for the five cycles) compared to after training (12.4 s for the

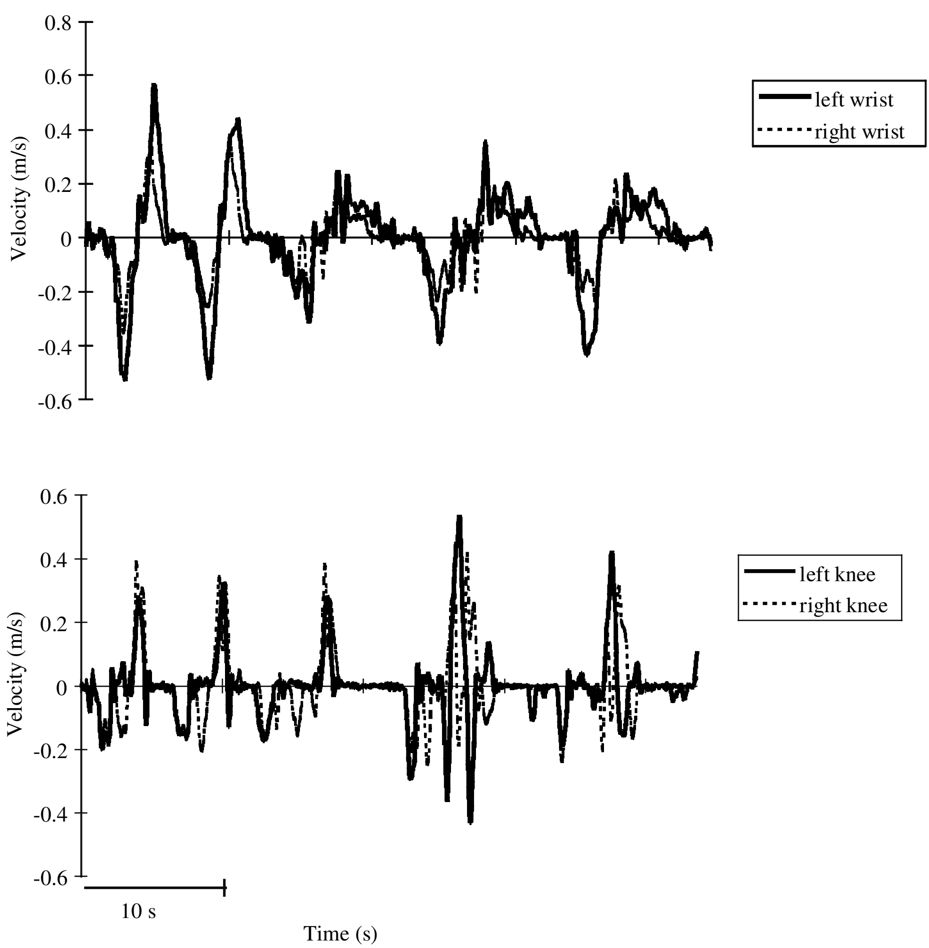

Figure 3. Velocity of the left and right wrists (top panel) and of the left and right knees (bottom panel) for participant 5 pre-training.

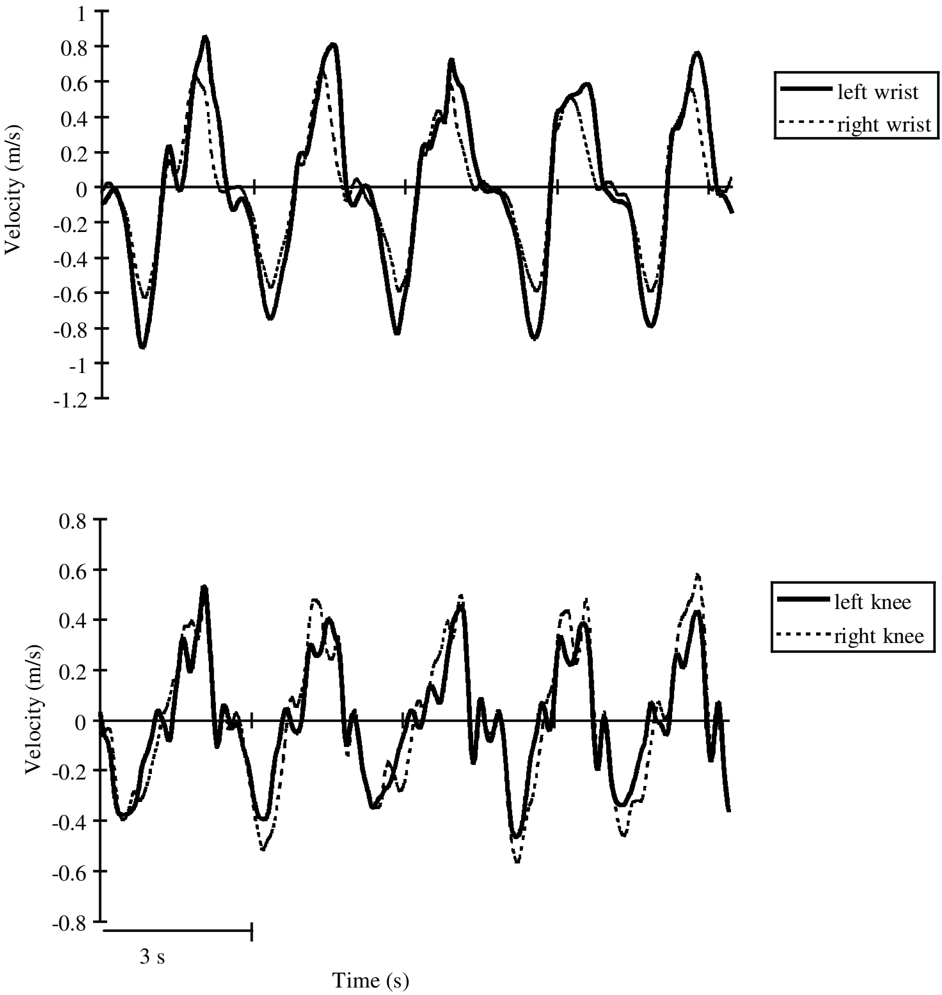

Figure 4. *Velocity of the left and right wrists (top panel) and of the left and right knee (bottom panel) for participant 5 post-training. Note that temporal scaling is different from figure 3.*

five cycles). Overall, the pattern after training was closer to what is observed in a control participant (figure 5). Thus, this participant showed a large improvement in multilimb coordination following the specific training programme.

Paired *t*-tests indicated that there was a significant difference in the temporal delay observed at the wrists pre- and post-training in the ST group ($t = 3.03$; $p < 0.01$). Results were not significant for the TMT group (see table 2). The difference in temporal delay pre- and post-training was 83 ms for the ST group and 13 ms for the TMT group (see figure 6). Similar results were found for the knees, the ST group showed significant improvement ($t = 3.67$; $p < 0.001$), whereas the TMT group did not show any significant changes. This reduction of temporal delay for maximum speed of the wrist and knees reflected improved synchronization of the upper and lower limbs after training. It is important to note that the two groups did not start with the same deficits in temporal coordination. Therefore, this should be considered in the interpretation of the results.

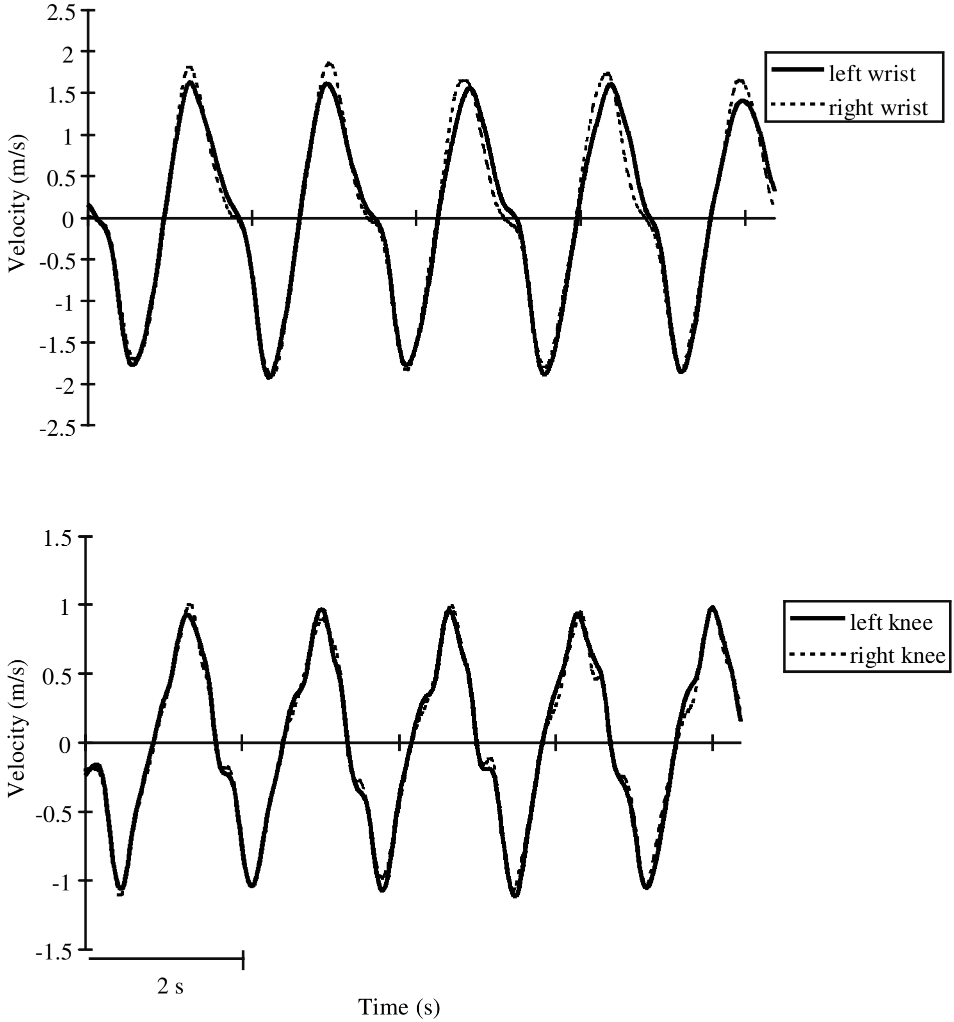

Figure 5. Velocity of the left and right wrists (top panel) and of the left and right knees (bottom panel) for a control participant. Note that temporal scaling is different from figure 4.

Table 2. Temporal delay of the wrists in ms

Groups	Participants	Pre-training	Post-training	Pre–post
ST	1	62.7 ± 76.0	23.1 ± 35.0	39.6 ± 42.0
	2	42.9 ± 38.0	56.1 ± 47.0	−13.2 ± 9.0*
	3	198.0 ± 155.0	25.7 ± 28.0	172.3 ± 128.0
	4	99.0 ± 76.0	56.1 ± 31.0	42.9 ± 45.0
	5	264.0 ± 289.0	89.0 ± 114.0	174.9 ± 175.0
TMT	6	89.1 ± 84.0	42.9 ± 44.0	46.2 ± 40.0
	7	128.7 ± 131.0	118.8 ± 68.0	9.9 ± 63.0
	8	52.8 ± 72.0	69.3 ± 59.0	−1.65 ± 13.0*

*Negative values indicate a deterioration in movement performance.

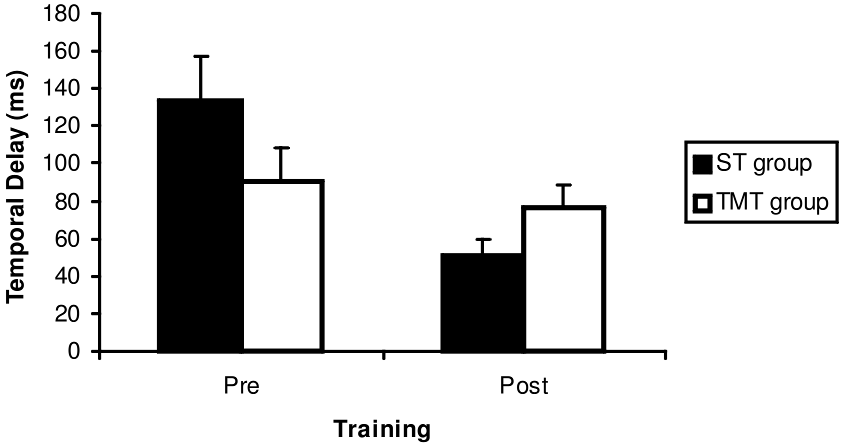

Figure 6. Mean temporal delays of the wrists, pre- and post-training for both groups.

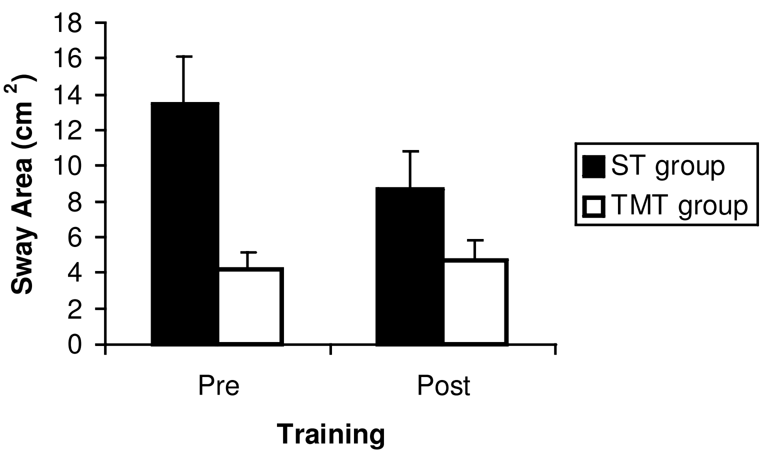

Figure 7. Mean sway area, pre- and post-training for both groups.

Analysis of balance

Paired *t*-test revealed significant differences in sway area between pre- and post-training for the ST group ($t = 2.14$; $p < 0.05$) but not for the TMT group (see figure 7).

Discussion

The primary goal of this preliminary study was to evaluate the efficiency of a combined aerobic dancing, Slide^{TM} and Step^{TM} training programme to reduce balance and coordination deficits in participants with TBI. The training programme was designed to stimulate the various processes involved in postural control, in particular proprioception and vestibular processes. This programme took into account individual differences and specificity of training, as suggested by Horak *et* *al.* [10]. In the Slide^{TM} portion of the programme, participants had to maintain a high level of attention in order to compensate for the difficulty of the task. Due to the slipperiness of the surface, this task afforded high proprioceptive training. The Step^{TM} training was chosen because of the frequent directional changes and modifications from single to double stance which provides high vestibular stimulation. The participants followed the same program,me but the speed of progression was adjusted to the needs and pace of each individual.

Temporal coordination in the ST group improved significantly with training while no significant changes were noted in the TMT group. Thus, the stimulation provided by these rhythmic movements allowed most participants to improve multijoint coordination. Also, as illustrated in figure 6, before training, the ST group had larger temporal delays compared to the TMT group. After training, the results of the ST group were clearly smaller than those of the TMT group, indicating that this type of muscular training had very little effect on multilimb coordination.

The sway area was visibly reduced after training in the ST group compared to the TMT group. This suggests that participation in this combined aerobic dancing, Step^{TM} and Slide^{TM} training programme lead to improvements in postural control. The fact that such changes did not occur in the TMT group suggests that balance rehabilitation is more effective when various postural control strategies are elicited [10].

Cohadon *et al.* [22] suggested that it is easier to regain a pre-morbid profile when the rehabilitation process is started as soon as possible after trauma. Some participants still showed improvements even if the TBI occurred many years prior to the beginning of training. This indicates that potential for improvement is still present many years after TBI if the appropriate training programme is adopted.

Certain participants exhibited large improvements while others had less or no improvement. Participant 1 demonstrated major changes in coordination but much less with balance. Before training, this participant could maintain balance for only one trial of condition 5 and 6 due to dizziness. However, after training, he completed both trials, although the sway area remained unchanged when compared to the pre-training values. One must remember that this participant had sustained his injury more that 8 years before beginning this study. Participant 2 demonstrated no improvement in coordination and balance. This may have been related to the fact that she was previously involved in a similar type of exercise training for the past 7 years. Prior experience probably improved her coordination, since she had the best evaluation before training among the participants. She was still included in the study since the selection criteria did not control for prior exercise experience. Thus, this probably minimized the impact of the programme. Participant 3 demonstrated large improvements in coordination and a smaller progression in balance. Because this participant had sustained injury more than 8 years before the beginning of the study, these modifications were unexpected. The participant had a left hemiplegia before starting the training programme. In most daily tasks, he used his right limb and rarely his left arm. In the training programme, both arms were stimulated equally and this could probably explain the improvements observed in coordination. Even though participant 4 completed his training 2 weeks before the rest of the group (because he moved to another city), he demonstrated marked improvement in the sway area and in coordination. This could be related to the fact that the training programme was started only 6 months after trauma. Participant 5 had the largest deficits in terms of balance and coordination before training and showed the most spectacular progression. Two factors probably influenced this outcome. Initially, she began training less than 10 months after her injury and was still involved in rehabilitation treatment on a daily basis during this study. Secondly, she was highly motivated and attended nearly all training sessions. Finally, three participants (#1, 3, 5) reported that following this programme they felt more efficient while executing daily activities, such as going from the sidewalk to the street and going up stairs without using the railing. Therapists working with these participants also confirmed these improvements in daily activities.

The TMT group was also heterogeneous. This group included participant 6, who had a mild HI. Participant 8 showed significant improvement in balance. Muscular training was probably the appropriate training for him, since his balance deficits were caused by a hemiplegia and muscular weakness. Participant 7 did not show any improvement in balance or coordination.

The Step™ training seemed to be an effective tool in stimulating various processes involved in balance control and in multi-limb coordination, since participants had to initiate directional changes and were constantly involved in weight shifting movements. The Slide™ training was also appealing, since it requires constant awareness of the body in space and necessitates adequate control of all body segments in order to maintain balance on the slippery surface.

Balance and coordination deficits are present in 33% of individuals with TBI [1]. These deficits may persist for several years after the injury [6]. Consequently, it is important to develop rehabilitation programmes that optimally challenge sensory and motor strategies in the control of standing balance as well as multi-limb coordination. The specific training programme suggested in this study was effective in stimulating all processes involved in balance control and coordination. Furthermore, this training programme was so effective that participants who had sustained a TBI more than 8 years prior to the initiation of the programme were still able to demonstrate improvement.

Another important aspect to consider in designing an adequate rehabilitation programme is motivation. Individuals enjoyed participating in this training programme, which led them to work to their full potential during each training session. This combined aerobic dancing, Slide™ and Step™ training programme was both stimulating and efficient. It offers structures training sessions where participants take charge of their own progression, resulting in a sense of independence and self-fulfilment. The potential recovery is maximized, which results in a better quality of life to the injured individual.

Conclusion

The results of this preliminary study indicate that a combination of aerobic dancing, Step™ and Slide™ is more effective in reducing balance and coordination deficits when compared to muscular based training. A key finding of this programme was that a reduction in balance and coordination deficits was still found in participants who had sustained a TBI several years before the start of the training. This may suggest that current rehabilitation treatment could focus more on long term care with this population. This specific aerobic dancing, Step™ and Slide™ training programme considers numerous facets of the individual, since it takes into account motor and sensory systems as well as cognitive and psychological processes.

Rehabilitation professionals should consider incorporating a training programme such as this in their interventions. Future research is needed to examine the effects of this type of aerobic dancing, Step™ and Slide™ training programme on a larger population.

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References

1. Wober, C., Oder, W., Kollegger, H. *et al.*: Posturographic measurement of body sway in survivors of severe closed head injury *Archives in Physical Rehabilatation*, **74**: 1151–1156, 1993.
2. Geurts, A. C. H., Knoop, J. A. and van Limbeek, J.: Is postural control associated with mental functionning in the persistent postconcussion syndrome? *Archives of Physical Medicine and Rehabilitation*, **80**: 144–149, 1999.
3. Wade, L. D., Canning, C. G., Fowler, V. *et al.*: Changes in postural sway and performance of functional tasks during rehabilitation after traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, **78**: 1107–1111, 1997.
4. Shumway-Cook, A. and Olmscheid, R.: A systems analysis of postural dyscontrol in traumatically brain-injured patients. *Journal of Head Trauma Rehabilibitation*, **5**: 51–62, 1990.
5. Dault, M. C. and Dugas, C.: Equilibrium assessement of head-injured participants with a modified version of the Romberg test. In: D. Drouin, C. Lépine and C. Simard (editors) *Proceedings of the 11th International Symposium for Adapted Physical Education* (Québec, Canada), pp. 59–70, 1999.
6. Geurts, A. C. H., Ribbers, G. M., Knoops, J. A. *et al.*: Identification of static and dynamic postural instability following traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, **77**: 639–644, 1996.
7. Ashley, M. J. and Krych, D .K.: Traumatic Brain Injury Rehabilitation (New York: CRC), 1995.
8. Vanier, M.: Traumatisme cranio-encéphalique grave: développement d'un système informatisé d'évaluation globale. *Le Clinicien*, **8**: 105–118, 1993.
9. Leahy, P.: Traumatic head injury. In: S. B. O'Sullivan, and T. J. Schmitz (editors) *Physical Rehabilitation: Assessment and Treatment* (Philadelphia: F.A. Davis), pp. 491–507, 1994.
10. Horak, F. B., Henry, S. M. and Shumway-Cook, A.: Postural perturbations: new insights for treatment of balance disorders. *Physical Therapy*, **77**: 517–533, 1997.
11. Gill-Body, K. M., Popat, R. A., Parker, S. W. *et al.*: Rehabilitation of balance in two patients with cerebellar dysfunction. *Physical Therapy*, **77**: 552–555, 1997.
12. Buchner, D. M., Cress, M. E., de Lateur, B. J. *et al.*: A comparison of the effects of three types of endurance training on balance and other fall risk factors in older adults. *Aging and Clinical Experimental Research*, **9**: 112–119, 1997.
13. Berrol, C. and Katz, S.: Dance/movement therapy in the rehabilitation of individuals surviving severe head injuries *American Journal of Dance Therapy*, **8**: 46–66, 1985.
14. Berrol, C.: Dance/movement therapy in head injury rehabilitation. *Brain Injury*, **4**: 257–265, 1990.
15. Hopkins, D. R., Murrah, B., Hoeger, W. W. K. *et al.*: Effect of low-impact aerobic dance on the functional fitness of elderly women. *Gerontologist*, **30**: 189–192, 1990.
16. Scharff-Olson, M., Williford, H. N., Blessing, D. L. *et al.*: The cardiovascular and metabolic effects of bench stepping exercise in females. *Medicine & Science in Sports & Exercise*, **23**: 1311–1318, 1991.

17. Reese, S. and Lavery, K.: Slide boards: a conditioning and rehabilitative tool. *National Strength Conditioning Association*, **13**: 22–24, 1991.
18. Hagan, M.: Slide training. *The program. Slide Training Seminar*, Toronto, 1992.
19. Bergego, C. and Azouvi, P.: *Neuropsychologie des traumatismes crâniens graves de l'adulte* (Paris: Édition Frisson-Roche), 1995.
20. Burton, A. W.: Applying principles of coordination in adapted physical education. *Adapted Physical Activity Quarterly*, **7**: 126–142, 1990.
21. Shumway-Cook, A. and Horak, F. B.: Assessing the influence of sensory interaction on balance. *Physical Therapy*, **66**: 1548–1550, 1986.
22. Cohadon, F., Richer, E., Reglade, C. *et al.*: Recovery of motor function after severe traumatic coma. *Scandinavian Journal of Rehabilitation Medicine Supplement*, **17**: 75–85, 1988.