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Benefits of activity and virtual reality based balance exercise programmes for adults with traumatic brain injury: Perceptions of participants and their caregivers

M. THORNTON[1], S. MARSHALL[2], J. McCOMAS[3], H. FINESTONE[4], A. McCORMICK[5], & H. SVEISTRUP[1,3]

[1]*School of Human Kinetics, University of Ottawa,* [2]*The Rehabilitation Center,* [3]*School of Rehabilitation Sciences, University of Ottawa,* [4]*Sisters of Charity of Ottawa Health Services, and* [5]*Children's Hospital of Eastern Ontario, Canada*

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Abstract

Objective: To explore multi-dimensional benefits of exercise participation perceived by adults with traumatic brain injury (TBI) and their caregivers.

Methods: Adults ($n = 27$, aged 18–66) with moderate or severe TBI 6 months or more earlier participated in focus groups following 6 weeks of an activity-based (ABE) or a virtual reality (VR) delivered balance exercise programme. Family members and care providers participated in separate focus groups. Perceptions related to programme participation as well as balance confidence and lower extremity function were extracted from focus group verbatim and quantitative scales, respectively.

Outcomes: Benefits in three domains, psychosocial, physical and programme, were identified from transcription and analyses of focus group verbatim. Improvements were noted in balance confidence and function in both groups. Substantially greater enthusiasm and knowledge was expressed by participants in the VR group and their caregivers.

Conclusions: Both exercise programmes offered benefits in addition to improved balance. The VR participants had greater improvements on quantitative measures and provided more comments expressing enjoyment and improved confidence. Applications in terms of community reintegration and quality of life are discussed.

Keywords: *Virtual reality, self-efficacy, self-concept, physiotherapy, balance confidence, community integration*

Introduction

According to the Brain Injury Association of America [1], 5.3 million people living in the US are currently disabled by the effects of a traumatic brain injury (TBI). Each year an additional 1.5 million people sustain a TBI and of these 80 000 begin the process of long-term recovery. While the estimated costs associated with TBI are $48.3 billion annually, it is not possible to quantify the physical and emotional strain from disability that the injured person and those close to them endure. Adolescents and young adults are most at risk for a TBI. Strikingly, after a TBI has occurred, the risk of a subsequent TBI increases three-fold [2].

Common functional deficits after TBI include balance and postural control problems that can persist for years and significantly affect quality of life [3]. These long-term problems are under-reported in the literature [4], even though their impacts are considerable. For example, impaired confidence in balance skills has been related to depression, fear of falling and limited ability to participate in social activity [5]. Physical limitations resulting from a TBI have also been shown to affect community independence, including a wide range of life habits from self-care to employment [6]. This suggests an important role for the provision of exercise programmes and balance rehabilitation for individuals with TBI.

Correspondence: Heidi Sveistrup, PhD, School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, 451 Smyth Road, Ottawa, ON K1H 8M5, Canada. Tel: 613-562-5800 ext 8016. Fax: 613-562-5428. E-mail: hsveist@uottawa.ca

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In general, physical activity and exercise can improve one's health through lowered risk of cardiovascular disease, diabetes, obesity, cancer and musculoskeletal conditions [7]. Exercise can decrease the functional decline of ageing and improve balance and muscle strength [8–10], while physical activity can reduce the risk of falls in older people if it is moderate in intensity, and directed towards flexibility, strength, co-ordination, reaction time and balance [11, 12]. Even if falls are not reduced through exercise participation, other benefits that are important to independent living occur. These include improved confidence in balance and better strategies to cope with a fall (for example calling for help and staying warm) [13]. Exercise can also help neurons to survive, generate new neurons and recruit neurons [14]. A positive relationship has been noted between exercise and cognition [15] and people who exercise often tend to be less depressed [16, 17].

Benefits of physical conditioning for people with TBI have been suggested and include increased endurance, reduced depression, help with self-confidence (by promoting independence) and improved individual autonomy [18]. These factors contribute towards better reintegration into the community, better behaviour (health and lifestyle), more recreational involvement and better social acceptance. In addition, exercise can improve sleep patterns and reduce fatigue which may increase an individual's ability to find and keep a job [19]. Even years after the injury, rehabilitation and exercise can increase function [20]. Improvements in functional balance and mobility have recently been reported from two balance retraining exercise programmes in people 6 months or more after a TBI [20]. Although improvements on balance scores were similar between the activity-based (AB) and the virtual reality (VR) exercise participants, more individuals from the VR exercise group demonstrated clinically significant changes suggesting a possible advantage of the VR system.

Physical impairments are clearly not the only major deficits resulting from TBI. Limited self-awareness of the effects of the injury on cognition, emotions and behaviour may create obstacles to rehabilitation [21] and achieving a sense of quality of life after TBI can be difficult. Self-concept, a way of defining one's self, is thought to be a useful model to understand problems and find solutions after brain injury [22]. Five self-concepts have been identified as the most highly valued to people with TBI: family self, physical self, moral self, personal achievement and social self [22]. Attaining satisfaction with valued areas of life can improve quality of life [23]. Strategies to improve spheres of self-concept, for example improving physical health through exercise, may also improve community integration by helping individuals with TBI develop positive self-images [22].

Finding strategies to improve self-concept after TBI can be challenging as there are often multiple systems damaged including cognitive, behavioural and movement [24] resulting in complex disorders. Furthermore, after a TBI, individuals may be forgetful of new information, show decreased attention and organization and may poorly judge their own abilities [25]. Balance problems for example can be worse if cognitive problems exist. In fact, people with TBI tend to over-estimate their abilities, especially if they are unsure of them [25]. Persons with brain injury most likely to over-estimate their abilities are those who tend to have more severe brain injuries, for example bilateral or multi-site brain lesions [26]. Individuals who are less aware of their areas of impairment may try to do activities that are beyond their ability, putting them at greater risk of falls [3].

Durgin [27] describes an intervention approach consisting of graduated 'real-world' trials where a person with TBI is able to work towards more challenging tasks in the community through progressively increased demands, helping them move towards their previous level of skill or to learn new skills. Virtual reality may provide such a vehicle allowing for added flexibility in designing interventions that will address social and cognitive impairments and disabilities after TBI. The technology has the potential to offer experiences that are engaging and rewarding. Virtual Reality shifts the focus from the person's efforts to that of interaction with the VR environment and allows enjoyment of a meaningful activity [28]. Specifically, it can improve cognitive function and concentration through an individual's interaction with a pleasant activity [29]. The enjoyment experienced while working with VR may increase the level of participation. In addition to generating realistic situations for testing, intervention and collection of data [30], the provision of positive feedback through VR has been shown to increase self-esteem and empowerment in adults with various impairments including cerebral palsy, spinal cord injury (SCI) and stroke [31].

The Disability Creation Process Model (DCPM) [32, 33] is a model which identifies factors that limit ability to perform daily activities and fulfil social roles valued by an individual. The DCPM stresses all aspects that affect one's ability to perform daily activities and social responsibilities, for example personal and environmental factors. Noreau and Fougeyrollas [34] reported that aspects such as personal relationships and employment were not only important to social participation but contributed to overall health of the individual, in this case persons with SCI. Where there is more disability,

there is generally more difficulty with daily activities. Restrictions in areas like fitness, mobility, recreation and employment most disrupted an individual's feeling of accomplishment. Strategies to create accessible community resources for fitness and recreation could lead to improved self-concept and overall better health.

The purpose of this study was to (1) determine if qualitative perceptions from participants and their caregivers or families identified exercise benefits beyond the initial targeted goal of improving functional mobility and balance, for example in expressions of confidence and pleasure and to (2) compare the groups (VR, AB and caregivers) to see if perceptions of exercise participation differed as a function of programme delivery.

Methods

This project was undertaken as part of a larger exercise study regarding balance retraining after TBI. Further details on participant selection and methods can be found in Thornton et al. [20].

Participants

The sample in the current study included 27 individuals from a possible 34 individuals who participated in the initial balance retraining programmes. One subject was African-American and one was Southern European and the remaining were Caucasian. Additional subject characteristics appear in Table I. These individuals had sustained a TBI at least 6 months prior to their participation. In addition, individuals were included if they had a Glasgow Coma Score at the time of injury of 12 or less, were no longer involved in inpatient rehabilitation, had ongoing balance problems since their TBI, were able to stand independently for 2 minutes with no mobility aid, could understand instructions in English or French and were able to interact with a computer system. Exclusion criteria included vestibular, vertigo or orthopaedic problems that severely limited mobility. Participants were quasi-randomly assigned to one of two balance retraining groups using baseline Berg Balance Scale Scores. The AB exercise programme incorporated conventional tools of balance retraining with activities such as walking and running supplemented with equipment including balls and stools. The VR approach used a modified IREX* computerized programme that required participants to make large full body movements to interact with virtual objects in a virtual environment. Briefly, virtual reality is a computer technology that simulates real-life learning while providing augmented feedback. The VR activities used in the current study could be graded for different levels of complexity. Moreover, virtual environments provide individuals with safe access to interactive situations that could otherwise be inaccessible to them due to motor, cognitive and physiological limitations. The 50-minute exercise sessions took place three times per week for 6 weeks in a designated room at a regional rehabilitation centre.

Participants completed two questionnaires at baseline and after the exercise programmes: The Activities-specific Balance Confidence Scale (ABC) and the Lower Extremity Functional Scale (LEFS). Upon completion of the exercise programmes, participants and caregivers including family members were invited to participate in focus groups. Travel and parking expenses for study participants were covered. The research ethics board of the rehabilitation centre approved the study methodology. Participants were asked to sign a consent form that allowed for proxy consent if the participant was unable to fully understand certain details.

Measures

Balance and function questionnaires. Each participant completed two questionnaires at three measurement times: prior to, immediately after and 3-months after the exercise programme. The approach of using several measures was taken to determine changes on the different aspects of balance and function being addressed in the interventions [35, 36].

The Activities-specific Balance Confidence Scale (ABC) identifies an individual's level of confidence

Table I. Subject characteristics.

Group	Gender	Age range (mean)	# Subjects ≤3 years post-TBI	Number of subjects using a mobility aid	Number of subjects reporting falls/near falls in previous year	Baseline BBS range (mean, median)	Need for prompting[1]	Subjects living alone/with others
ABE	10 male 2 female	18–66 (37)	3	2 cane 2 wheelchair & cane	7/9	28–56 (49, 53)	$6^a/3^b/3^c$	4/8
VRE	9 male 6 female	19–64 (42)	4	4 cane 2 walker	6/11	21–56 (48, 52)	$10^a/2^b/3^c$	3/12

[1] Need for prompting: [a] Completely independent, [b] independent once at Rehabilitation Centre, [c] needs help to training room.

in performing activities of daily living (ADL). Participants were asked how confident they were that they would not lose their balance or become unsteady when doing 16 functional activities of varying levels of difficulty. Scores ranged from not confident (0%) to completely confident (100%) [37]. While the ABC was not designed for the TBI population, it is a reliable and valid, objective measure of confidence in balance designed for older adults who live in the community [37–39], who often demonstrate both cognitive and physical limitations similar to those seen in individuals with TBI. A minimum clinically important difference is seven points.

The Lower Extremity Functional Scale (LEFS) is a 20-item self-report functional status measure designed for individuals with musculoskeletal conditions of the lower extremity [40]. Participants were asked to indicate whether their lower extremity function resulted in difficulties with activities such as walking, putting on shoes, squatting and running. Scores ranged from extreme difficulty (0) to no difficulty (4). No previous work has been published using this scale with the TBI population; however, reliability and validity testing has been done with individuals with a wide spectrum of lower extremity orthopaedic conditions. The tool was intended for use with all patients with lower extremity disability [41, 42]. The minimum clinically important difference is nine points. Since the subject number was small, analysis was limited to the calculation of descriptive statistics for the ABC and LEFS (SPSS Version 11). The summary data are plotted to illustrate group trends.

Focus groups. Two separate focus groups were carried out for each exercise group and consisted of (1) participants in the balance retraining programme, (2) family members including partners, children or caregivers. Four individuals who could not make the scheduled focus group sessions were interviewed separately. Each 1-hour focus group session was held in the balance testing room. Participants in the focus groups were informed that the purpose of the session was to obtain broad feedback on the exercise programme. Pre-determined open-ended questions provided a structure to the focus group sessions (see Table II). Moderators, experienced with qualitative research and focus group facilitation, led the sessions. Individuals directly involved in the balance exercise programmes were not involved in the focus groups. Sessions were tape-recorded and manually recorded notes were printed on flip charts visible to all participants during the session. Concurrence with written concepts was determined by reviewing flip chart notes at the end of each focus group session.

Table II. Focus group questions.

(1) How useful did you (your family member) find the exercise sessions?
What things were good?
What things were bad?
(2) Have you noticed any differences in your balance (the balance of your family member)?
Give specific examples if possible.
(3) Did participating in the exercise sessions change anything else in your life (the life of your family member)?
Give specific examples if possible.
(4) Are there specific things that we could do better?
(5) What was the most important exercise that you did and why?
(6) Thinking about the whole experience of participating in the study, what was the best part?
(7) Again, thinking about the whole experience of participating in the study, what was the worst part

Verbal consent for participating and audio taping was requested prior to starting the session.

Analysis of focus group materials was done by listening to and transcribing the audio tapes and carefully studying the verbatim and notes taken from the sessions. A coding system was applied to the comments, which were then grouped according to themes. Perceptions of participants regarding their experiences, comparing participant and family comments, grouped according to intervention type were examined, to identify common themes and distinctions that emerged.

Results

Baseline, post-intervention and 3-month follow-up scores for ABC (Figure 1(a)) and LEFS (Figure 1(b)) are plotted for the two groups. The ABC group mean scores for the AB group increased slightly each time from 74.6 to 76.4 and 78.2. Mean group scores for VR also increased each time from 74.8 to 80.2 and 81.2. The LEFS group mean scores for the AB group improved from 55.8 to 57.4 and 60. For the VR group, the group means initially improved from 57.1 to 59.2 and then decreased slightly at 3-month follow-up to 58.8. Although both exercise groups improved on both measures, the changes were not statistically or clinically significant. Three participants in the AB group and five in the VR group made clinically significant improvements of seven points or more on the ABC between the baseline and post-intervention testing (Figure 1(c)). Two participants in each exercise group made clinically significant improvements of nine points or more on the LEFS between the baseline and post-intervention testing (Figure 1(d)).

The comments from the focus groups were coded and grouped by themes. The themes derived from the comments were categorized into the

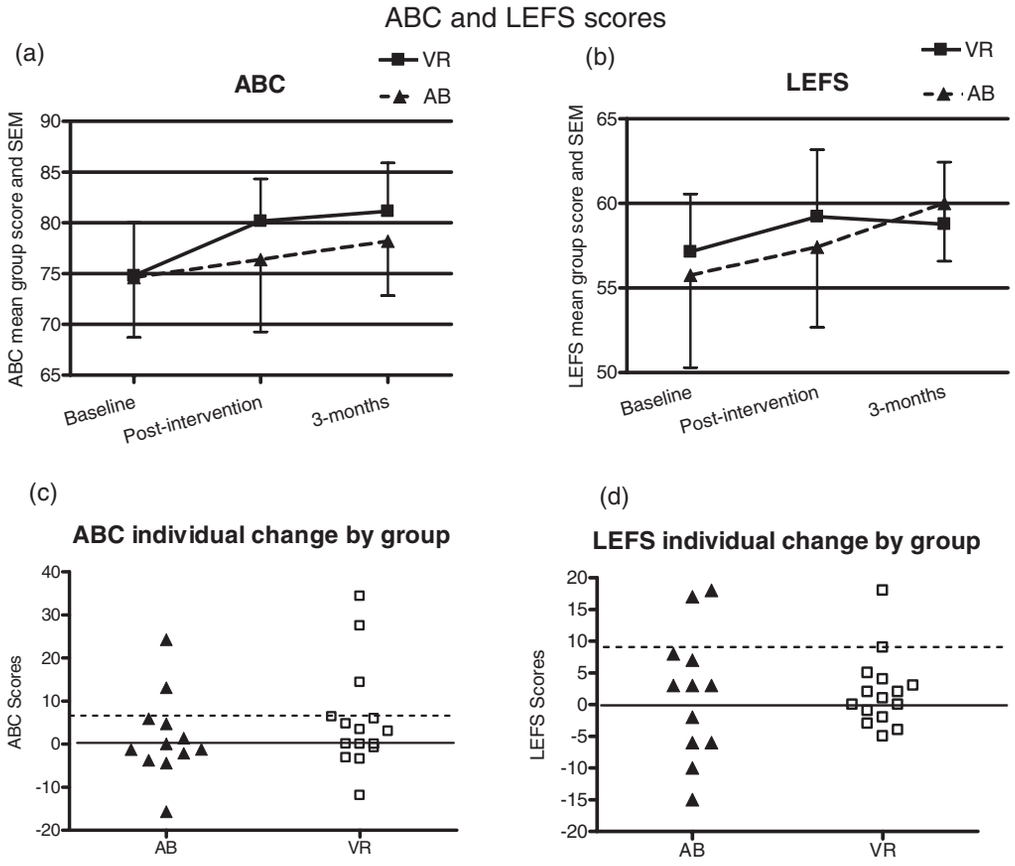

Figure 1. Mean group data (±SEM) for ABC (a) and LEFS (b) at three time periods illustrates the effect of the balance retraining programmes on perceptions of balance confidence and lower extremity function. The baseline to post-intervention difference in individual scores for the ABC is illustrated in (c) and for the LEFS in (d). The dashed horizontal lines on (c) and (d) indicate the value corresponding to a clinically significant change for the specific measure.

following three domains: psychosocial, physical and programme.

Psychosocial comments

The psychosocial comments included the following themes: enjoyment, confidence, self-esteem, purpose/structure, attitude and awareness.

Enjoyment. The focus group data clearly indicated that one of the benefits of both balance retraining programmes was enjoyment. Both programmes were said to offer the participants an enjoyable experience that improved their confidence, allowed them to socialize and become more organized and added structure to their lives. In general, the VR participants expressed greater enjoyment. One participant wanted to share the VR experience with her children, so asked if her children could try the activities. FF's son noted:

> We have tried in the past to have him involved in things but he seemed uninterested . . . with these exercises he was trying to explain what he was doing, he was interested in what he was doing, he was looking forward to going.

RS (VR) had seen some of the AB participants working and he commented that the VR seemed more enjoyable:

> When you are doing exercise without the computer, there is failure, when you drop a ball for example. With the computer, it's ok, the ball goes off the screen, another one arrives, and you just go on.

While several comments in the AB group reflected enjoyment of the overall experience, some participants indicated disappointment at not being part of the VR group and a desire to try those exercises.

Confidence. Both AB and VR participant groups discussed confidence with reference to broad implications. Using the local bus system and keeping appointments were discussed as confidence builders. JL's husband (VR group) commented:

> Eighteen times she drove the route where the accident happened and was successful. This gave her . . . confidence that we were returning to normal

> life again . . . Rather than being unsure of her abilities, now she says, 'I can do this. I am capable'.

The VR group indicated more strongly that their balance was better due to increase in confidence. FL said:

> I just feel more confident. I am supposed to use my cane in the winter but I looked at it this morning and thought, 'Do I really need it? I feel very confident going without it'. The exercises helped me feel confident in my balance.

RS said, 'I am more likely to try something that I wouldn't have before'. JL's partner spoke of his wife as being quite inactive since the accident. 'She is exercising again and that has improved her self-image. It was exactly what she needed'. JL said:

> Last week I went to one of my son's hockey games and I stepped down a distance that I hadn't done . . . I thought, 'Wait a minute, I never stopped to try to figure out how far I had to step'. It was more like what I would have done [before the accident]. That's confidence . . . I credit this programme with improvements, the structuring of the day, exercising again, driving again, driving where the accident happened. It was a real confidence builder.

Other comments about confidence reflected the potential for over confidence and increased risk-taking. For example, one participant from the VR group indicated he felt more confident and would like to try waterskiing, which was a new sport to him. It is possible that by offering safe ways to do more challenging activities, a person's awareness might be heightened, increasing their attention to the task, as well as to the choices they make in how to safely challenge themselves. These ideas were evident in the following comments. RS (VR group) thought trying new activities did not necessarily mean risk-taking. Increased awareness from the exercises meant that you could try things more safely. 'It is probably better because you are more aware of it or paying more attention to how you do it'. BL's family member was afraid that the confidence and other benefits would regress to pre-study status, when the study was over.

From the AB group, QQ said:

> My confidence definitely improved. Before, my wife used to go with me everywhere, whereas now, I don't need her to lead me around; I can get somewhere on my own.

Self-esteem. This theme emerged from the VR group and is illustrated by comments such as one by RS who said:

> It was just nice being around other people who have gone through a similar experience . . . to see that they are living with their problems and its ok.

KA said, 'I think it makes you feel better about yourself, that it is not just you', referring to doing activities with other people with TBI.

Purpose/Structure. Another psychosocial theme was having a sense of purpose and structure. For one individual this was described as a willingness to try new things. From the VR group, ZKF said:

> I have motivation to do different things or to look into doing other things. I've always been active, but this gave me new enthusiasm to keep trying. I feel like I am letting myself down if I let myself get back into a slump.

While volunteering was suggested by FL as one way to stay active, participants in both groups mentioned the idea of 'helping science' and having a sense of importance through being involved in the study. FL said:

> It's not the same to simply volunteer or go to a social group . . . We [referring to participants in the study] are all struggling to make ourselves better [referring to herself and other individuals with TBI and their ability to contribute to development of improved intervention strategies].

The most strongly expressed comments about purpose and structure were in the VR group. For example, II said:

> I really enjoyed the programme. I liked being out early in the morning; it added structure to my day. The structure helped organize the day and the week.

FF's son from the VR group said:

> Because FF is not working now, he found it like a job. There was structure to the day, purpose, a reason to get up and be somewhere by a set time that had significance.

FL commented on the value and purpose of the exercise programme for her. 'I can't do a lot of sports because of my balance, but this helped me work on some of the skills I need for sports'.

Attitude. The theme of attitude includes feelings of organization, wellness, fatigue, fitness and appreciation. This theme was apparent in the comments of several participants in the AB group especially. Several felt the programme helped them and that early intervention would be better. XC said, 'I found it very useful and it's too bad it didn't start . . . years ago right after my accident'. QQ talked of feelings of organization and fitness being important to him. He said:

> You had to find your way around the building. You had to . . . allow time to get to the exercises by bus. Even to get out and do exercise is good for the body.

Physical comments

Comments related to the perception of physical status were divided into two themes: balance/mobility and co-ordination. Importantly, many comments reflected improvements in broad categories including ADL's and purposeful activities.

Balance and mobility. The VR group indicated more strongly that their balance or awareness of balance was better. KA spoke of correcting her balance if she was feeling unsteady. 'Because of the testing, I realize when something is not right; I know if I just change slightly, things will be alright'. Similarly CA stated, 'I saw myself moving and how much I swayed, so I saw how I did'. CA used that information to try to get more stable.

Concrete improvements in functional balance were also noted as when CR said:

> Because of my improvement in balance, my dad and I signed up for doubles badminton weekly. I don't think I would have tried it before the programme.

LV (AB group) credited the study for his balance improvement. He was able to travel by the public transit system, which he had been unable to do since the accident because of his decreased standing balance. 'I came here by bus—not Para [parallel transportation], I can get on to a regular bus now. I can stand and hold on'.

Individuals with higher-level balance skills at the start of the study tended not to report as significant an impact on their functional ability as individuals with initial moderate levels of balance ability although measures of balance indicated improvement. Specifically, the Community Balance and Mobility Scale showed changes greater than the minimum clinically important score for eight out of 10 individuals with the highest baseline scores. For example, one individual with moderate balance reported that programme participation resulted in his ability to take public transportation independently rather than requiring assistance (i.e. parallel transportation). Comments from individuals with higher-level balance skills focused primarily on increased stamina and enthusiasm. AB family members stated that a longer study would be necessary to better demonstrate any balance differences.

Improved mobility was illustrated in comments made by FF's son (VR group). 'He is not shuffling as much when he walks'. FF's stair climbing abilities were described by his son:

> Before, he used to pull himself up . . . he used to hold the banister and try to climb the stairs sideways. Today, he took his steps, holding on as a regular person would.

Since the accident, KL's husband stated that KL would not go up or down stairs alone. 'Since the balance study, she is carrying laundry to the basement without hesitating or asking for help'.

FL (VR group) stated that, since completing the balance retraining programme, she could put her shoes on in the way she used to before the accident:

> I usually [since the accident] sit on the floor to put my shoes on. This morning I put one foot up on my knee, tied my shoe while I was standing. This is the first morning since my accident that I didn't sit on the floor . . . to put my shoes on.

Co-ordination. The theme of improved co-ordination was more evident in comments of VR participants. RS spoke about the soccer game:

> You could see where the ball was coming from and anticipate where you had to be to stop it. At first I would just look where my hand was to block one ball but then as you got used to the game, you could plan ahead and look for the next one. I was concentrating on where my hands were initially. Afterwards, I didn't have to think about it so much, you could see the ball coming on one side of the screen, be ready for it and still be watching the next one.

RS (VR group) continued:

> My spatial sense is notably better. I was prone to spilling coffee when I reached for one. I haven't spilled any like that in about a month. There is better hand-eye co-ordination. Soccer and juggling seemed to help me that way.

Programme comments

The programme comments included themes such as space, the exercise providers, equipment and logistics of time distance, travel and location.

Exercise providers. Comments regarding the exercise providers emphasized the socialization resulting from programme participation. The AB group tended to have more comments about the exercise providers, perhaps because there was more contact and direction required for this type of session. QQ said, 'The instructors were both excellent. They could talk and laugh and they almost duplicated the exercises'.

Activities and equipment. There were more comments from the AB group identifying limitations in equipment such as the balls being too small or not well inflated and that overall space was limited. Significantly, fewer comments about equipment were made by VR participants. While 'Some games did not behave the way you would expect

them to each time' only one participant had trouble seeing the screen well while a second complained of feeling dizzy while doing some of the activities. KA said:

> It depends how fast you are doing some of the movements. If you are going up and down, sometimes I needed to stop . . . The problem came mostly with the up and down movements, or stop and go.

Some activities were identified as boring in both programmes. People expressed a need to have variety and progression of the level of difficulty. RS said of the VR programme, 'In 6 months it would have to go somewhere, more difficult or something'. The opposite was also mentioned. Some participants thought the routine was more important than the activity. Familiarity was comfortable for some people.

In response to the question 'If you had access to these VR games at home, how confident would you feel about using them on your own?' CR replied, 'I would play with them 24/7' while other participants indicated a preference for working under supervision.

Generally all AB activities were thought to be useful as they were similar to daily activities (stairs, walking, reaching, lifting), although sometimes the activities were thought to be too simple. Many of the activities used related to sports, which were not identified with by some individuals.

Some people in the AB group indicated that they would have preferred to be in the VR group. QQ said, 'Initially I was disappointed. I wanted to be in the VR group because I thought the conventional programme would be boring but it actually ended up ok'.

Logistics (time, distance, travel, location). Comments in this area generally reflected interest in having the equipment more accessible. For many individuals, study participation required a large time commitment due to travel in addition to programme time. However, most VR participants agreed, 'It was enjoyable enough to put up with the travel time'. While it was a big time commitment, comments indicated that, because it was enjoyable, it was worth the inconvenience of travel distance and location. In fact, some people travelled for 1 hour in winter to participate three times per week for 6 weeks. The significant commitment of time required and the fact that only one participant (from the AB group) out of 34 was unable to complete the study protocol due to scheduling problems speaks to the value placed on the programme by the participants.

Overall benefits

Overall benefits of the VR programme were expressed by FB:

> My participation not only helped me physically but it also helped me with my ability to be social, with interacting with people [four participants agreed], with my mental ability, like my ability to remember things.

The VR family members expressed a strong desire for follow-up both in respect to an ongoing programme of exercises and wanting to know the results. They were more likely to want to have access to the programme on an ongoing basis. There were substantially more comments reflecting overall feelings of confidence, balance and enjoyment made by VR group participants.

Facilitator IL, commenting about the AB programme, said:

> Generally, family had less knowledge of the specific activities that were being done by the participants. No exercise really stood out and families were not very aware of the exercises the subjects were doing at sessions.

The AB group participants tended to have more negative comments and suggestions for improvements that could be made to the programme. In contrast, the VR group participants showed greater enthusiasm and excitement with the exercise programme. In general, family members were appreciative of study organizers for involving them and participants reported that they would like to have started sooner after their accident. Both approaches to balance retraining offered an opportunity to contribute to scientific research and to experience balance retraining in a way not currently available.

Discussion

Determining the effectiveness of two exercise programmes on functional balance was the primary reason for bringing participants together in this study. The study had importance and meaning to the participants because residual balance deficits were identified as problematic. However, this study shows that many other benefits in addition to changes in balance were accrued. The focus group comments identified three primary domains affected by the balance retraining interventions: physical, psychosocial and programme. The five self-concepts identified earlier [22] as important for adults with TBI directly relate to two domains identified, specifically psychosocial and physical. The psychosocial domain, incorporated themes such as enjoyment and confidence, which reflected the concepts of family self, social self and moral self proposed

by Man et al. [22]. These themes highlighted the relationship between social participation and the individual's physical well-being. The importance of meeting people and socializing was stressed in the current study. Themes grouped within the physical domain included comments about balance and co-ordination that relate to Man et al.'s [22] proposed concepts of personal achievement and physical self. The programme domain incorporating themes such as location and exercise equipment does not appear in the model proposed by Man et al. [22].

Disability creation process model

A more comprehensive model, the DCPM [32, 33], incorporates all domains identified in this study. The DCPM provides a paradigm to explore how the relationship between personal factors and environmental factors influence life habits. In general, risk factors, the cause of disease or trauma such as TBI, affect personal factors. These personal factors in turn define degrees of integrity/impairment and ability/disability. The interaction of these personal factors with environmental factors influence life habits including activities of daily living. For example, for individuals with TBI, their balance (a personal factor), in combination with environmental factors (such as a steep stairwell), facilitate or limit accomplishments of life habits (such as laundry, a component of household maintenance). Other life habits include working, travelling, staying fit and interacting in society.

In the current study, bringing people together for the purpose of balance exercise drew attention to the broader, multi-dimensional effects of balance and exercise. For instance, social roles incorporating life habits such as employment and social integration (inter-personal relations) were specifically mentioned by participants in both exercise groups. These are among the categories of life habits that most disrupt a person's level of accomplishment [34]. The regular routine imposed by study participation required personal commitment, travel and a degree of social interaction. For several participants, the perception of employment provided additional value to them which, along with functional independence, has been reported to be highly associated with quality of life after TBI [43] and SCI [34]. In addition, participants commented that interactions arising with others as a result of study participation improved their self-esteem. Participants identified better relations with family and attributed these to their involvement with something they wanted to talk about and that gave purpose to their day.

In addition, many of the comments were associated with aspects of fun and health. Participation in the programme was perceived as recreational, involving fitness and mobility. These life habits have been categorized as ADL's by Fougeyrollas et al. [32] and can either allow social participation or create a handicap situation. It has previously been shown that functional balance improves with a balance exercise programme in this population [20]. While not statistically significant, confidence and function ratings in both exercise groups improved after the 6 weeks of exercises with the VR group showing a greater average improvement in confidence. The relationship between exercise participation and improved confidence was reflected in comments by many participants. For example, several participants in this study stated that their balance or ambulation was better. Other individuals indicated stair climbing was easier. Mobility can also involve travelling longer distances. Several participants in this study commented that they were better able to take public transit, to go places unsupervised and to find their way to appointments more independently since they were involved in the study. Finally, some participants indicated that their mobility was better because there was more confidence in their abilities (both self-confidence and from others), while others indicated that the improvement in their balance or organizational skills allowed them to be more mobile. Thus, it is clear that while the initial goal of this study was one-dimensional, the effects were multi-dimensional and interactive.

Outcome after TBI has been defined based on one's level of independent living, the control one has over one's life and the need to rely on others [44]. Social isolation, common after TBI, affects community re-entry and has been attributed to inactivity and decreased agility after TBI [45]. Improved mobility through developing better balance may help with social isolation. It has been recommended that interventions be found that address functional independence and ultimately attempt to improve quality of life [43]. The participants and family members indicated that their study participation resulted in a positive impact on all of these factors.

Virtual reality

Careful study of the focus group verbatim and extraction of quotes clearly demonstrated a stronger perception of balance improvements by individuals in the VR than the AB group. There were substantially more comments about the various VR activities improving ones abilities to do day-to-day activities as was evident in one comment indicating that the participant could put their socks on more easily. The VR approach was seen as more positive in general by participants and there were stronger comments

about balance and confidence improvement. Participants in the VR group talked more about improved structure and purpose being added to their day. The visual feedback on the screen was seen as more positive.

Moreover, when comparing comments regarding the two exercise delivery modalities, VR was noticeably perceived as fun, novel and interesting. In a previous study with a small cohort of young adults with CP, it was found that participants had a preference of one game over another [46]. In the present study, people liked Soccer, as it was more fatiguing and challenging than the other scenarios. Individual interest varied, however, with one individual reporting a lack of interest in sports, the focus of certain VR applications. Alternatively, one participant had strong reactions, screams and large avoidance movements, to the sharks appearing in Shark Bait. In general, comments indicated that if the VR were more available, it would be used.

A positive reaction to the novel technology was also reported by the AB group participants, since both groups met in the same space (although they did not exercise at the same time). There was heightened interest in the VR and enthusiasm to try the new technology. In fact, several AB participants indicated that they would like to try the VR programme. It is possible that the enthusiastic comments from both VR and AB participants were a function of the novelty of the approach and that the effect would disappear and that the effect would disappear when the novelty wears off. Moreover, comments from the present study may have been influenced by the shorter length of the exercise programme (6 weeks with a 3-month follow-up). Previous studies have used exercise interventions ranging from 8 weeks to 3 months with follow-up after 6 months, 1 or 3 years. Dropout in one study was seen to occur after 6 weeks [47]. Whether the novelty of the approach would increase the compliance to longer exercise regimes and whether there are certain types of people who might best respond to VR exercise remain to be determined.

It is significant that comments from the VR group suggested that there was family interest in the intervention. The spouse of a VR participant commented that 'The kids would really like to have the programme available at home to play with'. While the opportunity exists for home use, the benefits and challenges of using it independently should be carefully weighed. A strong theme in this analysis was the social benefit of interacting with people that was afforded by exercise participation. This does not, however, support the development of programmes that are primarily social in nature. It has been demonstrated that control groups receiving primarily social interaction show no improvements on the primary variable of interest, balance [48]. Thus, optimal programming would suggest that socialization be used to maximize attendance and participation through promoting a fun and supportive environment. Additional arguments in favour of making VR available in a community centre rather than in a person's home came from a family who indicated the benefit of some respite time when the participant was involved in the programme of exercise. This participant was motivated to attend the exercises and wanted to talk about his experiences when he returned, providing a very positive experience for both the participant and family.

In addition to the benefits potentially afforded for socialization, there is the need to consider the safe use and appropriate exercise progression. Guidelines for safe, independent use and greater accessibility would be important issues to consider in future studies addressing length of the programme, location and accessibility (having it available at home or in community centres). In the current study, safety issues were discussed throughout the period of the study. Subject behaviour was encouraged when appropriate. For example, when participants made decisions that would result in safe recovery of a ball in the ABE programme, the decision was positively reinforced. Many subjects spoke with the exercise providers at the end of the study to discuss how they could continue to maintain an active lifestyle and incorporate activity into their schedule. The exercise providers, although not specifically addressing safety issues, focused on helping participants choose appropriate activities that would promote safe movement.

Conclusions

Specific areas for future research have been identified including: (1) possibility of improved compliance through the use of exercise modalities that are more engaging; (2) need for accessible programming in the community and/or home; (3) safe guidelines for unsupervised programmes and means for supervised programmes to access these guidelines; and (4) programme length and intensity for achieving balance improvements.

This study demonstrates that people with TBI will participate in exercise activities that have meaning and value for them. Although participants in both exercise programmes reported broad impact when asked about their participation in the balance study, there was evidence of substantially stronger, more positive perceptions of impact elicited from the VR group participants. The VR group participants were more enthusiastic and knowledgeable about their programme. In addition they expressed greater

interest and excitement and appeared more engaged during the exercise sessions than did the AB group participants. Finally, the VR participants indicated strongly that their participation increased their independence and confidence. Importantly, while both groups demonstrated improved functional balance scores, balance confidence scores and positive participation comments, the greater degree of interest and excitement elicited through VR could potentially impact on the desire and ability of adults with TBI to continue an exercise programme when supervised programmes are no longer available.

In view of these results and the vast amount of information recommending exercise to maintain a healthy lifestyle, active living in general should be encouraged. This is consistent with the literature about the elderly, which encourages active living for greater safety in mobility [9, 49]. By finding activities, with guidance from health care professionals, that are accessible, enjoyable and appropriate based on level of function, interests and fitness, people with TBI will show improved levels of community integration. A general focus on activity may be the most realistic approach at present, given funding constraints and time required to implement new programmes. Condeluci [50] suggests focusing on capacities, relationships and community services. There is a need for opportunities in the community for people to find activities that are meaningful to them that allow them to stay involved and active.

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