ECRONICON OPEN ACCESS

EC NEUROLOGY

Review Article

Analysis of Body Balance Training Protocols Using Biofeedback Instruments in Hemiparetic Individuals: A Historical Review

Leonardo Grilo Gomes*

Póst Graduate Departament, Positivo University, Curitiba, Paraná, Brazil

***Corresponding Author**: Leonardo Grilo Gomes, Professor, Póst Graduate Departament, Positivo University, Curitiba, Paraná, Brazil.

Received: April 15, 2020; **Published:** April 30, 2020

Abstract

The Body Balance control allows human been to move their limbs in an upright stance position. In a situation whose it is lose the movement of one side of the body, it is called "hemiparesis" and the neurological system that compound orthostatic control needs organizing body position through center of gravity or pressure on hip and feet. The upright stance control is one of the primary aims in biofeedback-assisted rehabilitation through wide range of instruments for hemiparetic patients. Biofeedback practices guide the process of motor training with sensory feedback by supporting a patient's audio-visual and physiological responses-a process that leads to improvement in balance control. This historiography review of the biofeedback-assisted rehabilitation protocols focuses on strategies of body balance training and different evaluation methods, following descriptions of biofeedback guidelines, as well as details of the range of equipment used in weight bearing, and weight distribution training for achieving better balance control.

Keywords: *Biofeedback; Body Balance Training; Instrumentation*

Introduction

Worldwide, millions of people suffer from cerebrovascular disease. About all countries, a total disease burden is due to cerebrovascular-disease related problems such as stroke. Patients with hemiparesis experience physical and neuropsychological pathology including: a) Impairments of body structure and function (e.g. diminished muscle tone and power, psychomotor and perceptual deficits); b) Limitations in daily activities (e.g. reduced work, leisure and mobility involvement, feeding and hygiene limits) and; c) Restrictions participating in social interactions (e.g. dyadic or group participation restrictions) that prevent them from seeking new or ongoing social or occupational activities [1-3].

Also, the neurocognitive deficits includes changes in patient's self-perception of greater or lesser degrees of mobility, self-perception of body parts, muscle coordination, and body balance. These deficits may contribute to injuries and falls and are independent of other physical limitations and restrictions mobility or coordination For example, Beschin., *et al*. [4] reviewed the way stroke patients underestimate their deficit in 'sensory, perceptual motor affective and cognitive functioning due to a brain lesion', a phenomenon known as "anosognosia". This self-perception difficulties accounts for the largest proportion of injuries and falls. Many patients experience neurological and other symptoms such as low self-esteem, signs of depression, and even suicidal ideation besides the obvious physical limitations associated with hemiplegia caused by a stroke [5-9]. Financial costs of physical therapy associated with treating physical mental and cognitive symptoms of cerebrovascular disease and stroke, especially who experience paralysis or hemiparesis, results in large public and private expenditures. New clinical approaches such as using biofeedback allows the costs to decrease when treating stroke patients [10-16].

Biofeedback as a rehabilitation treatment method started in the 1960's in the United States of America and provides feedback in real time about progress in the physiologic control. As a conceptual model, biofeedback rehabilitation techniques have been called "physiologic mirrors" or using electronic instruments to monitor (amplifying, and processing) specific physiologic signals, helping individuals to observe and therefore understand real-time physiologic body changes: cardiac, respiratory and muscles activity signals [17-20].

Biofeedback protocols during the rehabilitation facilitates positive changes in daily activities, social life, and promotes a sense of independence. This historiography review emphasize two ways of biofeedback protocols for balance control training to improve mobility among hemiparetic patients. One way compare the usability of some biofeedback devices (clinical, handcraft and videogames), and the other way describes assessments, and tests to measure postural stability.

Biofeedback for body balance training

Handcraft and designed instruments

Postural instability is a major difficulty for stroke patients especially who have dystonia. Biofeedback rehabilitation protocols begin by training upright stance using sensors that provide visual and vestibular information to facilitate the work in the postural muscles. Continued posture training is designed to increase muscle tonus and the sensory information to "win" against the anti-gravitational forces, providing greater body balance control [21,22].

Rehabilitating body balance control among hemiparetic patients requires feedback training. For decades, simple physical therapy devices (e.g. hand-crafted wood or metal weights) were used to provide feedback during stroke rehabilitation. Rudimentary biofeedback procedures for balance control training have used a bathroom scale to train the weight distribution in the lower limbs, providing both visual and tactile (e.g. body weight swinging) feedback (Figure 1). More recently in the 1990's, biofeedback instrumentation was incorporated into weight-bearing rehabilitation protocols; however, Lee and Wong [23] have argued that biofeedback procedures are too complex practitioners to master, and therefore the subjects with impaired posture or gait may not get the opportunity to benefit from biofeedback procedures. The excessive complexity can easily be resolve with appropriate displays. For example, Cheng., *et al*. [24], used a vertical support mechanism, a screen with lights for perception of the body balance, in hemiparetic individuals, (Figure 1).

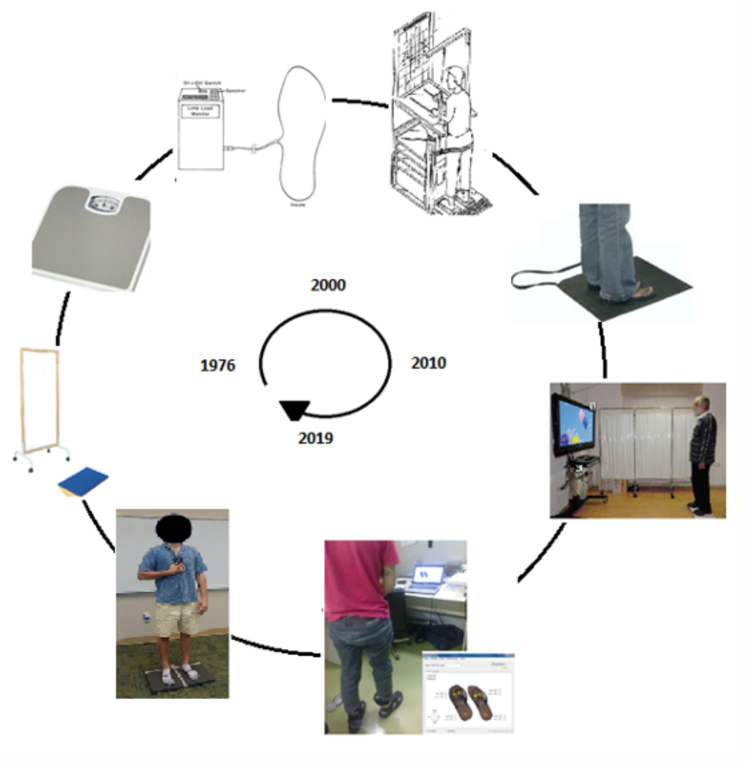

Figure 1: *The bearing-weight devices development by years in a cycle image. Sources: [18,24,28-31].*

Furthermore, Liston and Brouwer [25], placed sensors over a platform for monitoring eye line positions during movements to and from the gravitational center on a screen, training patients to maintain balance in a central point. Others; Simmons., *et al*. [26], and Gatev., *et al*. [27] used a camera system to monitor physical points attached to the body, calculating the gravity center position, training patients to correct the upright stance. The figure below shows a historical overview through the years (arrow in the shape of a circle in the center of the image, with the years on its periphery), of the development of equipment with biofeedback for balance training.

Clinical, commercial or developed video games

Whereas the use of force platforms (stabilometer) provides a complex approach to training postural control and assesses the pressure centers under the feet of hemiparetic patients, it has been suggested that the flexibility of biofeedback instruments can be applied in complex cases to accelerate the rehabilitation process [18,32,33]. No matter the complexity of the case, the most effective biofeedback protocols use pressure and muscle sensors placed on the body or insoles of footwear to provide feedback about foot pressure and muscle tension [34] (See figure 1).

Many Clinical or developed biofeedback systems cost thousands of dollars and are too expensive for clinicians and patients; however, lower price devices to help the patients in biofeedback training for balance control may be available [35,36]. For example, commercial biofeedback systems used in conventional video games may be adapted for use in the body balance training and rehabilitation. Patients can learn to use this type of 'gaming' equipment in their own houses, following the therapist's instructions, reducing clinic visits [30]. For example, Nitz., *et al*. [37], utilized a wireless video-game system to change awareness of body swing and posture, where patients showed a better control of the trunk capacity. Similarly, Gil-Gómez., *et al*. [30], modified a commercial game platform for balance control training among seventy nine hemiparetic patients, showing promising results.

Biofeedback portables devices

With the arrival of more modern portable devices with more advanced functioning capabilities, cell phones and tablets have become very effective tools for assessing and training balance and preventing falls [31,38,39] analyzed a commercial wireless device to capture information on the soles of the feet. Such equipment has great precision to analyze the movements of the body, as well as the action of gravity and pressures (Figure 2a). Likewise, insoles with sensors and applications for smartphones can assist in low cost weight training and facilitated interactivity (Figure 2b) [40]. A clinical application with children, adults and the elderly people using a insoles wireless system carried out by Gomes., *et al*. [34] compared the speed of learning among hemiparetics volunteers during weight-training sessions. Such research defends the use of a portable system for motor training within the activities of daily living.

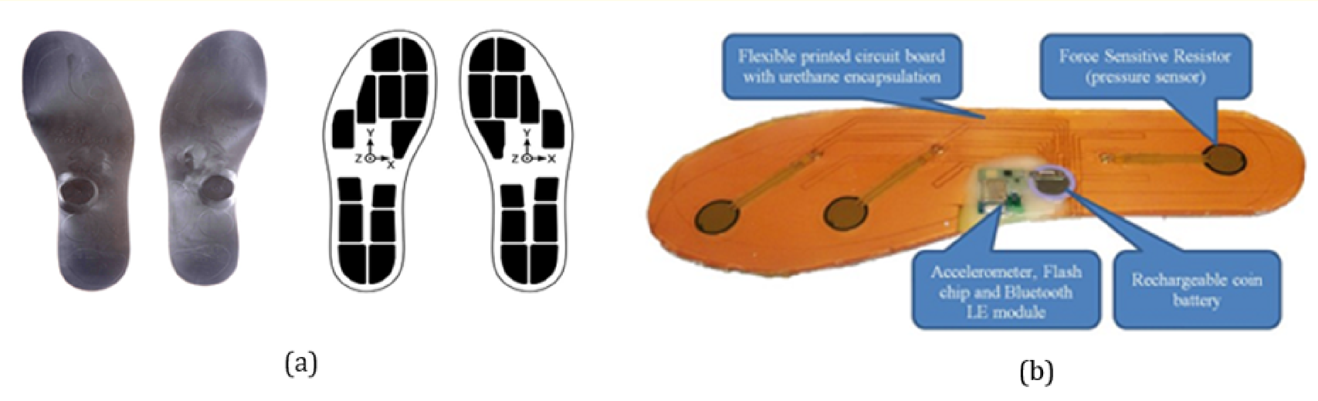

Figure 2: *Images of commercial insoles to training body balance using wireless system. a) OpenGo instrument insoles source [38]; b) SmartStep insole monitor. Source: [40].*

Body balance performance assessments and tests

Clinical studies associated with subjective or more accurate electronic gathering and/or computerized assessment mechanisms data-based on that, 73% of hemiparetic patients who suffer falls, wherein 34% have serious injuries. Thus, the physical tests aim to reducing the imbalance using different types of evaluation. It have concluded that the weight-bearing training by sensory information (Biofeedback) increased the individual's ability to stand within the activities of daily life with more quality [25,30,41-46]. There are several tests for assessing body balance controls of hemiparetic patients.

Below are some of the main tests performed and the evaluation mechanism:

- Angle moment f body sway ("h" point): The angular point of body imbalance deviation from the center of mass and fall.
- Barthel scale index: Ten variables measurements for daily living activities.
- Berg Balance Scale (BBS): This is a 14-item test to measure static balance and fall risk in adults.
- Brunnstrom Recovery Scale (BRS): This is a seven stages test to measure motor control after stroke.
- Centre of gravity (COG): The point is a downward pull or force that the earth exerts on your body. This is the point around which all parts of your body are balanced.
- Center of Pressure (COP): The analysis of variables calculated medial-lateral heel pressure ratio.
- Computadorized Adaptative Test (C.A.T.): This is a computer-based test that adapts to the examinee's ability level. Designed to measure body balance in stroke individuals.
- Computerized isokinetic dynamometer (Chattecx): Postural sway through four electronic pressure transducers placed under the medial and lateral aspects of the heel and forefoot.
- Dynamic Balance (DB): Someone to stay upright and steady.
- Fugl-meyer assessment: Five domains to evaluate and measure recovery in post-stroke.
- Fullerton Advanced Balance Scale (FABS): Test of both static and dynamic balance under varying sensory conditions. Designed to measure balance in highly-active older adults.
- Functional Independence Measure (FIM™*): This is an 18-item test to explore an individual's physical, psychological and social function. This tool is to measure the disability level.
- Multiple Video Recordings of movement (Vicon, MVR): Motion capture system.
- Postural Assessment scale stroke (PASS): The 12-item performance-based scale for postural control after stroke.
- Trunk impairment scale: To evaluate the trunk after stroke.
- Timed Up&Go: The test for mobility. Requiring both static and dynamic body balance.

A set of researches were placed in the following table for the temporal and technological analysis of the biofeedback equipment used for the tests of body balance in hemiparetic individuals. With the same aim, healthy individuals were analyzed to sometimes to make feasible the equipment developed or the methodology that can be applied in neurological patients.

Researchers	Year	Nº	W.	Device	Ages	Sequelae	T.A.
Peper., *et al.*	1976	1	8	Bathroom scale	50	Hemiparesis	Other
Lee., *et al.*	1996	30	5	Lab. device	30 - 60	Hemiparesis	B.R.S.
Liston., *et al.*	1996	20	1	Stabilometer	40 - 70	Hemiparesis	B.M.
Batavia., *et al.*	1997	1	7	Auditory device	74	Hemiparesis	F.I.M.
Simmons., *et al.*	1998	1	6	Force plates	71	Hemiparesis	Other
Cheng., *et al.*	2001	54	3	Lab device	60 - 70	Hemiplegics	C.O.P.
Condron., *et al.*	2002	20	48	Stabilometer	20 - 30	Healthy	Chatecx
Dault., *et al.*	2003	30	11	Force plat-form	22 - 70	Hemiparesis	B.R.S.
Betker., *et al.*	2007	3	3	Developed Game	30 - 40	Hemiparesis	C.O.P.
Cikajlo., *et al.*	2009	10	4	Lab. device	55 - 65	Hemiparesis	B.B.S.
Acar., *et al.*	2010	26	1	Balance platform	15 - 80	Hemiparesis	B.B.S.
Rougier., *et al.*	2010	56	1	Force plat-form	42 - 72	Healthy	C.O.P.
Nitz., *et al.*	2010	10	10	video game	30 - 58	Healthy	Step test
Barcala., *et al.*	2011	12	5	video game	40 - 60	Hemiparesis	B.B.S.
Gil-gómez., *et al.*	2011	79	5	Developed Game	16 - 90	Hemiparesis	B.B.S.
Badke., *et al.*	2011	29	7	Lab. device	18 - 50	Hemiparesis	B.B.S.
Clark., *et al.*	2011	20	3	video game	20 - 30	Healthy	VICON
Duclos., *et al.*	2012	7	1	Lab. device	60 - 70	Healthy	Other
Bateni., *et al.*	2012	12	4	video game	50 - 90	Healthy	B.B.S.
Hung., *et al.*	2014	28	12	video device	> 18	Hemiparesis	T.U.G.
Chen., *et al.*	2014	17	1	Lab. Device	33 - 84	Hemiparesis	Other
Hsieh., *et al.*	2019	30	1	video device	60 - 70	Healthy	C.O.P.
Hsieh., *et al.*	2019	54	12	Clinical	55 - 70	Hemiparesis	B.B.S.

Table 1: *A summary of devices and interactive tasks used for assessing and treating sequalae's of stroke is organized by year in table 1 (below). The data provide a comparison among the methods applied by researchers. (Researcher, Protocol, interface, cost, ages, volunteers conditions). The table is organized to show researchers; number of volunteers (Nº), numbers of weeks (Weeks); Type of equipment (device), research year (year); the age of volunteers (Ages); type of sequelae (Sequelae); Tests and assessments (T.A.). Definitions: Other: alternative method of evaluating. BRS: Brunnstrom Scale; BBS: Berg Balance Scale; FIM: Functional Independent Measure; Lab device: Customized or Developed Device for the Experiment; BM: Balance Master; FIM: Functional Independent Measure; C.O.P: Center of Pressure; B.R.S.: Brunnstrom Recovery Scale; VICON: Video Recorder of Motion; T.U.G.: Timed Up and Go.*

Discussion

Biofeedback training protocols can improve volitional motor control and assist in the sensory apparatus of the orthostatic position. Commercial electronic video game can be more effective and playful than conventional clinical devices for weight-training therapies. Weight-bearing training with commercial electronic video games are used in different parts of the world and in different people with different neurological pathologies that affect body balance, such as Parkinson's and multiple sclerosis [56]. The neuromuscular rehabilitation of patients with motor disabilities is a big challenge for health professionals, whose work with a series of functional problems [59]. The key for the success on biofeedback is likely the amount of independence. For example, learning balance control training in hemiparetic adults with bathroom scales to provide feedback was an economical intervention, one that was cheaper and easier in terms of acquisition, and with good, visible results [60]. Physical therapy for stroke patients gain of movements is relatively slow and expensive for maintain daily sessions; biofeedback assisted protocols that allow patients to perform training at homes using easily available technology such as a bathroom scale or modified video game technology that provide hope for a faster rehabilitation. For example, the center of pressure control training might be done into the patients' houses with a notebook; associated at videogames and probably could be more funning and effective.

Another contribution from researches is use of the C.O.P. and C.O.G. swinging to evaluate body balance. Hence, those variables are mostly increased in neurological disorders, and associated with visual feedback training tend to decrease the values swinging of these two variables [42]. According to Betker., *et al.* [61] that showed a gain, and a decreasing of 2 cm, in the body balance deviation, comparing with the laboratory tests results carried out by Dozza., *et al.* [62], which showed a gain of 1 cm in the body deviation with body balance instrumentation in vestibulopathy. The challenge is not only the technology development but it is also providing the strategies to motivate the patient to practice the motor learning. The body balance control is a motor task that requires an integrative process that involves visual, proprioceptive, tactile and vestibular systems.

Computerized measurements provide accurate and functional information from ability to stay upright and balanced. Based on old studies, in which balance and weight training were trained, the center of pressure (C.O.P.) could be evaluated in its direction and speed. The deviation components from the pressure center were quantified according to the average speed of the C.O.P. Hsieh., *et al.* [58] developed a PC Gamer to assess the center of pressure by displacing of the trunk. The study resulted in an improvement in the oscillation of the trunk, and giving possibility to conclude that: "The use of a platform is better than commercial video games, normally used in physical therapy for rehabilitation to hemiparetic patients". Gomes., *et al.* [34] created a shoe with sensors that communicate wirelessly to a computer to detect pressure differences in the rearfoot and forefoot s of hemiparetic individuals soles, using the interactive interface. In the same direction, Garcia., *et al.* [39], have englobed computer technologies at body balance training and ankle movements by tablet interface camera. Such methods allow everybody in everyplace can training the feet position and weight bearing. The major disadvantage is that the device need to be held with both hands.

Chen., *et al.* [57] compared the reliability of physical tests for balance with the results provided by computerized equipment. Physical tests are inexpensive and easy to apply, but they are not very accurate. In contrast, computerized balance measures are more effective and more reliable to most patients and requiring professional assistance. The specific devices developed to assess and train balance, on the other hand, have become more accessible and guarantee accurate results and sometimes do not require the assistance of a specialized professional, and their results may be analyzed by a wider range of professionals.

The body balance assessments described in the table above and it is notable that the assessments are the most reliable measures used in most surveys around the world in healthy or pathological individuals. Mainly in individuals with hemiparesis. However, the Berg Balance scale evaluation shows a high level of relative results and with little precision to a larger number of individuals after physical therapy or motor training [44]. The accuracy of the outcomes increase associate at the C.A.T. and the equipment that evaluate in an automatically way, such as computerized platforms and smart phones offer simultaneous and accurate results. The C.A.T. is used to assess and measure body balance within the patient's difficulties. For example: Chen., *et al.* [57] developed a C.A.T. for balance to compare the results of commercial equipment for body balance training and concluded that commercial equipment is more practical and functional compared at the computerized tests (C.A.T.).

More recently, smartphones and tablet became popular and useful in all houses. Those population and new companies whose are called "startups" can developing tools to help and train people with impaired body balance. Hsieh., *et al.* [31] have trained thirty older adults to use a smartphone as body balance trainer and gathered relevant and interesting information to the future for the portable devices.

Final Considerations

Many types of rehabilitation equipment such as a baropodometry, stabilometry or motion captures systems, are sophisticated, complex, and quite expensive and limit practice at home. Relatively inexpensive biofeedback equipment and training protocols can help in training balance control. For example, training a stroke patient to move from sitting to an upright stance with biofeedback equipment, reinforces balance control beyond the training session, improving activities of daily living and decreasing the chance of falls [63].

Biofeedback-assisted rehabilitation efficacy is determined by the training accuracy and clinical outcomes [16]. It should be noted that the effects of biofeedback protocols generalize beyond balance control, because biofeedback protocols often incorporate relaxation and behavior therapies, including physical education [64].

The View of the Future

The use of ordinary instruments, such as mirrors, crafted material as well as bathroom scales, are still of great use in a patient's home. However, in terms of time gain, general interest is set on the use of technology in rehabilitation materials. In the future, biofeedback protocols will increasingly be infused into rehabilitation procedures to teach hemiparetic patients ways to assess and reduce motor function difficulties. The techniques of biofeedback will be used along with wearable physical body sensors, directly aiding in controlling balance during everyday activities.

Bibliography

1. Redzuan Nor Shahizan., *et al*. "Effectiveness of a Video-Based Therapy Program at Home after Acute Stroke: A Randomized Controlled Trial". *Archives of Physical Medicine and Rehabilitation* 93.12 (2012): 2177-2183.
2. Mercer Vicki Stemmons., *et al*. "Recovery of Paretic Lower Extremity Loading Ability and Physical Function in the First Six Months after Stroke". *Archives of Physical Medicine and Rehabilitation* 95.8 (2014): 1547-1555.
3. Kaur Gurpreet., *et al*. "How Physically Active Are People with Stroke in Physiotherapy Sessions Aimed at Improving Motor Function? A Systematic Review". *Stroke Research and Treatment,* (2012).
4. Beschin Nicoletta., *et al*. "Anosognosia and Neglect Respond Differently to the Same Treatments". *Neuropsychological Rehabilitation* 22.4 (2012): 550-562.
5. Glanz Morton., *et al*. "Biofeedback Therapy in Poststroke Rehabilitation: A Meta-Analysis of the Randomized Controlled Trials". *Archives of Physical Medicine and Rehabilitation* 76.6 (1995): 508-515.
6. Gray VL., *et al*. "Patterns of Muscle Coordination during Stepping Responses Post-Stroke". *Journal of Electromyography and Kinesiology* 25.6 (2015): 959-965.

7. Tancredi L., *et al*. "Stroke Care in Young Patients". *Stroke Research and Treatment* (2013): 1-7.

8. Geiger Ruth Ann., *et al*. "Balance and Mobility Following Stroke: Effects of Physical Therapy Interventions with and Without Biofeedback/Forceplate Training". *Physical Therapy* 81.4 (2001): 995-1005.

9. Adams Jack A. "Historical Review and Appraisal of Research on the Learning, Retention, and Transfer of Human Motor Skills". *Psychological Bulletin* 101.1 (1987): 41-74.

10. Dickstein R., *et al*. "Foot-Ground Pressure Pattern of Standing Hemiplegic Patients. Major Characteristics and Patterns of Improvement". *Physical Therapy* 64.1 (1984): 19-23.

11. Dickstein Ruth., *et al*. "Effects of Integrated Motor Imagery Practice on Gait of Individuals with Chronic Stroke: A Half-Crossover Randomized Study". *Archives of Physical Medicine and Rehabilitation* 94.11 (2013): 2119-2125.

12. Malouin Francine., *et al*. "Slowing of Motor Imagery after a Right Hemispheric Stroke". *Stroke Research and Treatment* (2012).

13. Spruit-Van Eijk Monica., *et al*. "To What Extent Can Multimorbidity Be Viewed as a Determinant of Postural Control in Stroke Patients?" Archives of Physical Medicine an*d Rehabilitation* 93.6 (2012): 1021-1026.

14. Ijmker Trienke., *et al*. "Effect of Balance Support on the Energy Cost of Walking after Stroke". *Archives of Physical Medicine and Rehabilitation* 94.11 (2013): 2255-2261.

15. Takeuchi Naoyuki and Shin-ichi Izumi. "Rehabilitation with Poststroke Motor Recovery". *Stroke Research and Treatment* (2013): 1-13.

16. Lavaque Theodore J., *et al*. "Special Issue on Special Issue of Biofeedback on Research Methodology". *Biofeedabck* 30.2 (2002): 2.

17. Peper E., *et al.* "Biofeedback an Evidence Based Approach in Clinical Practice". *Japanese Journal of Biofeedback Research* 36.1 (2009): 3-10.

18. Peper E and J a Robertson. "Biofeedback Use of Common Objects: The Bathroom Scale in Physical Therapy". *Biofeedback and Self-Regulation* 1.2 (1976): 237-240.

19. Jonas WB. "Advising Patients on the Use of Complementary and Alternative Medicine". *Applied Psychophysiology and Biofeedback* 26.3 (2001): 205-214.

20. Bolek Jeffrey E and Jennifer Yost. "Motor Control Recovery After a Severe Brain Injury: Applications of Quantitative Surface Electromyography". *Biofeedback* 41.2 (2013): 50-55.

21. Bolek Jeffrey E. "Uncommon Surface Electromyography". *Biofeedback* 38.2 (2008): 52-55.

22. Rosa Marlene Cristina Neves., *et al*. "Lower Limb Co-Contraction during Walking in Subjects with Stroke: A Systematic Review". *Journal of Electromyography and Kinesiology* 24.1 (2014): 1-10.

23. TFT Lee MY and Wong MK. "Improve Balance and Postoral Control". IEEE Engineering in Medicine and Biology (1996): 112-116.

24. Cheng Pao Tsai., *et al*. "Symmetrical Body-Weight Distribution Training in Stroke Patients and Its Effect on Fall Prevention". *Archives of Physical Medicine and Rehabilitation* 82.12 (2001): 1650-1654.

25. Liston Rebecca AL and Brenda J Brouwer. "Reliability and Validity of Measures Obtained from Stroke Patients Using the Balance Master". *Archives of Physical Medicine and Rehabilitation* 77.5 (1996): 425-430.

26. Simmons Roger W., *et al*. "Balance Retraining in a Hemiparetic Patient Using Center of Gravity Biofeedback: A Single-Case Study". *Perceptual and Motor Skills* 87 (1998): 603-609.

27. Gatev P., *et al*. "Feedforward Ankle Strategy of Balance during Quiet Stance in Adults". *The Journal of Physiology* 514 (1999): 915-928.

28. Betker Aimee L., *et al*. "Video Game-Based Exercises for Balance Rehabilitation: A Single-Subject Design". *Archives of Physical Medicine and Rehabilitation* 87.8 (2006): 1141-1149.

29. Schwartz MS and Andrasik F. "Biofeedback: A practitioner's guide". 3rd edition., New York: Guilford Press (2003).

30. Gil-Gómez José Antonio., *et al*. "Effectiveness of a Wii Balance Board-Based System (EBaViR) for Balance Rehabilitation: A Pilot Randomized Clinical Trial in Patients with Acquired Brain Injury". *Journal of Neuro Engineering and Rehabilitation* 8.1 (2011): 30.

31. Hsieh Katherine L., *et al*. "Smartphone Technology Can Measure Postural Stability and Discriminate Fall Risk in Older Adults". *Gait and Posture* 67 (2019): 160-165.

32. Batavia Mitchell., *et al*. "An Augmented Auditory Feedback Device". *Archives of Physical Medicine and Rehabilitation* 78.12 (1997): 1389-1392.

33. Arnold Allison S., *et al*. "Muscular Coordination of Knee Motion during the Terminal-Swing Phase of Normal Gait". *Journal of Biomechanics* 40.15 (2007): 3314-3324.

34. Gomes LG., *et al.* "Analysis of Heel Weight-Bearing Control Training in Individuals with Equine Foot Syndrome: Comparative Study on Different Ages Using Sensorial Biofeedback". *EC Neurology* 11.7 (2019): 506-513.

35. Bateni Hamid. "Changes in Balance in Older Adults Based on Use of Physical Therapy vs the Wii Fit Gaming System: A Preliminary Study". *Physiotherapy* 98.3 (2012): 211-216.

36. Pennycott Andrew., *et al*. "Towards More Effective Robotic Gait Training for Stroke Rehabilitation: A Review". *Journal of Neuro Engineering and Rehabilitation* 9.1 (2012): 65.

37. Nitz JC., *et al*. "Is the Wii FitTM a New-Generation Tool for Improving Balance, Health and Well-Being? A Pilot Study". *Climacteric* 13.5 (2010): 487-491.

38. Oerbekke Michiel S., *et al*. "Concurrent Validity and Reliability of Wireless Instrumented Insoles Measuring Postural Balance and Temporal Gait Parameters". *Gait and Posture* 51 (2017): 116-124.

39. Garcia Jaime Andres and Karla Felix Navarro. "The Mobile RehAppTM: An AR-Based Mobile Game for Ankle Sprain Rehabilitation". *SeGAH 2014 - IEEE 3rd International Conference on Serious Games and Applications for Health, Books of Proceedings* (2014): 279.

40. Sazonov Edward S., *et al*. "Development of SmartStep: An Insole-Based Physical Activity Monitor". *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society EMBS* (2013): 7209-7212.

41. Nott CR., *et al*. "Relationships between Frontal-Plane Angular Momentum and Clinical Balance Measures during Post-Stroke Hemiparetic Walking". *Gait and Posture* 39.1 (2014): 129-134.

42. Rougier Patrice R and Samir Boudrahem. "Visual Feedback of Force Platform Displacements for Balance Control Training: What Postural Ability Do Healthy Subjects Have to Develop to Decrease the Difference between Center of Pressure and Center of Gravity Movements?" *Motor Control* 14.2 (2010): 277-291.

43. Badke Mary Beth., *et al*. "Tongue-Based Biofeedback for Balance in Stroke: Results of an 8-Week Pilot Study". *Archives of Physical Medicine and Rehabilitation* 92.9 (2011): 1364-1370.

44. Hiengkaew Vimonwan., *et al*. "Minimal Detectable Changes of the Berg Balance Scale, Fugl-Meyer Assessment Scale, Timed 'up and Go' Test, Gait Speeds, and 2-Minute Walk Test in Individuals with Chronic Stroke with Different Degrees of Ankle Plantarflexor Tone". *Archives of Physical Medicine and Rehabilitation* 93.7 (2012): 1201-1208.

45. Jijimol G., *et al*. "Correlation of Trunk Impairment with Balance in Patients with Chronic Stroke". *Neuro Rehabilitation* 32.2 (2013): 323-325.

46. Frykberg Gunilla E., *et al*. "Impact of Stroke on Anterior-Posterior Force Generation Prior to Seat-off during Sit-to-Walk". *Gait and Posture* 35.1 (2012): 56-60.

47. Lee MY., *et al.* "Improve Balance and Postoral Control". IEEE Engineering in Medicine and Biology (1996): 112-116.

48. Condron Joanna E and Keith D Hill. "Reliability and Validity of a Dual-Task Force Platform Assessment of Balance Performance: Effect of Age, Balance Impairment, and Cognitive Task". *Journal of the American Geriatrics Society* 50.1 (2002): 157-162.

49. Dault Mylène C., *et al*. "Effects of Visual Center of Pressure Feedback on Postural Control in Young and Elderly Healthy Adults and in Stroke Patients". *Human Movement Science* 22.3 (2003): 221-236.

50. Cikajlo Imre and Zlatko Matjačić. "Directionally Specific Objective Postural Response Assessment Tool for Treatment Evaluation in Stroke Patients". *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 17.1 (2009): 91-100.

51. Acar Merve and Gulcin Kaymak Karatas. "The Effect of Arm Sling on Balance in Patients with Hemiplegia". *Gait and Posture* 32.4 (2010): 641-644.

52. Rougier Patrice R and Dominic Pérennou. "Upright Standing after Stroke: How Loading-Unloading Mechanism Participates to the Postural Stabilization". *Human Movement Science* 64 (2019): 47-54.

53. Barcala Luciana., *et al*. "Análise Do Equilíbrio Em Pacientes Hemiparéticos Após o Treino Com o Programa Wii Fit". *Fisioterapia Em Movimento* 24.2 (2011): 337-343.

54. Clark Ross A., *et al*. "Validity of the Microsoft Kinect for Assessment of Postural Control". *Gait and Posture* 36.3 (2012): 372-377.

55. Duclos Cyril., *et al*. "Dynamic Stability Requirements during Gait and Standing Exergames on the Wii Fit System in the Elderly". *Journal of Neuro Engineering and Rehabilitation* 9.1 (2012): 28.

56. Hung Jen Wen., *et al*. "Randomized Comparison Trial of Balance Training by Using Exergaming and Conventional Weight-Shift Therapy in Patients with Chronic Stroke". *Archives of Physical Medicine and Rehabilitation* 95.9 (2014): 1629-1637.

57. Chen Chia Hsin., *et al*. "Comparison of the Test-Retest Reliability of the Balance Computerized Adaptive Test and a Computerized Posturography Instrument in Patients with Stroke". *Archives of Physical Medicine and Rehabilitation* 95.8 (2014): 1477-1483.

58. Hsieh Hsieh Chun. "Use of a Gaming Platform for Balance Training After a Stroke: A Randomized Trial". *Archives of Physical Medicine and Rehabilitation* 100.4 (2019): 591-597.

59. Mirelman Anat., *et al*. "Audio-Biofeedback Training for Posture and Balance in Patients with Parkinson's Disease". *Journal of NeuroEngineering and Rehabilitation* 8.1 (2011): 35.

60. Peper Erik., *et al*. Biofeedback: An Open-Ended Future 14 (1998): 31-32.

61. Betker Aimee L., *et al*. "Video Game-Based Exercises for Balance Rehabilitation: A Single-Subject Design". *Archives of Physical Medicine and Rehabilitation* 87.8 (2006): 1141-1149.

62. Dozza Marco., *et al*. "Audio-Biofeedback Improves Balance in Patients with Bilateral Vestibular Loss". *Archives of Physical Medicine and Rehabilitation* 86.7 (2005): 1401-1403.

63. Sienko Kathleen H., *et al*. "Biofeedback Improves Postural Control Recovery from Multi-Axis Discrete Perturbations". *Journal of Neuroengineering and Rehabilitation* 9.1 (2012): 53.

64. Stahl John S., *et al*. "Medical Treatment of Nystagmus and Its Visual Consequences". *Journal of the Royal Society of Medicine* 95.5 (2002): 235-237.

Volume 12 Issue 5 May 2020