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Proprioception and developmental motor training: A new treatment for chronic-phase stroke patients

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Abstract

This novel protocol introduces an approach to the recovery and care of chronic-phase stroke patients. The approach uses developmental learning techniques and proprioception-building exercises to reintegrate brain hemispheres with each other and the body. This protocol allows basically trained practitioners to work with post-therapy stroke patients in ongoing recovery without the expense of and need for expensive facilities and equipment. With stroke prevalence and longevity increasing, this need is vital in today's medical community. Through this protocol, practitioners with a bachelor's degree and specialized training can treat this emerging population inexpensively and effectively.

Introduction

Stroke is the number one cause of disability and long-term disability in the world today and is increasing in prevalence [1-5]. However, it is one of the most ignored when it comes to long-term care. Stroke patients need help far beyond the completion of physical and occupational therapy [6-7]. This is essential for those who are seriously disabled due to their stroke but are left untreated due to current guidelines surrounding health care and insurance. In short, the USA is doing a poor job caring for those in the chronic phase of stroke recovery.

This manual is designed to guide exercise specialists in caring for, treating, and improving the functionality of stroke patients who are no longer being treated with formal physical or occupational therapy. This program is designed to be performed in any standard exercise facility, without the need of medical equipment.

We do this by treating the stroke victim not as an injured adult, but an uninjured child. For example, it takes a child years to learn proper gait movements. It is unrealistic to think the same movements will be relearned in a matter of weeks.

During post-stroke physical training, intact cortical circuits have been shown to sprout between the premotor cortex and the somatosensory cortex [8]. Intact cortical circuits are reorganized both spontaneously and via training. Indeed, "the commonly used term 're-learning after stroke' should be subject to scrutiny" [8]. This program is based on the concept that patients are not re-learning movements in the way therapists commonly describe in rehabilitation, but are learning, anew, basic movements and actions much in the way a child learns new movements.

In other words, don't reteach. Just teach. The goal is to create a cadre of professionals who can work with these patients and their families without the expense of formal medical attention in a hospital or other outpatient setting. This protocol uses the same techniques designed for developmental motor training, exercise training, and basic health and wellness training, with a focus on proprioception.

This protocol was shown to be effective through both case studies and a small-cohort validation study [9,10].

Stroke and its impact

Whatever the cause of a stroke, it is generally accepted that most functional recovery occurs within the first six months post-stroke [2,11,12]. As a result, the majority of rehabilitation practice is focused upon the initial recovery, while there is little research on rehabilitation for the chronic phase of stroke [13]. For this program, the chronic phase is defined as four or more years post-stroke. Four years was chosen because current research ends at the four-year mark. While it could theoretically be used earlier, this protocol is designed to pick up where other means have ended.

However, while initial recovery is stressed, it is estimated that 33-42% of stroke survivors will require help with activities of daily living, and more than one-in-three continue to require daily aid five years later [5].

Increased medical competency and technological advancements, especially in the treatment of stroke upon presentation, has led to more affected patients surviving their strokes, and living longer with more complex, debilitating, or involved disabilities [14]. Also, post-stroke patients contend with deterioration of injured neuronal axons and their myelin sheathes. Such deterioration results in increased disability and can continue long after the initial stroke insult [15]. Thus, to better understand and improve quality of life for stroke patients, there is an increased need for improvements to chronic stroke patient care that leads directly to functional recovery [6,11].

Dynamic systems theory

Rehabilitation therapies based on motor learning strategies have proven to increase brain activity [12]. The dynamic systems theory using the model of constraints is often used by those with this perspective. It is pictured as a triangle with constraints at each point [16,17] (Figure 1).

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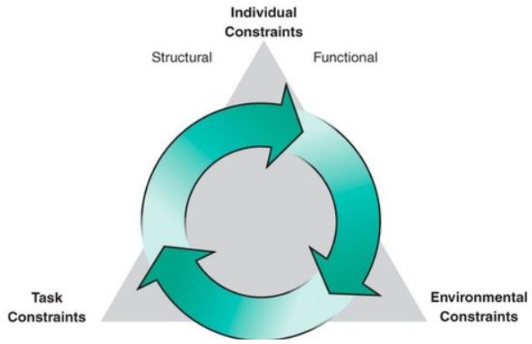

Figure 1. Model of Constraints

Principle one suggests movement emerges from interactions of three constraints; (1) The individual's structural and functional constraints; (2) The environmental constraints; and (3) The task constraints. Principle two states human movement arises when multiple physiological systems act together to produce movement, with no one system having priority. One system, though, can act as a limiter to the rate of development. For example, the muscular system might limit the development of standing infants since the legs must be strong enough to support body weight. Principle Three states human movement is discontinuous, even when a system undergoes continuous change, with new patterns replacing old ones [17]. For example, in the case of an infant, leg strength can increase continuously with growth or training, but standing on the legs is possible only when that strength reaches a threshold level.

New patterns replacing old is crucial to stroke recovery. Davis and Broadhead [18] suggested variations in movement are essential to movement, and that such variances are not problems to be fixed or eliminated. They further suggested the goals of individual tasks should remain constant across a variety of instructional methods and variations. For example, students of tennis best practice their strokes with high balls, low balls, balls with spin, balls without spin, and so on, rather than balls in the identical location from swing to swing.

With this in mind, the variations and sub-optional movements exhibited by stroke patients can be observed as the normal variations a practitioner would observe in healthy children. If addressed similarly, as an integral part of learning movement, such changes could be used to help the brain re-map neural pathways to demonstrate successful movement [18]. If that is so, those in the chronic phase of stroke recovery could use such methods to restore levels of self-care and self-sufficiency. That is, full recovery might be achieved not by repeating the exact same movement but by practicing many small varieties of that movement.

Brains have both adaptive and maladaptive means for repairs which can be used in rehabilitation and learning [19]. In the absence of normal function, such as what occurs during the post stroke phase, the brain will use available information, even if incorrect, as the sensory input that lays down new learning pathways [19]. Not only does the use of incorrect pathways solidify incorrect movement, but "the longer this disrupted learning continues, the better these maladapted motor patterns are learnt" [19]. For example, for a stroke patient with foot drop, caused by hemiparesis, the longer the foot drop goes unattended, the more difficult it will be for the patient to learn control of the foot.

Development of balance and proprioception

One of the key components to a child's mobility is his or her demonstrated ability to maintain balance through learning proprioceptive boundaries. According to the Center for Development – Pediatric Strategies, early movement skills such as crawling, and creeping begin the processes of hemispheric integration. Crossing the body's midline develop neurointegration skills necessary for movement as well as cognitive processes such as reading, writing, and mathematics. Although crawling and walking are not solely responsible for neurointegration, they are a primary means of accomplishing this among infants. In particular, balance and the proprioception necessary for mobility requires use of both brain hemispheres.

Stroke can impair any, or all, of the afore mentioned processes. Also, stretch receptors providing information to the proprioceptive system work in conjunction with other senses when learning new skills or relearning skills damaged by stroke [19]. Movement utilizing stretch receptors and corresponding antagonistic Golgi-tendon organs may increase learning of skills and movements. This protocol proposes the same activities facilitating motor development in children can improve rehabilitation in stroke patients.

Play-based routines

A common means of reinforcing cross-brain integration in children is the use of "reaching games," such as patty cake. Body midline skills are automatically encouraged when a child uses both hands together at the midline. Crossing of the midline in games such as patty cake, singing rhymes such as Head, Shoulders, Knees and Toes, and The Hokey Pokey, or crossing the arms with self-hugs, all encourage children to reach across the midline and build greater total body awareness. This enhances cross-brain integration. These play-based routines start simply and build toward greater and more complex environmental navigation [19].

Sensory integration

Sensory integration requires humans to know, innately and without being told, what information in the body is important and receives attention, as well as what can be ignored or screened out. For example, when sitting in a theater, watching a film, people automatically ignore the sensory input of their clothing rubbing the skin, while focusing extra attention on the visual and auditory stimuli received from the theater's screen activity and sound system. Sensory regulation allows the nervous system to receive information and organize it in order to create appropriate response.

The games used in this protocol are adapted for victims of stroke in an attempt to improve lost sensory integration function in chronic-phase stroke patients.

The development of neurointegration is vital for standing balance and appropriate gait patterns [20]. Reed's study connects the need for neurointegration to the need for stability and gait, which, as stated earlier, is a prime indicator of overall stroke recovery. Specifically, the stability of the head is crucial to improve the biomechanical efficiency of sitting and standing balance. As Reed states, "In standing up and locomoting, the head leads the way" [20].

For the rehabilitation of injury, Reed states that these variations in force can "result in the same joint angle history and, in turn, many combinations of agonist and antagonist muscle forces will result in the same overall movement of force" [20]. The result can be the creation of task-oriented movements in gait, despite differences in physiology and biomechanics, including starting position, even in the event of injury or pathology [20]. For stroke victims, techniques and treatments used to develop multiple motor actions and the coordination of agonistic and antagonistic muscle forces in children may effectively create these same skill-facilitating neural pathways to replace injured neural pathways.

Exercise protocol

This is a six-month intervention that requires the patient to meet with their practitioner two times each week for one-hour sessions. A sample outline of this program can be seed in table 1, however practitioners are encouraged to use creativity and personal insight of the patients to craft individualized programs.

Initial testing includes the Berg Balance Test, The Stroke Specific Quality of Life Scale, and the Fugl-Meyer Test. All test measures are followed by a rest period, with testing sessions completed with muscular strength and endurance testing to determine a baseline for resistance training. These same procedures are repeated every six weeks to ensure consistency of test results. Strength testing assesses improvements and provides insight for modifications as needed.

Warm up exercises

Each session begins with a 12-minute gentle warm up using a NuStep cardiovascular exercise machine (Figure 2). The NuStep integrates contralateral movements of the arms and legs to provide active and passive cross integration of all major muscle groups. In addition, the NuStep allows those with hemiparesis to strap hands and feet onto the machine, thus providing passive stretching of the arms and legs.

Floor exercises for 10 minutes include passive and active stretching, with specific attention paid to the stretching of agonist and antagonistic muscle sets directly affected with either paresis or spasticity. Three minutes of cross-crawling in a supine position is used to begin muscular regeneration while adding cross-neural communication through the midline (Figure 2).

Figure 2. NuStep Exerciser

Table 1. 24-week outline for intervention training

Week 1	Initial Testing	Rest Period	Initial Strength Testing
Week 2	Stability Training	Resistance Training	Neural Developmental Exercises
Week 3	Stability Training	Resistance Training	Neural Developmental Exercises
Week 4	Stability Training	Resistance Training	Neural Developmental Exercises
Week 5	Stability Training	Resistance Training	Neural Developmental Exercises
Week 6	Retesting	Rest Period	Retesting
Week 7	Stability Training	Resistance Training	Neural Developmental Exercises
Week 8	Stability Training	Resistance Training	Neural Developmental Exercises
Week 9	Stability Training	Resistance Training	Neural Developmental Exercises
Week 10	Stability Training	Resistance Training	Neural Developmental Exercises
Week 11	Stability Training	Resistance Training	Neural Developmental Exercises
Week 12	Retesting	Rest Period	Retesting
Week 13	Stability Training	Resistance Training	Neural Developmental Exercises
Week 14	Stability Training	Resistance Training	Neural Developmental Exercises
Week 15	Stability Training	Resistance Training	Neural Developmental Exercises
Week 16	Stability Training	Resistance Training	Neural Developmental Exercises
Week 17	Stability Training	Resistance Training	Neural Developmental Exercises
Week 18	Retesting	Rest Period	Retesting
Week 19	Stability Training	Resistance Training	Neural Developmental Exercises
Week 20	Stability Training	Resistance Training	Neural Developmental Exercises
Week 21	Stability Training	Resistance Training	Neural Developmental Exercises
Week 22	Stability Training	Resistance Training	Neural Developmental Exercises
Week 23	Stability Training	Resistance Training	Neural Developmental Exercises
Week 24	Exit Testing	Rest Period	Exit Testing

Neuro-integrative exercises level 1

Sitting exercises begin in either an armless chair, or a stool with no support on any side. The practitioner ensures the patient is safe and sitting upright with good posture. During these exercises, patients are constantly reminded to keep their posture straight and to keep their gaze focused ahead, thus limiting visual dependency. Initially patients work on achieving a straight and stable posture. Once able to sit without sway, the practitioner lightly pushes patients forward, back, and to either side, causing a perturbation in posture and enhancing reactive balance. This progresses to patient-originated movement while seated, beginning with body-weight and slowly adding either free weights or resistance bands.

While seated, the practitioner and patient play cross-body-activity games, such as Patty Cake. This requires the patient to move out of alignment while remaining stable, while simultaneously crossing the midline with one or both hands. This has a similar proprioceptive gain effect as cross crawling but in a much more usable posture. Finally, the patient remains seated while the practitioner tosses or bounces a gym or Swiss ball to them. This causes the patient to reach out, catch the ball, stabilize, and then throw the ball back.

Neuro-integrative exercises level 2

At this level, the stool is replaced with a size-appropriate Swiss Stability Ball. The stability ball exercises are identical in progression to the seated exercises, with the exception of the practitioner pushing on the ball to further destabilize the patient.

Neuro-integrative exercises level 3

At this point the stability ball is removed and the patient stands. Having the patient stand by, or lean against, a wall or other support structure aids in this transition. The patient uses the wall for balance and visual support while performing balance and coordination exercises. These include lifting one foot off the ground, dorsiflexion and plantarflexion, knee raises, squats, and leg raises. A set of parallel bars, if available, can also be used in lieu of a wall.

Standing exercises progress in a similar fashion to the seated and stability ball exercises with special attention paid to removal of postural sway. The practitioner can act as a stabilizer at first, allowing the patient to hold the practitioner's arms or shoulders. Once standing with aid, progress should be focused on standing with only one hand holding on to the practitioner, and then free standing.

Neuro-integrative exercises Level 4

Once free standing is achieved, the patient and practitioner progress to free-standing patty-cake games (Figures 3.1 and 3.2). The patient pictured gave his consent to be photographed for use as an example in this manual. Since many stroke patients have significant ocular dependencies, this movement requires a patient slowly shed such dependencies. The feel of the wall acts as a proprioceptive enhancer, removing some ocular dependency and increasing afferent proprioceptor signaling. At no point is the practitioner out of reach, removing the chance the patient might sway or fall without support (Figure 3).

Resistance training program

Standard resistance exercise machines are used following American College of Sport Medicine (ACSM) exercise guidelines. Specific muscular strength and endurance exercises should be chosen to strengthen all major muscle groups with particular attention paid to the muscles of posture and ambulation. In particular, strengthening of the core muscles for balance and stability should be emphasized. Special attention is also paid to any muscle group that has atrophied in the particular patient. For this population, machines are preferable as the equipment includes standard weight plates attached to fixed motion resistance exercises for both upper and lower extremities. This reduces risk of injury and allows the patient to learn self-sufficient exercise protocols.

Resistance training programs should fit within patient time constraints to encourage and support compliance. Generally, the exercises should focus on Activities of Daily Living (ADL) strength and endurance with one set of muscle groups worked per each session (Tables 2 and 3).

Ambulation

Once standing balance is achieved, ambulation progresses along similar lines to those used for standing balance. The patient holds the practitioner's arms or shoulders, or parallel bars if available, while

Figure 3.1. Supported Standing Patty Cake

Figure 3.2. Multi-directional Patty cake

taking steps. Focus continues to be on upright posture, lack of sway, heel-to-toe stepping, standard gait patterns, and looking ahead instead of at the ground. As the patient progresses in walking, the practitioner moves from the patient holding both arms with the practitioner walking in front, to the patient holding one arm and the practitioner walking besides.

This progresses to the practitioner walking in front without the patient holding on and culminating in the practitioner walking beside the patient with no aid given. Finally, the patients progress to walking towards the practitioner from a short distance of three or four steps, and then longer distances of 15 or 20 steps.

Table 2. Resistance training program for legs

	Seated Calf Plantar flexion	Seated Calf Dorsiflexion	Leg Press	Leg Curl	Leg Ext.
Weeks 1-4	Baseline Weight	Baseline Weight	Baseline Weight	Baseline Weight	Baseline Weight
Week 5	Increase 10%	Increase 10%	Increase 10%	Increase 10%	Increase 10%
Weeks 6-8	10%	10%	10%	10%	10%
Week 9	Add Second Set	Add Second Set	Add Second Set	Add Second Set	Add Second Set
Weeks 10-12	2 Sets	2 Sets	2 Sets	2 Sets	2 Sets
Week 13	Increase 10%	Increase 10%	Increase 10%	Increase 10%	Increase 10%
Weeks 14-16	10%	10%	10%	10%	10%
Week 17	Add Third Set	Add Third Set	Add Third Set	Add Third Set	Add Third Set
Week 18-20	Add Third Set	Add Third Set	Add Third Set	Add Third Set	Add Third Set
Week 21	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15
Week 22-24	Final Sets	Final Sets	Final Sets	Final Sets	Final Sets

Table 3. Resistance training program for core body areas

	Seated Abdominal Crunch	Seated Spinal Extension	Lat Pull-Down	Triceps Extension	Bicep Curl
Weeks 1-4	Baseline Weight	Baseline Weight	Baseline Weight	Baseline Weight	Baseline Weight
Week 5	Increase 10%	Increase 10%	Increase 10%	Increase 10%	Increase 10%
Weeks 6-8	10%	10%	10%	10%	10%
Week 9	Add Second Set	Add Second Set	Add Second Set	Add Second Set	Add Second Set
Weeks 10-12	2 Sets	2 Sets	2 Sets	2 Sets	2 Sets
Week 13	Increase 10%	Increase 10%	Increase 10%	Increase 10%	Increase 10%
Weeks 14-16	10%	10%	10%	10%	10%
Week 17	Add Third Set	Add Third Set	Add Third Set	Add Third Set	Add Third Set
Week 18-20	Add Third Set	Add Third Set	Add Third Set	Add Third Set	Add Third Set
Week 21	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15	Increase Reps from 10-15
Week 22-24	Final Sets	Final Sets	Final Sets	Final Sets	Final Sets

Table 4. Neurodevelopmental training program

	Cross Crawling	Balance	Interrupted Balance	Ball Tossing
Week 1	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 2	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 3	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 4	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 5	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 6	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 7	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 8	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 9	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 10	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 11	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 12	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 13	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 14	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 15	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 16	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 17	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 18	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 19	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 20	30 Seconds	30 Seconds	30 Seconds	5 Tosses Front Only
Week 21	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 22	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 23	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side
Week 24	45 Seconds	45 Seconds	45 Seconds	15 tosses – 5 front and 5 per side

Intervention program neurodevelopmental and stability training

Developmental training progresses every 6 weeks, following assessment, at which point the patient progresses to the next stage of exercises or remains at their current level until appropriate advancement is demonstrated. The progression of exercises proceeds: Supine Cross Crawling – Seated Balance Control – Seated Cross Crawling – Swiss Ball Balance Control – Standing Cross Crawling – Standing Balance Control – Ambulation. This progression and exercises is demonstrated in table 4.

References

1. Oliveira R, Cacho E, Borges G (2006) Post-stroke motor and functional evaluations: a clinical correlation using Fugl-Meyer assessment scale, Berg Balance Scale and Barthel Index. *Arq Neuropsiquiatr* 64: 731-735. [Crossref]
2. Taylor JB (2009) My stroke of insight, a brain scientist's personal journey. New York, NY: Penguin Group.
3. Stinear C (2010) Prediction of recovery of motor function after stroke. *Lancet Neurol* 9: 1228-1232. [Crossref]
4. Korpershoek C, van der Bijl J, Hafsteinsdottir T (2011) Self-efficacy and its influence on recovery of patients with stroke: a systemic review. *J Adv Nurs* 67: 1876-1894. [Crossref]
5. Teasell RW, Fernandez MM, Mcintyre A, Mehta S (2014) Rethinking the Continuum of Stroke Rehabilitation. *Arch Phys Med Rehabil* 95: 595-596. [Crossref]
6. Dhamoon MS, Moon YP, Paik MC, Boden-Albala B, Rundek T, et al. (2009) Long-term functional recovery after first ischemic stroke: The northern Manhattan study. *Stroke* 40: 2805-2811. [Crossref]
7. Oremus M, Santaguida P, Walker K, Wishart L (2008) Methodological Issues in Evaluation of Innovative Training Approaches to Stroke Rehabilitation. *Rockville (MD): Agency for Healthcare Research and Quality* [Crossref]
8. Luft A (2011) The scientific basis of stroke rehabilitation. *Schweizer Archive for Neurology and Psychiatry* 162: 167-168.
9. Friedmann AJ (2015) Proprioception and developmental motor training: A new treatment for chronic phase stroke patients. Ann Arbor, MI: ProQuest, LLC.
10. Friedmann AJ (2017) A nearly full recovery from AVM hemorrhagic stroke 17 years after insult using a new integrated neurodevelopmental approach. *Medicine (Baltimore)* 96: e8026. [Crossref]
11. Geurts A, Haart M, van Nes I, Duysens J (2005) A review of standing balance recovery from stroke. *Gait Posture* 22: 267-281. [Crossref]
12. Whitall J, McCombe-Waller S, Silver KHC, Macko RF (2000) Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. *Stroke* 31: 2390-2395. [Crossref]
13. Anderson V, Spencer-Smith M, Leventer R, Coleman L, Anderson P, et al. (2009) Childhood brain insult: can age at insult help us predict outcome? *Brain* 132: 45-56. [Crossref]
14. Yang Y, Chen Y, Lee C, Cheng S, Wang RY (2007) Dual-task-related gait changes in individuals with stroke. *Gait Posture* 25: 185-190. [Crossref]
15. Globus C, Lam JM, Zhang W, Imanbayev A, Hertler B, et al. (2011) Mesencephalic corticospinal atrophy predicts baseline deficit but not response to unilateral or bilateral arm training in chronic stroke. *Neurorehabilitation and Neural Repair* 25: 81-87. [Crossref]
16. Haywood K, Getchell N (2001) Life Span Motor Development Champaign. Available at http://www.humankinetics.com/lifespanmotordevelopment
17. Thelen E, Ulrich BD (1991) Hidden skills: a dynamic systems analysis of treadmill stepping during the first year. *Monogr Soc Res Child Dev* 56: 99-104. [Crossref]
18. Davis W, Broadhead G (2007) Ecological task analysis and movement. Champaign, *IL: Human Kinetics*
19. McCabe P (2010) Advances in motor learning: Emerging evidence and new ideas. Acquiring knowledge in speech, language, and hearing. 12: 3-5.
20. Reed ES (1989) Changing theories of postural development. In M. H. Woollacott & A.Shumway-Cook (Eds.), Development of posture and gait across the lifespan (p. 3-24) Colombia, South Carolina: University of South Carolina Press