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Editor
Mieczyslaw Pokorski
Opole Medical School
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Bioprogressive Paradigm in Physiotherapeutic and Antiaging Strategies: A Review

Mieczyslaw Pokorski, Giovanni Barassi, Rosa G. Bellomo, Loris Prosperi, Matteo Crudeli, and Raoul Saggini

Abstract

This review updates the knowledge on the use of bioprogressive philosophy in current rehabilitation paradigms, focusing on age-related ailments and antiaging strategies. It is a holistic approach that combines aspects of biology and function into the realm of rehabilitation therapy. The bioprogressive philosophy, with assistance of modern technological developments, such as microgravity-producing devices and techniques, enables personalized and targeted therapeutic approach that seems the most effective in rehabilitation and prevention of neuro-myo-sensory disorders that compromise the homeostatic body harmony, particularly in old age. The review defines the aging, discusses the most common physical dysfunctions, linked to posture, balance, or gait, and gives cues to modern antiaging rehabilitative approaches. The emphasis is put on the proprio-neuromuscular facilitation, a combination of stretch technique that steps into the bioprogressive approach, as currently the best method in the world of physical rehabilitation.

Keywords

Aging · Antiaging strategy · Bioprogressive paradigm · Physical dysfunction · Physiotherapy · Proprioceptive neuromuscular facilitation · Rehabilitation

1 Bioprogressive Rehabilitation

Aging is usually defined as a progressive loss of function accompanied by increasing morbidity and mortality. Causes of the aging process are multifactorial and can be classified into two groups: intrinsic (notably genetic modifications) and extrinsic (environmental) factors. Several studies convincingly demonstrate the fast pace of aging of the general population worldwide and how this process is going to advance in the next few years. As the elderly population grows in terms of age and size, so do the requests for assistance for senior persons (Christensen et al. 2009). The main feature of this phenomenon is the elderly need for care which is required to maintain their healthy condition, for instance, performing some kind of exercise aimed to

M. Pokorski (✉)
Opole Medical School, Opole, Poland
e-mail: m_pokorski@hotmail.com

G. Barassi, L. Prosperi, M. Crudeli, and R. Saggini
Department of Medical and Oral Sciences and Biotechnologies, "G.d'Annunzio" University Chieti, Chieti, Italy

R. G. Bellomo
Department of Biomolecular Sciences, "Carlo Bo" University Urbino, Urbino, Italy

avoid the risk of falling or to begin a rehabilitation protocol (Israely et al. 2018; Zur et al. 2018; Aalen et al. 2014; Arbeev et al. 2009).

A bioprogressive multisensory rehabilitation approach has proven the most suitable to face a physiological reduction in stability. The approach, supported by modern technology, enables the creation of a changing training environment, with the aim to increase proprioceptive perception and balance reaction (Bellomo et al. 2009). Improvements can be monitored in a modern gait analysis laboratory to describe variations in balance reactions, which enables the therapist to periodically adapt the training program to changes in the patient condition to reach increasingly important therapeutic goals (Basile et al. 2016). Parkinson's patients treated with a bioprogressive rehabilitation paradigm, consisting of a combination of dynamic antigravity postural system (SPAD), auditory cue system (metronome), high-intensity vibratory system (VISS), and active stretching based on virtual reality rehabilitation system (VRRS) for several months, experience a distinct improvement in balance stability and gait pattern, with a reduction in falls and overall enhancement of quality of life (Bellomo et al. 2014). Modern assistance methods enable the elderly to access the training facilities at any time and to use them in a safe environment while continuing to provide instructions for rehabilitation and monitoring of progress (Akushevich et al. 2013). Some innovative examples for the preventive and rehabilitative intervention, which illustrate this increasingly diversified scope and ever-changing future perspective of the intervention program, have been described by Young (1983).

Aging concerns physical, cognitive, and social spheres of individuals. The cardiovascular system, muscle-skeletal mass, osteoarthritic structure, immuno-humoral metabolism, and central nervous system disorders predominate in the aged, altering the organism's functionality (Israely et al. 2018; Carmeli et al. 2016). Diabetes and cardiovascular diseases, closely linked to inflammation and oxidative stress, belong to at least partly modifiable risk factors, with a proper diet and correct lifestyle. Such pathologic frameworks often occur in adulthood, and behaviors are generally modifiable through a series of rehabilitative interventions (Atkins et al. 2014; Barzilai et al. 2012; Bergman et al. 2007). Thus, nutrition, frequency of physical activity, and other crucial factors need to be examined to develop the appropriated lifestyle, which would also provide succor to metabolic activity, cerebral functionality, and postural control (Si and Liu 2014; Bosma-den Boer et al. 2012; Misirli et al. 2012; Agnoli et al. 2011; Hu 2002).

Studying the inter-system correlations and the rules that underlie the perceptive-motor pattern holds a central role in the understanding of relationships between movement, function, environment context, and psycho-behavioral characteristics of subjects. The human being forms a unique biosystem whose management requires a holistic approach, personalized for specific patient's characteristics (Saggini et al. 2012). Posture is identified as the morphological, sensorial, and motor expression of the evolved identity. The somatosensory system, visual and auditory structures, and vestibular receptors are essential for maintaining the brain-regulated body motion and balance, as well as a feel of one's comfort (Zimmermann et al. 2013). A potential alteration of sensory afferentation can be compensated through the redundancy characteristics of a system, which also respond to appropriate myofascial adaptations (Reghem et al. 2014). The aging process underlies a progressive deterioration of the delicate mechanisms of neurological osteomuscular-fascial optimization, manifesting as an altered "afferent stimulation" that determines "postural dysfunction" (Barassi et al. 2018a, b, c, d).

Already at gestational age week 5, a trilaminar embryo may be recognized, with the interposition of mesoderm between ectoderm and endoderm. The epithelial to mesenchymal cell transition emerges, during which the structure assumes its function and form. In this mechanism, muscular chains and fascial continuity appear to be the evolutionary expressions of the spinal cord (Barassi et al. 2018b). Paraxial mesodermal elements of the skeletal muscular system are formed as the splanchnic mesodermal derivations, in particular smooth muscles, derived from the occipital-to-sacral region somites and head-region somitomeres (Saggini et al. 1996).

It is known that fascial connective tissue is able to pick up nociceptive and proprioceptive information thanks to the presence of mechano- and nociceptors and its spatial organization (Van der Wal 2009). Studies also demonstrate that connective tissue creates a network between the musculoskeletal, neural, endocrine, circulatory, respiratory, and immune systems, creating a milieu for inter-tissue cooperation (Vecchiet et al. 1999). In particular, fascia is composed of cells that have the ability to contract and communicate with one another, ensuring the supervision of body activity, such as the transmission of tension created by muscles or management of interstitial fluids (Bordoni and Zanier 2015; Schleip 2003). One of the latest studies performed on fascia tissue demonstrates, using a confocal laser endomicroscopy, the presence of "reticular structures" in visceral submucosa and dermal periarterial stroma, which are hypothesized to be an extension of the interstitial space (Benias et al. 2018). There appears a plausibility that such structures play a central role in the body's self-management of edema to recreate homeostatic harmony (Johnson 1977). Thus, contrarily to the old physiological tenet of functional neutrality of connective tissue, purportedly serving the creation of a parenchymal scaffold for cell arrangement, connective cells appear to host a multitude of active functions, inter alia, inter-cell communication, proprioceptive signal transmission, regulation of extracellular space fluid, and others (Bordoni and Zanier 2015). Nowadays, these cells appear to underlie the effectiveness of the bioprogressive rehabilitation paradigms that are set to affect their function to restore a proper body neuro-myo-sensory integration, as schematically depicted in Fig. 1.

2 Stretch Exercise

One of the most common exercise techniques is muscular-fascial stretch. Stretching technique modifies the Golgi apparatus activity which, via the spinal cord, decreases the firing rate of alpha

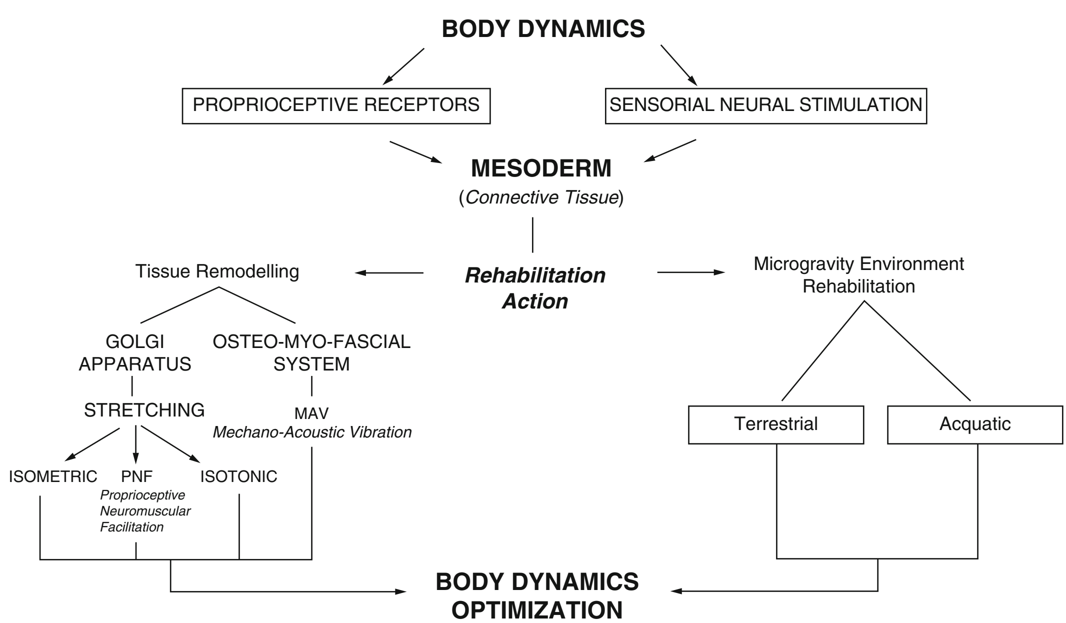

Fig. 1 Schematic diagram of the bioprogressive philosophy of physiotherapeutic interventions, pointing to the central role of connective tissue in maintaining the neuro-myo-sensory integration

motor neurons, and, in turn, muscle tone, for instance, as occurs in Yoga posture (Barassi et al. 2018c; Schleip 2003). There exist various types of stretching technique. The unresolved issue with physical stretch is what it should be like in the setting of health-care practitioners, particularly those engaged in sports training or rehabilitative framework in the elderly (Caplan et al. 2009). There are three types of stretch exercise: static stretching, dynamic stretching, and proprioceptive neuromuscular facilitation (PNF) (Fig. 1). A combination of these approaches guarantees autogenic inhibition, mutual inhibition, stress relaxation, and a reduction of pain consequently to the gate control theory, all of which leads to improvements in the range of motion of joints (Nelson et al. 2005; Wicke et al. 2014; Hindle et al. 2012). Static stretching consists of holding muscles in an elongated position for an extended period. Contrarily, dynamic stretch consists of moving joints through their range of motion. There are pros and cons of both types of stretch. Static isometric exercise, although being physically motionless, is a strong respiratory stimulant that provides succor to arterial blood and, consequently, tissue oxygenation. It also increases heart rate and blood pressure (Pokorski et al. 1990). These effects, thought of as typical and beneficial from the standpoint of physical rehabilitation or training, may jeopardize the frail elderly due to abruptly increased metabolic rate. Static stretch may also lead to muscle weakness, which hampers subsequent physical performance. Dynamic stretch, on the other hand, gives proneness to injuries, which may actually hamper the range of motion that already declines with age but is important for daily life activities (Konrad and Tilp 2014). Dynamic stretch, however, increases the nerve conduction velocity, muscle compliance, enzymatic turnover, and the central control running down from the brain to muscles (Wicke et al. 2014). The PNF combines the stretching and contraction of reciprocally related muscle groups in a cyclical pattern. "Contract-relax" (CR) and "contract-relax-antagonist-contract" (CRAC) methods are the representative techniques of PNF. In the CR technique, the target muscle is lengthened and held in that position, while rehabilitant contracts the muscle isometrically to its maximum for a certain amount of time, followed by a brief phase of passive stretching. CRAC is an extension of the former technique in which after the maximum isometric contraction of the agonistic muscle, rehabilitant contracts the corresponding antagonistic muscle for a certain amount of time. Ultimately, it seems that a mix of stretch modes, in particular static stretch followed by dynamic stretch, optimizes the benefits gained from physical rehabilitation, simultaneously reducing the number of exercise-induced muscle impairments or injuries (Rowlands et al. 2003). To this end, meditation techniques consisting of a variable motion ingredient and resembling the CRAC sequence of stretches, such as is *Tai Chi* and the like, advance in popularity of late (Hindle et al. 2012). An additional benefit of meditation is the improvement in mood, emotional stability, and cognition (Pokorski and Suchorzynska 2018; Lam et al. 2014).

3 Aging and Rehabilitation

Old age should not be seen as a disease or pathology but as a stage of life that can be fully explored to pursue personal and social goals. Human functionality has an outstanding plasticity and is capable of compensating for the lost structural elements caused by the age-related dampening of cellular metabolism. That may be exemplified, for instance, by the adaptive hyperventilatory responses to strenuous stimuli, such as exercise, in old age, despite a severe structural deterioration of the lungs and airways, limiting the alveolar gas exchange area and thus oxygen diffusion (Pokorski and Marczak 2003). Likewise, cognitive brain functions are maintained due to a greater neuronal synchronization and a flexible use of cognitive reserve or recruitment of alternative neuronal pathways, normally constituting a dormant reserve. The antiaging strategy is a process that not only involves combating the disease and its effects but also a large psychological component that is closely linked to behavior, personality traits, and other factors (Angel and Hogan

1992). Exercise is an antiaging strategy linked to physical and cognitive rehabilitation, development of positive stress, and lifestyle changes (Rebelo-Marques et al. 2018). The mind-to-body connection is indispensable for a motivated engagement in antiaging behaviors, such as exercise, and in physical rehabilitation in case of a disease-induced handicap (Wrycza and Baudisch 2012; Depp and Jeste 2009). Exercise has a protective effect on cognitive functions and helps combat the deleterious effects of stress and aging. The practice of proper physical exercise can improve physiological and functional responses, notably cardiovascular fitness and respiratory function, and thus physical health and quality of life of the elderly (Bellomo et al. 2017). Exercise also plays a key role in the assessment and prevention of frailty in the elderly (Singh 2002). In adulthood, aerobic skills and general physical activity are associated with lower mortality and morbidity from cardiovascular diseases. Benefits of physical activity also include reductions in a risk for stroke, diabetes mellitus, cancer, and osteoporosis (Ruiz et al. 2008; Lee and Skerrett 2001; Bijnen et al. 1999; Hakim et al. 1998; Paffenbarger et al. 1993).

Aging is inherently involved with a loss of muscle mass and function leading to sarcopenia and, consequently, to postural dysfunction (Carmeli 2017; Lin and Bhattacharyya 2012). Sarcopenia is underlain by a reduction in protein synthesis and an increase in muscle protein degradation (Delli Pizzi et al. 2017). Further, the ability of muscle regeneration is severely compromised by aging, which can lead to disability, particularly in patients with concomitant diseases or organ failures. Skeletal muscle dysfunction can be ameliorated by well-suited exercise that improves the function of muscle mitochondria (Barbieri et al. 2015). Beneficial effects of focal vibrations on the well-being of ailing elderly patients are beyond doubt when analyzing the results of studies on proprioception, muscle tone, and quality of gait (Toosizadeh et al. 2018; Saggini and Bellomo 2015). Vibrations of 300 Hz effectively increase muscle strength, acting on neuromuscular receptors, Golgi tendon organs, Pacini corpuscles, as well as through the regulation of genes that are responsible for expression of sarcomeric proteins and for recruitment of satellite cells. Integrated treatment with focused mechano-acoustic vibrations has a beneficial effect on bone mineral density (BMD) and T-score and on muscle strength and quality of life of osteoporotic subjects (Kwak et al. 2017; Saggini et al. 2017).

The body's agility to react to external forces plays a central role in rehabilitation. Acting on this mechanism enables the most individual adaptation of a therapeutic protocol and thus the use of the entirety of the rehabilitation power and also the exposition of compensative reactions and rebalancing of human body network (Fig. 1). To this end, microgravity environment is particularly effective in reversing functional detriments and limits concerning daily activities in patients with muscle and balance disorders (Kaneda et al. 2008). The exemplary is the aquatic microgravity environment, produced by immersion in water, which improves body stability due to a decrease in neural system activation caused by a central redistribution of the blood volume (Barassi et al. 2018a). A decrease in sympathetic activity, accompanied by increased parasympathetic activity, promoting vasodilation and blood circulation, increases blood flow, accelerates cellular metabolism and removal of unwanted materials, and decreases pain sensitivity (Forestier and Françon 2008). The autonomic nervous system remodeling positively affects the perception pain and fatigue associated with musculoskeletal disorders due mostly to decreasing muscle tension (Barassi et al. 2018d; Bellomo et al. 2012; Yasui et al. 2010). The rebalancing of gait pattern involves the development of relatively stable changes in spinal and supraspinal networks that are modeled by proprioceptive and somatosensory sensory information specific for the task. The development of specialized training protocols for assisted exercise in the microgravity environment hinges on the realization of the importance of locomotor learning and how the use of specific devices alters the demand stemming from motor tasks (Wolpert et al. 2001). The literature unambiguously shows that a specific reeducation protocol in relieving body weight can improve the static and dynamic balance, leading to a better overall motor performance (Moreno et al. 2013; Threlkeld et al. 2003). In our daily practice, we implement the single-photon avalanche detector (SPAD), a photon detecting system for optical communications. SPAD is a device able to compose a microgravity environment during gait motion, which optimizes the body tridimensional alignment in the body weight support modality. It has a dual action: mechanical, which allows for a cortical-subcortical neuromotor retraining aimed at the reacquisition of a body scheme in three planes of the space, and functional, which minimizes the energy consumption and increases the proprioceptive signal inflow to cortical areas during gait (Delli Pizzi et al. 2017; Saggini et al. 2004). Thus, SPAD improves postural stability through an increase in exteroceptive and proprioceptive sensitivity. The technique is also useful in therapy of sarcopenic patients for muscle strengthening and pain resolution, along with a postural and gait rehabilitation. This innovative therapeutic approach combines a motor and sensory feedback task with creation of feed-forward stimulation in the microgravity environment (Di Pancrazio et al. 2013).

In elderly patients, clinical relevance of exercise-based rehabilitation and nutritional interventions, such as increased ingestion of essential nutrients, results in the long-term improvements in strength and muscle mass and in functional capacity and decreases a risk of chronic metabolic disorders (Snijders et al. 2009). This integrated, personalized therapeutic and precautionary approach to health and disease, with characteristics of adaptability and biological progressiveness, improves quality of life in adulthood. This is a holistic strategy, contained within the biopsychosocial model, developed by Engels (1977), which emphasizes, but is not limited to, biological determinants for maintaining health, and does not overlook the overall importance of psychological or socioeconomic factors. All of them may integrate to act as physical traumas to the body system and compromise the homeostatic harmony. The neuro-myo-sensory integration of the bioprogressive philosophy combines aspects of biology and function into the realm of rehabilitation therapy (Fig. 1). It enables the optimization of redundant biological circuits and arrangements through personalized therapeutic interventions rather than application of rigidly fixed therapy schemes (Trieschmann 1987). Further research should scrutinize the physiological underpinnings of the bioprogressive approach to better understand its function and potential benefits to be gained in physiotherapy.

Ethical Approval This review article has been written in compliance with the ethical standards of the institutional and/or national research committees and with the 1964 Helsinki declaration and its later amendments. The article does not contain any studies with human participants or animals performed by any of the authors.

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