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SHORT COMMUNICATION

THE IMPORTANCE OF MOVEMENT FOR THE FUNCTIONING OF THE BRAIN

ZNACZENIE RUCHU DLA FUNKCJONOWANIA MÓZGU

Bartosz Bagrowski
Wiktor Dega Orthopedic and Rehabilitation Clinical Hospital, Clinic of Pediatric Orthopedics and Traumatology, Poznan University of Medical Sciences, Poland

ABSTRACT
Movement is an inseparable part of human life; therefore, it is one of the most natural remedies. Its effects on the nervous system are both physiological and epigenetic in nature; therefore, movement affects the brain in a multidimensional and multimodal manner. However, it turns out that the neurorehabilitation therapist may also affect the nervous system through specific motor acts as a result of proprioceptors stimulation, the relationship between coordination abilities and cognitive functions, and the involvement of individual areas of the central nervous system in intensive and effective work. This paper presents the current state of knowledge regarding the influence of movement on the functioning of the nervous system, and in particular the brain, at the cognitive, systemic and molecular levels.

Keywords: cognitive functions, movement, neuroplasticity, neurorehabilitation, proprioception

STRESZCZENIE
Ruch jest nieodłącznym elementem ludzkiego życia, dlatego stanowi jeden z najbardziej naturalnych środków leczniczych. Jego wpływ na układ nerwowy ma zarówno naturę fizjologiczną, jak i epigenetyczną, dlatego też ruch oddziałuje na mózg wielopłaszczyznowo i multimodalnie. Okazuje się jednak, że również terapeuta prowadzący neurorehabilitację może oddziaływać na układ nerwowy za pośrednictwem określonych aktów ruchowych poprzez stymulację prprioceptorów oraz wskutek związku zdolności koordynacyjnych z funkcjami poznawczymi, a także angażowania poszczególnych obszarów ośrodkowego układu nerwowego do intensywnej i efektywnej pracy. Niniejsza praca prezentuje aktualny stan wiedzy dotyczący wpływu ruchu na funkcjonowanie układu nerwowego, a w szczególności mózgu, zarówno na poziomie poznawczym, systemowym, jak i molekularnym.

Słowa kluczowe: funkcje poznawcze, ruch, neuroplastyczność, neurorehabilitacja, propriocepcja

Movement and physical activity

Movement and physical activity are integral parts of human life. In physiotherapy, movement is used as a therapeutic agent because it is natural and beneficial for the human body (Pasek *et al.*, 2011). Movement, i.e. any change in the position of the body, is associated with energy expenditure, as well as the involvement of the circulatory system, the musculoskeletal and nervous systems. Therefore, it is an agent that can be used to

Author responsible for correspondence:
Bartosz Bagrowski
Clinic of Pediatric Orthopedics and Traumatology
University of Medical Sciences
28 Czerwca 1956 No 135/147
61-545 Poznań, Poland
Email: bbagrowski@orsk.ump.edu.pl
https://orcid.org/0000-0001-7402-8418

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restore lost functions and affect systemic performance (Chaput *et al.,* 2014; Tonelli *et al.,* 2018). Movement is any activity that is associated with physical effort, i.e. the work of skeletal muscles leading to functional changes in the body. However, thanks to movement and physical effort, it is also possible to activate compensation mechanisms and influence the functioning of the nervous system (Jakicic, Otto, 2005; Tonelli *et al.,* 2018).

The influence of exercise and physical activity on the nervous system

Movement and physical effort stimulate the central nervous system and increase the development of neuromuscular synapses. In this way, not only motor engrams of memory are developed, but also motor skills, such as speed, agility, and endurance, which in turn increase the development of lateralisation, coordination skills and the speed of reaction to external stimuli (Jakicic, Otto 2005; Schwartz 2016). Movement activates the maturation of the motor centers in the brain and increases the speed of conduction of nerve impulses. In this way, movement and physical activity affect not only the body's efficiency but also the improvement of the functions of the nervous system at supraspinal levels (Donnelly *et al.* 2016; De Giorgio *et al.* 2018).

Even short-term but intense physical activity strengthens the connections between neurons, e.g. in the hippocampus, thus improving memory and cognitive abilities. This is because of both the better oxygenation of the brain and the epigenetic effects of physical activity. It activates the expression of the Mtss1L gene, which codes for a protein responsible for the elasticity of cell structures, which in the nervous system promotes the growth of dendritic spines, as a result of which new synaptic connections are formed in the hippocampus (Chatzi *et al.* 2019). Physical activity also induces the expression of the BDNF gene, which encodes a brain-derived neurotrophic factor – a protein belonging to nerve growth factors and influencing neuronal plasticity (Żołądź and Pilc 2010; Nascimento *et al.* 2015; Myers *et al.* 2017). The presented examples show the importance of movement and physical activity for the functioning of the nervous system at the molecular level. It is worth noting, however, that the beneficial effects of physical activity on the nervous system also take place at the cognitive (Mualem *et al.* 2018; Dyrla-Mularczyk and Giemza-Urbanowicz, 2019), systemic (Chaddock-Heyman *et al.* 2018), and neuronal processing levels (Singh *et al.* 2019), which indicates the multi-level beneficial effect of movement on the nervous system.

The influence of movement on the brain in terms of therapeutic concepts

Movement affects the nervous system not only as a result of biochemical and epigenetic changes induced by exercise but also through the proprioceptive, vestibular and tactile stimulation itself, which is related to the movement act performed. In an electrophysiological study performed on patients undergoing rehabilitation using the PNF (proprioceptive neuromuscular facilitation) method, it was shown that functional movements performed with the help of a physiotherapist (especially movements exceeding the midline of the body) cause stimulation in the patient in the dorsolateral prefrontal cortex and parietal cortex (Lial *et al.* 2017). In the Feldenkrais method, it is pointed out that focusing on the motor act performed causes learning the ability to organize the body in motion, which in turn improves neuromuscular coordination and mental activity (Clark, Schumann, Mostofsky 2015; Mattes 2016; Myers 2016). It is also noted that conscious performance of motor acts has a positive effect on the development of balance, mobility and motor coordination, and also plays an important role in the mechanisms of learning, concentration, autonomic regulation and shaping the body schema (Stephens and Hillier 2020). Although even passive movement performed by a physiotherapist activates the primary somatosensory cortex,

primary motor cortex, posterior parietal cortex and secondary somatosensory cortex (Onishi 2018), it is noted that engaging the patient's cognitive attention in the performed motor tasks increases neuroplastic abilities and thus this and the therapeutic effect of movement exercises (Hunt, Paez, Folmar 2017). Therefore, it turns out that to support cognitive functions and their neural correlates, as well as to stimulate the mechanism of neuroplasticity, movement (even passive movement) must take place while crossing the midline of the body and that it is performed consciously and without distractions.

Focusing on the movement and the accompanying proprioceptive, vestibular and tactile stimuli allow patients to build their own body schema (Holmes and Spence 2004). Coordination skills, crossing the midline of the body and shaping the body schema are related to bilateral integration, i.e. the coordination of the work of both cerebral hemispheres (Cardoso and Castro Magalhães 2009; Cauraugh and Summers 2005), which is particularly important in the context of neurodevelopment (Białas-Paluch 2017). The strong relationship between motor coordination and cognitive functions is noted by many researchers (Dalziell *et al.* 2019; Fernandes *et al.* 2016; Higashionna *et al.* 2017), and this relationship may result partly from the aforementioned bilateral integration and partly from the functioning of the cerebellum which is responsible not only for the control of the body in space but also for working memory, learning mechanisms, shifting attention or cognitive flexibility (Koziol, Budding and Yamazaki 2014; Starowicz-Filip *et al.* 2013). Proprioception may be responsible for the strong relationship between motor coordination and cognitive functions (Boyle *et al.* 2020; Renault *et al.* 2018). Most likely, the proprioceptive incentives from the locomotor system sent via the spinal-cerebellar pathways to the cerebellum, activate it not only for a motor response but also for more efficient cognitive functioning. Proprioceptive stimulation supports cognitive processes in people affected by neuropathology (Müller *et al.* 2002), which makes it very important in neurorehabilitation, especially in the Proprioceptive Neuromuscular Facilitation method, where the sense of deep feeling plays a special role at every stage of therapy (Lee, Park and Na 2013).

According to the presented articles, movement is significantly related to neuroplasticity and cognitive processes, especially with executive functions, working memory, as well as cognitive control and flexibility. The effect of the movement used in rehabilitation is not only to consolidate motor memory (consolidate the sequence of muscle activity) but also to improve cognitive functions.

Movement and sensory integration – effects on the brain

The more multifaceted therapeutic activities are implemented, the better the effectiveness of rehabilitation. Therefore, the therapeutic movement should also be accompanied by other forms of interaction, especially in the field of sensory integration, which engages the brain to work even more intensively. Its task is to receive, interpret and integrate stimuli with different modalities in order to build a complex perception and increase the integrity of the nervous system (Bagrowski 2020; Lane *et al.* 2019).

Sensory Integration Therapy is a method that combines movement with sensory stimulation because each exercise is performed in the company of sensory stimuli, e.g. with the use of colourful toys or rhythmic sounds (rhythmization of movement – important, e.g. in shaping the gait function) (Alqaraan, Ahmad, Hammad 2018), as well as substrate instability (stimulation of the sense of balance and proprioception) (Hedayatjoo *et al.* 2020). Combining sensory modalities and movement also influences the formation of coordination skills, which also plays an important role in building neuronal integrity (Abuin-Porras *et al.* 2018; Rizzo *et al.* 2020). Integrating various sensory stimuli and simultaneous involvement in the performed movement makes the

method of sensory integration a very important factor in shaping the proper functioning of the brain and cognitive development of a child, as well as building the body schema (Noel, Wallace, Blake 2015; Crasta *et al.* 2020).

Summary

Motor activity is important for the functioning of the brain, especially in the context of neuroplasticity and cognitive processes. There is a significant relationship between motor coordination and cognitive functions in the literature, which suggests that coordination exercises may support cognitive processes. It turns out that the movement associated with the therapy also has a significant effect on the brain, and each therapeutic method and concept mentioned in this study uses neurophysiological phenomena to maximize the therapeutic effect. In this context, particular attention should be paid to Proprioceptive Neuromuscular Facilitation, Feldenkrais Method and Bilateral Coordination Therapy. Sensory Integration Therapy is a method that tries to influence the nervous system not only by movement and contact with the patient but also by integrating sensory incentives. However, it should be noted that each of the aforementioned methods and concepts may demonstrate different effectiveness in different patients; therefore the process of neurorehabilitation should be characterized by complex interactions and take into account the individual circumstances of patients. Personalized therapy allows for the maximization of therapeutic effects.

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