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Ageing and mobility—motor control in the circle of life

When we are young, we cannot imagine the problems of elderly people—but we will be confronted with them one day. This article offers a perspective by looking across the entire lifespan. By observing the youngest and their reactions to manual medicine treatments, we may be able to reveal new aspects of understanding manual medicine in elderly people.

Acute or chronic pain, balance problems, and falls are common issues for the aged and represent an increasing burden on healthcare systems. Therapeutic options are often limited due to a variety of existing comorbidities and polypragmasia.

Thanks to its low-risk access to the musculoskeletal system, manual medicine can make an important contribution to an interdisciplinary approach. Profound knowledge of all parts of the mobility and pain systems as well as their connections to motor control and development enables practitioners to offer diagnosis and treatment by means of their hands.

Motor control

No beginning, no end: a circle

And all spring from one, which has no beginning, nor no end that I can find; for where there is a circle there is no beginning (Hippokrates 460-370 BC)

Movement is the essence of life. It underlines our actions, behavior, and communication.

But how do we control movement? Many different models have been devel-

oped over the past decades and the actual processes are still in the focus of science.

A current explanation is the *forward model* [9]. This means that our central nervous system (CNS) plans the whole movement in advance using so-called internal models. These are neural circuits where, for example, fixed lengths of our limbs are represented.

Especially remarkable is the fact that the CNS estimates future sensory inputs based on motor outputs. To achieve this, every motor command bonds together with a so-called corollary discharge, better known as efference copy. It acts as a neural simulator for the movement. It speeds up reaction time, as every sensory input will be compared to this efference copy. From that point on, it is known as the *inverse model* [9]. Consequently, the results of input and output must be the same; differences can be recognized immediately and corrected if necessary. Mesencephalic and spinal reflexes, as described by Sherrington among others, probably play a role in control. However, reflexes only play a subordinate role in motor control.

The *forward and inverse model* is a two-in-one system, i.e., it is predictive and controlling. The prediction converts motor commands into expected sensory consequences, whereas the control transforms desired sensory consequences into motor commands [9].

For an acceptable outcome, a perfectly working sensorimotor system is necessary. To show this, we need to describe motor control right from the beginning.

Motor development

Initiating the circle

... in the core of every beginning lives magic

Magic that protects us and helps us live (Phases, Hesse)

The first observable movement in the human body is the beating of the heart. It starts at 5 to 6 weeks of gestation.

The earliest body movements occur at 7 weeks and 2 days of gestation and consist of sideward bending of the neck. A few days later, the nervous system generates different motor patterns such as simple startles or hiccups, but also more complex patterns such as stretching or general movements which involve the whole body in variable sequences of neck, arm, trunk, and leg movements [4, 5].

General movements are endogenously generated, almost rhythmic movements that arise from neuronal networks of the brainstem—the so-called central pattern generator (CPG). They occur without sensory trigger and independently of external stimuli.

Depending on activity, proprioception develops in the following 7 weeks. In the last two thirds of gestation, proprioceptive feedback increasingly modulates CPG activity.

Take home message

Form follows function, function follows form! As we have seen above, movement is an essential part of our life from the very beginning. As a result of these early movements, morphologic structures, muscles, tendons, and fasciae develop as well as the sensorimotor system.

General movements can be observed from the ninth week of gestation up to 5 months after term, and appear to be similar to early fetal life until the second month after term. Around term age, they are termed writhing movements, which have a smaller range of motion than fetal or preterm general movements. At the age of 6–9 weeks, writhing movements gradually disappear and another CPG activity emerges to produce fidgety movements.

These very small movements occur in a complex and variable way through the whole body, particularly in shoulder, hip, wrist, and ankle joints, and seem to play a role in recalibration of the proprioceptive system.

At the same age, around 3 months, several behavioral patterns change. For example, head controls starts to develop, sucking patterns change, body posture changes from bodyorientated to spaceorientated, and cortical control of vision (including binocular vision) and modulated cooing develop [3].

Vision is crucial for head control and development of the upright position. Blind infants show abnormal fidgety movements as well as a delay in head control, vestibular function, and gaining the upright position [11].

After the age of 5 months, arbitrary motor skills increasingly take over and general movements disappear.

The sensorimotor system

Part of the circle

After considering this development, it is obvious that the sensorimotor system is formed by the circular connection of sensors in different body structures. Many different sensors and systems are involved. As shown above, the visual system plays a major role, not only in locating our body in space, but also in detecting the position and relation of body parts and motion of our body [14]. The vestibular system is sensitive to two types of information: the position of the head in space and sudden changes in the direction of movement of the head. This is important for maintaining postural stability and stabilizing our eyes [14].

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Abstract

Ageing starts with the first day of life. The way in which we and our musculoskeletal system age depends greatly upon how much we move. From the very beginning, movement is the essence of life—starting in the eighth week of gestation with autonomic movements, so-called general movements. These early movements are essential to development of the proprioceptive system, which is necessary to plan and control movement itself. As is every other system in the body, the visual, vestibular, and perceptive

systems are subject to an ageing process. Together with degenerative processes of the musculoskeletal system, these changes lead to the common problems of elderly people: chronic pain, balance problems, falls. Manual medicine, with its low risk approach, can help to improve these problems.

Keywords

Musculoskeletal manipulations · Motor skills · Aged · Embryonic and fetal development · Accidental falls

Altern und Mobilität – motorische Kontrolle im Laufe des Lebens

Zusammenfassung

Das Altern beginnt mit dem ersten Lebenstag. Wie wir alt werden, wie unser Bewegungsapparat alt wird, hängt stark davon ab, wie viel wir uns bewegen. Bewegung ist von Anfang an die Essenz des Lebens; sie beginnt in der 8. Schwangerschaftswoche mit autonomen Bewegungen, den „general movements“. Diese frühen Bewegungen sind wesentlich für die Entwicklung des propriozeptiven Systems, welches zur Planung und Steuerung der Bewegung selbst erforderlich ist. Das visuelle, vestibuläre und perzeptive System unterliegt wie jedes andere System im Körper einem Alterungsprozess.

Zusammen mit degenerativen Prozessen des Bewegungsapparats führen diese Veränderungen zu den allgemeinen Problemen älterer Menschen: chronische Schmerzen, Gleichgewichtsstörungen, Stürze. Manuelle Medizin mit ihrem risikoarmen Ansatz kann dabei helfen, die beschriebenen Probleme zu verbessern.

Schlüsselwörter

Muskuloskeletale Manipulationen · Motorische Fähigkeiten · Senioren · Embryonale und fetale Entwicklung · Akzidentelle Stürze

Stabilization of the head and eyes is also dependent on the proprioceptors, primarily on receptors in the cervico-occipital junction, as described by Hasenstein [7]. Proprioceptors are mainly located in the myofascial system and connective tissue [10]. Furthermore, afferent information from skin receptors is important for proprioception. Edin et al. were able to demonstrate this for slowly adapting receptors in the innervation area of the lateral femoral cutaneous nerve, which are capable of detecting knee joint positions [2].

Changes in fascia

A problem of ageing?

All these structures and systems are affected by an ageing process. Our eyes lose their contrast sensitivity and spatial resolution, and neural processing of optical information declines. The vestibular system becomes less sensitive. Due to sarcopenia, muscles are degenerated and restructured. The CNS loses its potential for integrative information processing. Are these changes an inescapable fact, simply fate? Of course, there is a genetically regulated physiological ageing process. However, considering the fascial system and motor control, we see that physical activity or inactivity determines both health and the development of chroni-

cally degenerative processes [10]. Ageing starts from the first day of life and, as can be seen in the fascial system, also depends on movement.

Fascia is a bundle of fibrous collagenous tissue surrounding, penetrating, and supporting the muscle fibers and building a network throughout the whole body. It is certainly the most important organ for proprioception. The superficial fascia layers of the body are much more densely populated with sensory nerve endings than the more internally situated connective tissue [13]. The structure of young fasciae is described as lattice like, wavy, and crimp, and it can store kinetic energy. This allows our muscle fibers to glide smoothly and enables us to move fluently and elegantly [13]. Due to aging or immobility [8], the structure of the fascia changes. It becomes less organized and more irregular, and loses the capacity to store kinetic energy. The degenerative process starts. Movements become less fluent and elegant. The myofascial system becomes rigid; joints lose their range of motion (ROM) and joint play. Because of the rigidity of the myofascial system, muscle spindles and other proprioceptors lose their function.

Pain and an altered sensory input lead to inaccuracy in the internal models. This, in turn, significantly complicates the ability of the brain to compute accurate sensorimotor transformation [9]. A vicious circle!

The circle of life

Therapeutic approach

With training, we can regain some of the crimp structure. Since “form follows function, function follows form” is also valid in fascia, we can, with proper training, keep or regain the youthful structure of the fascia.

The collagen fibrils in a healthy body are replaced every 6 months. Therefore, an expected replacement of 30% of collagen fibrils every 6 months and 75% in 2 years is predicted [12].

However, certain requirements must be met for adequate training. First, we have to ask our patients what they were capable of in the past—which movement

patterns can we expect to be reactivated? By drawing the patient's attention to past movement patterns, they can recall them in their internal model and use them accordingly.

The second question should be: “What are your recent restrictions?” An exact analysis of the musculoskeletal system will provide us with the status quo. The first aim is to increase joint play via manual therapy. Adequate techniques must be chosen with regard to age and frailty. Once this objective has been reached, a training therapy can be started. Nutritional considerations should also be included. Dehoust et al. describe this in their *3 Säulen Therapie* (“Three-pillar therapy”) [6].

A positive side effect is that every touch increases perception in the treated region. A useful and simple technique used in treatment of infants, nonspecific exteroceptive–proprioceptive stimulation, the so-called *Pritschen* [1], can be easily adapted to elderly people. As a result of improved perception, even the “old” brain can do its best to create a successful integration and complex movements.

This leads us to our last question: “What has improved after therapy and how can you continue this effect?” According to subjective demands, age-adapted objectives and exercise are necessary to motivate the patient to improve endurance, coordination, and strength.

All this will help to regain a smooth and elegant way of moving, just like a fetus and a newborn baby do with general movements. All this will help to improve balance and movement and may help to prevent falls.

We assume that continuing movement will keep our musculoskeletal system in good shape and function. “Use it or lose it!” should be kept in mind.

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Compliance with ethical guidelines

Conflict of interest. A. Sammer and F. Sammer declare that they have no competing interests.

For this article, no studies with human participants or animals were performed by any of the authors. All studies performed were in accordance with the ethical standards indicated in each case.

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