EÖTVÖS LORÁND UNIVERSITY
FACULTY OF EDUCATION AND PSYCHOLOGY

Theses of the Doctoral Dissertation

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Preventive study of physiological curvatures and functional function of the spine in adolescent students
A gerinc fiziológiás görbületeinek és funkcionális működésének prevenciós célú vizsgálata serdülő korú tanulók körében

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Introduction

The sedentary lifestyle is rapidly spreading among the younger generation, with most adolescents failing to meet the recommendations for moderate and vigorous physical activity levels (at least 60 minutes of exercise every day) (Németh et al., 2019). According to data from the Central Statistical Office, the number of children in Hungary struggling with spine disorders increased by 26.8% from 2003 to 2017 (KSH, 2019). During my career, I spent more than two decades in public education. As time passed, I observed that children are becoming less active, with declining motor coordination, endurance, and posture. This trend has been exacerbated by the digitization of lifestyles, leading to an increase in postural disorders even in physical education classes.

During adolescence, these problems are exacerbated by a combination of "physiological" laziness (Virág, 2021) and hormonal changes that contribute to a temporary decline in athletic performance and the development of postural problems (Elpeze & Usgu, 2022). Regular physical activity can improve and maintain muscle strength and flexibility. Correct posture can be learned, practiced and consciously developed (Somhegyi, 2003). Correct posture allows the body to be maintained in a vertical position, limiting the movement of the centre of mass to provide maximum stability with minimum muscle effort. The amplitude of thoracic kyphosis and lumbar lordosis, which serve to stabilise the spine, prevents the development of curvature in other planes. The central nervous system tries to counteract gravitational forces on the body by adjusting the positions of body segments (Żurawski et al., 2020). Posture represents both physical and mental health (Edington et al., 2016; Dima et al., 2022).

Optimal posture depends on various factors, but one of the most important is to engage in physical activity of appropriate intensity and reduce sedentary lifestyles (O'Donovan et al., 2010; Bergmann et al., 2013; McMaster et al., 2015). Incorrect posture deviates from the physiological position in which the load on the spine would be most favourable (Celenay & Kaya, 2017). Muscle imbalance occurs (Đokić & Stojanović, 2010; Yang et al., 2020; Homola et al., 2022), reducing the load-bearing capacity of the trunk and back muscles. Overloading of the cooperating joints leads to the development of degenerative joint diseases in adults (Bagi et al., 2016). It is therefore crucial to help establish and reinforce correct posture as muscle function is restored.

During puberty, children's skeletal growth accelerates, and with rapid growth comes changes in the biomechanical state of the body (Stokes, 2007). The endocrine system regulates individual growth and maturation (morphogenesis), coordinates organ responses to external and internal environmental stimuli (integration) and ensures dynamic stability of the internal environment (Mészáros et al., 2011). However, the different rates of bone and muscle development can lead to postural dysfunction (Latalski et al., 2013). Muscles may struggle to keep up with this sudden growth, resulting in relative muscle weakness as the load-bearing capacity of the trunk and back muscles decreases (Yang et al., 2020). The muscles responsible for posture may weaken in some areas and become tight and contracted in others.

Research aims and hypotheses

The thesis outlines three main research aims. The first part of the study is a retrospective examination of motor development in infancy and early childhood. Our aim was to identify correlations between infant and early childhood motor development and the onset and

escalation of postural problems in adolescence. In the second phase of the research, in a cross-sectional study, we analyzed the physiological condition of the spine of both athletic and non-athletic children and investigated the relationship between poor posture and postural weakness. In addition, our research aims to investigate the physiological curvatures of the spine and improve the identified conditions of poor posture. In my dissertation, I aim to test the validity of the hypothesis that initiating postural correction programs at school age, which help to establish proper muscular balance and consequently correct posture, can reduce the prevalence of poor posture and postural weakness.

Research hypotheses:

Hypothesis 1: Early disturbances in motor development influence spinal development. Hypothesis 2: Early disruptions in motor development affect the development of fine motor skills in primary school.

Hypothesis 3: The time of a baby's first standing is related to the development of fine motor skills in primary school.

Hypothesis 4: Athletic children's spines will be in better condition than their non-athletic counterparts.

Hypothesis 5: Athletic adolescents, both boys and girls, will have a higher proportion of values within the reference range for certain sections of the spine than non-athletic boys and girls.

Hypothesis 6: Regular performance of targeted exercises will improve posture.

Hypothesis 7: The intervention program will improve spinal mobility.

Hypothesis 8: The intervention program will improve spinal stability.

Hypothesis 9: Changes in the lumbar and thoracic spine segments will be significantly different following the intervention program.

Methods

Spinal Mouse

The Spinal Mouse device is suitable for radiation-free, comprehensive assessment and analysis of the spine (Topalidou et al., 2014; Büyükturan et al., 2018). It provides objective information about the static and functional status, shape, stability, mobility, loading capacity, possible degree of spinal curvature, and restricted or excessive motion segments of the spine. Research findings (Mannion et al., 2004; Livanelioglu et al., 2015; Topalidou et al., 2015; Demir, 2020) indicate that the device is reliable and suitable for obtaining repeatable results in research. The device, which resembles a computer mouse, contains two roller heads that follow the line of the spinous processes of the vertebrae. The Spinal Mouse can be used to study the morphological characteristics and mobility of the vertebral column in the frontal and sagittal planes. The device can be rolled along the spinous processes of the C7-S3 vertebrae on the spine.

Matthias test

Performing the Matthias test is part of the measurements with the Spinal Mouse, as the software of the device contains the necessary parameters. A detailed description of the test can be found in the following paragraphs. The test provides information about the strength of the pelvic and shoulder girdle muscles, which play an important role in posture (Kempf & Fischer, 1993; Vass & Bohner-Beke, 2015, p. 59; Kaposvári et al., 2019).

Anthropometric data collection

Height and weight measurements were taken using the stadiometer and the OMRON BF511 body fat percentage measuring device available in the school's equipment. These instruments are used in NETFIT measurements and are therefore available in every educational institution (Kaj et al., 2014).

Questionnaire

The questionnaire used in the research consisted of a first part derived from elements of the Global Physical Activity Questionnaire (GPAQ, WHO, 2021) and the TÁRKI Household Monitor questionnaire (TÁRKI, 2012). This part focused on students' demographics, physical activity, sports habits, regularity and duration, and participants were required to complete it. The second part of the questionnaire related to the subjects' movement development during infancy and early childhood and was prepared with the help of the chief midwife of the Public Health Department of Vas County Government Office.

Document Analysis

We used document analysis as a method to study the fine motor development of primary school children. We evaluated the end of year reports stored in the Mozanapló system, accompanied by a review of the teachers' written notes on the pupils who participated in the research.

The 12 target exercises of the Special Postural Correction

“Exercise Set of the Hungarian Spine Society (MGT) are also a semi-objective test suitable for testing the strength and flexibility of postural muscles, i.e. muscle balance. Exercises 1-6 primarily assess muscle strength, and exercises 7-12 primarily assess muscle flexibility". (Tóthné & Tóth, 2015, p. 22.) The test was conducted at the beginning and at the end of the intervention work.

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Data processing

Statistical analyses were performed using the Statistica for Windows 13.2 software package and IBM SPSS Statistics for Windows, version 23.0 (IBM Corp. 2015; Armonk, NY: IBM Corp.). Cross-tabulation analysis (Fisher's exact test, Pearson's chi-squared test) was used to examine the association between gross movements and sex. Independent samples t-test was used to analyze differences in handwriting performance between the sexes. One-way ANOVA was used to examine differences in posture, physical activity, and fine motor skills between the three groups. Pearson's chi-squared test (χ^2) was used for categorical variables and factorial ANOVA for scale variables. Differences in mean anthropometric and body composition values by sex

and examination were analyzed using one-way ANOVA. Changes in mean values of spinal regions (mean of three measurements) were analyzed using repeated measures ANOVA, post hoc and Tukey's method.

Findings

We found no evidence of a relationship between early motor development, in our case large movements during infancy (climbing, crawling), and fine motor skills (writing) at school age. The results of the research show that educational factors may play a more important role in the acquisition of fine motor skills in early school age, and that there is no close relationship between the large movements that develop in infancy and the development of fine motor skills that develop in early school age.

On the basis of their findings, it can be said that postural disorders occurred in a similar proportion of athletes and non-athletes. In the sample we studied, a large percentage of male athletes (66.7%) for dorsal kyphosis and female athletes (62.5%) for lumbar lordosis were outside the reference range, so it cannot be said that the results of athletes are better than those of non-athletes when it comes to the physiological state of the spine.

As a result of the intervention work, 43.75% of the participants had a value within the reference range for the sacral angle before the intervention, and this was characteristic of 87.5% of the participants after the program. Before the intervention, 50% of the students had physiological levels of lumbar lordosis during standing measurements. As a result of the intervention, this rate increased to 93.75%. Regarding dorsal kyphosis, 56.25% of the participants before the intervention and 50% after the intervention had values in the reference range. (Three were below reference, no one was above reference). After performing the Matthiass test, 43.75% of the students at the beginning of the intervention and 68.75% at the end of the intervention had a back kyphosis value in the reference range. Overall, our results show that a 16-week posture improvement program can improve the condition of the spine in pubescent children. We consider it important to develop the methodological guidelines for physical education in schools, so that more emphasis can be placed on the preventive spinal mobilization and stabilization exercises, which can be used to counteract the alarming deterioration of the spinal condition.

Proving hypotheses

My first hypothesis, that impaired motor development in infancy influences the development of the spine in adolescence, has not been confirmed. There were only four pupils in my sample who had problematic or delayed infant motor development. One had to attend early movement development for bipedalism, one for disjointed movement, one for hip dislocation and one for a bound hip joint. Two of these had participated in the postural improvement program, but there is no evidence that this is related to infantile hip dislocation or a hip joint joint.

My second hypothesis, that infant movement development (pre-erect movement patterns) affects the development of fine motor skills in early childhood, was partially confirmed. Among boys, some groups of pre-erection movements (crawling and crawling and climbing) showed statistically significant differences in writing performance. Boys who crawled before standing (quadriceps) scored higher (26.3±3.3) on the writing test than those who both crawled and crawled (22.5±4.5). Girl pupils who had omitted crawling and crawling from their range of movements during infant development were slightly behind their peers in writing performance.

My third hypothesis, that the time of the first set-up in infancy is related to the development of fine motor skills in early school age, was not confirmed. There was no statistically significant association between time of standing up and writing performance in either boys ($t(26) = 0.636$, $p = 0.533$, gHedges = 0.25) or girls ($t(25) = -0.799$, $p = 0.440$, gHedges = 0.36). There is no consensus in the international literature that the development of gross motor skills and fine motor skills are related. Escolano-Pérez and colleagues (2020) found no correlation between the development of these domains, similar to our study, but de Waal (2019) reported contradictory results.

My fourth hypothesis, that the spines of children who play sports are in better condition than those of their non-athletic peers, was partially confirmed. For boys, no significant differences were found between the athlete and non-athlete groups when examining dorsal kyphosis, and these results are in line with those of Chertman et al. (2010). For this spinal segment, the results of girl athletes are better than those of their non-athlete counterparts. For lumbar lordosis, athletes have a higher proportion of values within the reference range than their non-athlete counterparts, and for sacral angle, representing pelvic posture, the results of athletes are better overall, but the proportion of non-athletes is slightly higher in the boys' group.

My fifth hypothesis, that both boys and girls in groups of athletic adolescents would have a higher proportion of scores within the reference range for each section of the spine than non-athletic boys and girls, was partially confirmed. With regard to dorsal kyphosis, the statement holds true for girls who play sports, but not for boys. Conversely, for lumbar lordosis, the claim is true for boys and similar proportions of values within the reference range for girls for both groups. Our results are consistent with those of Mucha and colleagues (2015). In terms of sacral angle, only the results for girls playing sports are better.

My sixth hypothesis, that posture improves with regular performance of targeted exercise sequences, was confirmed. The results of the measurements taken with the Spinal Mouse device and the test tasks developed by the Hungarian Spinal Society also confirmed that the postural improvement program was successful. Significant changes in postural parameters were achieved in all three regions we studied, as confirmed by the results of the test exercises.

My seventh hypothesis, that the intervention program would improve spinal mobility, was confirmed. The low values of sacral angle and lumbar lordosis obtained in the first measurement were related to the absence or very slight presence of lumbar lordosis. As a result of the postural improvement program, the degree of pelvic tilt and, in parallel, the physiological curvature of the lumbar lordosis were within the age reference values for most participants (15/16), improving spinal flexibility.

My eighth hypothesis, that the intervention program would improve spinal stability, was confirmed. For the Matthiass test, the intervention group scores improved for all three spinal segments, and the results of the associated test exercises also showed improvement.

My ninth hypothesis, that both lumbar and dorsal spine effects of the intervention program would show a significant difference, was partially confirmed. Significant results were achieved in the lumbar spine during the program, with improvements in instrument readings and test scores. For dorsal kyphosis, only 50% of the subjects had a reference value at the end of the intervention when measured during standing, compared to 68.75% after the Matthiass test. For the dorsal spine, it can be said that an additional training program is needed to compensate for

the increased curvatures, as the intervention we performed was short enough to achieve a change in all spinal segments that would bring our results in line with the physiological curvatures.

Summary

When examining the relationship between literacy and climbing and crawling, we found that only boys showed a significant difference. There was no significant difference in the relationship between writing performance and time to stand up for either sex. Based on the results of our own research, we can conclude that the presence/absence of large movements in infancy and the time of onset of standing and walking do not affect the development of fine motor activities in early childhood.

When examining the relationship between sport participation and postural quality, a high percentage of boys (66.7%) and girls (62.5%) fell outside the reference range for dorsal kyphosis and lumbar lordosis, respectively. There were significantly better results for sloppy posture and postural weakness in athletes, but overall we cannot say that the spine of adolescent athletes is in better condition. For dorsal kyphosis, the results are better for girls and for lumbar lordosis for boys, but for the other parameters studied, no significant differences were found between the two groups.

As a result of the maintenance improvement program, we have achieved improvements in all parameters. The results measured by the Spinal Mouse were assessed for three regions (sacral angle, lumbar lordosis, dorsal kyphosis), first in the standing position and secondly after the Matthiass test, also in the standing position. However, the results obtained in the assessment of dorsal kyphosis draw our attention to the increased problems of this spinal segment. At the end of the intervention, it was found that the four-month duration of the program was not sufficient to produce a significant change in the change in dorsal kyphosis scores in 50.0% of the participants. There were only three pupils who had previously had values outside the reference range and by the end of the program their values had moved into the physiological range. Postural weakness improved to a greater extent as a result of the exercises performed than the degree of back curvature measured in the standing position, but our results cannot be considered satisfactory. The values measured with the instrument and the results obtained after the exercises were performed agree. In the tests measuring muscle strength and extensibility, the strength of the anterior muscles of the thigh was tested, with one subject failing to perform the exercise without error during the input and output measurements. For all other test tasks there was an improvement in the results of the post-intervention assessment.

New research findings

The special feature of our research is that such a thorough, in-depth analysis has never been carried out on adolescents using the Spinal Mouse device. The data we measure accurately determine the physiological curvatures of the spine, the position of the pelvis and the values of segmental stability and mobility of the spine. The experience with the device can be broadly applied to our research and is appropriate. If it were more widely used, it could help school health screening to map spinal changes more accurately.

After the individual analysis, we developed and applied specific exercise sequences for the students participating in the intervention. Our results confirmed the effect of the school improvement program, as the measurement after the closures caused by the pandemic

confirmed a drop in scores. It has therefore been demonstrated that these programs can only achieve sustainable results if they are used continuously to maintain the results achieved.

When we looked at the relationship between sport and spinal health, we found that there was a high percentage of increased back kyphosis in athletic boys. This suggests that athletes are also exposed to spinal problems, and we would emphasise important preventive measures for active children as well.

In the light of our results, we would recommend that posture-improving exercises be included in the daily physical education curriculum, and that they be placed in the introductory part of the lesson, between the warm-up exercises, and during the debriefing at the end of the lesson.

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