

Intervention strategies for functional disorders of the pediatric musculoskeletal system

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Abstract

This study presents a novel approach addressing the increasing concern over the effects of sedentary lifestyle on children's musculoskeletal health. The objective is to explore alternative strategies for improving students' muscular systems by integrating a diverse movement program into primary school physical education. **Materials and Methods:** The sample included 73 students, consisting of 36 boys (average age 10.23±0.37 years) and 37 girls (average age 10.51±0.23 years). The intervention involved an 18-week movement program incorporating musical-motor and dance-based activities performed twice weekly for 45 min during physical education classes. Data were collected using a standardized test recommended for primary education by Jurašková, Junger and Junger (2019), assessing eight shortened (postural) and five weakened (phasic) muscle groups. Statistical analysis was performed using the Wilcoxon signed-rank test, with significance set at the 0.05 level. **Results:** The findings revealed muscular imbalance in 46.14% of tested primary school pupils at baseline, with a higher incidence in boys (27.7%) than girls (19.1%). The rectus femoris was the most frequently shortened muscle in both sexes, occurring in 50% of boys and 35.1% of girls. The most weakened muscle group comprised the hip extensors. The intervention program, involving musical-motor and dance activities integrated into school physical education, had a statistically significant impact on the frequency of shortened muscle groups in boys in the following segments: m. rectus femoris, knee flexors, hip adductors, m. quadratus lumborum, and m. erector spinae ($p>0.05$); and in girls: m. triceps surae, m. rectus femoris, knee flexors, and hip adductors ($p>0.05$). Positive effects were also observed in the strengthening of phasic muscle groups in boys: hip extensors and mm. abdomen ($p>0.05$) and in girls: hip extensors, neck flexors, and lower scapular fixators ($p>0.05$). **Conclusions:** Our study's findings demonstrate the potential of a movement program integrating musical-motor and dance-based activities to positively influence muscular imbalances and reduce functional disorders of the muscular system in primary school students. With its inspiring potential, this promising strategy offers hope for improving children's physical health and should interest educators, researchers, and health professionals, motivating them to consider similar interventions.

Keywords: Dance, Musical-Movement Program, Muscle Imbalance, Physical Education

Introduction

A fundamental prerequisite for the healthy development of an individual from the perspective of postural health is the assurance of sufficient physical activity in childhood (Jurášková & Bartík, 2010; Kanášová, 2008; Azor et al., 2025). Early physical activity can prevent the onset of musculoskeletal disorders and related complications later in life (Andrieieva et al., 2021; Slováková et al., 2022; Mandzáková & Slováková, 2023). However, there is also a growing concern regarding inappropriate functional loading—whether excessive or qualitatively unsuitable (e.g., unilateral, prolonged, or uneven loading)—which can lead to the development of muscle imbalance and consequently to poor posture (Abdolahzadeh & Daneshmandi, 2019). A condition in which the musculoskeletal system cannot adequately meet usual functional demands is referred to as functional insufficiency or weakness of the motor system, or as a disturbance in the functional relationship between the postural and phasic muscular systems.

This means that the muscles cannot perform their normal functions, leading to potential issues such as poor posture, pain, and altered movement patterns. Persistent muscle imbalance may result in syndromes characterised by a combination of shortened and weakened muscles, disturbed movement patterns, altered spinal statics and dynamics, poor posture, pain, and pathological conditions. If addressed early, these conditions are often reversible. Nevertheless, postural disorders are a frequent trigger of chronic conditions due to generalised functional weakness and imbalance in the muscular and ligamentous systems in children. This may lead to diminished physiological functional reserves and impaired adaptive responses of the organism. Entering the school system represents a significant shift in a child's daily routine, with reduced physical activity and prolonged sitting contributing to the weakening of the musculoskeletal system. Children spend approximately one-third of their waking hours in static positions during school (Kolisko & Fojtíková, 2003). As a result,

improper postural habits are frequently observed even among primary school pupils. It is crucial to correct these habits early to prevent spinal degeneration, associated pain, and limited functional capacity in later life (Weinstein, 2019). Rapid growth can affect balance, coordination, and posture, exacerbate postural issues if not adequately address (Lenková et al., 2018).

Therefore, intervention and reinforcement to correct postural habits should begin early in school. The need for early intervention is urgent and cannot be overstated. Inadequate primary prevention from childhood is a contributing factor to the development of vertebral disorders in adulthood, with a prevalence ranging from 6% to 80%. These disorders are closely associated with poor posture and muscular imbalance (Bendíková, 2022). Musculoskeletal dysfunctions rarely occur in isolation, often in conjunction with other disorders at various levels (Vařeka & Dvořák, 2001). Murphy, Buckle, and Stubbs (2004) described that prolonged sitting in classrooms can contribute to back pain in children. Grimmer & Williams (2000) and Masiero et al. (2008) also reported a decline in the number of children capable of maintaining upright posture without excessive muscular effort, frequently accompanied by spinal pain. According to the National Report on Youth Policy in the Slovak Republic for the Council of Europe, an increasing number of chronic health conditions is observed in the 0–18 age group, highlighting the need for intensified preventive care (Sobihardová et al., 2005). One promising avenue involves enhancing the educational process through physical education, incorporating preventive and corrective interventions for the musculoskeletal system.

To make physical activity preventive and engaging, school-based intervention programs are being developed. These programs emphasise health-oriented exercises while also promoting motor skills development. Importantly, the content must be engaging and appealing to pupils. A notable study by Grygus et al. (2020) focused on preventing and correcting musculoskeletal disorders in children aged 11–12—their program integrated dance activities tailored to the individual functional status of children's muscular and cardiovascular systems.

The results demonstrated improvements in postural symmetry, correct posture, spinal flexibility, and scapular alignment. Similarly, Andrieieva et al. (2021) observed significant improvements ($p < 0.05$) in parameters such as body posture, biogeometric profiles, muscle strength, and foot alignment following dance-based conditioning programs. Strength gains included a 41.9% increase in back muscle strength and a 57.1% increase in abdominal strength, alongside enhancements in flexibility and balance. Fong et al. (2018) conducted a meta-analysis of dance interventions lasting more than 28 days, involving 1,276 participants. Across various dance genres, these interventions improved blood biomarkers, musculoskeletal function, body composition, and cardiovascular performance.

The authors recommended incorporating dance-based activities into educational settings as a safe and effective form of physical education. Despite these findings, the number of studies demonstrating a positive impact of musical-movement and dance activities on the musculoskeletal health of 9–to 10-year-old pupils remains limited, as Mishenko et al. (2023) also noted. In light of this, Kashuba et al. (2020) advocate for the incorporation of innovative, high-motivation approaches into school physical education programs. The present study contributes to this field by expanding the knowledge on potential tools within school physical education to prevent and correct muscular imbalances in children through engaging musical-movement and dance-based programs.

This study aimed to examine the effectiveness of a movement program incorporating musical-motor and dance-based elements in influencing musculoskeletal system disorders among younger school-aged pupils.

Material and methods

Participants

By the goal, the group included on the whole $\Sigma n = 73$ pupils ($n = 36$ boys, $n = 37$ girls) of the region of Banská Bystrica, Slovak Republic, aged 9–10 years, i.e. pupils of early school age, willing to participate in research, with the consent of their parent's takers and the school. Pupils participated voluntarily with written parental consent. Ethical approval was obtained from the ethical committee at the Matej Bel University under project number 1522/2022. Evaluating the impact of an 18-week musical-movement program in 10-year-old students was carried out by the ethical standards as laid down in the 1964 Declaration of Helsinki. The anthropometric data of the groups are presented in Table 1.

Table 1. Anthropometric data of the research group ($n = 73$)

Measured values	Research group ($n = 73$)	
	Boys ($n = 36$)	Girls ($n = 37$)
Age/years	10.23 $\pm$ 0.37	10.51 $\pm$ 0.23
Body weight/kg	42.71 $\pm$ 7.34	35.82 $\pm$ 7.65
Body height/cm	146.11 $\pm$ 6.21	138.2 $\pm$ 6.24
BMI kg/m ²	20.01 $\pm$ 2.22	18.75 $\pm$ 2.31

Notes: kg - kilogram, cm - centimetre, BMI - Body mass index, kg/kilogram per square meter

Measurement organisation

The research occurred in the academic year 2021/2022 at an elementary school in Banská Bystrica. After thoroughly preparing the research to achieve the goal, initial diagnostics (V1) of somatometric indicators were carried out in February, and a diagnostic of body posture was evaluated by a standardised test used in school practice.

Subsequently, an exercise programme aimed at promoting the musculoskeletal health of pupils was included in the content of compulsory physical education, was included in the teaching content of compulsory physical and sports education (supported by studies: Andrieieva, 2021; Kashuba, 2021; Mischenko, 2023) twice a week for 45 minutes, for 18 weeks, a total of 36 lessons. Each lesson of the exercise program included music-implementing exercise and dance activities, contained a 10-minute warm-up, a 25-minute central part and a 5-minute Cool-Down. Every lesson included a 10-minute warm-up with stretching. The central part included 30 minutes of continuous musical-movement and dance activities, such as aerobic (low), modern, folk dances, dance aerobic, dance games, on the wall bars, on the over ball and stability ball, and skipping rope games. In the last part of the lesson, the participants were given 5 minutes. Cool down. It included muscular strength exercises with slow and relaxing rhythm music. A qualified teacher with years of experience led the process of teaching. Subsequently, output testing (V2) of the same indicators was performed.

Measurement Taking

To assess the current condition of postural (prone to shortening) and phasic (prone to weakening) muscles in selected pupils, a frontal muscle testing protocol was employed, based on the methodology proposed by Jurašková, Junger & Junger (2019). This approach is also recommended for physical education practice at the primary school level. The testing was conducted during regular physical education classes. Eight postural muscles (susceptible to shortening) and five phasic muscles (susceptible to weakening) were evaluated.

Frontal testing of eight shortened postural muscles:

M. triceps surae, M. rectus femoris, Flexors of the knee joint, Adductors of the hip joint, M. quadratus lumborum, M. erector spinae, M. pectoralis major, M. trapezius, pars superior

Frontal testing of five weakened phasic muscles:

Extensors of the hip joint, Deep flexors of the neck, Abdominal muscles, Abductors of the hip joint, Lower fixator of the scapula

Data Analyses

In terms of data processing methods, mathematical and statistical methods were used to process the collected data and to calculate basic descriptive statistics: arithmetical mean ($\bar{x}$) and standard deviation (SD), percentage frequency analysis (%). To ascertain the statistical significance of achieved results in the level of body posture, the Wilcoxon signed-rank test was used, $p < 0.05$ –statistically significant at the 5 % level.

Results

Our research confirmed the presence of muscle imbalance in 46.14% of the tested primary school pupils at the outset of the study. Muscle imbalance was more prevalent among boys (27.7%) than girls (19.1%). Boys were more affected by muscle shortening than girls, a result that aligns with the findings of Jurašková & Bartík (2010) and Jurašková, Junger & Junger (2019).

Prevalence of Shortened and Weakened Muscles in the Experimental Group of Boys

In the experimental group of boys ($n = 36$), the most frequently shortened muscle identified during the initial assessment was the rectus femoris, with a prevalence of 50%. Other commonly affected muscles included the knee flexors and the quadratus lumborum (see Figure 1). The pectoralis major was the least affected, with only 11.1% of boys showing shortening in this muscle at the baseline assessment. After completing an 18-week intervention program consisting of musical movement and dance activities conducted twice weekly, a post-intervention assessment was conducted to evaluate the program's impact on muscle shortening. The results demonstrated a statistically significant improvement in muscle shortening among boys across five observed muscle groups (see Table 2), confirming the positive effect of the implemented intervention.

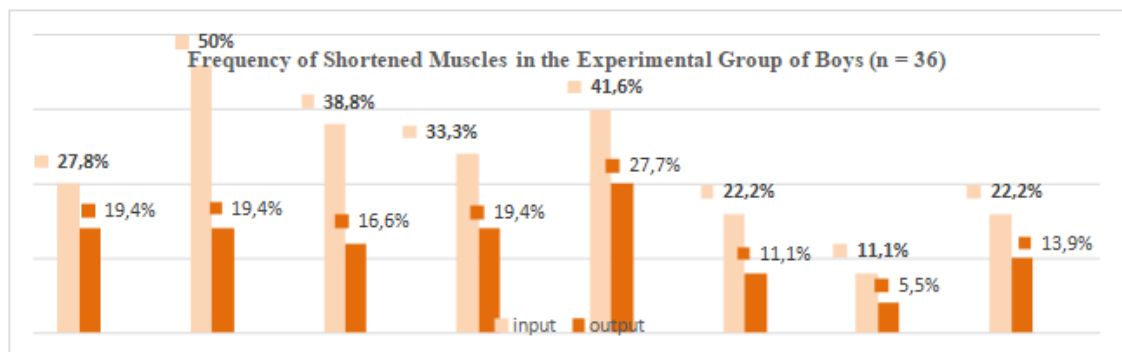


Figure 1. Frequency of Shortened Muscles in the Experimental Group of Boys ($n = 36$)

Statistical analysis showed that in Segment 1 – the triceps surae (calf muscle) – no statistically significant difference was observed between pre- and post-intervention results ($\lambda = 0.08152$; $p > 0.05$). Post-intervention testing indicated that 19.4% of the boys ($n = 7$) still presented with shortened calf muscles (see Figure 1). According to Hamel (2021), untreated shortening of the calf muscles over time may contribute to various deformities in the ankle and foot regions, potentially leading to new muscular imbalances and resulting in poor posture. In the case of the quadratus lumborum, post-intervention data showed shortening in 27.7% of the boys ($n = 10$). However, statistical analysis confirmed a statistically significant improvement in this spinal segment following the compensatory program ($\lambda = 0.01744$; $p < 0.05$). The quadratus lumborum, as described by Sanchis-Moysi et al. (2013), plays a key role in several daily and sport-specific movements, such as kicking a ball or executing tennis strokes. Repeated performance of these activities without adequate compensation may cause asymmetric hypertrophy between the dominant and non-dominant sides of the body in both children and adults. This muscle imbalance is often associated with lower back pain. The most significant progress in muscles with a tendency toward weakness was observed in the hip extensors and abdominal muscles ($\lambda = 0.02736$; $p < 0.05$) following implementation of the intervention program (see Table 2). The hip extensors and the lower scapular stabilisers were the most weakened muscles in the initial and final assessments. Notably, pain in the lower back is considered one of the most common musculoskeletal pains experienced by individuals.

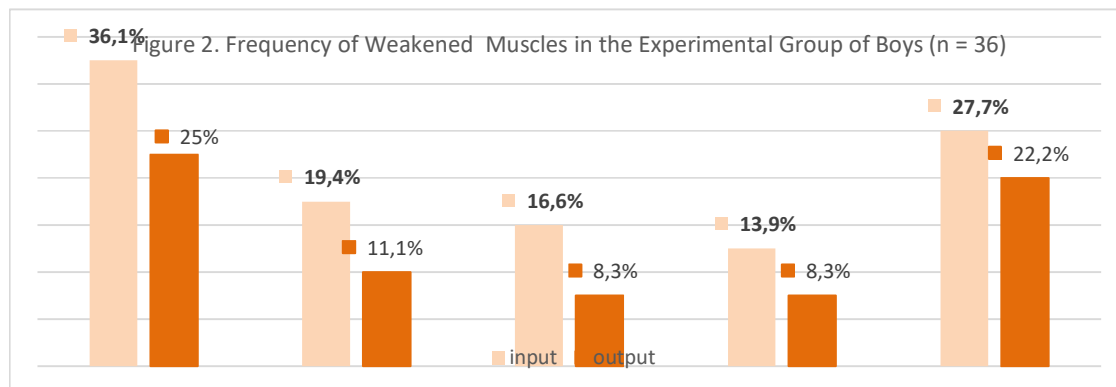


Figure 2. Frequency of Weakened Muscles in the Experimental Group of Boys ($n = 36$)

Table 2. Statistical Analysis of the Impact of the Intervention Program on the Incidence of Shortened and Weakened Muscles in the Male Research Sample

Shortened muscles	m. triceps surae	m. rectus femoris	Knee flexors	Hip adductors	m. quadratus lumborum	m. erector spinae	m. pectoralis major	m. trapezius
boys	0.08152	0.0004547*	0.002981*	0.01744*	0.01744*	0.02736*	0.1729	0.05556
Weakened muscle	Hip extensors	Flexors of the neck	Abdominal muscles	Hip abductors	Fixator of the scapula			
boys	0.02736*	0.07446	0.02736*	0.1729	0.1729			

Notes: Wilcoxon Paired Test, Statistical Significance Level 0.05. * Indicates significant p-values."

Frequency of Shortened and Weakened Muscles in the Experimental Group of Girls

In the initial testing, the most frequently shortened muscle among girls was the rectus femoris, with a prevalence of 35.1%. This was followed by the knee flexors (24.3%) and the triceps surae (21.6%). The least shortened muscle in girls, similar to the boys' group, was the pectoralis major, with no cases of shortening recorded after the application of the intervention program (see Figure 3). Functionally, the pectoralis major is notable for its ability to contract in separate parts. As a whole, it contributes to arm adduction, flexion, and pronation. When the upper limb is fixed, it raises the ribs, playing a role in respiration. According to Bueno et al. (2017), maintaining this muscle in proper functional condition is essential.

Following the intervention program, a statistically significant reduction in muscle shortening was observed in four muscle groups among the girls: the triceps surae, rectus femoris, knee flexors, and hip adductors (see Table 3). Shortening of the trapezius muscle was detected in only one girl during the post-intervention assessment. Shortening of the cervical portion of the trapezius muscle is commonly associated with poor posture. Choudhari et al. (2012) noted that this condition often leads to maladaptive postural changes and neck pain. Such discomfort is frequently linked to muscle imbalances around the scapular and shoulder regions.

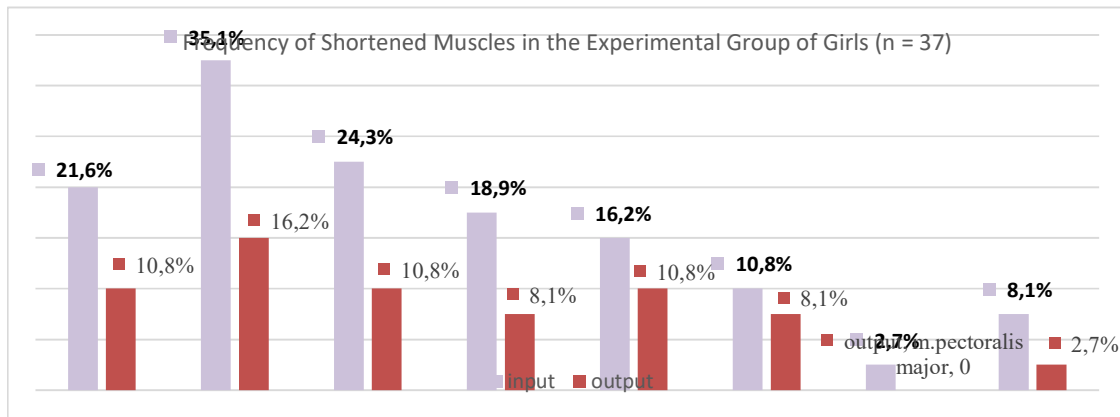


Figure 3. Frequency of Shortened Muscles in the Experimental Group of Girls (n = 37)

The study's results indicate a higher prevalence of muscles with a tendency toward weakness in girls than boys. Like the boys' group, the most weakened muscles were the hip extensors (46.9% of girls) and deep neck flexors (43.8% of girls at initial testing; see Figure 4). Following the implementation of the intervention program, a statistically significant reduction in muscle weakness was observed in the hip extensors ($\lambda = 0.03473$; $p > 0.05$). These muscles work together to stabilise the pelvis and facilitate movements such as walking, running, jumping, and standing. Significant improvements were also recorded in deep neck flexors ($\lambda = 0.03473$; $p > 0.05$) and lower scapular stabilisers ($\lambda = 0.01924$; $p > 0.05$; see Table 2) among the girls. The deep neck flexors are part of the body's deep stabilisation system. Multiple studies (Arora & Veqar, 2010; Lenková, Boržíková et al., 2018; Lin, Wang & Wilkinson, 2022) emphasise their importance in maintaining neck stability, enabling nodding motion, and supporting the head. Well-conditioned deep neck flexors help prevent neck pain. According to Kim & Kwag (2016), exercises targeting activation of the deep cervical flexors have been shown to reduce pain, restore function, and correct forward head posture in patients experiencing neck discomfort.

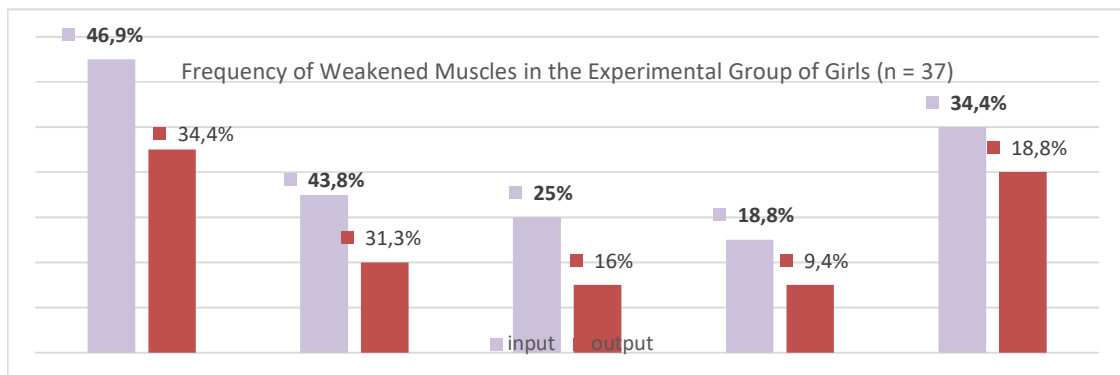


Figure 4. Frequency of Weakened Muscles in the Experimental Group of Girls (n = 37)

Table 3. Statistical Analysis of the Effect of the Intervention Program on the Occurrence of Shortened and Weakened Muscles in the Experimental Group of Girls (n = 37)

Shortened muscles	m.triceps surae	m.rectus femoris	Knee flexors	hip adductors	m. quadratus lumborum	m. erector spinae	m. pectoralis major	m. trapezius
girls	0.03473*	0.005457*	0.01924*	0.03473*	0.1729	0.5	0.5	0.1729
Weakened muscle	Hip extensors	Flexors of the neck	Abdominal muscles	Hip abductors	Fixator of the scapula			
girls	0.03473*	0.03473*	0.06546	0.06546	0.01924*			

Notes: Wilcoxon Paired Test, Significance Level 0.05. * Statistically Significant p-values

Discussion

The present study highlights the impact of music-based movement and dance activities incorporated into physical education classes on correcting muscle imbalance in the observed children. Numerous studies emphasise the growing concern of decreasing physical activity and unhealthy lifestyles, which manifest in

functional musculoskeletal disorders and obesity, even in the youngest age groups (Rajan & Koti, 2013; Bettany-Saltikov et al., 2019). Furthermore, the phenomenon of initiation of muscle imbalance in primary school children is often linked to the beginning of formal schooling, where children's natural physical movement decreases significantly (Bursová & Langmajerová, 2006; Bartík, 2007; Yao et al., 2011). Bendíková & Rozim's (2020) study investigating functional disorders of postural health found that up to 48% of girls and 50% of boys exhibited muscle imbalance (8-9-year-old children in Slovakia), which was associated with poor posture. The most significant difference in shortened muscle groups between girls and boys was found in the pectoralis major ($\chi^2 p < 0.01$) and tensor fasciae latae ($\chi^2 p < 0.05$). It was noted that boys showed dominance in weakened muscle groups, such as the abdominis, trapezius pars descendens (lower trapezius), and scapular stabilisers ($\chi^2 p < 0.01$). Meanwhile, girls displayed a higher prevalence of weakened gluteus muscles ($\chi^2 p < 0.05$) and deep cervical flexors. Similar findings were reported in Vařeková & Vařeka's (2005) study, which diagnosed muscle imbalance in 183 girls and 192 boys aged 6–14.

The authors observed a high prevalence of shortened and weakened muscles even at younger school ages. The most frequently shortened muscle group in boys was the knee flexors; in girls, it was the upper scapular stabilisers. The weakest muscles in both genders were the lower scapular stabilisers. Our findings confirm that the rectus femoris was the most shortened muscle in boys (50%) and girls (35.1%). The most frequently weakened muscles were the hip extensors (36.1% of boys and 46.9% of girls). Based on our analysis, we found that boys more often suffer from muscle shortening, whereas girls had a higher percentage of muscle weakness, a finding that aligns with research by Jurašková & Bartík (2010) and Jurašková, Junger & Junger (2019).

Untreated and neglected muscle imbalances lead to further complications, which may result in reduced movement abilities and severe spinal deformities. Poor postural health further leads to a decline in overall health, affecting quality of life (Weinstein, 2019). Muscle imbalance requires corrective exercises or treatments to stabilise, reduce, or prevent such imbalances (Acasandrei & Macovei, 2014). Nosko et al. (2016) highlight the potential of physical education tools to positively influence muscle imbalances during class. Similarly, Kashuba et al. (2020) included postural preventive exercises (e.g., Pilates, exercises on fit balls, and yoga breathing exercises) in their curriculum. Their study demonstrated that the intervention program improved the respondents' biogeometric profile index ($p < 0.05$). Černický et al. (2018) recommend incorporating healthy spine school methodology into physical education classes.

Their findings revealed that 80 out of 260 schoolchildren exhibited postural disorders, emphasising the importance of playful, engaging physical activities that use motivational tools such as words, music, and colourful props to enhance student participation. The findings of this study are consistent with the motivation-enhancing effect of music-based movement and dance activities in promoting physical activity. This approach successfully addresses the initiation of postural disorders in students and engages them in physical activity in a non-coercive, enjoyable way.

A limitation of this study is the absence of a control group, which hinders the generalizability of the results. Additionally, the visual method used to assess shortened and weakened muscle groups may be subject to subjective interpretation. Another limitation is the insufficient teacher competence in music-based movement and dance activities, which could negatively affect the program's implementation in physical education classes. The strengths of this study include the presentation of unique results regarding musculoskeletal health and the potential to influence functional disorders or prevent their occurrence through music-based movement and dance activities during physical education classes. The program proposed is also cost-effective, requiring little financial or material investment in practical implementation.

Conclusion

The movement program incorporating music-based movement and dance activities into school physical education classes significantly impacted the frequency of shortened muscle groups in boys in the following segments: rectus femoris, knee flexors, hip adductors, quadratus lumborum, and erector spinae ($p > 0.05$). For girls, it impacted triceps surae, rectus femoris, knee flexors, and hip adductors ($p > 0.05$). A positive effect was also observed in strengthening muscles with a tendency to weakness: hip extensors and abdominis ($p > 0.05$) in boys and hip extensors, neck flexors, and lower scapular stabilisers ($p > 0.05$) in girls. Student motivation is crucial to achieving active student participation and maximising the effectiveness of exercise time. Compensatory exercises are often perceived as dull and monotonous, especially in younger age groups, making it difficult to maintain the necessary level of focus.

Our proposed program demonstrated that music-based movement and dance activities, paired with music, serve as a motivational factor. The results of this study confirm the importance of including an intervention movement program in the school curriculum to prevent muscle imbalances or correct mild cases. The proposed program can be recommended for inclusion in physical education classes at least twice a week, with age-appropriate music to enhance engagement.

Conflicts of interest: *The authors declare that there is no conflict of interest.*

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