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The effect of therapeutic physical exercise on muscle electrical activity in students with chronic diseases

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Abstract- Physical inactivity among children and adolescents is a growing public health concern associated with impaired physical development, reduced muscle strength, poor motor coordination, and an increased risk of non-communicable diseases. Students with chronic diseases frequently experience restricted participation in physical education, highlighting the need for evidence-based therapeutic exercise programs that support their physical functioning and promote inclusive participation in school-based physical activity. Objective: To investigate the effects of a therapeutic physical exercise program on muscle strength and muscle electrical activity in students with chronic diseases. Methods: A single-group quasi-experimental study was conducted with 30 secondary school students diagnosed with chronic diseases. Anthropometric characteristics, flexibility, handgrip strength, back muscle strength, and waist and hip circumferences were assessed before and after the intervention. Surface electromyography (sEMG) using a Noraxon system was performed to evaluate the electrical activity of the rectus abdominis, rectus femoris, thoracic erector spinae, and gastrocnemius muscles. Data were analyzed using descriptive statistics, paired and independent *t*-tests, Pearson correlation analysis, one-way analysis of variance (ANOVA), and Cohen's *d* effect size. Statistical significance was established at $p < 0.05$. Results: Following the therapeutic exercise program, significant improvements were observed in flexibility, handgrip strength, and back muscle strength. Surface EMG demonstrated significant reductions in the electrical activity of all examined muscles during follow-up measurements ($p < 0.001$), indicating greater neuromuscular efficiency. Strong positive correlations between baseline and follow-up EMG measurements ($r = 0.946–0.988$) confirmed the high reliability of the measurements. Large effect sizes further supported the effectiveness of the intervention. Conclusion: Therapeutic physical exercise significantly enhanced muscle strength, flexibility, and neuromuscular efficiency in students with chronic diseases. These findings suggest that school-based therapeutic exercise programs may represent an effective strategy for improving physical function and supporting inclusive physical education for students with chronic health conditions.

Keywords: Therapeutic exercise; Surface electromyography; Muscle strength; Physical education; Noraxon

1. INTRODUCTION

In recent years, rapid social and technological development, urbanization, and increasingly sedentary lifestyles have led to a global decline in physical activity levels among children and adolescents. According to reports from the World Health Organization, most children aged 5–17 do not meet the recommended 60 minutes of moderate to vigorous physical activity per day [1]. Reduced physical activity negatively affects physical development, muscle strength, motor coordination, and cardiovascular function, while also increasing the risk of non-communicable diseases [2][3][4]. Physical activity in children and adolescents not only supports physical health but also has positive effects on cognitive development, psychological well-being, and academic performance [5][6]. The school environment is one of the most important settings for promoting physical activity, and physical education plays a key role in developing students' motor skills, physical fitness, and healthy lifestyles [7][8]. Therefore, there is an increasing need to implement student-centered, inclusive, and health-promoting teaching methods in modern education systems. For students with chronic diseases or special needs, participation in physical education classes is often limited. As a result, their physical activity levels decrease, leading to reduced muscle strength, impaired coordination, and delayed physical development [9][10]. In contemporary educational research, the concept of inclusive physical education is gaining importance, aiming to actively involve students with health conditions in physical activity programs [11]. In this context, developing and implementing exercise programs tailored to students' health conditions is essential. Therapeutic physical exercise is widely used in rehabilitation and kinesiology, focusing on improving muscle strength, restoring movement, and enhancing balance and coordination [12]. Previous studies have shown that structured exercise programs positively affect muscle strength, aerobic capacity, motor performance, and functional ability in children and adolescents [13][14]. Additionally, exercise programs for children with chronic conditions have been found to improve physical capacity and quality of life [10]. To evaluate muscle function, modern research widely uses surface electromyography (sEMG). This non-invasive method measures muscle electrical activity using electrodes placed on the skin and is used to study muscle activation patterns, activity levels, and neuromuscular coordination [15][16]. It is commonly applied in movement analysis, sports physiology, and rehabilitation research, providing real-time data on muscle function [16]. Numerous studies have shown that exercise not only increases muscle strength but also improves neuromuscular coordination. After strength training, muscle activation patterns change, leading to more efficient movement performance [17][18]. Studies using EMG analysis have demonstrated that exercise improves both muscle activation levels and motorcontrol [19][20]. Although studies using EMG in children and adolescents are relatively limited, some findings suggest that exercise positively influences muscle activation regulation and movement performance [21][22]. Combining muscle strength measurements with EMG analysis allows for a more precise evaluation of exercise effects [23]. Despite growing evidence supporting the benefits of therapeutic exercise, relatively little is known about its effects on both muscle strength and muscle electrical activity in school-aged students with chronic diseases. Most previous studies have focused either on functional performance or muscle strength alone, whereas investigations combining objective neuromuscular assessment using sEMG with conventional muscle strength measurements remain scarce. Moreover, evidence regarding school-based therapeutic exercise programs for students with chronic diseases is particularly limited, especially within educational settings where inclusive physical education is increasingly emphasized. Addressing this knowledge gap is essential for developing evidence-based therapeutic exercise interventions that facilitate safe and effective participation in physical education while promoting physical development and neuromuscular function among students with chronic diseases. Furthermore, objective evaluation of therapeutic exercise using both muscle strength assessment and sEMG may provide valuable scientific evidence for improving educational practice, rehabilitation strategies, and inclusive physical education policies. Therefore, the present study investigated the effects of a school-based therapeutic physical exercise program on muscle strength and muscle electrical activity in students with chronic diseases using both conventional physical fitness measurements and surface electromyography. To evaluate changes in muscle strength and muscle electrical activity in students with chronic diseases and to determine the effects of therapeutic physical exercise.

2. THEORETICAL BACKGROUND

Health, Physical Inactivity, and Chronic Disease in Adolescents: The theoretical foundation of this study is grounded in the World Health Organization's conceptualization of health as a state of complete physical, mental, and social well-being, rather than merely the absence of disease. Within this framework, regular physical activity is regarded as a core determinant of health across the lifespan, and the WHO Guidelines on Physical Activity and Sedentary Behaviour explicitly recommend that children and adolescents accumulate at least 60 minutes of moderate-to-vigorous physical activity daily [1]. Physical inactivity is theorized to operate as a modifiable risk factor that, over time, contributes to reduced muscular strength, impaired motor coordination, and an elevated risk of non-communicable disease, relationships that are well documented across pediatric populations [2][3][4]. For students living with chronic diseases, this risk pathway is compounded: medical exemption from physical education, while often clinically necessary, removes a key opportunity for structured physical activity and may accelerate the very physical decline that health guidance seeks to prevent.

Inclusive Physical Education: A second theoretical strand informing this study is the framework of inclusive physical education, which holds that students with health conditions or disabilities should not be passively excluded from physical activity but instead provided with individually adapted programs that allow safe and meaningful participation [9][10][11]. This perspective reframes chronic disease not as a barrier to physical education but as a parameter that must be accounted for in program design, shifting the pedagogical task from exclusion toward adaptation. It is this framework that underlies the diagnostic stratification and condition-specific activity modifications adopted in the present study (Table 1).

Therapeutic Exercise Theory and the FITT Principle: Therapeutic physical exercise, as conceptualized by Kisner, Colby, and Borstad, is defined as the systematic, planned performance of movements intended to remediate impairments, restore or maintain function, and prevent secondary complications associated with disease or injury [12]. Its theoretical rationale rests on the principle that controlled, progressive loading of the neuromuscular system produces measurable adaptations in strength, flexibility, and movement efficiency, even in populations with pre-existing health limitations. To operationalize this principle in an individualized and safe manner, the present study applied the Frequency, Intensity, Time, and Type (FITT) framework established by the American College of Sports Medicine, which provides a structured basis for adjusting exercise parameters according to each participant's functional capacity and medical condition [27].

Motor Skill Acquisition: Gentile's Taxonomy: The sequencing and progression of exercise tasks within the intervention were further informed by Gentile's taxonomy of motor skills, which classifies movement tasks according to the stability of the body and the regulatory demands of the environment in which they are performed [28]. According to this model, learners progress most effectively when tasks are initially presented under stable, predictable conditions and are only gradually made more variable and complex as functional capacity improves. This principle guided the design of the therapeutic exercise program, which began with low-intensity, closed, and predictable motor tasks before advancing to more complex movement demands as each participant's tolerance and functional response allowed.

Neuromuscular Adaptation and Surface Electromyography: The final theoretical component concerns the use of surface electromyography (sEMG) as an objective window into neuromuscular function. sEMG is grounded in the principle that the electrical signal recorded over a muscle reflects the recruitment and firing rate of the motor units activated to produce a given movement or force [15][16]. Building on this, the concept of neuromuscular adaptation proposes that structured exercise training alters both central (corticospinal drive, motor unit recruitment and synchronization) and peripheral (excitation-contraction coupling, muscle-tendon compliance) mechanisms, such that a task that previously required substantial motor unit activation can, after training, be performed with comparatively less electrical activity for an equivalent or improved functional outcome [25]. This theoretical model provides the interpretive basis for the present study's central hypothesis: that a decline in sEMG amplitude following the therapeutic exercise program reflects improved neuromuscular efficiency rather than a loss of muscular capacity.

Integrated Conceptual Framework: Taken together, these theoretical perspectives form an integrated conceptual framework for the present study: the WHO's health and physical activity guidelines establish the public-health rationale; the inclusive physical education framework establishes the pedagogical justification for adapting, rather than exempting, students with chronic diseases; therapeutic exercise theory and the FITT principle provide the operational structure for prescribing safe, individualized exercise; Gentile's taxonomy guides the sequencing of motor tasks within that prescription; and neuromuscular adaptation theory, assessed through sEMG, provides the physiological mechanism and outcome measure through which the effects of the intervention can be objectively evaluated. This framework directly informs the research design, exercise prescription, and outcome measures described in the following Methodology section.

3. RESEARCH METHODOLOGY

This study was conducted using a quasi-experimental design based on a single-group model. The absence of a control group in this study was primarily attributable to practical constraints associated with implementing random group allocation within the general secondary school setting. Random assignment of students to intervention and control groups was not feasible under routine school conditions. Furthermore, students were exempted from physical education for a wide range of medical conditions with heterogeneous diagnoses and functional limitations, making it impractical to establish a clinically comparable control group. In light of these methodological and practical considerations, a single-group pretest–posttest experimental design without a control group was considered the most appropriate approach for conducting this study.

A total of 30 participants who consented to participate were included. Inclusion criteria were students enrolled in general education schools, diagnosed with chronic diseases, not regularly participating in physical education classes, and voluntarily agreeing to participate. Our experimental study initially invited all 33 Grade 11 students with health conditions who were exempt from participating in physical education classes at Secondary School No. 14 of Ulaanbaatar, along with their parents or legal guardians, to participate in the research. One student and the parents of two additional students declined participation. Consequently, 30 students voluntarily agreed to participate and provided written informed consent, which was documented through signed consent forms.

Before data collection, all participants and their parents or legal guardians were fully informed that the study adhered to the fundamental ethical principles of voluntary participation, informed consent, confidentiality, protection of participants' rights, and non-maleficence. Comprehensive information regarding the study objectives, potential risks, and anticipated benefits was provided, after which written informed consent was obtained. All collected data were treated confidentially, and participants were informed that they were free to withdraw from the study at any stage without any adverse consequences.

Participants who declined to participate or were unable to perform therapeutic exercises because of their medical condition were excluded from the study. Before data collection, all eligible participants and their parents or legal guardians received detailed information regarding the study objectives, procedures, potential risks, and expected benefits. Written informed consent was obtained from all participants prior to enrollment.

The health conditions of the participating students were reviewed before designing the intervention program. Based on medical records, participants were classified into four diagnostic categories: cardiovascular disorders (33.3%), musculoskeletal disorders (26.7%), renal disorders (20.0%), and metabolic or digestive disorders (20.0%). These health characteristics were systematically considered when developing individualized physical education activities.

Students with cardiovascular disorders participated only in low- to moderate-intensity activities because prolonged or vigorous exercise may reduce exercise tolerance and increase cardiovascular risk. For students with renal disorders, exercise intensity was individually adjusted to minimize the risk of symptom exacerbation associated with excessive physical exertion. Students with musculoskeletal disorders were prescribed therapeutic and corrective exercises, while activities involving jumping, running, heavy resistance, or unilateral loading were modified or excluded according to functional limitations. Students with metabolic or digestive disorders participated in appropriately prescribed physical activities with careful monitoring to minimize fatigue, hypoglycemia, and other metabolic complications.

The individualized adaptation of instructional content according to students' medical conditions was considered a fundamental strategy for implementing inclusive physical education and ensuring safe participation throughout the intervention.

Table 1. Distribution of Participants by Health Condition

Health condition	**n**	**%**	**Curriculum implications**
Cardiovascular disorders	10	33.3	Low-to-moderate intensity exercise; avoidance of prolonged or competitive activities
Musculoskeletal disorders	8	26.7	Therapeutic and corrective exercises; restrictions on jumping, running, unilateral loading, and resistance exercises
Renal disorders	6	20.0	Individually regulated exercise intensity; avoidance of excessive physical exertion
Metabolic and digestive disorders	6	20.0	Moderate-intensity exercise with monitoring for fatigue and metabolic complications
Total	**30**	**100.0**	Individualized physical education program

Baseline demographic and clinical characteristics were recorded before the intervention, followed by pre-intervention assessments. Individualized therapeutic exercise programs were then developed according to **Gentile's taxonomy of motor skills**, taking into account each participant's functional capacity, physical and psychological characteristics, and environmental context.

Exercise prescription followed the **Frequency, Intensity, Time, and Type (FITT)** principle. The intervention commenced with low-intensity, simple motor tasks and progressed gradually by increasing exercise complexity and workload according to each participant's functional response and tolerance.

All participants received standardized exercise instructions before beginning the intervention. They were advised to perform the prescribed exercises regularly, avoid exercising when hungry or experiencing excessive fatigue, begin each session with low-intensity movements and an appropriate warm-up, and discontinue exercise immediately if pain, discomfort, or other adverse symptoms increased during the session.

Habitual physical activity was assessed using the **Physical Activity Questionnaire for Adolescents (PAQ-A)**, a standardized and validated self-report instrument developed by Kowalski, Crocker, and Donen at the University of Saskatchewan, Canada. The questionnaire consists of nine items rated on a five-point Likert scale, with higher scores indicating higher levels of habitual physical activity.

To assess muscle function more precisely, muscle electrical activity (EMG) was measured using a Noraxon device. Measurements were taken twice: at baseline and after the therapeutic exercise intervention. EMG recordings were obtained from the right and left upper rectus abdominis, rectus femoris, thoracic erector spinae, and gastrocnemius muscles. After the intervention period, all initial measurements were repeated, and pre- and post-results were compared. EMG signals were sampled at 1500 Hz using the Noraxon Ultium EMG system (Noraxon USA, Scottsdale, AZ) and band-pass filtered at 10\u2013500 Hz with a 50 Hz notch filter to remove power-line interference. Raw signals were full-wave rectified and smoothed using a root-mean-square (RMS) algorithm with a 50 ms moving window prior to amplitude analysis. For each muscle, EMG amplitude was normalized to a percentage of the maximal voluntary isometric contraction (%MVIC), obtained from a 5-second maximal isometric contraction performed against manual resistance immediately before testing, in order to control for inter-individual and inter-session variability in electrode\u2013skin impedance and tissue characteristics. Bipolar Ag/AgCl surface electrodes (20 mm inter-electrode distance) were placed over the muscle belly parallel to the presumed direction of the underlying muscle fibers, following the SENIAM electrode-placement recommendations for the rectus abdominis, rectus femoris, thoracic erector spinae, and gastrocnemius [16]; the skin was shaved, lightly abraded, and cleaned with alcohol beforehand to reduce inter-electrode impedance, and a reference electrode was positioned over an electrically neutral bony landmark.

Statistical Analysis: Physical Activity Questionnaire for Adolescents (PAQ-A) **-** Descriptive statistics, including the mean (M), standard deviation (SD), minimum, maximum, frequencies, and percentages, were calculated to summarize participant characteristics and physical activity levels. Participants were classified into three categories according to the established PAQ-A cut-off scores: very low (1.00–1.50), low (1.51–2.50), and moderate (2.51–3.50) physical activity. Sex-specific descriptive statistics were calculated to compare habitual physical activity between male and female participants. Because the study employed a single-group pretest–posttest experimental design, intervention effects were evaluated using paired-samples t-tests. Statistical significance was established at $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics (Version XX; IBM Corp., Armonk, NY, USA).

Muscle electrical activity (EMG) - Descriptive statistics were used to summarize the data. Paired t-tests were applied to evaluate differences between pre- and post-measurements. Pearson correlation coefficients were calculated to assess relationships between variables. Independent t-tests were used to compare differences between groups, and effect sizes were determined using Cohen's d. Statistical analysis was performed using SPSS 25.0, with significance set at $p < 0.05$.

4. RESULTS AND DATA ANALYSIS

Table 2. PAQ-A Scores of Participants

Variable	Total (n=30)	Male (n=17)	Female (n=13)
Mean (M)	1.94	1.97	1.90
Standard deviation (SD)	0.58	0.60	0.55
Minimum	1.16	1.19	1.16
Maximum	3.16	3.16	2.94

Table 3. Distribution of Physical Activity Levels

PAQ-A category	Total n (%)	Male n (%)	Female n (%)
Moderate	6 (20.0)	3 (17.6)	3 (23.1)
Low	15 (50.0)	9 (52.9)	6 (46.2)
Very low	9 (30.0)	5 (29.4)	4 (30.8)

The mean PAQ-A score of the study participants was 1.94 ± 0.58, indicating an overall low level of habitual physical activity. Male students demonstrated a slightly higher mean PAQ-A score (1.97 ± 0.60) than female students (1.90 ± 0.55); however, the difference was minimal.

Based on the PAQ-A classification, 20.0% of participants were categorized as moderately active, whereas 50.0% and 30.0% were classified as having low and very low physical activity levels, respectively. Consequently, 80.0% of the participants exhibited insufficient physical activity, indicating a substantial need for individualized interventions aimed at increasing daily movement and promoting health.

The consistently low PAQ-A scores observed in this study are comparable to previous international findings, which have reported lower habitual physical activity among adolescents with health limitations than among their healthy peers. These findings also align with the World Health Organization's recommendations identifying insufficient physical activity as a major public health concern among adolescents worldwide.

Muscle electrical activity (EMG) - To assess muscle function more precisely, muscle electrical activity (EMG) was measured using a Noraxon device. Among the 30 participants, comparing EMG values measured by the Noraxon device by sex, the electrical activity of the upper rectus abdominis (right side) was 0.061±0.005 µV in females (n=13) and 0.061±0.008 µV in males (n=17). On the left side, it was 0.058±0.005 µV in females and 0.059±0.008 µV in males. For

the rectus femoris muscle, electrical activity on the right side was 0.084±0.009 µV in females and 0.086±0.013 µV in males, while on the left side it was 0.081±0.011 µV in females and 0.080±0.0 µV in males.
The thoracic erector spinae muscle showed electrical activity on the right side of 0.059±0.006 µV in females and 0.059±0.008 µV in males, and on the left side 0.061±0.005 µV in females and 0.061±0.007 µV in males.
Additionally, the medial gastrocnemius muscle showed electrical activity on the right side of 0.081±0.011 µV in females and 0.080±0.015 µV in males, and on the left side 0.084±0.008 µV in females and 0.085±0.012 µV in males (Table 4).

Table 4. Baseline results of muscle electrical activity in study participants (n = 30)

Variable name	**Female (n=13) Mean±SD (95% CI)**	**Male (n=17) Mean±SD (95% CI)**
Rectus abdominis (upper), right (µV)	0.061±0.005 (0.058-0.064)	0.061±0.008 (0.057-0.065)
Rectus abdominis (upper), left (µV)	0.058±0.005 (0.055-0.061)	0.059±0.008 (0.055-0.063)
Rectus femoris, right (µV)	0.084±0.009 (0.079-0.089)	0.086±0.013 (0.079-0.093)
Rectus femoris, left (µV)	0.081±0.011 (0.075-0.088)	0.080±0.015 (0.072-0.088)
Thoracic erector spinae, right (µV)	0.059±0.006 (0.056-0.063)	0.059±0.008 (0.055-0.064)
Thoracic erector spinae, left (µV)	0.061±0.005 (0.058-0.064)	0.061±0.007 (0.057-0.065)
Gastrocnemius, right (µV)	0.081±0.011 (0.075-0.088)	0.080±0.015 (0.072-0.088)
Gastrocnemius, left (µV)	0.084±0.008 (0.080-0.089)	0.085±0.012 (0.079-0.092)

When the results of repeated measurements of muscle electrical activity (EMG) measured using the Noraxon device were compared with the previous measurements, the mean EMG values of most muscles in both female and male participants tended to decrease. For the rectus abdominis muscle (upper part), electrical activity on the right side was 0.054±0.005 µV in females and 0.053±0.008 µV in males, while on the left side it was 0.052±0.005 µV in females and 0.051±0.008 µV in males. For the rectus femoris muscle, electrical activity on the right side was 0.075±0.008 µV in females and 0.078±0.013 µV in males, and on the left side it was 0.072±0.011 µV in females and 0.073±0.015 µV in males. For the thoracic erector spinae muscle, electrical activity on the right side was 0.053±0.006 µV in females and 0.052±0.008 µV in males, and on the left side it was 0.055±0.005 µV in females and 0.054±0.007 µV in males. For the medial gastrocnemius muscle, electrical activity on the right side was 0.072±0.011 µV in females and 0.072±0.014 µV in males, and on the left side it was 0.075±0.008 µV in females and 0.079±0.012 µV in males (Table 5).

Table 5. Results of repeated measurements of muscle electrical activity in study participants (n=30)

Variable name	**Female (n=13) Mean±SD (95% CI)**	**Male (n=17) Mean±SD (95% CI)**
Rectus abdominis (upper), right (µV)	0.054±0.005 (0.051-0.057)	0.053 ± 0.008 (0.049-0.057)
Rectus abdominis (upper), left (µV)	0.052±0.005 (0.048-0.055)	0.051 ± 0.008 (0.048-0.055)
Rectus femoris, right (µV)	0.075±0.008 (0.070-0.080)	0.078 ± 0.013 (0.072-0.085)
Rectus femoris, left (µV)	0.072±0.011 (0.066-0.079)	0.073 ± 0.015 (0.065-0.081)
Thoracic erector spinae, right (µV)	0.053±0.006 (0.050-0.057)	0.052 ± 0.008 (0.048-0.056)
Thoracic erector spinae, left (µV)	0.055 ± 0.005 (0.052-0.058)	0.054 ± 0.007 (0.050-0.057)
Gastrocnemius, right (µV)	0.072 ± 0.011 (0.065-0.078)	0.072 ± 0.014 (0.065-0.080)
Gastrocnemius, left (µV)	0.075 ± 0.008 (0.070-0.080)	0.079 ± 0.012 (0.072-0.085)

Using a paired t-test to evaluate differences between baseline and follow-up measurements of muscle electrical activity, statistically significant changes were observed in all muscles ($p < 0.001$) (Table 6). Electrical activity of the rectus abdominis decreased by 0.0074±0.0017 µV on the right side and 0.0071±0.0021 µV on the left side. For the rectus femoris, electrical activity decreased by 0.0081±0.0020 µV on the right side and 0.0079±0.0021 µV on the left side. The thoracic erector spinae showed a decrease of 0.0068±0.0021 μV on the right side and 0.0070±0.0021 μV on the left side, while the medial gastrocnemius decreased by 0.0085±0.0021 μV on the right side and 0.0081±0.0029 μV on the left side. The reduction in muscle electrical activity in follow-up measurements indicates that less muscle activation was required to perform the same movements. This suggests improved movement efficiency and enhanced neuromuscular coordination among the study participants. Pearson correlation analysis between baseline and follow-up measurements showed strong positive correlations for all muscles (r=0.946-0.988, p<0.001) (Table 3). For the upper rectus abdominis, correlations were r=0.965 on the right side and r=0.950 on the left. The rectus femoris showed very high correlations, with r=0.984 on the right and r=0.988 on the left. For the thoracic erector spinae, correlations were r=0.957 on the right and r=0.946 on the left, while the medial gastrocnemius showed strong correlations of r=0.987 on the right and r=0.962 on the left.

Table 6. Comparative analysis of muscle electrical activity measurements in study participants (n = 30)

Variable	**Mean Changes± SD**	**95% CI**	**Cohen's d**	**p value**	**r**	**p value**
Rectus abdominis (upper), right (μV)	0.0074 ± 0.0017	0.0068-0.0081	4.38	<0.001	0.965	<0.001
Rectus abdominis (upper), left (μV)	0.0071 ± 0.0021	0.0064-0.0079	3.40	<0.001	0.950	<0.001
Rectus femoris, right (μV)	0.0081 ± 0.0020	0.0074-0.0089	3.99	<0.001	0.984	<0.001
Rectus femoris, left (μV)	0.0079 ± 0.0021	0.0071-0.0086	3.81	<0.001	0.988	<0.001
Thoracic erector spinae, right (μV)	0.0068 ± 0.0021	0.0061-0.0076	3.31	<0.001	0.957	<0.001
Thoracic erector spinae, left (μV)	0.0070 ± 0.0021	0.0062-0.0077	3.35	<0.001	0.946	<0.001
Gastrocnemius, right (μV)	0.0085 ± 0.0021	0.0077-0.0093	4.03	<0.001	0.987	<0.001
Gastrocnemius, left (μV)	0.0081 ± 0.0029	0.0070-0.0092	2.81	<0.001	0.962	<0.001

For female participants (n=13), differences between baseline and follow-up measurements of muscle electrical activity were evaluated using a paired t-test, and statistically significant differences were found for all muscles (p<0.001) (Table 7). The electrical activity of the upper rectus abdominis decreased by an average of 0.0068±0.0018 μV on the right side and 0.0067±0.0019 μV on the left side. The rectus femoris showed decreases of 0.0092±0.0012 μV on the right and 0.0090±0.0011 μV on the left. Similarly, the thoracic erector spinae decreased by 0.0061±0.0013 μV on the right side and 0.0062±0.0013 μV on the left. The medial gastrocnemius showed reductions of 0.0096±0.0006 μV on the right side and 0.0098±0.0006 μV on the left. Effect sizes calculated using Cohen's d ranged from 3.59 to 17.17, indicating a very large effect between baseline and follow-up measurements. The decrease in muscle electrical activity in female participants suggests that less muscle activation was required to perform the same movements. Pearson correlation analysis between baseline and follow-up measurements showed statistically significant strong positive correlations for all studied muscles (p<0.001) (Table 4). For the upper rectus abdominis, correlations were r=0.934 on the right side and r=0.937 on the left. For the rectus femoris, very high correlations were observed (r=0.991 on the right and r=0.995 on the left). The thoracic erector spinae showed strong correlations (r=0.977 on the right and r=0.966 on the left), while the medial gastrocnemius demonstrated extremely high correlations (r=0.999 on the right and r=0.998 on the left)

Table 7. Comparative analysis of muscle electrical activity measurements in female participants (n = 13)

Variable	Mean Changes ± SD	95% CI	Cohen's d	p value	r	p value
Rectus abdominis (upper), right (µV)	0.0068 ± 0.0018	0.0057-0.0079	3.75	<0.001	0.965	<0.001
Rectus abdominis (upper), left (µV)	0.0067 ± 0.0019	0.0056-0.0078	3.59	<0.001	0.950	<0.001
Rectus femoris, right (µV)	0.0092 ± 0.0012	0.0085-0.0099	7.82	<0.001	0.984	<0.001
Rectus femoris, left (µV)	0.0090 ± 0.0011	0.0083-0.0097	8.12	<0.001	0.988	<0.001
Thoracic erector spinae, right (µV)	0.0061 ± 0.0013	0.0053-0.0068	4.79	<0.001	0.957	<0.001
Thoracic erector spinae, left (µV)	0.0062 ± 0.0013	0.0054-0.0070	4.75	<0.001	0.946	<0.001
Gastrocnemius, right (µV)	0.0096 ± 0.0006	0.0092-0.0099	17.17	<0.001	0.987	<0.001
Gastrocnemius, left (µV)	0.0081 ± 0.0029	0.0070-0.0092	2.81	<0.001	0.962	<0.001

When the difference between the initial and repeated measurements of muscle electrical activity in male participants (n=17) was evaluated using a paired t-test, a statistically significant difference was observed for all muscles (p<0.001) (Table 8). The electrical activity of the rectus abdominis muscle (upper part) decreased on average by 0.0079±0.0015 µV on the right side and 0.0075±0.0023 µV on the left side. The electrical activity of the rectus femoris muscle decreased by 0.0073±0.0022 µV on the right side and 0.0070±0.0022 µV on the left side. Additionally, the electrical activity of the thoracic erector spinae muscle decreased by 0.0074±0.0024 µV on the right side and 0.0076±0.0024 µV on the left side. The electrical activity of the gastrocnemius muscle decreased by 0.0077±0.0025 µV on the right side and 0.0068±0.0033 µV on the left side. When the effect size was evaluated using Cohen's d, it ranged from 2.08 to 5.36, indicating a large effect between the initial and repeated measurements, and the decrease in muscle electrical activity suggests that less muscle activation was required to perform the same movement. When the relationship between the initial and repeated measurements of muscle electrical activity in male participants was evaluated using Pearson correlation analysis, a statistically significant strong positive correlation was observed for all muscles (p<0.001) (Table 5). For the rectus abdominis muscle (upper part), a high correlation was observed between measurements, with r=0.981 on the right side and r=0.956 on the left side. Similarly, for the rectus femoris muscle, very high correlations were found, with r=0.986 on the right side and r=0.989 on the left side. For the thoracic erector spinae muscle, strong correlations were observed, with r=0.955 on the right side and r=0.948 on the left side, while for the gastrocnemius muscle, high correlations were found, with r=0.988 on the right side and r=0.963 on the left side.

Table 8. Comparative results of muscle electrical activity measurements in male participants (n=17)

Specifications	Paired t-test (Average ± SD	95% CI	Cohen's d	p value	r	p value
Rectus abdominis (upper), right (µV)	0.0079 ± 0.0015	0.0072-0.0087	5.36	<0.001	0.965	<0.001
Rectus abdominis (upper), left (µV)	0.0075 ± 0.0023	0.0063-0.0086	3.30	<0.001	0.950	<0.001
Rectus femoris, right (µV)	0.0073 ± 0.0022	0.0062-0.0085	3.31	<0.001	0.984	<0.001
Rectus femoris, left (µV)	0.0070 ± 0.0022	0.0059-0.0082	3.13	<0.001	0.988	<0.001
Thoracic erector spinae, right (µV)	0.0074 ± 0.0024	0.0062-0.0086	3.12	<0.001	0.957	<0.001
Thoracic erector spinae, left (µV)	0.0076 ± 0.0024	0.0063-0.0088	3.17	<0.001	0.946	<0.001
Gastrocnemius, right (µV)	0.0077 ± 0.0025	0.0064-0.0089	3.09	<0.001	0.987	<0.001
Gastrocnemius, left (µV)	0.0068 ± 0.0033	0.0051-0.0085	2.08	<0.001	0.962	<0.001

The differences in changes of muscle electrical activity among the four disease groups were evaluated using a one-way ANOVA (Table 9). The results showed that, for the rectus femoris muscle, a statistically significant difference was observed between the groups (right: F (3,26) =7.688, p=0.001; left: F (3,26) =6.935, p=0.001). However, for the rectus abdominis muscle (right: F(3,26)=2.331, p=0.098; left: F(3,26)=2.688, p=0.067), the thoracic erector spinae muscle (right: F(3,26)=1.597, p=0.214; left: F(3,26)=1.617, p=0.210), and the gastrocnemius muscle (right: F(3,26)=2.203, p=0.112; left: F(3,26)=1.073, p=0.378), no statistically significant differences were found between the groups (p>0.05). According to the results of Levene's test, for most muscles, the differences in variance between groups were not statistically significant (p>0.05), indicating that the assumption of homogeneity of variances was met. However, for the gastrocnemius muscle (right side), the difference in variance was statistically significant (p=0.006).

Table 9. Differences in changes of muscle electrical activity among the four disease groups (n=30)

Specifications	**F (3,26)**	**p value**
Rectus abdominis muscle (right)	2.331	0.098
Rectus abdominis muscle (left)	2.688	0.067
Rectus femoris muscle (right)	7.688	0.001
Rectus femoris muscle (left)	6.935	0.001
Thoracic erector spinae muscle (right)	1.597	0.214
Thoracic erector spinae muscle (left)	1.617	0.210
Gastrocnemius muscle (right)	2.203	0.112.
Gastrocnemius muscle (left)	1.073	0.378

From the results of the post-hoc analysis, the change in electrical activity of the rectus femoris muscle in the group with metabolic and digestive system disorders (4) showed a statistically significant difference in the right-side muscle compared to the cardiovascular disorder (1), renal disorder (2), and musculoskeletal disorder (3) groups (p<0.05). For the left-side muscle, the cardiovascular disorder (1) and renal disorder (2) groups showed statistically significant differences compared to the group with metabolic and digestive system disorders, whereas no statistically significant difference was found between the musculoskeletal disorder (3) group and the metabolic and digestive system disorder (4) group (p>0.05) (Table 10). When the relationship between changes in muscle electrical activity and changes in flexibility and back strength was evaluated using Pearson correlation analysis, no statistically significant correlation was found (p>0.05).

Table 10. Results of the analysis of differences in rectus femoris EMG changes between groups (n=30)

Comparison group	**Rectus femoris muscle (right) mean change (μV)**	**p value**	**Rectus femoris muscle (left) mean change (μV)**	**p value**
1 – 4	-0.00354	0.001	-0.00350	0.002
2 – 4	-0.00368	0.002	-0.00362	0.004
3 – 4	-0.00266	0.020	-0.00239	0.053

Note: Group coding: 1 – cardiovascular disorders, 2 – renal disorders, 3 – musculoskeletal disorders, 4 – metabolic and digestive system disorders

5. CONCLUSION

The results of the study show that after therapeutic exercise, flexibility, hand strength, and back muscle strength increased with statistical significance, indicating that physical exercise is effective in improving muscle function in children and adolescents. In particular, a high level of effect (Cohen's d>1.0) was observed in right- and left-hand strength and flexibility indicators, suggesting that the therapeutic exercise program led to notable positive changes in muscle function.

These findings are consistent with the study by Feigenbaum et al. (2009), which demonstrated that resistance training programs in adolescents significantly increase muscle strength and concluded that regular exercise load improves neuromuscular coordination [13]. Similarly, the study by Behm et al. (2017) showed that physical exercise not only increases muscle strength but also improves movement control and stability [23]. In line with this, studies by Lloyd et al. (2014) emphasized that physical training in children and adolescents plays an important role in improving muscle function [24].

In our study, changes in muscle electrical activity measured using the Noraxon device showed that the mean EMG values of all studied muscles decreased during repeated measurements. This indicates that less muscle activation was required to perform the same movement. In other words, it can be interpreted that movement efficiency improved after the exercise intervention. According to Enoka et al. (2016), during training, adaptations occur in the neuromuscular system, leading to more efficient regulation of motor unit activation required for movement execution. As a result, muscle electrical activity may decrease while movement performance improves [25].

From a physiological standpoint, the decline in EMG amplitude observed after the therapeutic exercise program can be explained through several complementary mechanisms rather than a simple loss of muscle activity. First, improved intramuscular coordination \u2014 that is, more synchronized recruitment and rate coding of motor units \u2014 allows a comparable force output to be generated with fewer active motor units, which is registered as a lower surface EMG signal for the same task. Second, repeated practice of the therapeutic movements likely reduced unnecessary co-contraction of antagonist and stabilizer muscles, a compensatory pattern that is common among individuals with limited habitual physical activity or an underlying chronic disease and that tends to inflate EMG amplitude before training. Third, adaptations in passive tissue properties, such as increased muscle\u2013tendon unit compliance and improved joint range of motion \u2014 consistent with the concurrent gains in flexibility observed in this study \u2014 may have reduced the mechanical resistance against which the muscles had to work, further lowering the electrical demand required for the same movement.

These changes are broadly consistent with the concept of neuromuscular adaptation described by Enoka and Duchateau [25, 27], which distinguishes between central and peripheral contributions to improved movement efficiency. Central adaptations may include enhanced corticospinal drive and more selective activation of agonist muscles alongside reduced activation of antagonists, reflecting improved motor learning of the therapeutic exercises over the course of the intervention. Peripheral adaptations may involve more efficient excitation\u2013contraction coupling and improved mechanical transmission of force along the muscle\u2013tendon unit, both of which can occur over relatively short training periods without necessarily involving changes in muscle fiber type or cross-sectional area. Because this study did not include direct measures of central drive (e.g., voluntary activation assessed via interpolated twitch) or muscle architecture (e.g., ultrasound-based fascicle length or pennation angle), these explanations should be regarded as plausible interpretations rather than directly confirmed mechanisms, and represent a specific direction for future research.

Furthermore, a very strong positive correlation ($r = 0.946–0.988$) was found between the initial and repeated EMG measurements, indicating high repeatability and reliability of the measurements. Previous studies have confirmed that EMG is a reliable method for assessing muscle function.15,16 When analyzed by sex, both male and female participants showed positive changes in muscle strength and EMG indicators; however, the magnitude of change was relatively greater in male participants. Some studies suggest that this may be related to differences in muscle mass and hormonal factors in males [26]. Nevertheless, statistically significant improvements were also observed in female participants, indicating that the therapeutic exercise program can be effective regardless of sex.

This pattern of reduced EMG amplitude alongside preserved or improved functional performance has also been reported in other populations undergoing structured therapeutic or resistance exercise. Studies examining neuromuscular adaptation to training have similarly found that a period of structured exercise decreases the EMG amplitude required to perform a standardized submaximal task, a finding that is generally interpreted as improved neuromuscular efficiency rather than reduced muscular capacity, consistent with the training-related activation changes reported by H\u00e4kkinen et al. [17] and Aagaard et al. [18]. The magnitude of change observed in the present study \u2014 approximately 0.007\u20130.009

\u03bcV, corresponding to large effect sizes (Cohen\u2019s d = 2.08\u20134.38) \u2014 is broadly comparable in direction, though not necessarily in absolute size, to the moderate-to-large training effects reported in EMG-based studies of adolescent and young-adult populations; direct numerical comparison is limited, however, by differences across studies in the muscle groups examined, EMG normalization procedures, and intervention duration. Notably, most prior EMG research in this area has focused on healthy or athletic adolescents [17][19][20], whereas the present findings extend this evidence to school-aged students with chronic diseases \u2014 a population in which gains in neuromuscular efficiency may carry particular clinical relevance given their baseline activity limitations and elevated risk of impaired motor coordination.

When comparing changes in muscle electrical activity between disease groups, a statistically significant difference was observed only for the rectus femoris muscle. This suggests that this muscle, which plays an important role in lower limb movement and stability, may be more sensitive to load responses in certain disease conditions. However, no differences were observed between groups for other muscles, indicating that the effect of therapeutic exercise may generally be similar regardless of the type of disease among participants.

A strength of this study is that it evaluated both muscle strength and muscle electrical activity together, and by using the Noraxon device for EMG measurement, it was possible to more precisely determine changes in muscle function. However, limitations include the relatively small sample size and the absence of a control group. Future studies with larger sample sizes and long-term controlled experimental designs would be valuable for more accurately determining the effects of therapeutic exercise.

The results of this study show that therapeutic exercise for students with chronic diseases significantly improved muscle strength and flexibility. Additionally, the decrease in muscle electrical activity measured by the Noraxon device during repeated measurements indicates reduced muscle activation required to perform the same movement, reflecting improved movement efficiency and neuromuscular coordination. Therefore, this study demonstrates that therapeutic exercise is an effective method for supporting physical development and muscle function in students with chronic diseases. Together with the standardized EMG acquisition and normalization protocol applied in this study — including 1500 Hz sampling, band-pass and notch filtering, RMS smoothing, %MVIC normalization, and SENIAM-guided electrode placement — these findings provide methodologically grounded evidence that the observed reduction in muscle electrical activity reflects genuine neuromuscular adaptation, involving both central mechanisms (improved motor unit recruitment and reduced antagonist co-activation) and peripheral mechanisms (more efficient excitation–contraction coupling and increased muscle–tendon compliance), rather than measurement artifact. The high test–retest correlations observed between baseline and follow-up measurements (r = 0.946–0.988) further support the reliability of this interpretation. From a practical standpoint, these results support the integration of individualized, FITT-based therapeutic exercise programs into inclusive physical education curricula for students with chronic diseases, and highlight surface EMG as a valuable objective outcome measure for monitoring neuromuscular progress in future school-based interventions. Given the single-group design and limited sample size of the present study, controlled trials with larger and more diverse cohorts are recommended to confirm and extend these findings. This study has several limitations that should be considered. First, the use of single group quasi-experimental design without a control group restricts the ability to establish a clear causal relationship between the therapeutic exercise program and the observed outcomes. Second, the relatively small sample size (n=30) may have limited the statistical power of subgroup analyses, including comparisons across disease groups. Lastly, because all participants were recruited from a single secondary school, the generalizability of the findings to broader populations may be limited.

REFERENCES

[1] World Health Organization. (2020). *WHO guidelines on physical activity and sedentary behaviour*.
[2] Strong, W. B., Malina, R. M., Blimkie, C. J. R., Daniels, S. R., Dishman, R. K., Gutin, B., Hergenroeder, A. C., Must, A., Nixon, P. A., Pivarnik, J. M., Rowland, T., Trost, S., & Trudeau, F. (2005). Evidence based physical activity for school-age youth. *The Journal of Pediatrics, 146*(6), 732–737. https://doi.org/10.1016/j.jpeds.2005.01.055
[3] Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), Article 40. https://doi.org/10.1186/1479-5868-7-40
[4] Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity, 32*(1), 1–11. https://doi.org/10.1038/sj.ijo.0803774
[5] Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. *Journal of School Health, 76*(8), 397–401. https://doi.org/10.1111/j.1746-1561.2006.00132.x
[6] Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity, 5*(1), Article 10. https://doi.org/10.1186/1479-5868-5-10
[7] Sallis, J. F., McKenzie, T. L., Beets, M. W., Beighle, A., Erwin, H., & Lee, S. (2012). Physical education's role in public health. *Research Quarterly for Exercise and Sport, 83*(2), 125–135. https://doi.org/10.1080/02701367.2012.10599842
[8] Fairclough, S., & Stratton, G. (2005). Physical activity levels in middle and high school physical education: A review. *Pediatric Exercise Science, 17*(3), 217–236. https://doi.org/10.1123/pes.17.3.217
[9] Rimmer, J. A., & Rowland, J. L. (2008). Physical activity for youth with disabilities: A critical need in an underserved population. *Developmental Neurorehabilitation, 11*(2), 141–148. https://doi.org/10.1080/17518420701688649
[10] Verschuren, O., Peterson, M. D., Balemans, A. C. J., & Hurvitz, E. A. (2016). Exercise and physical activity recommendations for people with cerebral palsy. *Developmental Medicine & Child Neurology, 58*(8), 798–808. https://doi.org/10.1111/dmcn.13053
[11] Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., & Olson, R. D. (2018). The physical activity guidelines for Americans. *JAMA, 320*(19), 2020–2028. https://doi.org/10.1001/jama.2018.14854
[12] Kisner, C., Colby, L. A., & Borstad, J. (2018). *Therapeutic exercise: Foundations and techniques* (7th ed.). F. A. Davis.
[13] Faigenbaum, A. D., Kraemer, W. J., Blimkie, C. J. R., Jeffreys, I., Micheli, L. J., Nitka, M., & Rowland, T. W. (2009). Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *Journal of Strength and Conditioning Research, 23*(5 Suppl.), S60–S79. https://doi.org/10.1519/JSC.0b013e31819df407
[14] Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Howard, R., De Ste Croix, M. B., Williams, C. A., Best, T. M., Alvar, B. A., Micheli, L. J., Thomas, D. P., Hatfield, D. L., & Cronin, J. B. (2015). Long-term athletic development—Part 1: A pathway for all youth. *Journal of Strength and Conditioning Research, 29*(5), 1439–1450. https://doi.org/10.1519/JSC.0000000000000756
[15] De Luca, C. J. (1997). The use of surface electromyography in biomechanics. *Journal of Applied Biomechanics, 13*(2), 135–163. https://doi.org/10.1123/jab.13.2.135
[16] Farina, D., Merletti, R., & Enoka, R. M. (2004). The extraction of neural strategies from the surface EMG. *Journal of Applied Physiology, 96*(4), 1486–1495. https://doi.org/10.1152/japplphysiol.01070.2003
[17] Häkkinen, K., Alen, M., Kallinen, M., Newton, R. U., & Kraemer, W. J. (2000). Neuromuscular adaptation during prolonged strength training, detraining and re-strength-training in middle-aged and elderly people. *European Journal of Applied Physiology, 83*(1), 51–62. https://doi.org/10.1007/s004210000248
[18] Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology, 93*(4), 1318–1326. https://doi.org/10.1152/japplphysiol.00283.2002

[19] Escamilla, R. F., Yamashiro, K., Paulos, L., & Andrews, J. R. (2009). Shoulder muscle activity and function in common shoulder rehabilitation exercises. *Sports Medicine*, *39*(8), 663–685. https://doi.org/10.2165/00007256-200939080-00004
[20]Andersen, L. L., Magnusson, S. P., Nielsen, M., Haleem, J., Poulsen, K., & Aagaard, P. (2006). Neuromuscular activation in conventional therapeutic exercises and heavy resistance exercises: Implications for rehabilitation. *Physical Therapy, 86*(5), 683–697. https://doi.org/10.1093/ptj/86.5.683
[21] Falk, B., & Dotan, R. (2006). Child-adult differences in the recovery from high-intensity exercise. *Exercise and Sport Sciences Reviews, 34*(3), 107–112. https://doi.org/10.1249/00003677-200607000-00004
[22] Lloyd, R. S., & Oliver, J. L. (2012). The youth physical development model. *Strength and Conditioning Journal, 34*(3), 61–72. https://doi.org/10.1519/SSC.0b013e31825760ea
[23] Behm, D. G., Young, J. D., Whitten, J. H. D., Reid, J. C., Quigley, P. J., Low, J., Li, Y., Lima, C. D., Hodgson, D. D., Chaouachi, A., Prieske, O., Granacher, U., & Ramirez-Campillo, R. (2017). Effectiveness of traditional strength vs. power training on muscle strength, power and speed with youth: A systematic review and meta-analysis. *Frontiers in Physiology, 8,* Article 423. https://doi.org/10.3389/fphys.2017.00423
[24] Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Oliver, J. L., Jeffreys, I., Moody, J. A., Brewer, C., Pierce, K. C., McCambridge, T. M., Howard, R., Herrington, L., Hainline, B., Micheli, L. J., Jaques, R., Kraemer, W. J., Best, T. M., Chu, D. A., Alvar, B. A., & Myer, G. D. (2014). Position statement on youth resistance training: The 2014 international consensus. *British Journal of Sports Medicine, 48*(7), 498–505. https://doi.org/10.1136/bjsports-2013-092952
[25] Enoka, R. M., & Duchateau, J. (2016). Translating fatigue to human performance. *Medicine & Science in Sports & Exercise, 48*(11), 2228–2238. https://doi.org/10.1249/MSS.0000000000000929
[26] Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed.). Human Kinetics.
[27] Oyundelger Tserendorj, Dolgorsuren Aldartsogt, Bat-Otgon Batsuren, Begz Nadmid, Lkhamsuren Vanya. Effects of therapeutic exercises on physical development in students with pathological conditions. International Journal of Social Science and Humanities Research-MIYR, 2026, 6(1), 64~72.https://doi.org/10.53468/mifyr.2026.6.1.64

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