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# The effect of regular physical activities on neurological status, developmental parameters, and physical fitness in preschoolers

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## ABSTRACT

The aim of this study is to compare the neurological status, developmental parameters and physical fitness of children who engage in regular physical activity in the preschool period versus those who do not. The study included 305 healthy children aged 4–6 years, consisting of 154 girls and 151 boys. In addition to evaluating the demographic characteristics of children; Touwen Neurological Examination, Denver Developmental Screening Test (DDST) II, and Preschool Physical Fitness (PREFIT) test battery were used to assess neurological status, developmental parameters, and physical fitness, respectively. A statistically significant difference was found between neurological status ( $p=0.046$ ), developmental parameters ( $p=0.000$ ) and physical fitness (Standing Long Jump ( $p=0.008$ ), handgrip ( $p=0.006$ )) of preschool children who engaged in regular physical activity compared to those who did not. Preschool children who participated in regular physical activity had no neurological problems and exhibited better developmental parameters and physical fitness than their inactive peers.

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Regular physical activities;  
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## 1. Introduction

Preschool period is a process marked by rapid and effective neuromotor development. This period, which lays the groundwork for a child's future, entails the simultaneous and interconnected development of gross motor skills, fine motor skills, cognitive abilities, language proficiency, self-care, and social-emotional competencies, with each area of development complementing and supporting the others (Alkan, Mutlu, & Haliloğlu, 2021; McCollum, 1999; Metin, 2016). Mastery of skills and behaviors during this period is essential for acquiring higher and more complex abilities (Moriarty, 2002). In addition, important changes are experienced with the maturation process of the nervous system (Tanaka, Hikiyara, Ohkawara, & Tanaka, 2012). While this process of maturation and changes is generally normal and influenced by environmental factors, it may sometimes show a non-optimal developmental form. Although the exact mechanism underlying this condition remains unclear, this non-optimal development process in the brain is linked to abnormal neurotransmitter function (M. Hadders-Algra, 2000). This can result in problems with coordination, including uncertain movements in daily life activities, impaired posture and muscle tone, and insufficient motor movements, which reflect the child's neurodevelopmental level. In other words, this condition, which is defined as Minor Neurological Dysfunction (MND), may be seen as complex MND according to the number of increasing of these areas (M. Hadders-Algra, 2002).

Physical activity has a significant impact on child health and development (Bouchard, Blair, Haskell, & Haskell, 2007). The child's muscles, physical skills, and mental skills develop through

movement and recognition of the environment (Tomprowski, McCullick, & Pesce, 2015). Regular physical activity in children results in enhanced cardiovascular system endurance and muscular fitness, improved bone health, better cardiovascular fitness and body composition, and reduced instances of depression (Barbosa & Oliveira, 2016; Kerkez, 2012). Moreover, adequate and regular physical activity has been reported to have positive effects on cognitive and psychosocial aspects (Çağlak, 1999; Strong et al., 2005) and future health protection (Raitakari et al., 1994; Waxman & World, 2004). In contrast, physical inactivity in children and adolescents aged six years and above has been linked to low muscle strength, low cardiopulmonary fitness, low bone density, metabolic risk factors, and cardiovascular diseases (Smith et al., 2014). Physical activity, which is defined as the ability to successfully perform physical activity (Gutin, Yin, Humphries, & Barbeau, 2005), is also the main determinant of physical fitness (Ortega, Ruiz, Castillo, & Sjostrom, 2008). Therefore, researchers state that the level of physical activity should be followed in every period of life (Certain & Kahn, 2002; Fowler-Brown & Kahwati, 2004; Gordon-Larsen, Nelson, & Popkin, 2004). Thus, researchers have become increasingly interested in studying the beneficial effects of physical activity on child health and development, as well as the negative consequences of sedentary behavior (Kelly, 2000).

The literature currently lacks a study that compares the neurological status, developmental parameters, and physical fitness of preschool children who engage in regular physical activity versus those who do not. Therefore, our aim in this study is to address this gap by conducting a comparative analysis of these variables between the two groups.

## 2. Methods

### 2.1. Participants

A sample of 305 healthy children aged 4–6 years, consisting of 154 girls and 151 boys, was selected from schools of Muş Province under the Ministry of National Education. The sample size was determined using the G\*Power program version 3.1.9.4 (Heinrich-Heine-Universität Düsseldorf, Germany) (Faul, Erdfelder, Lang, & Buchner, 2007). Based on similar articles (Gezen bölükbaş, Vatansever, & Güngör, 2022), the power ratio of the sample was determined as  $\beta = 80\%$  and  $\alpha = 0.05$ , and the number of children engaged in at least 35 regular physical activity during school screening. Ethical permission was obtained on 04/10/2022 from the Scientific Research and Muş Alparslan University's Publication Ethics Board, with decision number 77279-56. The schools where the study was conducted were randomly determined. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and informed consent, witnessed and formally recorded, was obtained from all children and parents.

### 2.2. Measurements

Before conducting the measurement tests, demographic data and information on regular physical activity engagement of the participating children were obtained from their families. The types of activity (swimming, ballet, gymnastics, etc.) were recorded.

#### 2.2.1. Touwen neurological examination

The Touwen examination, originally developed by Touwen and Prechtel in 1970, is a comprehensive method for evaluating neural functions. This evaluation assesses eight key areas: posture and muscle tonus, reflexes, involuntary movements, coordination and balance, fine motor movements, associated movements, sensory functions, and cranial nerve function (Mijna Hadders-Algra, 2010). In these areas, children with no dysfunction in any area were defined as 'normal'; children with dysfunction in one or two areas were defined as 'Simple MND'; children with dysfunction in three or more areas are defined as 'Complex MND' (M. Hadders-Algra, 2002). The Touwen examination is a standardized, detailed, and age-specific assessment method that includes 97 items, providing a strong and

precise measure of motor behavior (Mijna Hadders-Algra, 2010). Thus, in addition to assessing the quality of the child's performance in relation to their age, the examination also evaluates the brain functions through observed behavior and determines the presence of MND. Each child in the study was assessed according to the above information. When the children were assessed, different positions such as sitting, standing, walking, and lying was used (Mijna Hadders-Algra, 2010).

### **2.2.2. Denver Developmental Screening Test II**

Denver Developmental Screening Test (DDST) II is a widely used screening instrument that aims to identify developmental problems in children aged 0–6 years, specifically in the domains of personal-social, language, fine motor, and gross motor skills (Frankenburg, Dodds, Archer, Shapiro, & Bresnick, 1992). Comprising 134 items, the DDST II includes both caregiver-report questions and performance-based assessments, offering a valuable means of identifying developmental concerns, validating suspected cases with objective measures, monitoring children at risk, and referring them to appropriate specialists (Yalaz, 2018).

The developmental status of children was determined by evaluating their performance on age-appropriate items and warning items. Children who were able to complete age-appropriate tasks or had only one warning item were categorized as having 'normal' development. Those who were unable to complete one item had two or more warning items or were unable to complete one item and had one or more warning items were classified as 'suspicious' in terms of development. Children who were unable to complete two or more items were considered to have 'abnormal' development (Frankenburg et al., 1992; Yalaz, 2018)

### **2.2.3. Physical fitness**

To assess the physical fitness in children, PREschool Physical FITness (PREFIT) Test Battery, which was developed in Europe for children aged 4–6 years, was used. This battery is a reliable and straightforward method for evaluating physical fitness in young children. The PREFIT battery comprises weight, height and waist circumference to assess anthropometry, a 20 m shuttle run test (SRT) to assess cardiorespiratory fitness, handgrip strength (upper limbs) and standing long jump (lower limbs) tests to assess muscular strength, 4 × 10 m SRT to assess speed-agility, and one-leg stance test to assess balance (Cadenas-Sanchez et al., 2016; Martinez-Tellez et al., 2016).

**Handgrip strength test.** Muscular strength of the upper body and upper extremities was assessed using a hand dynamometer (TKK 5001, gripA, Takei, Tokyo) with a grip span of 4 cm, which has a range of 0–100 kg and an accuracy of 0.5 kg. Hand grip strength test assesses isometric muscle strength of the upper body and upper extremity. During the measurement, the children standing in a bipedal position were asked to squeeze the dynamometer continuously for at least 2 or 3 s without bending the elbow and contacting the body. The best value from two trials for each hand was chosen, and the average of both hands was registered (kg) (Cadenas-Sanchez et al., 2016; Martinez-Tellez et al., 2016).

**Standing long jump test.** The Standing long jump (SLJ) test was used to assess the muscular strength of the lower body and lower extremities. This test consisted of jumping as far as possible behind the starting line with feet together (separate from each other approximately at the shoulder's width on a hard, non-slippery surface,) and remaining upright. Children performed three jumps, and the best of these attempts were recorded (cm) (Cadenas-Sanchez et al., 2016; Martinez-Tellez et al., 2016). The starting line was marked, and the jump distance was measured using a scale that was designed to be easy for children to understand and use (Cadenas-Sanchez et al., 2016).

**4 × 10 m SRT.** 4 × 10 m SRT was used to assess speed and agility. The test involved running on a non-slippery surface between the two parallel lines (10 m apart) drawn on the floor, covering a distance of 40 meters by running back and forth as fast as possible. In each round, the children had to cross the

finish line with both feet and touch the hand of the researcher. The children repeated the test a second time, and the best result of two attempts was recorded in seconds (sec) (Cadenas-Sanchez et al., 2016; Martinez-Tellez et al., 2016). To ensure safety and ease of testing, while the tester was on one side of the parallel lines during the test, one of the parents was placed on the other side of the parallel lines (Cadenas-Sanchez et al., 2016).

**One-leg stance test.** One-leg stance test was used to assess the balance. According to this test, which evaluates the static balance, the children maintained their balance in this position as much as they could stand on one leg while the other leg was bended from the knee. A chronometer was started immediately after the children lifted their free leg off the floor, and they were allowed to use their arms to maintain balance if necessary. The test ended when the children were no longer able to maintain the required position, such as by holding something or moving their supporting foot, heel, or toe from the original position. The test was done once with each leg, and the mean of two attempts was registered in seconds (Cadenas-Sanchez et al., 2016; Martinez-Tellez et al., 2016).

**6-minute walk test.** The 6-Minute Walk Test (MWT) was used to assess cardiorespiratory fitness in preschool children. The 6MWT is similar to the shuttle run test assessing cardiorespiratory fitness in preschool children. Even with a single researcher, it has the advantage of being easily conducted without the need for a video signal and tape (Laboratories, 2002).

The 6MWT is a highly suitable method for evaluating functional exercise capacity at a submaximal level, as it can be conducted cheaply and without the need for specialized equipment. Validity studies of the 6MWT have been conducted in healthy children and adolescents, and its standard value has been specified. During this test, children were asked to walk as fast as possible on a flat, hard surface for 6 minutes, with verbal encouragement provided (Lammers, Hislop, Flynn, & Haworth, 2007). The test distance in the pediatric population was recommended as 15–20 m, and was determined to be 20 m (de Groot & Takken, 2011). The distance to be measured was marked with band, and the cone was placed at both ends. The total distance walked by children was recorded (m) (Laboratories, 2002).

### 2.3. Data analysis

Statistical analyses were performed using IBM Statistical Package for the Social Science software version 25. Visual (histograms and probability plots) and analytical methods (Kolmogorov–Smirnov) were used to determine the normal distribution of numerical variables. Descriptive statistics, including means and standard deviations, were presented for numerical variables with normal distributions, while categorical variables were summarized using frequency and percentage values. The Independent Sample T test was used for the comparison of two groups with normal distribution, while the Chi-square test was used for comparing categorical independent two groups. The total type-1 error level was accepted as 5%, and statistical significance was considered at  $p$ -value less than 0.05.

## 3. Results

The data on the descriptive characteristics of the preschool children included in the study were presented in Table 1. According to this table, the mean age of preschool children was 62 (months), with 50.5% being girls and only 11.5% engaging in regular physical activity (Table 1).

Table 2 presents the comparison of neurological status, developmental parameters, and physical fitness of preschool children according to their regular physical activity status. A statistically significant difference was found between neurological status ( $p = 0.046$ ), developmental parameters ( $p = 0.000$ ) and physical fitness (SLJ ( $p = 0.008$ ), handgrip ( $p = 0.006$ )) of preschool children who engaged

**Table 1.** Characteristics of the study population ( $n = 305$ ).

		Mean	SD	<i>n</i>	(%)
Age (months)		62	7		
Weight (kg)		19.3	3.1		
Height (cm)		109	6		
BMI (kg/m <sup>2</sup> )		16.27	1.74		
Gender	Girls			154	50.5
	Boys			151	49.5
Regular physical activity	Yes			35	11.5
	No			270	88.5
Physical fitness	Handgrip (kg)	7.13	1.61		
	One-leg stance (s)	19.01	13.86		
	SLJ (cm)	82	17		
	4 × 10 m SRT (s)	17.53	1.91		
	6MWT(m)	397	52		
DDST II	Normal			166	54.4
	Suspicious			128	42.0
	Abnormal			11	3.6
Neurological status	Normal			277	90.8
	Simple MND			28	9.2
	Complex MND			0	0.0

BMI: Body mass index, DDST: Denver developmental screening test, MND: Minor neurological dysfunction, MWT: Minute Walk Test, SLJ: Standing long jump, SRT: Shuttle run test, SD: Standard deviation.

in regular physical activity compared to those who did not. To put it more clearly, children who participated in regular physical activity had no neurological problems and exhibited better developmental parameters and physical fitness than their inactive peers (Table 2).

#### 4. Discussion

Childhood is a crucial neurodevelopmental period in which many health-related formations occur. During this period, physical activity has numerous beneficial effects on child health and development (Donnelly et al., 2016). Although there are limited studies reporting the opposite (Tandon et al., 2018), there is increasing evidence showing the positive effect of physical activity on neurological processes (cognitive functions, academic achievement, and psychosocial functions), particularly in school-age children (Donnelly et al., 2016; Fochesatto et al., 2023). This is due in part to the Brain-Derived Neurotrophic Factor (BDNF) protein, which is highly concentrated in the central nervous system and plays a critical role in neuron survival, differentiation, and development,

**Table 2.** Comparison of the neurological status, developmental parameters and physical fitness of preschool children who engaged in regular physical activity.

		Regular physical activity				<i>p</i>
		Yes ( $n = 35$ )		No ( $n = 270$ )		
		<i>n</i>	(%)	<i>n</i>	(%)	
Neurological status	Normal	35	100	242	89.6	0.046
	Simple MND	0	0.0	28	10.4	
	Abnormal	0	0.0	11	4.1	
DDST II	Suspicious	1	2.9	127	47.0	0.000
	Normal	34	97.1	132	48.9	
	Mean		SD	Mean	SD	
Physical fitness	SLJ (cm)	7.8	1.5	7.0	1.6	0.008
	Handgrip (kg)	25.0	17.6	18.2	13.1	0.006
	One-leg stance (s)	79	19	82	17	0.322
	4 × 10 m SRT (s)	17.4	2.2	17.5	1.8	0.723
	6MWT (m)	408	57	396	51	0.186

Independent sample *t* test, Chi-square, DDST: Denver developmental screening test, MND: Minor neurological dysfunction, MWT: Minute Walk Test, SLJ: Standing long jump, SRT: Shuttle run test, SD: Standard deviation

ultimately promoting learning and neural plasticity (Chandrasekaran, Pesola, Rao, & Arumugam, 2021; Fochesatto et al., 2023). Interestingly, the concentration of this protein in the blood also increases during physical activity (Chandrasekaran et al., 2021; Fochesatto et al., 2023). Therefore, in addition to the numerous beneficial effects of physical fitness in school-age children and adolescents, it is recommended to be developed for brain health (Fochesatto et al., 2023; Khan, Lee, Rosenbaum, Khan, & Tremblay, 2021). Although our study did not find any neurological problems in preschool children engaging in regular physical activity, Touwen's evaluation revealed that 10.4% of children who did not have regular physical activity had simple MND. The current study is noteworthy for being the first study to show the effect of regular physical activity on neurological status in preschool children.

Overall, physical activity during early childhood is crucial for promoting healthy development. It positively affects cognitive, motor, and social-emotional development, and can help lay the foundation for long-term health and well-being (Brière, Imbeault, Goldfield, & Pagani, 2020). Especially, when experienced and competent teachers design activities (such as play, drama, and music) in early childhood education classrooms by taking into account gross and fine motor skills, they can increase the likelihood of regular physical activity engagement. Studies have shown that physical activity during this period positively affects a child's physical, psychological, and cognitive development. Zeng et al. (2017) conducted a systematic review of studies examining the association between physical activity and early childhood development, finding that physical activity is positively associated with cognitive, motor, and social-emotional development in early childhood. The study also explored the relationship between physical activity and motor development in preschool children and found that physical activity was positively associated with gross motor development, as well as with hand and finger dexterity and eye-hand coordination (Zeng et al., 2017). Furthermore, Daly-Smith et al. (2020) examined the impact of a physical activity intervention on motor proficiency in preschool children and found significant improvements in motor proficiency, including locomotor and object control skills (Daly-Smith et al., 2020). Similarly, our study reported that preschool children engaging in regular physical activity not only had no abnormal development according to the DDST II test but also exhibited healthier developmental parameters. In contrast, 4.1% of children who did not engage in regular physical activity showed abnormal development.

Research consistently shows a positive relationship between physical activity, physical fitness, and early childhood development. For example, Hollmann (1991) found that regular physical activity with preschool children contributed to the development of physical fitness and motor skills such as running, jumping, and hopping (Hollmann, 1991). Similarly, Sun, Zhu, Shih, Lin, and Wu (2010) found that participation in physical activity programs had a positive effect on preschool children's physical fitness levels (Sun et al., 2010). Furthermore, Donnelly et al. (2016) examined the relationship between physical fitness, physical activity, and cognitive function in early childhood, finding that higher levels of physical activity and physical fitness were associated with better cognitive function, including improved executive function, attention, and memory (Donnelly et al., 2016). Similarly, another study examining the effect of regular physical activity on physical fitness parameters in preschool children has found that children engaging in regular physical activity affect physical fitness parameters (agility test, touching discs, flamingo balance test, ball bounce, and 30-second shuttle test). Our study argued that preschool children with regular physical activity achieved higher scores on the PREFIT test battery, which assesses physical fitness parameters specific to this age group, compared to the control group.

#### **4.1. Limitations**

This study has some limitations. First, we did not record the weekly frequency and duration of physical activity of children who engaged in regular physical activity, which could provide more detailed information about their level of activity. Second, we were not able to compare children's BDNF protein plasma levels due to technical constraints. Third, we did not consider variables such as

socio-economic status of the families of the children participating in the research, as well as parental attitudes.

## 5. Conclusions

Based on the results of the current research, while no neurological problem and abnormal development has determined in preschool children engaging in regular physical activity, their physical fitness has also been found to be better. Therefore, it is recommended that children engage in regular physical activity from an early age, taking into account the effects of brain health, developmental parameters, and physical fitness. Collaboration among children, families, teachers, and schools, is crucial to effectively guide the preschool education process and provide a supportive educational and learning environment that promotes physical activity and healthy development.

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Abdulhamit Karademir conceived the research idea. Abdulhamit Karademir and Halil Alkan developed the entire proposal, data processing and analysis. Halil Alkan and Mehmet Canlı drafted the manuscript. Abdulhamit Karademir, Halil Alkan, and Mehmet Canlı have contributed to the final manuscript by providing critical feedback on the results and their interpretation.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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