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Physical activity and cardiorespiratory fitness in school-aged children (9-10 years) at risk for type 2 diabetes

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Abstract:

The study aimed to describe the levels of physical activity and cardiorespiratory fitness in school-aged children (9-10 years) at risk of developing type 2 diabetes, in addition to investigating the degree of association between the level of physical activity and cardiorespiratory fitness.

In this study, we used a cross-sectional design. A total of 110 children at risk for type 2 diabetes met the criteria for participation in the assessment process. To determine overweight and obesity among the sample members, we relied on the body mass index (BMI). To determine the level of physical activity among the children under study, we used the PDPAR physical activity scale from ACTIVGRAM. To assess cardiorespiratory fitness, we relied on the PACER test protocol from FITNESSGRAM.

The study results indicated that a decrease in cardiorespiratory fitness is associated with a lower level of daily physical activity in children at risk of type 2 diabetes. A decrease in the rate of daily physical activity may lead to poor levels of cardiorespiratory fitness and thus an increased risk of developing type 2 diabetes in students aged 9-10 years.

Keywords: physical inactivity, cardiorespiratory fitness, type 2 diabetes, school-age children.

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1. INTRODUCTION

Increased sedentary behavior and physical inactivity are associated with a number of non-communicable diseases worldwide. (World Health Organization, 2014) Data indicate that approximately 1.9 million deaths worldwide annually are caused by physical inactivity. It has been identified as a major risk factor for the development of most chronic diseases (Neil-Sztramko et al, 2021), including prediabetes and type 2 diabetes. (Warburton & Bredin, 2006) A WHO report also indicated that 60% of the world's population does not engage in sufficient physical activity; therefore, a sedentary lifestyle is emerging as a threat to global health (World Health Organization, 2003).

Risk factors for chronic disease, including a sedentary lifestyle, may be present even in young children. (Sirard & Pate, 2001) It seems likely that there is a natural, biological decline in total physical activity throughout the lifespan. (Sallis, 2000) The prevailing view at that time was that the sharpest decline in total physical activity occurred between the ages of 12 and 18 years. (Kimm et al, 2000) (Caspersen et al, 2000) However, authors of more recent studies suggest that the early decline in total physical activity begins at 6 years of age. (Nyberg et al, 2009) (Basterfield et al, 2011) which may lead to overweight or obesity. (Lobstein & Jackson, 2007)

Low or unhealthy cardiorespiratory fitness is a strong, independent predictor of cardiovascular disease and all-cause mortality in adults (Ross et al, 2016). In young adults, cardiorespiratory fitness is an indicator of overall health, including heart and metabolic health (Lang et al, 2018; Ortega et al, 2008), premature cardiovascular disease (Högström et al, 2014), educational attainment (Santana et al, 2017), and mental health (Ortega et al, 2008; Lubans et al, 2016). Over the past six decades, cardiorespiratory fitness has declined internationally. This decline may be due to increased obesity, sedentary time, lower levels of moderate-to-vigorous physical activity, and socioeconomic changes (Tomkinson et al, 2019; Tomkinson & Olds, 2007).

However, there remains a dearth of studies examining the nature of the relationship between physical activity and cardiorespiratory fitness in children at risk of developing type 2 diabetes, particularly in Algerian school settings and in contexts where physical education and sports programs may be inadequate or ineffective. Therefore, there is a need to study this association to better understand the role of physical activity in improving cardiorespiratory fitness and thus reducing the risk of type 2 diabetes in this group. The results of this study provide



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scientific evidence and pave the way for comparative causal studies that contribute to the development of early prevention strategies and support the design of intervention programs that promote physical activity and improve health-related components of physical fitness in Algerian school settings. This may positively impact school health and reduce the likelihood of developing type 2 diabetes later in life.

This study aims to explore the relationship between the level of physical activity and cardiorespiratory fitness in school-aged children at risk of developing type 2 diabetes by asking the following question: What is the extent of the association between the level of physical activity and cardiorespiratory fitness in school-aged children (9-10 years) at risk of developing type 2 diabetes?

2. Methods and tools

2.1 Study design and participants

With permission from the Director of the Public Institution for Neighborhood Health, we carried out a survey prior to starting the current study in collaboration with the **School Health** Detection and Follow-up Units-Aflou during their recurring visits to primary schools for the 2022–2023 academic year. The study sought to determine how many 9–10-year-old children in urban primary schools in the Aflou District of Laghouat Province suffer from obesity and overweight. one hundred and fifty children in the fourth and fifth grades, both male and female, participated in the study.

We chose a pilot sample of 20 male and female students who shared the same characteristics as the original study sample after the statistical procedure was finished. In order to examine the general conditions of the study, identify the steps required for its advancement, and get past the challenges and barriers the study faced, they were later removed from the study list. We also received training on data collection instruments and confirmed their appropriateness and validity. With parental consent, the pilot study procedures were implemented for these students. The pilot study's findings proved the validity and dependability of the instruments used to gather information on the research variables.

To test the validity and reliability of the study tools, we relied on the test-and-retest method to measure the stability of the study tools, as shown in the following table:

Table 1. Results of calculating the reliability of the study tools

tool	Test application		Re-application		Correlation coefficient	Significance level	Significance at 0.05
	N=20		N=20				
	$\bar{x}_1$	S ₁	$\bar{x}_2$	S ₂			
PDPAR	1.56	.051	1.57	.046	.728	.000	Significant
PACER	35.83	.551	36.05	.901	.862	.000	Significant
BMI	35.83	1.25	23.25	1.29	.994	.000	Significant

The results shown in the table above indicate that the correlation coefficient between the test-retest results for the Physical Activity Scale (PDPAR) was estimated at 0.72, which is statistically significant at the 0.05 significance level. This indicates that the tool used to assess physical activity levels has a good level of reliability.

The results shown in the table above indicate that the correlation coefficient between the test-retest results for the Cardiorespiratory Fitness Index (PACER) was estimated at 0.86, which is statistically significant at the 0.05 significance level. This indicates that the tool used to assess physical activity levels has a good level of reliability.

The results shown in the table above indicate that the correlation coefficient between the test-retest results for the Body Mass Index (BMI) was estimated at 0.99, which is statistically significant at the 0.05 significance level. This indicates that the tool used to assess physical activity levels has a good level of reliability. To measure the validity of the study tools, the researcher relied on calculating self-validity, as this method is based on calculating the square root of the reliability coefficient, as shown in the following table:

Table 2. Results of calculating the self-honesty of the study tools

tool	stability coefficient	Self-honesty
PDPAR	.728	0.853
PACER	.862	0.928
BMI	.994	0.996

The self-reliability results for the study tools were as follows, as can be seen from the results in the above table:

- The self-reliability of the physical activity scale was estimated at 0.85, which indicates that the scale has a good level of reliability;

- The self-reliability of the cardiorespiratory fitness index was estimated at 0.92, which indicates that the scale has a high level of reliability;
- The self-reliability of the body mass index was estimated at 0.99, which indicates that the scale has a high level of reliability.

In this study, we employed a cross-sectional design to evaluate the association between school-age children at risk of type 2 diabetes and their level of physical activity and their physical fitness index, or cardiorespiratory fitness. Because it was appropriate for the study design, the descriptive approach was chosen. Children in the fourth and fifth grades of primary school in the urban areas of the Aflou district were the only participants in our study, provided that they were between the ages of nine and ten. For this study, we recruited participants using a nonrandom sampling technique. Through the administration of their school, we reached out to parents to get their permission to take part in the study and to ask for their attendance if necessary. In conclusion, 110 kids who were at risk for type 2 diabetes satisfied the requirements to take part in the evaluation. Twelve children did not attend the screening and assessment process, three children with other medical conditions were exempt, five children were excluded because of parental disapproval, and twenty children were excluded because they had participated in the pilot study.

2.2 Data collection procedures

This study spanned two days, from May 26 to May 27. All measurement and data collection procedures were conducted at the multi-sports hall of the martyr Ben Moawaz Abdelnabi-Aflou. Before beginning the data collection process, we defined the basic study variables procedurally as follows:

- **Physical activity level:** Physical activity in this study was defined as the average daily energy expenditure, expressed through the metabolic equivalent per minute, which was then classified into three levels.

Table (3) shows the cut-off scores for determining physical inactivity and physical activity levels according to the MET score (Strath et al, 2013).

Table 3. Physical activity levels according to metabolic equivalent score

low	Medium	High
1.6- 2.9 METs	3- 5.9 METs	≥ 6.0 METs

- **Cardiorespiratory fitness:** Cardiorespiratory fitness was defined as the maximum oxygen consumption (**VO2 max = ml/kg/min**) and was classified according to the FITNESSGRAM criteria into three categories or zones.

Table (4) shows the cardiorespiratory fitness levels for males and females according to the cardiorespiratory fitness index VO₂ max (Welk et al, 2011).

Table 4. Cardiorespiratory fitness categories according to the FITNESSGRAM criteria

Category		Healthy risk	Need for improvement	Health fitness
Males/Females	9 years	≤ 37.3	37.4- 40.1	≥ 40.2
	10 years			

- **Risk of Type 2 Diabetes:** The risk of developing type 2 diabetes was defined based on the presence of one of the primary risk factors, namely overweight or obesity, in addition to one of the other factors (family history of diabetes, sedentary time). (American Diabetes Association, 2018)

We collected various types of data using measurement tools appropriate to the nature of the variables under study, after obtaining authorization from the Director of Education for the state of Laghouat. (10) field assistants participated in the study, including middle and high school physical education and sports teachers and sports counselors, in addition to a school health doctor and a male and female nurse from the Aflou Public Institution for Neighborhood Health. A training workshop was conducted for the assistants on physical activity and cardiorespiratory fitness assessment tools and the division of tasks among them.

- **Anthropometric Measurements:** To determine overweight and obesity among the sample, we relied on the Body Mass Index (BMI) because it is a reliable and inexpensive measure. BMI is based on weight divided by the square of height (kg/m^2). The medical team participating in the study, consisting of a physician and assistants, measured weight and height in the presence of the children's parents. After stripping them of heavy clothing and shoes, the children's height and weight were measured using a special device consisting of an electronic scale and a millimeter tape attached to the scale.
- **Physical Activity Assessment:** To determine the physical activity level of the children under study, we used the Physical Activity Profile (PDPAR) scale, designed by ACTIVGRAM, which was specifically designed for school-age children. This tool is a self-report of physical activity levels based on recalling the previous day's physical activities. The questionnaire contains a set of questions describing the type, volume, and intensity of physical activity every



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half hour during the day, in addition to sedentary time, starting from 7:00 a.m. to 10:30 p.m. Before beginning to measure activity levels, we held a session with the students and their parents. This session provided a general overview of the types of physical activity and how to measure it, to facilitate the support team's work in collecting data. The support team began collecting data on physical activity levels by interviewing each student and their parent individually. Each interview lasted approximately 15 minutes. The children were asked a series of questions, which they answered with the help of their parents, to determine their daily physical activity level.

- **Cardiorespiratory Fitness Assessment:** We used the multi-stage PACER test protocol, which was created by FITNESSGRAM, to evaluate cardiorespiratory fitness. Running back and forth on a 20-meter track at a pace set by an audio recorder is the test's objective. We provided all test-related procedures prior to putting the cardiorespiratory fitness test protocol into action. Eleven groups of ten people each were created from the sample. Depending on how many kids were in each group, ten assistants took part in the assessment process. It was the duty of every assistant to document the outcomes for the child under their supervision.
- **Type 2 Diabetes Risk Assessment:** To identify the risk factors under study, the medical staff, prior to conducting medical examinations and anthropometric measurements, asked a series of questions about risk factors related to type 2 diabetes, if present, regardless of overweight or obesity. These risk factors were operationally defined in this study as (family history of type 2 diabetes and time spent in sedentary behavior). The physician asked parents about the presence of first-degree relatives previously diagnosed with diabetes, such as the mother, father, brother, grandfather, grandmother, etc. Sedentary behavior was established through the total time the children spent sitting, watching television, playing video games, sleeping (outside of bedtime), and eating.

2.3 Statistical methods

We used a set of statistical methods to describe and analyze the study data, relying on the (EXCEL) program in addition to the (SPSS) statistical package program. These methods were represented in (frequencies, percentages, arithmetic mean, standard deviation, Pearson correlation coefficient, linear regression analysis, analysis of variance (ANOVA)).

3. Results

Table (5) shows the arithmetic mean and standard deviation of physical activity in metabolic equivalents (METs) during the day, as well as the percentages and frequencies for the distribution of study sample members according to physical activity levels.

Table 5. Physical activity levels in children at risk for type 2 diabetes

variable	physical activity			mean	standard deviation	Sample orientation
Level	low	Moderate	High	1.66	0.08	low
frequencies	87	23	-			
percentage	79%	21%	-			

We note from Table (5) that the arithmetic mean value for the level of physical activity was estimated at (1.66) and the standard deviation was estimated at (0.08). The prevailing level of physical activity among children at risk of developing type 2 diabetes was the low level, representing 79% of the total number of children in the study sample. The percentage of children with a moderate level of physical activity was 21%, representing 23 children in the study sample. High physical activity did not achieve any significant results.

Table (6) shows the arithmetic mean and standard deviation values for the cardiorespiratory fitness index, the percentages, and the frequencies for the distribution of study sample members according to cardiorespiratory fitness levels classified according to the FITNESS-GRAM criteria.

Table 6. Cardiorespiratory Fitness Index in Children at Risk of Type 2 Diabetes

variable	Cardiorespiratory Fitness Index			mean	standard deviation	Sample orientation
Category	health hazard	Need for improvement	Health fitness	37.5	1.52	health hazard
frequencies	65	42	3			
percentage	59%	38%	3%			

We note from Table (6) that the arithmetic mean value for the cardiorespiratory fitness index was estimated at (37.50) with a standard deviation of (1.52). Children at risk of developing type 2 diabetes were classified within the health risk zone at a rate of 59%, equivalent to 65 children out of the total number of children in the study sample. The percentage of children in the improvement need zone was 38%, equivalent to 42 children out of the study sample. As for the health

fitness zone, only three children were recorded.

Table (7) shows the relationship between the level of physical activity and the cardiorespiratory fitness index among students at risk of developing type 2 diabetes, using the Pearson correlation coefficient.

Table 7. Correlation between the level of physical activity and the cardiorespiratory fitness index

		physical activity	Cardiorespiratory Fitness
physical activity	Pearson Correlation	1	.832*
	Sig. (2-tailed)		.000
	N	110	110
Cardiorespiratory Fitness	Pearson Correlation	.832*	1
	Sig. (2-tailed)	.000	
	N	110	110

*. Correlation is significant at the 0.05 level (2-tailed).

Table (7) shows a statistically significant, positive correlation between the level of physical activity and the cardiorespiratory fitness index among students at risk of developing type 2 diabetes at a significance level of 0.05. The correlation coefficient between them reached 0.832, which is a strong correlation.

▪ **Hypothesis Testing Using Linear Regression:**

Table (8) shows the expected effect of the independent variable (physical activity level) on the dependent variable (cardiorespiratory fitness index) among students at risk of developing type 2 diabetes using the linear regression analysis method. In addition, Table (9) shows the F value and significance level for the ANOVA model.

Table 8. shows the results of the linear regression analysis of the physical activity level and the cardiorespiratory fitness index.

Model Summary ^b				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.832 ^a	.692	.689	.84919
a. Predictors: (Constant), Physical activity				
b. Dependent Variable: Cardiorespiratory Fitness				

We note from Table (8) that the correlation coefficient between the level of physical activity and the cardiorespiratory fitness index reached (0.832), which is

a strong direct correlation, while the coefficient of determination reached (0.692). From this, we conclude that the independent variable (physical activity level) was able to explain 69% of the changes in the dependent variable (cardiorespiratory fitness index), which is a strong explanatory power. Other factors accounted for the remaining 31%. The t-test value reached -15.560, which is statistically significant at the significance level of 0.05. This means that the independent variable influences the dependent variable.

Table 9. ANOVA analysis of variance for the previous table (8)

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	174.584	1	174.584	242.099	.000 ^b
	Residual	77.882	108	.721		
	Total	252.466	109			
a. Dependent Variable: Cardiorespiratory Fitness						
b. Predictors: (Constant), Physical activity level						

We note from Table No. (9) for the analysis of variance that the calculated F value reached 242.099, which is statistically significant at the significance level of 0.05, which confirms the high explanatory power of the linear regression model from a statistical standpoint.

4. Discussion

Despite the World Health Organization's recommended guidelines for physical activity in school-age children, children aged 9-10 years at risk of type 2 diabetes under study do not meet these recommendations. Referring to Table (5) for the physical activity level of the study sample, we find that they actually have low levels of physical activity.

Recent evidence suggests that most children fail to meet these guidelines. For example, data collected from the International Pediatric Accelerometer Database (ICAD), an international consortium for accelerometer data, includes results from Europe, Australia, North America, and South America. Longitudinal results from 1997 to 2009 found that only 9% of boys and 2% of girls aged 5-17 years achieved the recommended 60 minutes of moderate-intensity physical activity (MVPA) each day. (Cooper et al, 2015)

The Global Alliance for Healthy Active Kids, which includes children from 49



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countries with varying human development indicators, found that only 20% of children aged 5 to 17 years achieved the recommended amount of physical activity based on WHO guidelines. (Aubert et al, 2018) This outcome is estimated to be lower for children of lower socioeconomic status, as research shows that the lower the socioeconomic status, the higher the levels of physical inactivity, with lower levels of moderate physical activity (Drenowatz et al, 2010). In the same vein, evidence suggests that people who participate in regular physical activity in childhood are more likely to be physically active as adults (Jones et al, 2013; Tammelin et al, 2014). Despite these benefits, several studies have found that physical activity levels in children have declined in recent decades (Bassett et al, 2015; Dalene et al, 2018), with a decline in outdoor play (Bassett et al, 2015), active transportation (Bassett et al, 2015; Booth et al, 2015), and physical activity and sports in particular (Bassett et al, 2015; Dollman et al., 2005).

On the other hand, the study results demonstrated that school-aged children (9-10 years) with risk factors for type 2 diabetes have low levels of cardiorespiratory fitness. If we refer to Table (6) for the cardiorespiratory fitness index results, we can see that they are indeed classified within the health risk zone according to standard levels of cardiorespiratory fitness.

Tomkinson et al. (2003) conducted a large study on a group of children and adolescents from primarily developed countries over two decades (1980-2000). They reported that aerobic fitness declined rapidly, with the most significant decline observed in older adults. A recent scientific statement from the American Heart Association (Raghuveer et al., 2020) also noted the importance of cardiorespiratory fitness (CRF) as an indicator of physical and mental health, as well as academic achievement, in young people. However, over the past six decades, the level of cardiorespiratory fitness has declined internationally. (Moraes et al, 2013; Tomkinson et al, 2019)

Expert guidelines suggest that children and adolescents with both type 1 and type 2 diabetes are less active and have lower cardiorespiratory fitness than their non-diabetic peers (Maahs & Daniels, 2014; Adolfsson et al, 2018). Despite these claims, the evidence is mixed. Some studies have documented significant deficits in physical activity and cardiorespiratory fitness in youth with type 2 diabetes (Nadeau et al, 2009), while others suggest that the differences are less profound (Wittmeier et al, 2012). Among youth with type 1 diabetes, some studies have found lower levels of physical activity and cardiorespiratory fitness (Nguyen et al, 2015), while many suggest no difference (Elmesmari et al, 2017) and, in some

cases, higher levels of physical activity. (Czenczek et al, 2019)

Cardiorespiratory fitness (Garcia-Hermoso et al, 2020; Ruiz et al, 2016) and daily physical activity (Ekelund et al, 2012) (Hay et al, 2012) are important modifiable factors for cardiometabolic disease in children and adults, including mortality. (Hogstrom et al, 2016) Referring to the results in Table (7) and Table (8), we find a strong direct correlation between low physical activity levels and cardiorespiratory fitness in school-aged children (9-10 years) at risk for type 2 diabetes, and that the decrease in cardiorespiratory fitness can be explained by low levels of physical activity.

Physical activity provides a range of health benefits across the lifespan. Moderate-to-vigorous physical activity (MVPA) is activity that stimulates energy expenditure of more than 3 metabolic equivalents (METs), such as brisk walking, running, and competitive sports. (WHO, 2018) In adulthood, physical activity has been associated with improved cardiovascular health and reduced rates of overweight and obesity, cancer, and other non-communicable diseases. (Reiner et al, 2013) In school-aged children, moderate-to-vigorous physical activity is associated with numerous health benefits, including improved cardiorespiratory fitness, along with a reduced risk of cardiovascular disease. (Sterdt et al, 2014). Adolescents with high cardiorespiratory fitness (Hurtig-Wennlof et al, 2007) (McGavock et al, 2009) and those who engage in regular daily physical activity (Ekelund et al, 2012; Hay et al, 2012) show lower blood pressure and lower central and total obesity and are less likely to develop heart disease in adulthood. Accordingly, regular physical activity (Chaput et al, 2020; van Sluijs et al, 2021) and improved cardiorespiratory fitness (Raghuveer et al, 2020) are consistent recommendations for optimal growth and health in children and adolescents, including those with type 2 diabetes. (Maahs & Daniels, 2014; Adolfsson et al, 2018)

Schooling is a critical period, not only for habit formation in adult life, but also because behavior during this period is also associated with medical conditions later in life (Howie et al, 2020). Preventive efforts such as increased physical activity (PA) undertaken during sensitive or critical periods can help reduce obesity-related outcomes and associated consequences. (Dietz, 1994) One such critical period may be mid-childhood (6–11 years), when the incidence of childhood obesity is highest (Hughes et al, 2018). al, 2011) and when the mass-specific cardiorespiratory fitness (CRF) stabilizes in boys and begins to gradually decline in girls. (Armstrong, 2013)



5. CONCLUSION

After analyzing and discussing the data from a study examining the relationship between physical activity and cardiorespiratory fitness in school-aged children (9-10 years) at risk of developing type 2 diabetes, we reached a set of important findings that contribute to a better understanding of the interrelationship between physical activity and cardiorespiratory fitness and their role in school health. The children in the study showed a decrease in their daily physical activity levels and an increase in their sedentary behavior. They were also classified as needing improvement in terms of their cardiorespiratory fitness index (VO2 max). The results also indicated a strong direct correlation between low levels of daily physical activity and a decline in cardiorespiratory fitness in this group of children. This negatively impacts metabolic indicators such as insulin resistance, blood glucose levels, and weight gain, thus increasing the likelihood of developing type 2 diabetes in adulthood or later in life.

Based on these findings, we recommend the following:

- Activate school physical activity and sports programs in primary schools by implementing daily hour-long classes containing age-appropriate semi-sports games.
- Programming large-scale awareness campaigns to educate parents and families about the importance of physical activity in preventing the risk of type 2 diabetes and training qualified teachers in the field.
- Adhering to preventive measures by conducting periodic examinations for children at risk of health, through coordination between physical education and sports teachers and school health screening and follow-up units.
- Designing intervention programs specifically for children in risk areas that target health-related physical fitness components, through coordination between physical education and sports teachers and youth and sports staff.
- Conducting future causal-comparative studies based on longitudinal designs and randomized trials to determine the magnitude of the impact of physical activity and cardiorespiratory fitness on preventing type 2 diabetes.

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