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Article

# Design and implementation effects of a biomechanics-based physical training program for preschool children

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**Abstract: Background:** Childhood is an essential period for psychological and physical development since it establishes the basis for lifelong physical activity and positive behaviors. Early experiences shape the physical capacities of preschool-aged children, who are growing at a rapid pace. Therefore, it is crucial to provide preschool-aged children with sufficient physical exercise to improve their motor skills, balance, and coordination, general physical and mental health. **Purpose:** The research's goal is to examine the impact of implementing a biomechanics-based physical training program for preschoolers. The program incorporates age-appropriate biomechanical concepts into planned exercises, emphasizing the development of motor skills, flexibility, strength, balance, and general physical development while encouraging social engagement and mental resilience. **Methods:** A total of 157 preschool children were randomly divided into two distinct categories for the analysis. The intervention group (IG) received a biomechanics-based physical training program, and the control group (CG) received standard physical training. Assessments conducted before and after the program included measures of physical fitness (motor proficiency, agility, and balance) and psychological well-being (emotional regulation, cognitive development, and self-esteem). **Results:** Furthermore, statistical analysis techniques (SPSS) were used to highlight how different variables affect the result within research. The data is analyzed using descriptive statistics, paired *t*-tests, correlation, and independent samples *t*-test to compare post-intervention data between groups. The IG showed significant improvements in motor proficiency, balance, and self-esteem, outperforming the CG. Independent samples t-test confirmed better outcomes in the IG, especially in Emotional Regulation (+6) and Self-Esteem (+5). Correlation analysis revealed strong associations between physical fitness and psychological well-being. **Conclusion:** The biomechanics-based physical training program for preschool children effectively enhances motor skills, physical fitness, and overall developmental outcomes, fostering a strong foundation for long-term health and well-being.

**Keywords:** biomechanics; physical training; preschool children; physical fitness; psychological well-being; statistical analysis

## 1. Introduction

Physical activity during preschool years (ages from 3 to 6) is crucial for a child's overall development. At this stage, children are experiencing rapid physical, cognitive, and emotional growth; it is an optimal time to introduce physical training programs that promote healthy habits [1]. These programs aim at the development of fundamental motor skills fundamental to the overall health of the body, and the growth of the intellect as well as the spiritual and psychological well-being of the child. The fundamental gross motor skills encompassing running, jumping and balancing are crucial for all preschoolers in their attempt to gain mastery and control over their bodies. These activities enhance physical strength, agility, and confidence, laying the groundwork for more complex motor tasks in later years [2]. One of the main benefits of physical activity for preschoolers is the development of basic motor skills. Preschool children are learning the basic motions like running, jumping, balancing, and throwing [3]. These exercises are designed to help children develop better motor skills as grow. Motor skills are significant in encouraging motor fitness since elementary forms of motor fitness are essential for the personal satisfaction of accomplishing a job related to motor fitness.

Physical activity also plays a key role in cognitive development. **Figure 1** denotes the physical activities of preschool children. Physical exercise helps to enhance brain function, improving memory, attention, and problem-solving skills [4]. Simple physical activities require concentration like balancing on one foot as well as following directions in a game that stimulate brain activity and even improve a child's ability to focus and learn in other areas of life [5]. As children mature, it aids in achieving better hypothetical performance.


**Figure 1.** Movement behavior in preschool-aged children.

In addition to cognitive benefits, physical activity supports social and emotional development. Preschoolers learn crucial social skills like cooperation, sharing, and taking turns through group activities or games. These programs also assist the child to interact on how to deal with anger, happiness, or success within a structured learning environment [6]. As children engage in physical activities, and learn to communicate with their peers and form friendships, which are important for their emotional well-being.

Physical training programs play a crucial role in enhancing various health aspects. Child obesity is another epidemic in the present-day world and exercise helps reverse this trend. Children who develop healthy behaviors early in life are more likely to stay physically active as become older, which lowers their risk of obesity and associated conditions like diabetes and heart disease [7]. Physical activity also strengthens muscles, bones, and the cardiovascular system, laying the groundwork for a lifetime of physical health. When designing a physical training program for preschool children, the activities must be fun and engaging. Preschool children are generally active, but struggle with engaging in games-like exercises instead of actual workouts. Children learn motor skills through games, songs, and dances hence keeping occupied [8]. The activities should be age-appropriate, focusing on simple movements like running, jumping, and balancing, while challenging to improve their coordination and strength. It's also important that the environment is safe, that is appropriate measures have been taken to make certain that a child can participate without encountering an injury.

The activities, which are implemented in an effective program should address all facets of physical development including strength, coordination, balance and flexibility. For example, children participate in jumping, crawling, throwing games, dancing and stretching doorway activities [9]. These activities keep the program exciting and provide a well-rounded experience, which promotes children' physical development in several ways.

In best respect, an illustrated physical training program for preschool children and students could be viewed as an essential part of a child's physical development. By focusing on fun, age-appropriate activities that build motor skills, foster social interaction, and promote physical health, these programs help to establish lifelong habits of fitness, boost cognitive function, and contribute to emotional well-being [10]. As children engage in physical activity, not only strengthen their bodies but also learn valuable skills that can help succeed in various areas of life. Despite the clear benefits of physical activity, the design of effective preschool sports training programs remains a challenge. While motor skill development is a well-established goal in early childhood physical education, the incorporation of biomechanics-based strategies into such programs is still underexplored. Biomechanics is a field that studies human movement by integrating biological, physical, and engineering principles, has the potential to optimize physical training by enhancing movement efficiency and reducing the risk of injury [11]. As such, biomechanics plays a pivotal role in the design of exercise programs tailored for young children, providing a scientific foundation for improving the effectiveness and safety of these programs.

Purpose of the Research: This research aims to explore how biomechanics-based sports training programs enhance both the physical fitness and psychological well-being of preschool children. To enhance children's health and long-term development by integrating biomechanics into early childhood physical education.

## Research contribution

- The objective of the research is to investigate the effect of a biomechanics-based physical training program on preschool children's physical and psychological development.
- Data has been collected from 157 preschool children, assessing various physical fitness and psychological well-being measures before and after the intervention.
- The participants were randomly separated into two groups: an IG (biomechanics-based training) and a CG (standard physical training).

- The data has been analyzed using statistical methods such as descriptive statistics, paired *t*-tests, correlation analysis, and independent samples *t*-test to compare pre-and post-intervention outcomes.

Research organization: Section 2 presents the research's related works, and Section 3 explains the methodology. The findings of the research are illustrated in Section 4. Section 5 demonstrates the discussion, and the conclusion is established in Section 6.

## 2. Literature review

This section shows preschool children benefit from physical activity, including cardiovascular health, muscular strength, emotional growth, self-esteem, social skills, effective motor skills, and reduced accidents.

### 2.1. The role of physical activity in preschool children's health

Regular physical activity in preschool-aged children is crucial for their physical and psychological development, promoting cardiovascular health, muscular strength, and motor coordination. Zou et al. [12] examined the physical fitness and health behaviours of 755 preschool children in southwest China. The findings indicated that whilst girls had lower heart rates and protein content, guys had greater muscle mass and longer jump lengths. Physical activity positively correlated with better fitness indicators and improved mental health outcomes. The findings were aligned, and suggested that incorporating cognitive and motor demands in physical activity maximizes mental health benefits [13]. The need for a two-dimensional model to evaluate these aspects, thus supporting the development of physical activity programs that target both physical and cognitive development for enhanced mental health outcomes. The study showed that children who engage in physical activities experience improved self-esteem and better social interactions, which contribute to a well-rounded emotional health foundation [14].

### 2.2. Biomechanics in preschool physical education

Sports biomechanics, the research of human movement through principles of physics and engineering, plays an important role in preschool sports training. By analyzing the forces and mechanical properties of movement, biomechanics helps to identify the most efficient and effective ways to perform physical activities, reduced the risk of injury and enhanced the performance [14]. The research on a total of 150 preschool children established that biomechanics-based intervention promotes motor skills learning in preschool sports programs since muscle strength, body shape, and cardiovascular systems are critical in shaping the children's overall fitness.

Additionally, biomechanics principles aid educators in developing personalized training plans for children, ensuring safe and challenging physical activities [15]. However, its role is restricted with regard to its usage in preschool education, though available literature is more concerned with children beyond preschool age or sports persons. Research on biomechanics' practical application in preschool settings is crucial for enhancing physical fitness, happiness and good health [16].

### 2.3. Physical and psychological benefits of exercise for preschool children

Moreover, sports and physical activities provide preschoolers with opportunities to develop social skills, including teamwork, conflict resolution, and communication, all of which contribute to a positive self-image and emotional well-being [17].

Additionally, Fang [18] examined the effects of parent-child exercises on the psychosocial growth of preschoolers. It found that, relative to the initial category, children in the investigational team had notable gains in cognitive capacity, emotional stability, willpower, and personality molding. Incorporating sports game activities into early childhood education programs can effectively support social adaptability and improved interpersonal relationships, according to the research, which also highlighted the significance of early engagement in sports game activities to promote psychological health and resilience. **Table 1** presents 2024's research on the physical and psychological benefits of exercise for preschool children, outlining the year, data, objectives, and limitations, providing a comprehensive overview.

**Table 1.** Overview of various articles related to exercise for preschool children.

| Ref | Published year | Type of Research | Objective | Data | Limitations |
|---|---|---|---|---|---|
| [19] | 2024 | Cross-sectional study | To investigate the relationship between toddlers' emotional self-regulation, sleep, and physical activity. | Baseline data from 1350 toddlers (2.2 ± 0.33 years) in the Let's Grow randomized controlled trial, including accelerometer data and parent-reported scales. | Limiting causal inferences; physical activity measures showed no significant associations with emotional self-regulation. |
| [20] | 2024 | Qualitative research | To explore the perspectives of key stakeholders on barriers, enablers, and motivators influencing the planning, execution, and sustainability of the "I'm an Active Hero" physical activity intervention for preschool children. | Focus groups with preschool employees ($n$ = 4), parents (4 mothers, 5 dads), and preschool principals ($n$ = 2) in Saudi Arabia using semi-structured interviews | Limited sample size and geographic focus (Saudi Arabia); findings can't be generalized to other regions or settings. |
| [21] | 2024 | Quantitative experimental research | Improving the way physical education programs are implemented in schools is the goal, focusing on fostering positive growth in both physical and psychosocial dimensions among teenagers. | 94 school children from Sidamulih's Public Junior High School participated in the research, divided into an experimental group and a control group, with data analyzed using an independent sample $t$-test. | The research's limitations include a small sample size and the focus on a single school, which can limit the generalizability of the findings. |
| [22] | 2024 | Prospective birth cohort research | To look at whether early exposure to green space in residential areas is linked to a change in young children's bone mineral density. | In January and February 2022, a data examination has been conducted on mother-child couples, monitoring for four to six years, using quantitative ultrasonic measurement to evaluate bone mineral density. | The research did not account for all potential environmental or lifestyle confounders and relied on residential geocoding for green space estimation, which can't fully represent exposure. |

**Table 1.** (*Continued*).

| Ref | Published year | Type of Research | Objective | Data | Limitations |
|---|---|---|---|---|---|
| [23] | 2024 | Qualitative research | To develop a better understanding of why active older persons who live alone are motivated to exercise. | 34 interviews with older adults were analyzed to identify key themes related to their motivation for exercise. | The research focused on a specific group of independently living active older adults, which can't be representative of the broader older adult population. The results are based on self-reported data, which can be subject to bias. |
| [24] | 2024 | Cross-sectional study | To examine the effects of multiple green exposure metrics (objective and subjective) on physical activity and health among young students, with a focus on the impact of campus green spaces (GSs). | Data were collected through self-reported questionnaires measuring subjective GS exposure, physical activity, and health status among 820 university students. | Limiting causal inference; it relied on self-reported data, which can introduce biases, and focused only on university students in one location, which does not generalize to broader populations. |
| [25] | 2024 | Conceptual analysis | To analyze and refine the concept of enjoyment in physical activity, specifically in children and adolescents, and understand its antecedents, attributes, and consequences. | The analysis was based on a review of 72 papers extracted from multiple databases. | The analysis relies on existing literature, which can't have variations in research designs and populations and does not include original empirical research or data collection. |
| [26] | 2024 | Correlational study | To examine the relationship between overall physical fitness and its components (speed, endurance, strength, coordination, and flexibility) with attention performance in adolescents. | The research complicated 140 adolescent students aged 15 to 18 years. Physical fitness was measured using the German Motor Test, and attention was assessed using the differentiation 2 (d2)-Test of Attention. | The research does not establish causal relationships, as it is correlational; it also focuses on a specific age group and sample size, which can't be generalized to other populations. |

### 2.4. Research gap

The importance of physical exercise for preschoolers is increasing, but there is a lack of research on biomechanics-based physical training programs. Current programs focus on motor skills without considering biomechanical concepts that maximize movement patterns and reduce injury risk. Few studies have explored how biomechanics-focused training can improve basic physical skills like strength, balance, and coordination. This gap allows for the investigation of how biomechanics-driven strategies can enhance young children's physical development, movement efficiency, and long-term health outcomes.

## 3. Methodology

This research aims to develop a biomechanics-based physical training program for preschoolers, focusing on fundamental motor skills, flexibility, strength, balance, and overall physical development. The program involves playful and interactive movements that promote social engagement and mental resilience. Data has been collected through pre-program and post-program assessments of physical performance, observation, and child-focused surveys. The 12-week program is conducted with regular sessions, and the program's effectiveness can be evaluated through statistical analysis of changes in physical abilities, mental well-being, and social behaviour and engagement. **Figure 2** denotes the comprehensive research process.

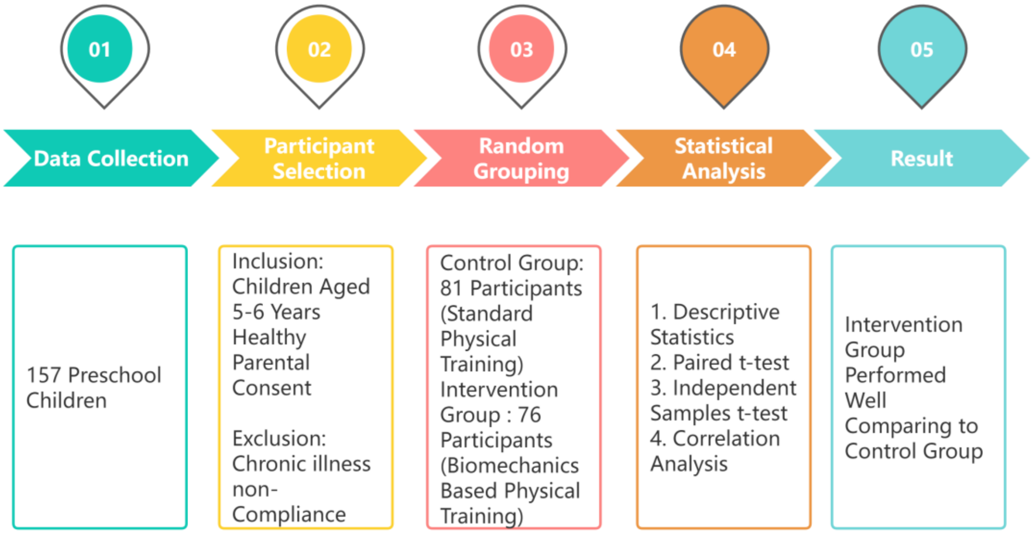


**Figure 2.** Outline of the research.

### 3.1. Data collection

The data collection process for the research complex gathering demographic and professional information, physical fitness, and psychological well-being data. Data were collected through structured assessments before and after the intervention. The demographic data included factors such as age, gender, height, weight, socioeconomic background, parental education level, dietary habits, sleep quality, screen time, and parental occupation. These variables were collected to understand the background characteristics of the participants and ensure a balance between the two groups. The physical fitness data consisted of measures such as motor proficiency, agility, balance, and strength, while the psychological well-being data focused on emotional regulation, cognitive development, and self-esteem. The measurements use a mix of standardized tools and self-developed instruments. Physical fitness includes motor proficiency, agility, and balance via standardized tests. Psychological well-being is assessed with scales like the five-point Likert scale for emotional regulation and the Rosenberg Self-Esteem Scale for self-esteem. Reliability and validity will be reported for all tools.

Individuals were separated into two collections: a CG (81 participants) received standard physical training, and an IG (76 participants) received a biomechanics-based physical training program for 12 weeks. Activities like coordination assignments, agility drills, and balancing exercises were all part of the biomechanics-based program, which aimed to enhance motor skills and guarantee safe, effective movement. Children were able to do exercises more easily and efficiently due to the use of biomechanical techniques, which reduced needless energy consumption during movement. Additionally, each child's posture, movement patterns, and muscular strength are evaluated using the biomechanical examinations. Individual exercises were designed to enhance motor control, balance, and coordination based on these evaluations. By encouraging a positive self-image and increasing self-confidence, the exercises were intended to improve emotional well-being in addition to physical strength.

### 3.1.1. Selection criteria

Selection criteria play a crucial function in the present research. The selection criteria can be classified into two sections, such as inclusion and exclusion criteria. The selection criteria classifications are defined below,

(1) Inclusion criteria

- Children aged 5 to 6 years.
- Children who can participate in physical activities.
- Only children with parental consent were included in the research.
- No serious health conditions can impede participation in the physical training program.

(2) Exclusion criteria

- Children with chronic illnesses or disabilities that can limit their ability to engage in physical activity.
- Children are unable to comply with the research protocols, including assessments or the intervention program.
- Children whose parents did not give permission to participate were excluded from the research.

## 3.2. Variable explanation

In the research, examine various types of exercises that contribute to preschool children’s development, focusing on physical fitness and psychological well-being. The physical fitness variables include motor proficiency, balance, and agility, which are essential for enhancing children’s movement skills, coordination, and overall health. Additionally, psychological well-being is addressed through emotional regulation and cognitive development, aiming to improve children’s ability to manage emotions and enhance cognitive abilities such as memory, attention, and problem-solving. These movements play a vital role in fostering both physical and mental growth in preschool children. **Table 2** presents various types of exercises designed for preschool children’s development. Key factors pertaining to preschoolers’ psychological and physical health are defined in this table. It describes motor proficiency abilities including agility and balance that are essential for both physical growth and activity performance. Emotional control and cognitive growth, which impact social and emotional health, are indicators of psychological well-being. Together, these factors help us understand how physical activity affects young children’s physical and mental development.

**Table 2.** Types of exercises for preschool children's development.

| Variable | | Definition |
| --- | --- | --- |
| Physical fitness | Motor Proficiency | The ability of preschool children to perform basic movement skills such as running, jumping, catching, and throwing, reflecting overall motor development. |
| | Balance | The ability to maintain control of the body's position, whether stationary or moving, which is essential for coordination and stability in physical activities. |
| | Agility | The ability to move quickly and easily, often involving changes in direction, speed, and coordination in response to stimuli during physical activities. |
| Psychological well-being | Emotional Regulation | The ability of children to recognize, understand, and manage their emotions in a healthy and appropriate way, which contributes to social and emotional well-being. |
| | Cognitive Development | The process by which preschool children develop the ability to think, reason, understand, and solve problems, including skills such as memory, attention, and processing speed. |
| | Self-esteem | The preschool children's overall sense of self-worth, self-respect, and confidence in their own abilities and value as a person. It reflects how preschool children perceive themselves, their beliefs about their competence and worthiness, and the degree to which they feel capable and deserving of love and success. |

### 3.3. Statistical analysis

The statistical analysis is to assess the impact of the biomechanics-based physical training program on preschoolers' motor skills and this research utilizes the statistical analysis techniques (SPSS) platform. The analysis determines whether there are significant improvements in physical performance as a result of the program. The research analyses the physical fitness and psychological well-being before and after an intervention, using descriptive statistics, paired *t*-tests, independent samples *t*-test, and correlation analysis to compare results. Descriptive statistics is utilized to summarize the basic features of the physical fitness and psychological well-being measures for both groups before and after the intervention. Paired *t*-tests were used to compare pre-and post-intervention data within each group, allowing for the identification of changes in physical fitness (motor proficiency, agility, and balance) and psychological well-being (emotional regulation, cognitive development, and self-esteem) over time. The biomechanics-based physical training program's effects on preschoolers were compared using an independent samples *t*-test to assess differences among the intervention and control group. By evaluating the direction and intensity of correlations between various variables, correlation analysis is used to determine the potential association between psychological well-being and gains in physical fitness. It provides on whether modifications in one area are linked to modifications in another. The paired *t*-tests highlighted significant within-group improvements, while the independent samples *t*-test revealed that the IG shows greater improvements in both physical and psychological consequences compared to the CG, suggesting the effectiveness of the biomechanics-based training program.

## 4. Performance analysis

The purpose of the research is to examine the effects of giving preschoolers a physical training program based on biomechanics. The program provides structured aerobics with biomechanical activities appropriate for different age groups, enhances their interaction and mental health, and strengthens motor skills, agility, strength, balance, and overall physical growth. The demographic, anthropometric characteristics and the efficacy of the biomechanics-based training program in improving physical fitness and psychological well-being in preschool children who participated in the research were measured using descriptive statistics, paired *t*-tests, and the independent samples t-test. The program's efficacy was supported by the findings, which revealed that the IG significantly outperformed the CG in both categories.

### 4.1. Demographical analysis

**Table 3** denotes the demographic and background characteristics of research involving two groups: there are intervention group and control group. The participants' average age, height, weight, and daily screen time are listed, along with the gender distribution in each group. Socioeconomic status is categorized into lower-middle and upper-middle class, with percentages reflecting the distribution in both groups. The parental education level is divided into high school, bachelor's degree, and postgraduate degree, showing the educational attainment of parents across both groups. Dietary habits (balanced or unbalanced) is also compared, and the sleep quality of the participants is categorized as good, average, or poor. Lastly, parental occupation is divided into professional jobs, manual labour jobs, and the service industry, illustrating the employment distribution of the participant's parents.

**Table 3.** Demographic data.

| **Variable** | | **Overall ($n$ = 157)** | **CG ($n$ = 81)** | **Intervention group ($n$ = 76)** |
|---|---|---|---|---|
| Mean of Age (years) | | 5.6 | 5.5 | 5.7 |
| Mean of Height (cm) | | 112 | 113 | 111 |
| Mean of Weight (kg) | | 20.2 | 20.1 | 20.3 |
| Mean of Daily screen time (hrs) | | 1.6 | 1.5 | 1.7 |
| Gender | Male | 81 | 41 | 40 |
| | Female | 76 | 40 | 36 |
| Socioeconomic background | Lower-middle class | 60% (94) | 62% (50) | 57% (44) |
| | Upper-middle class | 40% (63) | 38% (31) | 43% (32) |
| Parental education level | High school or below | 24.8% (39) | 30.9% (25) | 18.4% (14) |
| | Bachelor's degree | 18.5% (29) | 16.0% (13) | 21.1% (16) |
| | Postgraduate degree | 25.5% (40) | 25.9% (21) | 25.0% (19) |
| | Uneducated | 31.2% (49) | 27.2% (22) | 35.5% (27) |
| Dietary habits | Balanced | 70% (110) | 72% (58) | 68% (52) |
| | Unbalanced | 30% (47) | 28% (23) | 32% (24) |
| Sleep quality | Good | 50% (78) | 55% (45) | 44% (33) |
| | Average | 35% (55) | 33% (27) | 37% (28) |
| | Poor | 15% (24) | 12% (9) | 19% (15) |
| Parental occupation | Teachers | 45% (71) | 48% (39) | 42% (32) |
| | Construction workers | 28% (44) | 25% (20) | 32% (24) |
| | Labors | 27% (42) | 27% (22) | 26% (20) |

The demographics of the control group (CG, $n$ = 81) and the intervention group ($n$ = 76) are shown in this table along with the demographics of the entire sample ($n$ = 157). With a small variance between 5.6 and 5.7 years, the average age is comparable throughout the groups. There are also slight variations across the groups in terms of height, weight, and daily screen time. With 81 men and 76 women in the entire sample, the gender distribution is almost equal. Compared to the intervention group, a greater proportion of children in the CG come from lower-middle-class homes, according to socioeconomic characteristics. The educational backgrounds of the parents vary; some are ignorant, while a sizable fraction have bachelor's degrees, postgraduate degrees, and high school or less schooling. While sleep quality changes with more kids in the CG group describing good sleep than in the intervention category, dietary practices are broadly matched across the groups. Lastly, the professions of parents are generally uniform among groups, with the most prevalent vocations being artisans, educators and building employees.

## 4.2. Descriptive statistics

**Table 4.** Outcomes of descriptive analysis.

| **Variable** | | **Overall ($n$ = 157)** | **CG ($n$ = 81)** | **IG ($n$ = 76)** | **Difference (IG)** | ***p*-value** |
|---|---|---|---|---|---|---|
| Height (cm) | | 112 | 113 | 111 | −2 | 0.23 |
| Weight (kg) | | 20.2 | 20.1 | 20.3 | +0.2 | 0.40 |
| Age (years) | | 5.6 | 5.5 | 5.7 | +0.2 | 0.12 |
| Daily screen time (hrs) | | 1.6 | 1.5 | 1.7 | +0.2 | 0.09 |
| Gender | Male | 81 | 41（51%） | 40（52.6%） | - | 0.80 |
| | Female | 76 | 40（49%） | 36（47.4%） | | |
| Socioeconomic background | Lower-middle class | 60% (94) | 62% (50) | 57% (44) | −5% | 0.62 |
| | Upper-middle class | 40% (63) | 38% (31) | 43% (32) | +5% | |
| Parental education level | High school | 24.8% (39) | 30.9% (25) | 18.4% (14) | - | 0.27 |
| | Bachelor's degree | 18.5% (29) | 16.0% (13) | 21.1% (16) | | |
| | Postgraduate degree | 25.5% (40) | 25.9% (21) | 25.0% (19) | | |
| | Uneducated parents | 31.2% (49) | 27.2% (22) | 35.5% (27) | | |
| Dietary habits | Balanced | 70% (110) | 72% (58) | 68% (52) | −4% | 0.75 |
| | Unbalanced | 30% (47) | 28% (23) | 32% (24) | | |
| Sleep quality | Good | 50% (78) | 55% (45) | 44% (33) | - | 0.20 |
| | Average | 35% (55) | 33% (27) | 37% (28) | | |
| | Poor | 15% (24) | 12% (9) | 19% (15) | | |
| Parental occupation | Professional jobs | 45% (71) | 48% (39) | 42% (32) | - | 0.60 |
| | Manual labour jobs | 28% (44) | 25% (20) | 32% (24) | | |
| | Service industry | 27% (42) | 27% (22) | 26% (20) | | |

Descriptive statistics summarize the data collected from preschool children, such as their height, weight, and age. Data analysis techniques such as the independent $t$-test and chi-square test were employed to determine whether there were differences between the control and intervention groups in demographic categories. This ensures that any differences between the control and intervention groups are due to the physical training program rather than pre-existing differences between the two groups. The findings of a descriptive analysis comparing the two groups are shown in **Table 4**.

Both groups were comparable at baseline (control: age 5.5 years, height 113 cm, weight 20.1 kg; intervention: age 5.7 years, height 111 cm, weight 20.3 kg). Daily screen time for the CG was 1.5 hrs, and for IG was 1.7 hrs, ensuring no significant initial differences. This table contrasts a number of demographic traits between the intervention group (IG, $n$ = 76), the control group (CG, $n$ = 81), and the entire sample ($n$ = 157). Independent $t$-test and Chi-square test were used for testing group difference. It demonstrates that the two groups do not differ significantly in terms of height, weight, age, gender, daily screen time, socioeconomic background, or parental educational attainment ($p$-values > 0.05). Furthermore, there are no discernible variations in eating patterns, sleep patterns, or parental profession, suggesting that these factors are comparable between groups. Although these disparities are not statistically significant, there is a small variation in the parental occupation and socioeconomic background.

## 4.3. Paired *t*-tests

A paired $t$-test compares the physical performance of the same group of preschool children before and after the training program. It checks if the changes in their abilities are statistically significant, showing whether the program had a real impact. **Table 5** presents the results of paired $t$-tests conducted between the two groups.

**Table 5.** Outcomes of paired $t$-tests between both groups.

| **Variable** | **CG** | | **Difference (CG)** | ***t-value*** | ***p*-value** | **IG** | | **Difference (IG)** | ***t-value*** | ***p*-value** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Pre** | **Post** | | | | **Pre** | **Post** | | | |
| Motor Proficiency | 65 | 75 | +10 | −9.01 | $p$ < 0.001 | 64 | 78 | +14 | −13.59 | $p$ < 0.001 |
| Agility | 61 | 69 | +8 | −7.21 | | 61 | 73 | +12 | −10.43 | |
| Balance | 63 | 70 | +7 | −6.01 | | 64 | 73 | +9 | −8.70 | |
| Emotional Regulation | 55 | 62 | +7 | −6.31 | | 54 | 68 | +14 | −12.17 | |
| Cognitive Development | 62 | 70 | +8 | −10.26 | | 62 | 74 | +12 | −15.00 | |
| Self-Esteem | 57 | 67 | +10 | −9.01 | | 57 | 72 | +15 | −13.04 | |

From **Table 5**, it can be observed that after 12 weeks of training, both the CG and IG groups showed significant improvements in physical fitness and psychological well-being. The improvements in the IG group were particularly remarkable: the mean score of motor proficiency improved from 64 to 78 ($p$ < 0.001), agility from 61 to 73 ($p$ < 0.001), balance from 64 to 73 ($p$ = 0.00017), emotional regulation from 54 to 68 ($p$ < 0.001), cognitive development from 62 to 74 ($p$ < 0.001), and self-esteem from 57 to 72 ($p$ < 0.001). The CG also showed significant changes: the mean score of motor proficiency improved from 65 to 75 ($p < 0.001$), agility from 61 to 69 ($p < 0.001$), balance from 63 to 70 ($p = 0.00017$), emotional regulation from 55 to 62 ($p < 0.001$), cognitive development from 62 to 70 ($p < 0.001$), and self-esteem from 57 to 67 ($p < 0.001$). The motor proficiency, agility, balance, emotional regulation, cognitive development, and self-esteem ratings of the CG and the IG are contrasted in this table before and after the intervention. The CG showing modest improvements in motor proficiency (+10), agility (+8), balance (+7), emotional regulation (+7), cognitive development (+8) and self-esteem (+10). The IG, on the other hand, shows more significant gains in every category, including motor proficiency (+14), agility (+12), balance (+9), emotional regulation (+14), cognitive development (+12), and self-esteem (+15) ($p - value < 0.001$). This implies that the intervention's beneficial effects on these outcomes were more pronounced in the IG than in the CG.

## 4.4. Independent samples *t*-test

Independent samples t-test compares the physical improvements of two different groups of preschool children who can have different training conditions or starting abilities. It helps determine if any differences in performance are significant across the two groups. The results of an Independent samples t-test comparing two groups are shown in **Table 6**.

**Table 6.** Outcomes of independent samples *t*-test among the two groups.

| | CG (post) | IG (post) | Mean Difference | *t-value* | *p*-value |
|---|---|---|---|---|---|
| Motor proficiency | 75 | 78 | 3 | −2.21 | 0.03 |
| Agility | 69 | 73 | 4 | −2.78 | 0.007 |
| Balance | 70 | 73 | 3 | −2.08 | 0.04 |
| Emotional regulation | 62 | 68 | 6 | −3.96 | 0.0001 |
| Cognitive development | 70 | 74 | 4 | −3.85 | 0.0002 |
| Self-esteem | 67 | 72 | 5 | −3.3 | 0.0013 |

Compared to the CG, the IG gains were noticeably larger in emotional regulation (68, $p = 0.0001$), self-esteem (72, $p = 0.0013$), cognitive development (74, $p = 0.0002$), and agility (73, $p = 0.007$). The IG outperformed the CG in all outcomes. The post-intervention outcomes for the IG and CG across a number of factors are shown in this table. When compared to the CG, the IG exhibits noticeably greater gains in motor proficiency (+3, $p = 0.03$), agility (+4, $p = 0.007$), balance (+3, $p = 0.04$), emotional regulation (+6, $p = 0.0001$), cognitive development (+4, $p = 0.0002$), and self-esteem (+5, $p = 0.0013$). All differences are statistically significant ($p$-value $\leq 0.05$), with mean differences between the IG and CG ranging from +3 (motor proficiency and balance) to +6 (self-esteem). These results imply that the intervention group saw more significant improvements in every outcome that was assessed. The development of the children in the IG seems to have been significantly and consistently impacted by the intervention.

### 4.5. Correlation analysis

It is used to determine if improvements in physical fitness are associated with improvements in psychological well-being. To display the correlation coefficients between various variables, helping to understand how physical fitness measures (e.g., motor proficiency, balance) and psychological well-being measures (e.g., emotional regulation, cognitive development) are related both within and between the control and IG. **Figure 3** presents six important variables motor proficiency, agility, balance, emotional regulation, cognitive development, and self-esteem are shown by the correlation analysis between the CG and IG. With values ranging from 0.60 to 1.00, a heatmap graphically depicts these correlations and shows the different degrees of positive associations. A higher correlation between variables is indicated by values around 1.00. Different levels of correlation are represented by colours for clarity's sake: bright green for values around 0.6, dark blue for values near 0.7, ash for values near 0.8, and light green for values near 1. It is simpler to understand the relevance of the relationships thanks to these color-coded variables. The heatmap illustrates how indices of psychological well-being and physical activity interact, highlighting the possible advantages of bio-mechanics based techniques.


**Figure 3.** Graphical outcomes of correlation analysis between both groups.

### 4.6. Comparison of pre- and post-interventions

Significant improvements in a number of physical and psychological characteristics are seen in both the CG and IG when comparing pre- and post-intervention results. The IG showed greater improvement in every category, including motor proficiency, balance, agility, emotional control, and cognitive development, even though both groups showed advances. The children's physical skills and emotional health significantly improved as a result of the biomechanics-based physical training program, according to these findings. **Table 7** and **Figure 4** shows the findings of post improvements of both groups. The post-test results for the control and intervention groups are contrasted in this table for a number of characteristics. All aspects of the intervention group's performance have improved, but emotional regulation has increased the most (from 62 to 68). The intervention group shows better mean scores of motor proficiency, agility, balance, emotional regulation, cognitive development, and self-esteem. These findings imply that the participants' abilities and emotional health were positively impacted by the intervention. In every metric, the intervention group routinely performs better than the control group.

**Table 7.** Numerical outcomes of variations between the two groups.

| Variables | Values (Mean of Score) | |
|---|---|---|
| | **Control Group (Post-test)** | **Intervention Group (Post-test)** |
| Motor Proficiency | 75 | 78 |
| Agility | 69 | 73 |
| Balance | 70 | 73 |
| Emotional Regulation | 62 | 68 |
| Cognitive Development | 70 | 74 |
| Self-esteem | 67 | 72 |

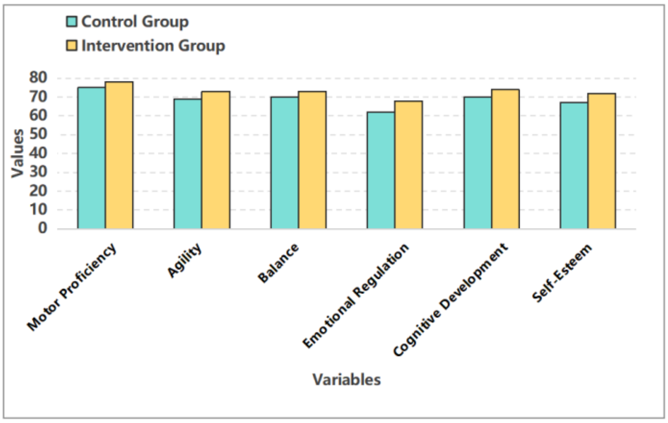


**Figure 4.** Graphical outcomes variations between the IG and the CG.

The research revealed significant variations in the IG and CG physical and psychological results. The CG had a score of 75 for motor proficiency, whereas the IG received a much better score of 78, demonstrating the beneficial effects of the biomechanics-based training. In terms of agility, the IG did better than the CG, scoring 73 compared to 69. The IG also performed exceptionally well in the area of balance, achieving 73 as opposed to the CG's 70. In the IG, emotional regulation increased by 4, reaching 68 as opposed to 62 in the CG. With an cognitive development score of 74 as opposed to the CG's 70, the IG showed a significant improvement. Additionally, with a score of 72, the IG's self-esteem was higher than the CG's 67. These results highlight the effectiveness of biomechanics-based training in improving mental and physical health.

## 5. Discussion

The focus on preschool-aged children, a developmental stage often underrepresented in biomechanical and physical activity. By integrating both physical and cognitive aspects of physical activity, it provides a holistic approach to child development, emphasizing the interplay between biomechanics, movement patterns, functional role of body structures and emotional well-being. The research also includes a diverse sample of preschool children from different regions, enhancing the generalizability of findings. Additionally, it highlights the practical application of biomechanics in preschool physical education, a relatively underexplored area in the literature [11,14]. The research incorporation of both physical and psychological benefits of exercise and its emphasis on individualized training plans further distinguish it from other research, offering valuable insights for enhancing preschool physical education programs. A strategy is used to collect data for the research, including professional and social characteristics such parental education, socioeconomic background, dietary habits, and occupation. Standardized tests for strength, balance, agility, and motor skills are used for evaluating physical fitness. The descriptive statistics, paired *t*-tests, independent samples *t*-test, and correlation analysis collectively highlight the significant improvements in the IG following the biomechanics-based training program. The IG showed substantial gains in motor proficiency, balance, agility, emotional regulation, cognitive development, and self-esteem, with *p*-values consistently below 0.05, indicating that these changes were statistically significant. Conversely, the changes in the CG were smaller, demonstrating the utility of the intervention. Correlational analysis followed the same line to reveal that changes in physical fitness measures had a significant positive relationship with improvement in indices of psychological health, confirming the positive effects on both physical and psychological results. The results indicated that the biomechanic based training remained affective and the IG performed better than the CG on all aspects measured.

## 6. Conclusion

The research explores the effectiveness of a biomechanics-based physical training program for preschool children, evaluating its impact on various developmental aspects such as motor skills, flexibility, strength, balance, social engagement, and mental resilience. The program aims to enhance overall physical and psychological well-being. The development and execution of a preschool-aged biomechanics-based physical training program have demonstrated benefits in improving motor skills and physical fitness. The curriculum enhanced children’s physical fitness and their body orientation as compared to lessons focusing on a basic motor skill that includes balance, coordination, and agility. In addition, it is possible to prevent early musculoskeletal disorders and promote appropriate physical development during increasingly specific age-related activities. Based on the findings, it can be recommended that the integration of biomechanical ideas in early childhood physical education program can be a functional approach as it contributes to the development of the children’s basic movement patterns and sets the foundation for exercise behavioural patterns in future. The biomechanics-based training program led to significant improvements in the IG. Paired *t*-tests showed increases in motor proficiency (+14, $p < 0.001$), self-esteem (+15, $p < 0.001$), and emotional regulation (+14, $p < 0.001$). Independent samples *t*-test confirmed greater gains in the IG, with motor proficiency (+3, $p = 0.03$), Agility (+4, $p = 0.007$), balance (+3, 0.04), emotional regulation (+6, $p = 0.0001$), cognitive development (+4, $p = 0.0002$), and self-esteem (+5, $p = 0.0013$) outperforming the CG. Correlation analysis revealed strong links between physical fitness and psychological well-being, such as motor proficiency with agility ($r = 0.78$) and balance ($r = 0.65$).

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**Limitation and future scope:** One limitation of the biomechanics-based physical training program is its reliance on specific equipment and structured environments, which cannot be easily accessible in all preschool settings. Future research will explore more adaptable training approaches, investigate long-term impacts on motor development, and assess the program’s scalability across diverse populations and cultural contexts.

**Conflict of interest:** The authors declare no conflict of interest.

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