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The Health Effects of Daily Physical Activity Behaviours in Children

Physical and Psychological Outcomes

Edited by
Josune Rodríguez-Negro and Juan de Dios Benítez Sillero

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Guest Editors

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About the Editors

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Article

Gender and Educational Stage Differences in Motivation, Basic Psychological Needs and Enjoyment: Evidence from Physical Education Classes

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Abstract: Background/Objectives: There is evidence that shows an association between basic psychological needs, motivation, and enjoyment in the context of school physical education. However, there are no studies that have included all of them in a single study. Therefore, the objective of this research was to determine if there are differences in motivation, basic psychological needs, and enjoyment in physical education classes between primary and secondary education students and between boys and girls. Methods: A total of 740 schoolchildren (410 girls, 55.4%) from primary education (n = 310; 41.9%) and secondary education (n = 430; 58.1%) between the ages of 10 and 17 participated (M = 13.60; SD = 2.03). The Perceived Locus of Causality in Physical Education Scale (PLOC Scale), the Basic Psychological Needs in Exercise Scale (BPNES), and the Physical Activity Enjoyment Measurement Scale (PACES) were administered. Results: Statistically significant differences were found in the educational stage factor with higher scores in primary education students in intrinsic regulation ($p < 0.001$), identified regulation ($p < 0.001$), introjected regulation ($p = 0.004$), perceived competence ($p < 0.001$), relatedness ($p < 0.001$), and enjoyment ($p < 0.001$). In terms of the gender factor, there were significant differences in intrinsic regulation ($p = 0.005$), identified regulation ($p = 0.007$), and enjoyment ($p = 0.010$), with higher scores in boys. Conclusions: Primary education students present greater self-determined motivation (intrinsic, identified, and introjected regulation), as well as a greater sense of competition, relatedness, and enjoyment than secondary education students. Boys have greater regulation and intrinsic enjoyment than girls in physical education classes.

Keywords: self-determination theory; primary education; secondary education; children; intrinsic motivation; external regulation; amotivation; competence; relatedness; autonomy

1. Introduction

The human being, by definition, is an active being, constantly adopting a wide variety of behaviors to survive [1], adapting to the environment, using both internal and external means, and responding to changes and needs as they arise [2].

The thinking, behavior, and way of acting of students in the field of physical education (PE) continue to be the object of study due to the implications they have [3], in addition to the information that helps teachers understand how motivation, enjoyment, or the feeling of competence combine and interact to impact student learning [4]. Therefore, it must be taken into account that, in childhood and adolescence, school PE is an ideal element to improve participation in physical activities since almost 100 percent of schoolchildren must go to school [5,6]. On the other hand, the key elements in this participation in physical activities are enjoyment [7,8], motivation [9,10], and the satisfaction of basic psychological needs (i.e.,

autonomy, competence, and relatedness [11] as drivers of participation in extracurricular physical activity [9,12]).

One of the most widely used theories for the study of motivation, the satisfaction of basic psychological needs, and enjoyment in PE is self-determination theory (SDT; [13]), understood as a broad framework for the explanation of motivation and human behavior [14]. SDT is made up of several mini theories, including the theory of basic psychological needs. These needs refer to the psychological construct that people need to feel motivated to behave and determine the existence of at least three basic psychological needs that explain human behavior: the need for autonomy, the need for competence, and the need for relatedness [14,15]. The first, autonomy, refers to the need that people have to have or feel the ability to make decisions for themselves in various life activities. If this ability is frustrated, passive and dependent behaviors may appear, as well as emotional futility and hopelessness [13–15]. The need for competence, and therefore to perceive one's own capabilities, is fundamentally related to the previous one in the sense that it is based on the ability to control what happens with one's own actions, but in this case it focusses on the belief that one has sufficient resources to carry out certain behaviors. It is the belief that we are capable and that the actions we choose to perform autonomously can be carried out successfully thanks to our capabilities and that they will, to a certain extent, influence what happens [15]. Finally, the need for relatedness has to do with the feeling or need to feel part of a group with which we can interact positively and form mutually supportive relatedness [16]. Satisfying these needs provides energy to perform certain behaviors, such as physical activity [13]. Previous research shows that meeting students' psychological needs has a positive effect on their enjoyment of PE [8,10]. In addition, different research has found differences in the satisfaction of these needs by gender [17].

Following the mini theory of causal orientations, the existence of three main types of motivation is established: intrinsic or autonomous, extrinsic or controlled, and impersonal or unmotivated [13,14]. In the case of intrinsic or autonomous motivation, it represents what motivates us to act from within and carry out a behavior because it is fun [14,18], since the three basic psychological needs are satisfied, which leads the individual to act based on their will and choice [15]. On the other hand, there are more extrinsic forms of motivation that can be divided into three types of controlled or extrinsic regulation [14]: external regulation, in which activities are carried out due to external stimuli or factors, such as to obtain a reward or, in the case of physical education, a good grade [18–20]; introjected regulation, in which activities are carried out due to internal pressures or thoughts (for example, the feeling of guilt); and identified regulation, in which the person acts due to the benefits that arise from carrying out the activity [18–21]. Furthermore, it is also necessary to include integrated regulation, which, according to self-determination theory (SDT), represents the highest level of the internalization of extrinsic motivation. In this type of regulation, people perform activities because they have fully integrated them into their personal identity and values [22]. For example, a student may participate in physical education classes not only because they recognize their benefits but also because physical activity has become an essential part of their healthy lifestyle. Finally, amotivation is derived from the feeling of a lack of competence and autonomy, where the subject thinks that actions have no effect on reality, has no interest, or feels incapable of carrying out an activity [13]. Previous research has shown that these different types of motivational regulation are associated with emotional consequences such as enjoyment [23]. Enjoyment is positively related to autonomous forms of motivation (intrinsic motivation) and negatively related to controlled forms of motivation [10]. These differences also hold with respect to gender [24]. Compared to girls, boys tend to show greater intrinsic motivation and identify and internalize rules to participate in physical education classes for fun and personal satisfaction [25,26]. In terms of basic psychological need satisfaction, boys reported being more satisfied with their needs for competence, autonomy, and relatedness, which translated into greater motivation for and enjoyment of physical activity [27]. In comparison, girls tend to have lower levels

of self-determined motivation, enjoyment, and satisfaction of these needs, which may negatively affect their experience in physical education classes [24,28,29].

Given the importance of a relationship between these constructs in the field of school PE and the practice of physical activity with learning, and given the current lack of scientific evidence on this matter, in our country, that combines these elements in primary and secondary education, the objective of this study was to determine whether there are differences in motivation, basic psychological needs, and enjoyment in PE classes between primary and secondary education students and between boys and girls, having as a starting hypothesis that the determined intrinsic motivation plus self-motivation, the satisfaction of basic psychological needs and enjoyment, will be greater in primary education students than in secondary education students and, in turn, will be greater in boys than in girls.

2. Materials and Methods

2.1. Design

This study was carried out using a cross-sectional observational design and correlation using a quantitative methodology [30].

2.2. Participants

The participants in this study belong to 8 primary and secondary education centers in the provinces of A Coruña, Lugo, and Pontevedra (Galicia, Spain), which were selected through non-probabilistic and convenience sampling based on the accessibility of the educational centers and the geographic proximity for researchers.

2.3. Instruments

The following instruments were used to collect data:

The Perceived Locus of Causality in EF Scale (PLOC Scale) was used [31]. A Spanish adaptation of the Motivation Scale towards PE Classes by Goudas, Biddle, and Fox [32]. It is made up of 12 items preceded by the statement "I participate in this PE class…". The items are on a Likert-type scale (where 1 means "totally disagree"; 2 "somewhat disagree"; 3 equals "somewhat disagree"; 4 means "neutral"; 5 "somewhat agree"; 6 "quite agree"; and, finally, 7 "totally agree"). The scale consists of the following five factors: intrinsic motivation (for example, "because PE is fun"), identified regulation ("because I want to learn sports skills"), introjected regulation ("because I want the teacher to think that I am a good student"), external regulation ("because that's what I'm supposed to do"), and amotivation ("but I don't understand why we should have PE").

The Basic Psychological Needs in Exercise Scale (BPNES). An adaptation to PE of the scale of basic psychological needs in exercise by Vlachopoulos and Michailidou [33]; for the Spanish context, a version by Menéndez and Fernández-Río [34] was used. The scale consists of 12 items headed with the phrase "During my Physical Education classes…". The items correspond to a Likert-type scale, from 1 (totally disagree) to 5 (totally agree). This scale has three factors: autonomy (for example, "the way I do the exercises matches perfectly with the way I want to do them"), competence (for example, "I feel that I have made a lot of progress with respect to the final result that I have proposed"), and relatedness with others (for example, "I feel very comfortable when I exercise with my other colleagues").

The Physical Activity Enjoyment Measurement Scale (PACES). The adaptation to physical education of the Physical Activity Enjoyment Scale (PACES) by Motl et al. [35] was used for the Spanish context [36]. The scale is composed of a total of 16 items headed by the statement, "When I am active". The items correspond to a Likert-type scale, ranging from 1 (totally disagree) to 5 (totally agree). It consists of a single factor: enjoyment (e.g., "I feel good").

2.4. Procedure

To carry out the study, the principals and physical education teachers of the participating schools were contacted, providing them with detailed information about the study

and requesting their collaboration. Once the authorization of the schools was obtained, permission was requested from the parents and/or legal guardians of the students. Only students with written authorization from their legal guardians participated in the study. The instruments were applied by the researchers during a physical education session in the middle of the school year in paper format. To avoid interference in the students' responses, the teacher was asked to be absent.

After offering a brief initial explanation and resolving any existing doubts, 15 min were given for each questionnaire, with a 5 min break between each one.

2.5. Statistical Analysis

Data analysis for this research was performed using SPSS 28.0 statistical software (SPSS v.28, IBM Corporation, New York, NY, USA) for all analyses. The level of statistical significance was $p < 0.05$.

The descriptive statistics of the variables studied were used to summarize the data. McDonald's omega was used to study the reliability of the instruments used. The Kolmogorov–Smirnov statistical test was used to determine the normality of the data. The analysis of the relationships between the study variables was determined using the Pearson correlation coefficient. Subsequently, a multivariate analysis (MANOVA) was performed for each variable studied (i.e., intrinsic regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy, competence, affinity, and enjoyment). Educational stage (primary versus secondary education) and gender (boy versus girl) were included as study factors. The Bonferroni statistic was used to analyze the main effects and the interactions between them. Statistical power was expressed using the eta squared statistic (η^2). The effect size was considered small (0.01), medium (0.06), or large (0.14 or more) [37].

2.6. Ethics

The study has followed the procedures of the Declaration of Helsinki [38] and was approved by the EDUCA Ethics Committee with the code number 10/2024.

3. Results

A total of 740 primary school students (n = 310; 41.9%) and secondary school students (n = 430; 58.1%) between the ages of 10 and 17 participated in this study (M = 13.60; SD = 2.03). Of the total sample, 410 were girls (55.4%) and 330 were boys (44.6%).

3.1. Reliability, Correlations, and Descriptive Statistics

The reliability analysis showed adequate results for the variables studied; thus, the reliability coefficients (McDonald's Omega) were as follows: intrinsic regulation, 0.82; identified regulation, 0.81; introjected regulation, 0.69; external regulation, 0.72; amotivation, 0.71; autonomy, 0.70; competence, 0.70; relatedness, 0.81; and enjoyment, 0.92.

The associations between the study variables showed that enjoyment was positively correlated with intrinsic regulation, identified regulation, introjected regulation, autonomy, competence, and relatedness among primary education students (Table 1). There was also a positive correlation between enjoyment and intrinsic regulation and identified regulation. A negative correlation was found between enjoyment and external regulation and amotivation.

Among secondary education students (Table 2), there were positive correlations between intrinsic regulation and identified regulation, introjected regulation, autonomy, competence, relatedness, and enjoyment, and negative correlations with external regulation and amotivation. Enjoyment was positively correlated with intrinsic regulation, identified regulation, introjected regulation, autonomy, and competence. Amotivation and external regulation were negatively correlated with enjoyment.

Table 1. Bivariate correlations between the studied dimensions of the PLOC, BPNES, and PACES of primary education students.

Dimensions	M	SD	A	K	1	2	3	4	5	6	7	8	9
1. Intrinsic regulation	5.83	1.32	−0.186	−0.237	1	0.742 **	0.375 **	−0.117 **	−0.312 **	0.188 **	0.064	0.050	0.524 **
2. Identified regulation	5.79	1.24	0.055	0.166		1	0.403 **	0.002	−0.212 **	0.156 **	0.044	0.035	0.448 **
3. Introjected regulation	4.25	1.43	−0.197	−0.368			1	0.476 **	0.161 **	0.168 **	0.088	0.008	0.145 *
4. External regulation	3.95	1.71	0,041	−0.966				1	0.426 **	−0.021	−0.004	−0.028	−0.256 **
5. Amotivation	2.36	1.56	0.071	0.136					1	−0.081	−0.016	−0.044	−0.238 *
6. Autonomy	3.52	0.90	−0.101	−0.278						1	0.448 **	0.293 **	0.228 **
7. Competence	4.13	0.71	−0.072	−0.346							1	0.431 **	0.193 **
8. Relatedness	4.40	0.77	0.234	0.167								1	0.165 **
9. Enjoyment	4.36	0.70	0.78	0.24									1

Note: M: mean; SD: standard deviation; A: asymmetry; K: kurtosis; ** The correlation is significant at the 0.001 level (bilateral). * The correlation is significant at the 0.05 level (bilateral).

Table 2. Bivariate correlations between the studied dimensions of the PLOC, BPNES, and PACES of secondary education students.

Dimensions	M	SD	A	K	1	2	3	4	5	6	7	8	9
1. Intrinsic regulation	5.02	1.43	0.77	0.25	1	0.798 **	0.390 **	−0.124 **	−0.325 **	0.180 **	0.149 **	0.137 **	0.426 **
2. Identified regulation	5.13	1.41	−0.82	0.05		1	0.448 **	−0.051	−0.330 **	0.213 **	0.151 **	0.144 **	0.398 **
3. Introjected regulation	3.93	1.43	−0.10	−0.50			1	0.381 **	0.114 *	0.175 **	0.058	0.180 **	0.151 *
4. External regulation	4.09	1.47	−0.07	−0.64				1	0.372 **	0.027	−0.014	0.040	−0.174 **
5. Amotivation	2.57	1.57	0.90	−0.15					1	−0.049	−0.084	−0.050	−0.258 **
6. Autonomy	3.40	0.88	0.18	0.34						1	0.575 **	0.561 **	0.112 *
7. Competence	3.72	0.85	−0.25	−0.43							1	0.399 **	0.120 *
8. Relatedness	2.95	0.96	0.37	0.65								1	0.094
9. Enjoyment	3.95	0.77	−0.57	−0.68									1

Note: M: mean; SD: standard deviation; A: asymmetry; K: kurtosis; ** The correlation is significant at the 0.001 level (bilateral). * The correlation is significant at the 0.05 level (bilateral).

The descriptive statistics showed that primary education students have higher scores than secondary students in intrinsic regulation, identified and introjected regulation, autonomy, competence, relatedness, and enjoyment (Table 3). However, secondary education students show higher scores in external regulation and amotivation, although the latter is much lower than the scores that appear in the other dimensions.

Table 3. Descriptive data of the analyzed variables of the PLOC, BPNES, and PACES. Mean and standard deviation according to gender and educational stage.

		Total		Boys		Girls	
Variable	**Educational Stage**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Intrinsic regulation (1–7)	Primary	5.83	1.32	5.92	1.14	5.76	1.45
	Secondary	5.02	1.43	5.25	1.26	4.82	1.53
Identified regulation (1–7)	Primary	5.79	1.24	5.89	1.13	5.71	1.32
	Secondary	5.13	1.41	5.32	1.31	4.97	1.47
Introjected regulation (1–7)	Primary	4.25	1.43	4.29	1.33	4.22	1.50
	Secondary	3.93	1.43	4.04	1.46	3.85	1.39
External regulation (1–7)	Primary	3.95	1.71	4.00	1.66	3.91	1.75
	Secondary	4.09	1.47	4.03	1.43	4.13	1.50
Amotivation (1–7)	Primary	2.36	1.56	2.43	1.58	2.30	1.54
	Secondary	2.57	1.57	2.60	1.62	2.55	1.53
Autonomy (1–5)	Primary	3.52	0.90	3.54	0.94	3.49	0.88
	Secondary	3.40	0.88	3.45	0.87	3.37	0.89
Competence (1–5)	Primary	4.13	0.71	4.18	0.70	4.10	0.72
	Secondary	3.72	0.85	3.64	0.87	3.78	0.83
Relatedness (1–5)	Primary	4.40	0.77	4.48	0.70	4.33	0.83
	Secondary	2.95	0.96	3.00	0.95	2.90	0.97
Enjoyment (1–5)	Primary	4.36	0.70	4.43	0.60	4.29	0.77
	Secondary	3.95	0.77	4.03	0.67	3.89	0.83

Note: M: mean; SD: standard deviation.

3.2. Multivariate Analysis Based on Gender and Educational Stage

The results of the MANOVA based on the educational stage factor indicate that there are statistically significant differences in intrinsic regulation [F (1, 736) = 61.505, $p < 0.001$, $\eta^2 = 0.077$]; identified regulation [F (1, 736) = 42.753, $p < 0.001$, $\eta^2 = 0.055$]; introjected regulation [F (1, 736) = 8.396, $p = 0.004$, $\eta^2 = 0.011$]; perceived competence [F (1, 736) = 51.720, $p < 0.001$, $\eta^2 = 0.065$]; relatedness [F (1, 736) = 476.531, $p < 0.001$, $\eta^2 = 0.392$]; and enjoyment [F (1, 736) = 52.509, $p < 0.001$, $\eta^2 = 0.066$]. In all the variables studied, primary education students obtained higher scores than secondary education students. No significant differences were found in external regulation ($p = 0.285$), amotivation ($p = 0.076$), or autonomy ($p = 0.102$).

The results of the MANOVA depending on the gender factor indicate that there are statistically significant differences in intrinsic regulation [F (1, 736) = 7.994, $p = 0.005$, $\eta^2 = 0.011$]; identified regulation [F (1, 736) = 7.216, $p = 0.007$, $\eta^2 = 0.055$]; and enjoyment [F (1, 736) = 6.670, $p = 0.010$, $\eta^2 = 0.009$]. In these three variables studied, boys obtain higher scores than girls. No significant differences were found in the rest of the variables ($p > 0.05$).

In pairwise comparisons, significant differences were found in intrinsic regulation ($p = 0.001$), identified regulation ($p = 0.006$), and enjoyment ($p = 0.040$) between secondary school boys and girls with higher scores in boys. Furthermore, significant differences have been found in intrinsic motivation ($p < 0.001$), identified regulation ($p < 0.001$), competence ($p < 0.001$), relatedness ($p < 0.001$), and enjoyment ($p < 0.001$) between children in primary education and secondary education, with higher scores in children in primary education.

Significant differences were found in intrinsic regulation ($p < 0.001$), identified regulation, introjected regulation ($p = 0.010$), competition ($p < 0.001$), relatedness ($p < 0.001$), and enjoyment ($p < 0.001$), among girls of both stages, with higher scores in primary school girls in all the variables studied.

4. Discussion

The objective of this study was to determine whether there are differences in motivation, basic psychological needs, and enjoyment in PE classes between primary and secondary education students and between boys and girls. Based on the results obtained, in general, primary education students have a higher intrinsic motivation, an important factor according to the SDT [14,39,40], which maintains that in order to improve intrinsic motivation, the satisfaction of psychological needs is necessary [41]. Furthermore, in general, primary education students obtain higher scores in two of the three basic psychological needs: competence and relatedness, as well as enjoyment. These results are in line with the theoretical assumptions described in the SDT [13,14], which indicates that higher scores in basic psychological needs would directly and indirectly imply greater enjoyment in PE classes [42]. Regarding the comparison between boys and girls, boys present greater intrinsic and identified motivation and greater enjoyment than girls, both in primary and secondary education, as occurred in previous research that demonstrated differences between boys and girls in terms of enjoyment of PE [8,17] and motivational regulation [7,43].

Regarding motivation, previous research has shown that motivation towards PE classes varies within age groups, especially between primary and secondary education students [12,44], as demonstrated by the results of our study. In younger children, there is a higher score in intrinsic, identified, and introjected motivation towards physical education, which would mean that these students have a more self-determined profile [45–47]. This may indicate the interest of primary education students in the subject, in which, despite it being mandatory in the educational curriculum and therefore subject to normative evaluation [44], participation can be associated with the pleasure of participating in classes and with fun and enjoyment [48], as demonstrated by the results. Regarding external regulation and demotivation, the scores are higher among secondary education students [12]. These scores are in line with the study by Jaitner et al. [49], and this may be because students must participate in PE sessions in a mandatory manner, either for fear of punishment or for

fear of failing the subject (external regulation), or simply because students believe that it is what they should do and it is the right thing to do, and that is why they are forced to participate in classes [50].

In relation specifically to boys, it was found that they presented a higher intrinsic and identified motivation than girls in both primary and secondary education [51], which is consistent with the scientific evidence that indicates that girls present a higher demotivation towards PE than boys [52], consequently showing higher levels of amotivation compared to boys. Girls also present lower scores in intrinsic motivation and introjected regulation, which could be associated with low perceptions of competence and lower interest in the tasks performed in PE classes [52,53].

Regarding the satisfaction of basic psychological needs, primary education students again present higher scores than secondary education students in competence and relatedness with others [8,17]. This could be due to the fact that primary education teachers foster a more collaborative and supportive environment than PE teachers in secondary education [17] or to the fact that the methodology in primary education tends to be more playful and participatory [51]. On the other hand, as in our study, those students who present higher scores in competence and relatedness also present higher scores in enjoyment. These results agree with previous studies that revealed that the satisfaction of students' psychological needs has a positive impact on enjoyment in the context of physical education; specifically, enjoyment has been related to perceived competence and social relatedness [26,54].

Regarding gender differences, and contrary to what occurs in our study, scientific evidence suggests that boys show higher levels of satisfaction in terms of competence and relatedness [55]. The results of our study may be motivated by the use of interpersonal methodological styles that focus on gender differences among students and try to address the tastes of each of them [56].

Regarding enjoyment in PE classes, primary education students obtain higher scores than secondary education students [48,51]. This may be due to the fact that the learning environment in primary education is usually more playful and less competitive [51]. In addition, primary education teachers tend to use more participatory and student-centered methodologies, which may increase enjoyment [48], or secondary education students may feel greater pressure to improve their academic performance, which may negatively affect their enjoyment of PE classes [57]. Furthermore, girls, both in primary and secondary education, obtain lower scores than boys. This may be motivated by several factors, including differences in socialization, present from an early age in which boys and girls are socialized in relation to sport differently [17], or having had previous negative experiences in PE classes such as feeling excluded or not receiving the same level of attention and support as boys, which can affect enjoyment [58].

As limitations of this study, we would like to highlight that, as it is a cross-sectional study, causality cannot be inferred from the data and the relationships obtained in each of the constructs analyzed, so future studies on this topic should approach it longitudinally to establish cause and effect. The data from this study correspond to an intentional and convenience sample, which would lead us to suggest that future studies attempt to carry out a representative random sample to improve reality. Furthermore, although there is emerging literature regarding the assessment of frustration and neglect of basic psychological needs in school contexts, these variables were not studied in the present study. Finally, as it is a cross-sectional study, this study only shows the student's thinking at a given time without taking into account the type of content that was being taught in PE classes, so the data should be taken with caution.

5. Conclusions

The results of the study allow us to conclude that primary education students present greater self-determined motivation (intrinsic, identified, and introjected regulation) than secondary education students. Likewise, these same students have a greater sense of com-

petition and relatedness than secondary education students. Finally, primary education students obtain higher scores in enjoyment in PE classes. This suggests that primary education students have a more self-determined motivational profile and greater satisfaction of their basic psychological needs than secondary education students. On the other hand, secondary education students present higher scores in external regulation and amotivation, although these differences are not statistically significant. This indicates a tendency towards less self-determination and greater dependence on external factors for their motivation.

Boys have higher motivation and intrinsic enjoyment than girls; that is, boys engage and participate in PE classes because of the pleasure and satisfaction they receive from their own practice. Furthermore, comparisons also show that boys in secondary education have significantly higher scores in intrinsic regulation, identified regulation, and enjoyment compared to girls. This suggests that boys in secondary education are more motivated by internal reasons and find more enjoyment in PE classes compared to girls in the same educational stage. Identified regulation implies that students see a personal value in the activity and consider it important to them.

6. Practical Applications

As practical applications of this study, we would like to highlight and show that self-determination in PE and sport consists of three components: emotions, feelings, and cognition. Therefore, students must perceive the subject of PE as pleasant, satisfying, and useful. Thus, these aspects are influenced by several factors, including relatedness with peers in the classroom, type of course, teaching style, methods, or content. Therefore, the teaching strategies necessary to increase student participation in PE classes must include and offer different methods to promote autonomy, provide feedback on the skills performed, and promote respect and care in the group.

Regarding the different methods, teaching strategies could be proposed that use active and participatory teaching methods; that is, using teaching methods that actively involve students, such as project-based learning or cooperative learning.

In terms of feedback, teachers should aim to provide positive and constructive comments that acknowledge students' achievements; for example, instead of simply saying "good job", one could say "You've really improved your throwing technique; keep it up", which helps students feel competent and motivated to keep improving.

Regarding the promotion of respect and care in the group, it is proposed, for example, to include activities that generate a classroom environment where positive relatedness between students is encouraged. For example, organizing team activities that require collaboration and mutual support, such as teamwork, empathy, and conflict resolution through the organization of cooperative tasks and games where students must work together to achieve a common goal; norms of respect and care can also be established within the class group, ensuring that all students feel valued and supported. For example, implementing a "buddy" system where students support each other during different tasks.

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children

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Article

Predictors of Social Exclusion among Adolescents: The Weight of Physical Self-Concept Dimensions

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Abstract: Background: Social exclusion victimization among adolescents causes significant damage and harm to development and social balance. Many of the aggressions that lead to this are based on social stigmas, particularly related to physical appearance in school settings involving physical and sports activities. This study investigates the relationship between victimization through social exclusion (both manifest and subtle forms) and physical self-concept, specifically examining ability, attractiveness, physical condition, and strength. **Methods:** A total of 876 adolescents (mean age = 14.91; standard deviation = 1.71 years), evenly divided between boys and girls, from secondary schools in Andalusia, Spain participated. They completed a self-report questionnaire assessing physical abilities, attractiveness, physical condition, and self-perceived strength, alongside an instrument measuring experiences of social exclusion and manifest exclusion. **Results:** Our findings indicate that physical ability, attractiveness, and condition are negative statistical predictors of both manifest and subtle exclusion victimization, while self-perceived strength is a statistical predictor of subtle exclusion. Manifest exclusion impacts both genders similarly, but girls are more vulnerable to subtle forms of exclusion. Regardless of gender, physical ability and attractiveness significantly predict both types of exclusion. **Conclusions:** Our results highlight the importance of physical self-concept for wellbeing and maintaining self-concept balance. The inclusion of interventions addressing social exclusion in physical education is crucial, particularly those that work to mitigate social stigmas against adolescents who struggle in physical or sporting activities. A gender-sensitive approach should also be incorporated. The growing field of research on adolescent social exclusion, both manifest and subtle, underscores the need for further exploration of its links to physical condition, physical activity, self-perception, and societal stereotypes.

Keywords: subtle exclusion; manifest exclusion; victimization; adolescents

1. Introduction

Adolescence is a critical phase in the life cycle during which young individuals actively seek to engage in activities and spend time with their peers to feel integrated within a group. Physical activity, whether in school or extracurricular settings, serves as a prime environment for adolescents to not only satisfy their strong social drive [1] but also to explore their self-identity, understand others, and develop essential social skills [2]. The quality and availability of these experiences play a critical role in shaping both individual and social development during adolescence. On a personal level, they contribute to the progression of self-concept and the establishment of positive self-esteem. Socially, these experiences foster improved communication skills, the formation of emotional bonds such as friendships, and the ability to adopt various social roles while adapting behavior to

meet group expectations. This comprehensive process facilitates the development of social competence, as well as the stabilization and adjustment of personality during a particularly sensitive and demanding stage of life [1,3].

However, the processes of social interaction among adolescents do not always generate healthy experiences and bonds, leading to problems and harm that condition their identity development and emotional well-being [4]. Victimization among peers is recognized as a public health problem [5,6]. In this regard, the general phenomenon of bullying stands out as the focus of a set of aggression and victimization problems that include various forms of stigmatization of a boy or girl by their peers. It refers to the harm a student suffers from their peers, intentionally, repeatedly, under a power imbalance, and through the perversion of the elementary principles of moral reciprocity [7]. This harm can not only be inflicted through clearly observable actions but can also occur through the omission of actions and active exclusion. It can also be subtly slid into social relationships that take place in the context of common activities. It is a type of discriminatory and/or exclusionary victimization [8,9] that manifests very clearly as a shared belief in the devaluation and rejection of a peer or as a subtle devaluation of that peer's competence, which can lead, consequently, to an avoidant or isolating attitude towards them. Among adolescents, victimization occurs largely through a relational aggression that generates social exclusion [10]. Relational aggression is often: (a) direct, where aggressors exclude the victim through explicit actions; or (b) indirect, where aggressors socially ostracize or deliberately ignore the victim, or isolate them from their peers through spreading rumors behind their back via the peer network to damage their image. Thus, social exclusion—whether more evident or more concealed—constitutes both a means and an end for these actions or an omission of actions among peers. It is a form of victimization that generates emotional imbalance, loss of well-being, low self-esteem, loneliness, stress, anxiety, and depression in the adolescents who experience from it. This seems to lead to demotivation and low academic performance, absenteeism and/or the dropping out of school, an increased risk of addictions, an increase in aggressive behavior, suicidal ideation, and even suicide [11,12]. Furthermore, there is considerable research on the long-term consequences of social exclusion during adolescence, especially its impact on adulthood. Studies show that adolescents who experience social exclusion are at a heightened risk of developing mental health issues, which can persist into adulthood [13,14]. These individuals often struggle with social integration, lower life satisfaction, and reduced well-being as adults. Additionally, social exclusion can affect decision-making processes, increase risk-taking behaviors, and lead to substance abuse in adulthood. Research also highlights how persistent social exclusion in adolescence can foster negative self-concepts and even lead to physical symptoms like chronic pain or stress-related conditions.

On the other hand, although physical and sports activities can be a vector for educational and social inclusion, the very nature of these activities requires boys and girls to have attitudes of personal assertion, high motivation to master or overcome obstacles, and a certain degree of self-confidence. When some of the social benefits that the group provides to the individual are altered or severely impaired, as occurs in social exclusion, the necessary self-esteem, motivation, enthusiasm, and positive expectations required by physical activity and sports can become vulnerable in children and adolescents who suffer from these experiences of rejection or isolation victimization [15–17]. Some research concludes that there is an association between lower physical conditions and being rejected—manifested in social exclusion—in the practice of physical or sports activities, especially in competitive and team-based ones [18,19]. For example, in the study by Faith et al. [20], it was observed that three out of four students were excluded from games and sports due to their body size. On the other hand, other studies provide evidence of hidden social exclusion among peers in sports practice, due to the perception that the victim is outside the normative group because of differences in the level of specific physical skills they exhibit; or their executive competence; or their access to, and mastery of, materials or equipment, among other factors [21].

Undoubtedly, when this exclusion becomes shared within reference groups, it reinforces a form of social stigma closely tied to the standards of appearance, aesthetics, and physical or bodily competence, which are highly influential during adolescence [21–24]. For instance, lower proficiency in motor skills has been associated with difficulties in peer relationships and an increased likelihood of experiencing social isolation, with this relationship being more pronounced among boys than girls [25,26]. On the other hand, girls appear to be more vulnerable regarding their self-perception of physical attractiveness, often showing a greater tendency than their male counterparts to perceive themselves as overweight [22].

1.1. Social Exclusion among Schoolchildren

Social exclusion among peers is a form of psychological and social violence caused by actions and/or omissions of actions that transgress the relational moral principles [27–29] necessary for groups to learn how to interact together. Discrimination, when it involves mistreatment or violence, generates and is based on social stigmas that lead to social marginalization [30]. The aggressor or aggressors of this type of violence stigmatize and exploit the differences of an individual in relation to the rest of the group, whether based on ethnic–cultural differences, sexual orientation, gender identity, disability, physical appearance, or aesthetics, among others. Boys and girls in the educational system who are considered to have special educational needs (SEN) are at greater risk of being discriminated against and socially excluded [9,31]. In this regard, sports and physical activity are fertile grounds for this type of social discrimination [32,33].

Although social exclusion is a multifaceted phenomenon [34], from the perspective of the schoolchild who suffers this discrimination [11] scientific literature seems to converge on the existence of two major subtypes: (a) victimization by active, direct, explicit social exclusion through rejection, where the victim is clearly and directly shown that they are not welcome or wanted in the group; and (b) implicit, through ostracism and isolation and other subtle forms of aggression where the victim feels socially ignored [35,36]. Both subtypes of social exclusion are more frequently suffered by people who are also part of minority groups, which tend to be stigmatized as such groups [37] due to their ethnic-cultural origin, disability, or sexual orientation, among others. Both manifest and subtle forms of social exclusion have been documented among schoolchildren based on their physical appearance during physical activities. For example, it has been observed that three out of four students have witnessed how their overweight or obese peers have been ignored, avoided, and subjected to negative rumors—subtle social exclusion—or rejected and excluded from social activities—manifest social exclusion [38]. However, subtle social exclusion is more difficult to recognize, as it is largely suffered through microaggressions. Examples of subtle social exclusion include avoidance, deliberately not being physically close to the victim, avoiding verbal and eye contact, refusing to share academic or sports activities, mocking their appearance, or spreading rumors and defamatory comments behind their back, among others [27,31].

A review of the scientific literature on social exclusion reveals that, despite profiling two subtypes—manifest and subtle, as previously described—there is a lack of instruments that record both subtypes. Currently, the study by González-Delgado et al., 2024 (in press) [39] aims to validate a self-report scale that is sensitive to manifest and subtle social exclusion victimization in pre-adolescents and adolescents.

1.2. Physical Self-Concept

Body image is the self-conscious representation of one's own body, the value attributed to it, and the confidence that one's body will be functional, operational, and sufficiently well accepted by others [40]. In this sense, physical self-concept is closely related to general self-concept, identity, and self-esteem [41,42]. However, self-image, like any image, is a product of thought that fluctuates in its assessment. Just as self-esteem is nourished by the esteem, consideration, and respect that others have for us, the contempt and devaluation

that peers direct at our person, and therefore our body, directly impacts self-assessment. As Fox [43] states, Physical Self-Concept is a "public" Self; a means by which we present ourselves to others and which also includes how the individual feels they are perceived and evaluated. There is evidence that schoolchildren considered unattractive or that have minor physical defects are more rejected and even excluded by their peers when it is perceived that they make no effort to improve their appearance [44]. A particular but widespread case in the Western world is the effect of being overweight. The confluence of being overweight and negatively self-perceiving one's physical appearance—body dissatisfaction—in adolescents tends to impact the physical, social, and psychological aspects of an adolescent's personality [45]. Some studies indicate that overweight and/or obese students may be more involved in bullying, either as victims, being more subject to mockery and verbal offenses than the rest of their peers [22,46], or in a mixed aggressor–victim role. At the same time, a good self-image—a positive self-perception of oneself—seems to mitigate the effects of being overweight and enhance satisfaction with one's own body [22,46,47], acting as a protective factor against bullying.

Physical self-concept is defined as the perception that a person has of their appearance and physical abilities and is considered a very important domain in general self-concept [48]. A significant association between physical activity and physical self-concept and its various domains has been consistently demonstrated in both children and adolescents [49]. Analysis of self-concept dimensions [50] has revealed a multidimensional and hierarchical model that, fueled by self-esteem, has been established as a construct of four dimensions: physical abilities, physical condition, physical attractiveness, and physical strength. Abilities are considered physical skills. Physical condition is conceived as bodily functions and state. Physical attractiveness refers to the aesthetic appearance of the body. Physical strength is considered the capacity and control exercised over physical objects.

Studies reveal that adolescent girls generally have a poorer physical self-concept than their male peers [49,51]. Boys excel in strength, speed, endurance, and coordination, while girls excel in flexibility [52,53]. It has also been observed that girls are more likely to describe their weight in terms of being overweight, which is also related to the self-perception of physical attractiveness [22]. Research has shown that gender differences in self-perception are more significant than differences in objective measurements of performance and physical competence. This seems to suggest that gender differences in physical self-concept are not due to differences in motor or sports tests, but rather to gender stereotypes.

Body satisfaction positively influences physical self-concept [54]. However, throughout adolescence, levels of body dissatisfaction tend to be higher than at other developmental stages; with girls being more prone to record lower levels than boys [55]. This same gender trend is observed in relation to self-esteem [56–58].

1.3. Victimization by Social Exclusion among Adolescents and Physical Self-Concept

A review of the scientific literature shows that there is a vast area of knowledge yet to be explored regarding the possible relationships between peer social exclusion victimization and physical self-concept. Some studies are beginning to provide indications of the specific weight that physical self-concept holds in schoolchildren in relation to social exclusion [57]. However, the results from these studies are not conclusive for various reasons; it is important to note that these studies have measured social exclusion with a single item, as a specific form of bullying victimization. Another reason for scientific concern is that the samples used in these studies tend to be small and are not always representative of the reference adolescent population in each context. Nevertheless, some of the most relevant contributions of these investigations are highlighted.

The study of the relationships between bullying victimization and the victims' physical appearance or aspect concluded that direct social exclusion is related to negative levels regarding their physical self-concept [59–61] For example, it has been observed that bullying victimization had an inverse relationship with self-perception of physical appearance, athletic competence, or body dissatisfaction. The study by Benítez-Sillero et al. [62] indi-

cates that a positive physical self-concept can reduce the inhibiting effect on participation in physical activities of adolescents who are victims of bullying or cyberbullying. The systematic review by Arcila-Arango et al. [63] concludes that improving self-concept through physical education classes can decrease bullying victimization.

1.4. The Present Study

Given that peer social exclusion victimization is a complex and multidimensional construct, as it is generated through various stigmas and involves multiple aspects of the social dynamics and personality of the schoolchildren involved, as well as being highly impacted by the settings, contexts, and social origins of those affected, a previous study [39], developed a sensitive, reliable, and comprehensive instrument for measuring this phenomenon, which has allowed for a clearer establishment of the construct. Based on the same sample, the present study has the following objectives:

1. To identify the possible relationships between the levels of manifest and subtle social exclusion victimization, and the levels of the four domains of physical self-concept (ability, condition, attractiveness, and strength).
2. To determine whether the levels of the four domains of physical self-concept and age are statistical predictors of manifest and subtle social exclusion victimization.
3. To examine whether there are gender differences in the levels of manifest and subtle social exclusion victimization and in the statistical predictors of both subtypes of exclusion.

This research aims to test the following hypotheses:

Hypothesis 1. *The four domains of physical self-concept are negatively related to the level of manifest social exclusion victimization.*

Hypothesis 2. *The self-perceived levels of ability and physical condition are negatively related to the level of subtle social exclusion victimization.*

Hypothesis 3. *The self-perceived levels of ability, condition, attractiveness, and physical strength are negative statistical predictors of manifest and subtle social exclusion victimization.*

Hypothesis 4. *Especially in girls, the self-perceived level of physical attractiveness is a negative statistical predictor of manifest and subtle exclusion victimization.*

2. Materials and Methods

2.1. Participants

A total of 876 adolescents aged 12 to 19 years (mean = 14.91; standard deviation = 1.71 years), from four high schools in Andalusia, Spain participated in the study. A total of 48.7% of them were girls and 51.3% were boys, The sample was selected by convenience.

2.2. Procedure

A cross-sectional descriptive study was performed. The study was performed after obtaining the respective permissions from the participants' educational centers as well as informed consent forms signed by their families. All national and international ethical standards were followed, such as the Declaration of Helsinki and personal data protection laws. Likewise, the project was approved by the Human Research Ethics Committee of the University of Cordoba. The participating students were informed of the objective of the study and the anonymous, confidential, and voluntary nature of their participation in it was highlighted.

2.3. Instruments

2.3.1. Social Exclusion

An ad-hoc questionnaire was designed [39], which included a series of questions related to sociodemographic aspects (e.g., educational center, academic year, and sex), as well as questions investigating possible experiences of social exclusion experienced in the social environment of their reference groups (school, classroom, classmates, and friends) (Appendix A). The variables related to the experiences of social exclusion were measured using a Likert-type scale with 10 items and four response options, ranging from 1 (strongly disagree) to 4 (strongly agree). All items are written from the victim's point of view, starting with headings such as: "I feel that . . ." "My classmates . . ." The internal consistency index shows satisfactory levels of reliability for the instrument (α = 0.932) and for each of its dimensions: (a) Manifest exclusion (ExN) = 0.906; and (b) Subtle exclusion (ExS) = 0.896.

2.3.2. Physical Self-Concept

The abbreviated eight-item format [64] of the Physical Self Concept Questionnaire [65] was used in the study. Participants responded to the questionnaire using a five-point Likert-type scale, where 1 represented "false" and 5 represented "true". Several sentences were used, for example, "I feel happy with my body image". The scores from the individual items were summed to obtain an overall score on general self-concept, although items five and seven were swapped. The questionnaire assessed physical self-concept across four dimensions: strength, attractiveness, ability, and condition. The internal consistency values of the test were found as α = 0.81.

2.4. Statistical Analysis

Bivariate correlation analysis was conducted using Spearman's test. Student's *t*-test was used for comparisons by sex. To determine the relationships between the physical self-concept, age dimensions, and the exclusion variables multiple linear regressions were carried out. Data coding and analysis were carried out using the Statistical Package for Social Sciences (SPSS), version 28.

3. Results

Table 1 presents the linear regression models where manifest exclusion and subtle exclusion are the dependent variables, while age, PC Skill, PC Physical Condition, PC Attractiveness, and Strength act as independent variables. The model for manifest exclusion explained 5.1% of the variability in manifest exclusion, and the model for subtle exclusion explained 10.3%.

Table 1. Linear regression analysis of age, strength PC, attractiveness PC, skill PC, and physical condition PC as predictors of manifest and subtle exclusion.

Variable	Manifest Exclusion		Subtle Exclusion	
	β	*t*	β	*t*
	R^2 = 0.051		R^2 = 0.103	
Age	0.005	0.144	0.045	1.387
PC Strength	0.045	1.157	0.075	2.004 *
PC Attractiveness	−0.093	−2.534 *	−0.130	−3.642 **
PC Skill	−0.195	−5.314 **	−0.210	−5.887 **
PC Physical Condition	−0.027	−0.654 *	−0.119	−2.917 **

Note. *p*-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *. β = Beta; *t* = *t*-test.

In both models, the predictors PC Attractiveness, PC Skill, and PC Physical Condition showed negative relationships with the dependent variables, suggesting that higher levels of attractiveness, skill, and physical condition in physical activity are associated with lower levels of both manifest and subtle exclusion. Additionally, in the subtle exclusion model,

the predictor PC Strength showed a positive relationship, indicating that higher levels of strength are associated with higher levels of subtle exclusion.

Table 2 presents the Spearman correlations between age, manifest exclusion, and subtle exclusion with the various variables of Physical Self-Concept (PC): skill, physical condition, attractiveness, and strength. A negative association was observed between age and subtle exclusion, as well as with PC Attractiveness and PC Physical Condition. Manifest exclusion showed a positive correlation with subtle exclusion, indicating that those who experience manifest exclusion also tend to perceive greater subtle exclusion. Additionally, negative relationships were found between manifest exclusion and PC Attractiveness, PC Skill, and PC Physical Condition, suggesting that manifest exclusion is associated with lower perceptions of attractiveness, skill, and physical condition in physical activity. Lastly, subtle exclusion also showed negative associations with PC Strength, PC Attractiveness, PC Skill, and PC Physical Condition.

Table 2. Spearman correlations between the different physical activity variables and age, manifest exclusion and subtle exclusion.

Variable	Age	Manifest Exclusion	Subtle Exclusion
Manifest Exclusion	0.039	-	-
Subtle Exclusion	−0.076 *	0.783 **	-
PC Strength	−0.025	−0.058	−0.099 **
PC Attractiveness	−0.162 **	−0.184 **	−0.238 **
PC Skill	0.011	−0.233 **	−0.265 **
PC Physical Condition	−0.094 *	−0.150 **	−0.220 **

Note. *p*-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *.

Tables 3 and 4 present the linear regression models for the dependent variables subtle exclusion and manifest exclusion, respectively, differentiated by gender. The independent variables are the same as those used in Table 1: age, PC Strength, PC Attractiveness, PC Skill, and PC Physical Condition.

Table 3. Linear regression analysis by gender, with manifest exclusion as the dependent variable and age, strength PC, attractiveness PC, skill PC, and physical condition PC as independent variable.

Variable	Manifest Exclusion			
	Boys		Girls	
	β	t	β	t
	$R^2 = 0.070$		$R^2 = 0.032$	
Age	−0.047	−1.009	0.050	1.013
PC Strength	0.071	1.385	0.003	0.050
PC Attractiveness	−0.122	−2.391 *	−0.073	−1.390
PC Skill	−0.222	−4.615 **	−0.160	−2.928 *
PC Physical Condition	−0.041	−0.736	−0.013	−0.220

Note. *p*-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *. β = Beta; t = t-test.

In the manifest exclusion model shown in Table 3, it was found to explain 7% of the variance in boys and 3.2% in girls. For this model, having lower PC Skill, in both boys and girls, is related to higher manifest exclusion. Additionally, PC Attractiveness also negatively predicted manifest exclusion in boys, but was not significant in girls.

Table 4 shows the subtle exclusion model, explaining 9.9% of the variance in boys and 9.5% in girls. In this model, both PC Attractiveness and PC Skill were significant negative predictors for both genders. Additionally, in boys, PC Physical Condition also acted as a negative predictor, meaning that poorer physical condition would imply greater subtle exclusion. However, the importance of the PC Attractiveness predictor was lower in boys compared to girls in this model.

Table 4. Linear regression analysis by gender, with subtle exclusion as the dependent variable and age, strength PC, attractiveness PC, skill PC, and physical condition PC as independent variables.

Variable	Subtle Exclusion			
	Boys		Girls	
	β	t	β	t
	$R^2 = 0.099$		$R^2 = 0.095$	
Age	0.003	0.076	0.084	1.774
PC Strength	0.060	1.188	0.076	1.476
PC Attractiveness	−0.112	−2.245 *	−0.142	−2.806 **
PC Skill	−0.221	−4.663 **	−0.200	−3.787 **
PC Physical condition	−0.137	−2.511 *	−0.085	−1.499

Note. p-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *. β = Beta; t = t-test.

Table 5 analyzes the differences between manifest exclusion and subtle exclusion based on gender. It shows that girls experience greater subtle exclusion compared to boys. However, no significant gender differences were found for manifest exclusion.

Table 5. Comparison of Manifest and Subtle Exclusion by Gender.

Variable	Girls n = 427	Boys n = 449	p	D
	M ± SD	M ± SD		
Manifest Exclusion	1.28 ± 0.49	1.25 ± 0.47	0.119	0.06
Subtle Exclusion	1.50 ± 0.65	1.43 ± 0.57	<0.001	0.11

Note. M = Mean; SD = standard deviation; p = p-value; D = D de Cohen.

Tables 6 and 7 present the stepwise linear regression models for the dependent variables manifest exclusion and subtle exclusion, respectively, differentiated by gender. The independent variables used are the same as those used in Table 6: age, PC Strength, PC Attractiveness, PC Skill, and PC Physical Condition.

Table 6. Stepwise regression analysis by gender, with manifest exclusion as the dependent variable and age, strength PC, attractiveness PC, skill PC, and physical condition PC as independent variables.

Manifest Exclusion					
Boys			Girls		
Variables	β	t	Variables	β	t
	Step 1 $R^2 = 0.060$			Step 1 $R^2 = 0.032$	
PC Skill	−0.248 **	−5.423	PC Skill	−0.185 **	−3.876
	Step 2 $\Delta R^2 = 0.010$				
PC Skill	−0.224 **	−4.796			
PC Attractiveness	−0.114 *	−2.438			

Note. p-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *. β = Beta; t = t-test.

Table 6 shows the manifest exclusion model differentiated by gender. For boys, in the first step, the negative predictor PC Skill explains 6% of the variance in the model. In the second step, the negative predictor PC Attractiveness is included, increasing the variance explained by the model to 7%. This suggests that, in addition to skill, attractiveness also contributes to manifest exclusion, providing additional explanation for the variance in the levels of exclusion observed in boys.

Table 7. Stepwise regression analysis by gender, with subtle exclusion as the dependent variable with age, strength PC, attractiveness PC, skill PC, and physical condition PC as independent variables.

Subtle Exclusion					
Boys			**Girls**		
Variables	***β***	***t***	**Variables**	***β***	***t***
	Step 1			Step 1	
	R^2 = 0.073			R^2 = 0.060	
PC Skill	−0.274 **	−6.026	PC Skill	−2.50 **	−5.312
	Step 2			Step 2	
	ΔR^2 = 0.020			ΔR^2 = 0.025	
PC Skill	−0.229 **	−4.869	PC Skill	−0.202 **	−4.194
PC Physical Condition	−0.154 **	−3.266	PC Attractiveness	−0.172 **	−3.572
	Step 3			Step 3	
	ΔR^2 = 0.007			ΔR^2 = 0.006	
PC Skill	−0.218 **	−4.616	PC Skill	−0.207 **	−4.296
PC Physical Condition	−0.113 *	−2.230	PC Attractiveness	−0.156 **	−3.208
PC Attractiveness	−0.109 *	−2.199	Age	0.092 *	1.966

Note. *p*-Values are indicated according to $p < 0.01$ ** $p < 0.05$ *. β = Beta; *t* = *t*-test.

For girls, only one step is shown in the regression analysis, where the negative predictor PC Skill explains 3.2% of the total variance in the model. This indicates that, for girls, skill has a lesser ability to explain manifest exclusion compared to boys.

The subtle exclusion model, differentiated by gender, is presented in Table 7. For boys, the model showed that in the first step, the inclusion of the negative predictor PC Skill explained 7.3% of the variance. This suggests that lower skill was associated with higher levels of subtle exclusion. Adding the negative predictor PC Physical Condition in the second step increased the explained variance to 9.3%. Finally, the inclusion of the negative predictor PC Attractiveness in the third step raised the model's total explained variance to 10%.

In contrast, the analysis for girls showed a different pattern. In the first step, the negative predictor PC Skill explained 6% of the model's variance, indicating that although skill was also relevant for girls, its impact on subtle exclusion was less compared to boys. When the negative predictor PC Attractiveness was added in the second step, the explained variance increased to 8.5%, suggesting that attractiveness played a more significant role in girls than it did for boys. In the final step, the inclusion of the positive predictor age increased the total explained variance of the model to 9.1%.

4. Discussion and Conclusions

A review of scientific literature has revealed that some studies indicate a negative relationship between peer rejection and both physical fitness and body size [18–20]. Consequently, the first hypothesis in this study predicted that victimization due to manifest exclusion would negatively correlate with the four domains of physical self-concept. However, the results show that such victimization is negatively related to ability, physical condition, and attractiveness but does not affect strength, confirming the hypothesis in part. It was also found that manifest exclusion correlates positively with feelings of subtle exclusion. These findings provide further insights beyond previous research. The aspects of physical self-concept most closely associated with experiences of manifest rejection in adolescents are ability, physical condition (fitness), and attractiveness (physical appearance). Notably, strength is the only dimension of physical self-concept that does not appear to be related to victimization through manifest social exclusion. Furthermore, it has been observed that victimization due to subtle exclusion was negatively related to all four domains of physical self-concept—ability, condition, attractiveness, and strength—and was positively correlated with manifest exclusion. This supports the second hypothesis, revealing that both physical strength and attractiveness play a role in subtle exclusion.

Expanding the scope of prior research, while self-perceived levels of physical abilities and physical condition were negatively related to subtle exclusion victimization [26,29], our findings offer additional insights. Not only are ability and physical condition associated with isolation victimization, but attractiveness and physical strength are also negatively correlated with the levels of subtle exclusion experienced. This broadens the understanding of how various aspects of physical self-concept contribute to feelings of social exclusion in adolescents.

Previous studies on bullying that include social exclusion as one of its forms have shown that the forms of exclusion victimization range from direct social exclusion (manifest exclusion) to more indirect or subtle forms of exclusion, such as malicious rumors through third parties in the peer network (aimed at causing isolation), and that this phenomenon was negatively related to the level of physical self-concept [56–58]. In addition, the observation that improving physical self-concept through physical education classes can reduce bullying—including certain forms of social exclusion—[62,63] contributed to the third hypothesis: that the four dimensions of physical self-concept would serve as negative statistical predictors for both manifest and subtle exclusion victimization. This hypothesis was partially supported, as ability, attractiveness, and condition were found to be negative predictors, while physical strength was positively associated with subtle exclusion.

The overall conclusion suggests that the profiles of victims of both forms of social exclusion among peers share poor perceptions of their ability, attractiveness, and physical condition, consistent with earlier findings that adolescents with lower physical fitness or body size are often rejected in competitive or team-based activities [19,20]. However, in the case of subtle exclusion, high self-perception of physical strength appears to predict vulnerability to subtle exclusion. This adds depth to the existing literature, which highlights that poor motor skills and poor physical condition are associated with difficulties in peer relationships and a greater likelihood of being socially isolated [26,29], and that being considered unattractive or having minor physical defects are conditions that greatly increase the likelihood of being rejected and excluded, especially when no effort is made to improve one's appearance [43]. Therefore, boys and girls with various disabilities or special educational needs related to these domains—abilities, attractiveness, competence, and strength—and who are socially stigmatized by these characteristics, may be more subject to subtle social exclusion among their peers. These findings also emphasize the role of physical education in enhancing self-concept and reducing victimization.

The findings that self-perceived physical strength acts as a positive statistical predictor for subtle exclusion victimization, while not influencing manifest exclusion victimization, offer several inferences. As adolescents mature, displays of physical strength that may cause harm to others are increasingly perceived by peers as inappropriate, disruptive, and undesirable behaviors. Furthermore, when an individual stands out due to qualities such as physical strength, they may become targets of avoidant behaviors from their peers, potentially driven by jealousy or envy [1,57,62]. It is hypothesized that adolescents with a high self-perception of physical strength might be more susceptible to subtle exclusion, as peers may engage in indirect forms of social exclusion—such as ignoring or isolating them—due to feelings of fear or jealousy. This type of exclusion represents a form of indirect aggression, wherein perpetrators perceive less risk in targeting a physically strong individual, as opposed to manifest exclusion, which requires direct confrontation and rejection.

Based on previous studies [54–57], the fourth hypothesis proposed that in girls, the self-perceived level of physical attractiveness would serve as a negative statistical predictor for both manifest and subtle exclusion victimization. This hypothesis was supported in the case of subtle social exclusion but not for manifest exclusion. The findings indicate that both physical ability and attractiveness negatively predict girls' likelihood of experiencing subtle social isolation or being ignored. In contrast, the likelihood of experiencing direct social rejection in girls is negatively predicted by their self-perceived physical ability.

Finally, the conclusions of this research also shed light from a gender perspective. While boys and girls are similarly affected by manifest exclusion, girls tend to be more

vulnerable to subtle forms of social exclusion. Both girls and boys tend to experience manifest exclusion at comparable rates, with this form of exclusion being overtly expressed among peers through direct rejection aimed at making the victim feel unwanted and undesirable [36,37]. However, girls are particularly susceptible to more subtle and indirect forms of social exclusion [10]. These forms of exclusion often involve socially isolating the victim, spreading malicious rumors within peer groups [35,37], or avoiding interaction with the victim, whether physically, verbally, or visually, in both academic and leisure contexts [27,31].

This study has certain limitations related to its design and methodology. Specifically, the coefficient of determination of the regression is low. Therefore, the results must be interpreted with caution. The cross-sectional approach, while providing valuable insights aligned with the study's objectives, limits the ability to identify causal relationships. Additionally, although the use of an anonymous self-report questionnaire is one of the most reliable and widely applied methods in victimization research, future studies could benefit from incorporating hetero-reports to achieve data triangulation. Building on the findings and methodology of this research, future investigations could adopt a longitudinal design to explore causal relationships and potential mediation effects. This study also opens new avenues for research, including a deeper examination of social exclusion victimization linked to social stigmas in relation to physical self-concept, physical activity, and physical education. Further studies could also focus on the connection between physical self-concept and outcomes such as self-esteem, wellbeing, or psychological disorders (e.g., anxiety, stress, and depression) in both victims and perpetrators of social exclusion in adolescence. Moreover, designing and testing psychoeducational programs aimed at preventing and reducing both manifest and subtle social exclusion, following the guidelines of this study, would be valuable, especially through longitudinal studies with experimental and control groups.

A comprehensive analysis of this study's conclusions suggests the need to design and implement psychoeducational programs in schools, starting from preadolescence, that not only encourage physical and sports activities but also foster the development of a balanced and healthy physical self-concept. Such programs could play a significant role in reducing both manifest and subtle forms of social exclusion victimization. Educational interventions should address all domains of physical self-concept—ability, attractiveness, condition, and strength—while placing particular emphasis on enhancing accurate self-perceptions of physical ability and attractiveness, as these are the strongest predictors of social exclusion victimization. Moreover, it is crucial for both general education and physical education to support the balanced development of physical strength, promote self-regulation in behaviors involving physical strength, encourage moral and interpersonal behavior, and teach the appropriate, non-violent use of physical strength in interpersonal and athletic contexts.

Similarly, these psychoeducational programs should incorporate a specific focus on gender. Given that research indicates girls are more affected by subtle social exclusion, with self-perceived physical attractiveness being a significant predictor of this form of exclusion, and prior studies showing that adolescent girls generally have a poorer self-perception of their physical appearance compared to boys [50], and are more vulnerable to concerns related to physical attractiveness, often perceiving themselves as overweight [22], it is recommended that these interventions include learning activities centered on self-perception and body image. These activities should address the aesthetic evaluation of the body, the conception of physical beauty, and the influence of societal and evolving stereotypes. It is essential for all adolescents, particularly girls, to develop socio-critical thinking regarding social stigmas to build positive self-esteem and life satisfaction. This will help them develop independent judgments and resist the pressures of dominant and shifting social stereotypes about body image and beauty. They should be encouraged to cultivate balanced physical development across all domains and to form a realistic and positive self-concept regarding their physical attributes, including ability, attractiveness, condition, and strength.

Educational strategies aimed at reducing biases related to appearance, aesthetics, and physical competence [22–25], while considering a gender perspective, should be applied to all adolescents. Since peer exclusion is an ecological phenomenon, it is crucial to prevent and mitigate it by raising awareness and actively engaging not only potential aggressors and victims but also bystanders.

This study offers a significant contribution by employing a self-report questionnaire specifically designed to assess two distinct subtypes of social exclusion—manifest and subtle—that lack previous precedents in the literature. This tool is unique in its ability to capture both forms of exclusion and is noted for its simplicity and strong psychometric properties, making it an effective instrument for measuring social exclusion victimization among adolescents. Its design aligns with prior categorizations of social exclusion, distinguishing between more overt rejection and more covert isolation [38].

The investigation of social exclusion, both manifest and subtle, during adolescence is a growing field of research. Building upon the established understanding of bullying and cyberbullying, this research has the potential to play a crucial role in addressing victimization during this critical developmental stage. There is an urgent need for further research examining social exclusion in relation to physical condition, physical activity and education, self-perception, and societal stereotypes. Such research is essential for the development of evidence-based prevention strategies and educational interventions that foster positive peer interactions and support the social and individual development of adolescents, thereby reducing associated risks and challenges.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of UNIVERSITY OF CORDOBA (11 December 2019).

Informed Consent Statement: Written consent was obtained from the parents of all participants involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ethical and privacy considerations to protect the confidentiality of participants.

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Appendix A. The Manifest and Subtle Social Exclusion Scale (ESMASU)

	Strongly Disagree	Disagree	Agree	Strongly Agree
1. My classmates make me feel different from them.	SD	D	A	SA
2. I feel undervalued by my classmates.	SD	D	A	SA
3. I feel odd among my classmates.	SD	D	A	SA
4. I feel that my classmates are rejecting me.	SD	D	A	SA
5. My classmates reject me to make me suffer.	SD	D	A	SA
6. I feel like I don't have a place in the group of classmates.	SD	D	A	SA
7. My classmates exclude me to hurt me.	SD	D	A	SA
8. I feel like my classmates ignore me.	SD	D	A	SA
9. I feel like I'm not welcomed by my classmates.	SD	D	A	SA
10. I feel like my classmates are sidelining or excluding me.	SD	D	A	SA

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Article

Perceived Physical Literacy Levels in Spanish Adolescents: Differences Between Sexes and Age Groups

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Abstract: Background/Objectives: Perceived physical literacy (PPL) appears to be a relevant strategy for combating the prevalent sedentary lifestyle among young people. Therefore, understanding their PPL levels will facilitate the implementation of appropriate strategies for this purpose. Therefore, this study aimed to analyze the differences in PPL considering the sex dimension (i.e., males and females) and the age-group (i.e., early compulsory secondary education, late compulsory secondary education and baccalaureate). **Methods**: Seven-hundred-and-four Spanish students (age = 14.3 ± 1.6 years old) belonging to three different Spanish secondary schools voluntarily participated in this study. To assess adolescents' perceptions of their physical literacy, the Spanish Adolescents' Perceived Physical Literacy Assessment (S-PPLI) was used. This instrument consists of nine items equally distributed across three categories: self-perception and self-confidence, self-expression and communication with others, and knowledge and understanding. **Results**: Males obtained higher scores in all the indicators of PPL, except for items 1, 8 and 9, compared to their female counterparts ($p < 0.05$), while the oldest age-group reported higher scores in the indicators of knowledge and understanding category compared to students in the early years of compulsory secondary education ($p < 0.01$). **Conclusions**: Programs based on increasing the PPL should be implemented specifically for females. Also, similar programs must be included into scholar curriculums from the beginning of secondary education, with the aim of promoting improvements in the health and physical condition of Spanish adolescents.

Keywords: education; physical activity; health; exercise; sex

1. Introduction

Perceived physical literacy (PPL) has emerged as a key multidimensional construct for promoting active and healthy lifestyles, particularly during childhood and adolescence [1,2]. Contemporary consensus defines this phenomenon as the combination of motor skills, knowledge, attitudes, motivation and confidence necessary to participate in physical activities across the lifespan, highlighting that PPL is not only related to physical competence, but also to emotional and social well-being [3]. Adolescence represents a pivotal developmental

juncture, characterized by profound physiological and psychological transitions toward adulthood, and the progressive decline in physical activity levels [4]. Concretely, PPL was significantly associated with physical fitness, body composition, and physical activity levels among secondary school adolescents aged 14–18 [5]. Thus, understanding the PPL level is essential to design effective strategies to mitigate a sedentary lifestyle and its consequences, such as increased obesity, metabolic disorders and mental health problems [2]. For this purpose, it is essential to have adequate assessment instruments that allow decisions to be made based on robust results. Regarding this, [6] tried to validate of the Spanish Perceived Physical Literacy Instrument (S-PPLI) questionnaire in Spanish adolescents, based on an original questionnaire designed and validated for physical education teachers [7]. The authors proved that the S-PPLI is a valid and reliable measure of physical literacy among Spanish adolescents, after the conduction of several statistical analyses (e.g., confirmatory factor analysis, analyses for convergent validity or intraclass correlation coefficient) with positive results. These results suggest that the S-PPLI is an adequate instrument to assess physical literacy in Spanish adolescents, so it is used, due to the necessity of evaluating this construct and to design and implement significative strategies in this population.

Prior studies in several countries [8–11] have revealed consistent gender-based disparities. In particular, it has been reported that males demonstrated significantly higher self-perceived athletic competence, whereas females reported lower confidence in physical activity contexts [9,11]. Likewise, social class also appears to be another determining factor influencing PPL, given that adolescents with lower economic incomes and from ethnic minorities in the United States tended to report higher levels of physical inactivity [8,10]. Concurrently, physiological factors substantially modulate PPL development. Elevated body mass index (BMI) consistently correlates negatively with PPL measures [12], potentially reflecting both biomechanical constraints and weight-related stigmatization. Furthermore, the biological transitions of adolescence interact complexly with academic pressures and psychosocial changes to influence physical literacy trajectories [10,11]. In this sense, Rojo-Ramos et al. [11] found a significant negative correlation between advancing adolescent age and motivation for physical activity, suggesting developmental windows where targeted interventions may prove most effective. Despite these findings, these patterns derive primarily from non-Spanish populations, with limited examination of how educational transitions (e.g., between compulsory and post-compulsory schooling) influence PPL trajectories.

Multiple contextual factors appear to modulate PPL levels in adolescents, including the prevailing prioritization of academic achievement over holistic development, persistent gender disparities in sports participation, and significant variability in the quality of school-based physical education programs [12,13]. A key contextual factor is the age, mainly during adolescence, in which different developmental stages of age take place, which suggests the need to analyze PPL based on age groups (i.e., early compulsory secondary education, late compulsory secondary education and baccalaureate). Critically, PPL currently lacks explicit inclusion as a curricular competency within mandatory educational frameworks, resulting in inconsistent pedagogical attention across primary and secondary institutions [2]. This institutional gap provides a plausible explanation for the low PPL levels documented among Spanish adolescents [2], a concern further compounded by contemporary sedentary trends. This factor, together with the well-documented increase in sedentary behaviors—such as prolonged screen time, great social media consumption and reduced daily physical activity—has been linked to lower PPL, especially among adolescents [14].

Considering the aforementioned literature and the importance of knowing the PPL in adolescents, the main aim of this study is to analyze the differences in PPL considering the sex dimension (i.e., males and females) and the age-group (i.e., early compulsory

secondary education, late compulsory secondary education and baccalaureate). Based on prior studies [9,11], we hypothesized that males would present higher levels of PPL than females, and that the oldest age-group would be better at self-management and self-confidence, while the youngest age-group would present the greatest values related to the enjoyment of physical activity.

2. Materials and Methods

2.1. Design

A descriptive, comparative and correlational design was implemented to deepen the knowledge of the level of PPL among Spanish adolescents by comparing between sexes and between age groups. One questionnaire of perceived physical literacy, which was previously validated in Spanish adolescents [6], was administered to the participants following the standardized procedures. In the same session, participants were asked to complete their sex and age, to be classified according to this. Questionnaires were completed using computers and mobile devices in the classroom with the supervision of the teacher for solving some questions, and lasted between 10 and 15 min.

2.2. Participants

Seven hundred and four Spanish students (age: 16.3 $\pm$ 1.6 years, body mass: 55.1 $\pm$ 11.7 kg, stature: 164.7 $\pm$ 10.4 cm) belonging to 3 different secondary schools participated in this study during the academic year 2024/2025. Schools were selected through a convenience sampling approach based on institutional accessibility and willingness to participate in the study. These schools were allocated in Andalucia, Madrid and Galicia regions, and all of them were public schools, with the students and their families being of a medium socioeconomic level. Three hundred and seventy-four participants were males (53.13%) and three hundred and thirty were females (46.87%). Regarding the classification by age-group, 255 students (36.22%) belonged to early compulsory secondary education, 265 students (37.64%) to late compulsory secondary education and 184 students (26.14%) to baccalaureate. To be included in the study, the following eligibility criteria had to be met: (1) be between 12 and 18 years of age, (2) accept to participate in the study, (3) have obtained the consent of parents/guardians, (4) have residency in Spain, and (5) have not presented pathologies preventing the practice of physical activity.

2.3. Ethics

The research received the approval of the Ethics Committee of the University of Córdoba (code: CEIH-24-47) and followed the ethical principles of the Declaration of Helsinki by the 64th General Assembly of the World Medical Association (Fortaleza, Brazil, 2013) and in compliance with Law 14/2007 on Biomedical Research.

2.4. Perceived Physical Literacy (PPL)

The Spanish Adolescents' Perceived Physical Literacy Assessment (S-PPLI) was used to assess adolescents' perceptions of their physical literacy. Data collection was conducted in person during physical education classes during the academic year 2024/2025. While the original S-PPLI consisted of 18 items, this study used the validated 9-item short version proposed by López-Gil et al. [6]. The abbreviated version was developed through confirmatory factor analysis and internal consistency testing, and demonstrated acceptable psychometric properties, including good reliability and construct validity (values from 0.53 to 0.77). The selection of the 9 items was based on statistical performance (e.g., factor loadings and item-total correlations) while maintaining theoretical coherence with the original construct. The final version retains a balanced structure, with three items representing each

of the following subscales: (1) self-perception and self-confidence, (2) self-expression and communication with others, and (3) knowledge and understanding, as shown in Table 1. Each item was rated on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). The total PPL score was calculated as the sum of all item scores. In the present study, the internal consistency of the instrument was good (Cronbach's alpha = 0.861), even when each subscale was analyzed in isolation (subscale 1 = 0.778; subscale 2 = 0.613; subscale 3 = 0.754).

Table 1. Spanish perceived physical literacy instrument (S-PPLI) used in this study.

Subscale 1. Self-perception and self-confidence.	
PPL1	I am physically fit, according to my age.
PPL4	I have self-management skills for fitness.
PPL5	I have self-assessment skills for health.
Subscale 2. Self-expression and communication with others.	
PPL6	I have strong social skills.
PPL7	I have confidence in wild/natural survival.
PPL8	I am able to handle problems and difficulties.
Subscale 3. Knowledge and understanding.	
PPL2	I have a positive attitude and interest in sports.
PPL3	I value myself or others by doing sports.
PPL9	I am aware of the health-related benefits of sports.

Note. PPL: perceived physical literacy.

2.5. Statistical Analysis

Data are presented as mean ± standard deviation (SD). The normal distribution of the data and the homogeneity of variances were tested using the Shapiro–Wilk and Levene test, and statistical parametric techniques were performed. A Confirmatory Factor Analysis (CFA) was performed to cross-validate and confirm the three-factor structure derived in the analysis. Pearson's product-moment correlation coefficient (r) with a 95% confidence interval (CI) was used to examine the relationship between PPL domains. The following scale of magnitudes was used to interpret the correlation coefficients: <0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and >0.9, nearly perfect [15]. The t-test for independent samples was performed to evaluate the differences according to sex (i.e., males and females). A one-way analysis of variance (ANOVA) with a least-significant-difference post hoc comparison (Bonferroni correction) was used to examine mean differences among age-groups (i.e., early compulsory secondary education, late compulsory secondary education and baccalaureate). A multivariate analysis of variance (MANOVA) was applied to simultaneously examine sex and age-group effects across the three PPL subscales. Mean differences were calculated in percentage (%Diff.) by the following formula: %Diff. = ((mean 1 − mean 2)/mean 2) × 100. Practical significance was assessed by calculating Cohen's effect size (ES) [16]. ES of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered large, moderate, small and trivial, respectively. Data analysis was carried out using the JASP 0.16.3.0 software (University of Amsterdam, Amsterdam, The Netherlands). Statistical significance was established at $p < 0.05$.

3. Results

The CFA showed the following values: chi square (x^2 = 72.800; df = 24; $p < 0.01$; CFI = 0.990; *RMSEA* = 0.056; and *SRMR* = 0.031), revealing that the three-factor validity of physical literacy was satisfactory (Figure 1).

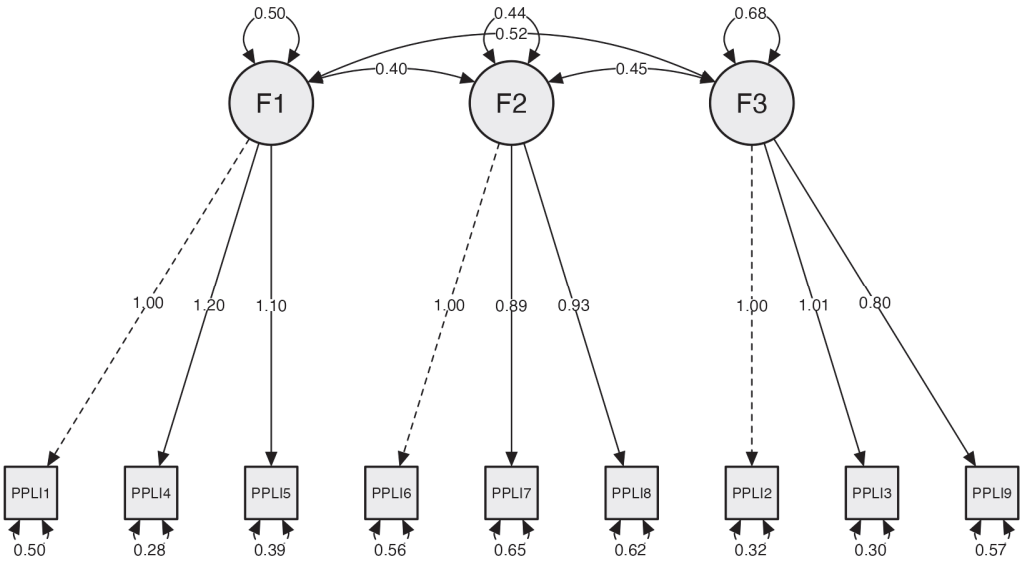

Figure 1. Factor loading of the three-factor model structure for the S-PPLI questionnaire.

Figure 2 displays the descriptive data of each domain of PPLI in Spanish adolescent students showing scores between 3.30 ± 1.16 AU in PPL7 and 4.46 ± 0.83 AU in PPL9. The total score recorded by the 704 students in PPLI was 33.89 ± 6.52 AU. All items (from PL1 to PL9) of S-PPLI demonstrated a significant correlation ($p < 0.001$, $r = 0.212$–0.633 [small to moderate effects]).

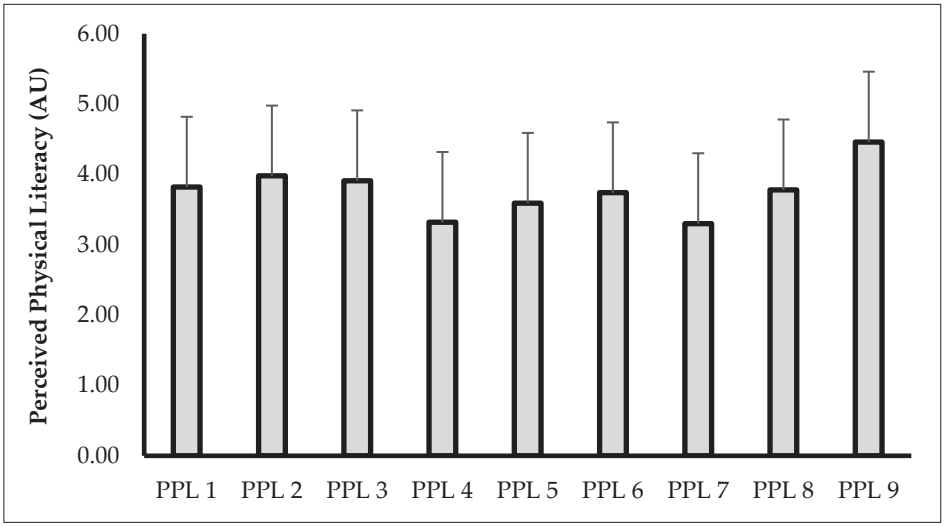

Figure 2. Descriptive data of perceived physical literacy (PPL) in Spanish students.

Table 2 shows the comparisons between males and females in each item and PPLtotal of S-PPLI. Males obtained higher scores from PPL2 to PPL7 ($p < 0.001$–0.027, ES = 0.17–0.67 [trivial to moderate effect]) and in PPLtotal ($p < 0.001$, ES = 0.38 [small effect]) in comparison to females, significantly. Otherwise, no significant differences ($p > 0.05$) were found in PPL1, PPL8 and PPL9 between Spanish males and females. Regarding to the analysis of the three subscales of the questionnaire, higher values were found in all of them in favor of male participants ($p = 0.002$ – <0.001; ES = 0.23–0.51 [small-moderate effect]).

Table 2. Spanish perceived physical literacy instrument (S-PPLI) according to sex in Spanish students.

Domains	Males		Females				
	Mean	SD	Mean	SD	%Diff.	*p*	ES
PPL1	3.85	1.09	3.79	1.02	1.69	0.413	0.06
PPL2	4.29	0.98	3.62	1.19	15.38	<0.001	0.67
PPL 3	4.11	0.99	3.68	1.09	10.53	<0.001	0.44
Subscale 1	11.04	2.78	10.40	2.55	5.80	0.002	0.23
PPL 4	3.48	1.15	3.15	1.16	9.44	<0.001	0.29
PPL 5	3.71	0.99	3.46	0.99	6.60	0.001	0.25
PPL 6	3.82	1.02	3.65	1.08	4.60	0.027	0.17
Subscale 2	11.12	2.34	10.49	2.40	5.67	<0.001	0.27
PPL 7	3.52	1.12	3.06	1.16	13.23	<0.001	0.42
PPL 8	3.78	0.95	3.79	0.98	0.18	0.926	0.01
PPL 9	4.50	0.84	4.40	0.81	2.29	0.100	0.12
Subscale 3	12.90	2.34	11.71	2.51	9.22	<0.001	0.51
PPLtotal	35.05	6.45	32.57	6.35	7.07	<0.001	0.38

Note. PPL: perceived physical literacy; SD: standard of deviation; %Diff.: mean differences in percentage; *p*: level of significance; ES: effect size.

The comparisons according to each group (i.e., early compulsory secondary education, late compulsory secondary education and baccalaureate) in each item and PPLtotal of S-PPLI are presented in Table 3. Baccalaureate students reported higher scores in PPL8 and PPL9 in comparison to early compulsory secondary education students (p = 0.003–0.007, ES = 0.29 [small effect]) and higher PPL8 score than late compulsory secondary education students (p = 0.004, ES = 0.31 [small effect]). Nevertheless, no significant differences ($p > 0.05$) were found from PPL1 to PPL7 between baccalaureate students and the other two age-groups. On the other side, no significant differences ($p > 0.05$) were reported in all PPL domains between early compulsory secondary education and late compulsory secondary education. No between-age groups differences were found attending to the analysis of the three subscales of the questionnaire ($p > 0.05$).

Table 3. Spanish perceived physical literacy instrument (S-PPLI) according to age-group in Spanish students.

Domains	Early Compulsory Secondary Education	Late Compulsory Secondary Education	Baccalaureate	Early vs. Late (%Diff.; *p*; ES)	Early vs. Baccalaureate (%Diff.; *p*; ES)	Late vs. Baccalaureate (%Diff.; *p*; ES)
PPL 1	3.79 ± 1.13	3.85 ± 1.06	3.82 ± 0.94	1.61; 1.000; 0.05	0.87; 1.000; 0.03	−0.73; 1.000; 0.03
PPL 2	4.01 ± 1.16	3.96 ± 1.14	3.97 ± 1.09	1.32; 1.000; 0.11	1.02; 1.000; 0.04	0.30; 1.000; 0.01
PPL 3	3.94 ± 1.12	3.85 ± 1.06	3.95 ± 0.99	2.23; 1.000; 0.08	0.13; 1.000; 0.09	2.36; 1.000; 0.09
Subscale 1	10.62 ± 2.72	10.78 ± 2.78	10.84 ± 2,52	1.48; 1.000; 0.06	2.03; 1.000; 0.09	0.55; 1.000; 0.02
PPL 4	3.27 ± 1.15	3.35 ± 1.20	3.35 ± 1.14	2.39; 1.000; 0.07	2.32; 1.000; 0.07	0.06; 1.000; 0.01
PPL 5	3.56 ± 1.05	3.58 ± 0.97	3.66 ± 0.97	0.67; 1.000; 0.02	2.89; 0.816; 0.10	2.24; 1.000; 0.08
PPL 6	3.73 ± 1.12	3.69 ± 1.07	3.84 ± 0.91	1.23; 1.000; 0.04	2.94; 0.797; 0.10	4.14; 0.341; 0.15
Subscale 2	10.84 ± 2.43	10.67 ± 2.48	11.03 ± 2.20	6.70; 1.000; 0.07	1.72; 1.000; 0.09	3.26; 0.336; 0.16
PPL 7	3.40 ± 1.12	3.29 ± 1.22	3.20 ± 1.13	3.21; 0.850;0.10	5.89; 0.224; 0.18	2.77; 1.000; 0.07
PPL 8	3.71 ± 0.98	3.70 ± 0.97	4.00 ± 0.90	0.43; 1.000; 0.02	7.03; 0.007; 0.29	7.43; 0.004; 0.31
PPL 9	4.35 ± 0.91	4.45 ± 0.83	4.61 ± 0.66	2.16; 0.546; 0.11	5.74; 0.003; 0.29	3.66; 0.098; 0.20
Subscale 3	12.30 ± 2.65	12.25 ± 2.49	12.53 ± 2.25	0.41; 1.000; 0.02	1.84; 1.000; 0.10	2.23; 0.756; 0.12
PPLtotal	33.75 ± 6.78	33.68 ± 6.66	34.38 ± 5.92	0.23; 1.000; 0.01	1.81; 0.973; 0.09	2.04; 0.792; 0.11

Note. PPL: perceived physical literacy; SD: standard of deviation; %Diff.: mean differences in percentage; *p*: level of significance; ES: effect size.

In addition, the MANOVA revealed no significant interaction effect between sex and age group on PPL subscales (p = 0.433).

4. Discussion

Understanding PPL could be a key strategy of compulsory secondary education to improve adolescents' physical activity levels, and thus to foster an active and healthy lifestyle that helps to reduce health problems in adulthood. In this regard, the main aim of this study was to analyze the differences in PPL considering the sex dimension and the age group among Spanish adolescents. This is the first study to examine PPL in Spanish adolescents, differentiation between three different age groups, which provides highly valuable information that covers a large part of adolescence, and its changes related to PPL. The main findings showed that males obtained higher scores in some indicators of PPL compared to females, and the oldest age-group reported higher scores in the indicators of knowledge and understanding subscale compared to students in the early years of compulsory secondary education.

To advance understanding of adolescents' PPL, analysis must extend beyond aggregate scores to examine individual categories comprised by the S-PPLI questionnaire. When considering the entire cohort, mean item scores consistently exceeded the scale midpoint, ranging from 3.30 $\pm$ 1.16 AU (Item 7: *I understand how physical activity benefits my health*) to 4.46 $\pm$ 0.83 AU (Item 1: *I feel confident when trying new physical activities*), with an overall mean of 3.77 $\pm$ 0.35 AU. The cumulative S-PPLI score of 33.89 $\pm$ 6.52 AU further reflects moderate-to-high PPL perceptions, a finding that contrasts with reports of low physical literacy in comparable populations [17]. This controversy may partly reflect methodological differences, as the cited study employed distinct assessment tools. Crucially, these results underscore the need for a more comprehensive investigation about the topic (i.e., sex and age-group differences) to inform targeted educational strategies. Also, these results could be influenced by the specific socioeconomic characteristics of the participants (i.e., medium level), who, in general, have access to different extracurricular activities related to physical activity and sport, which could be limited in low socioeconomic contexts.

Traditionally, it has been observed that females tend to have lower levels of physical fitness and physical activity compared to males [18,19]. Therefore, it seems necessary to compare their levels of PPL, as this could provide relevant evidence to help reduce these inequalities [2]. In our study, males scored significantly higher than females on items PPL2 to PPL7 and on the total PPL score. Also, these differences were found in the three subscales. In this way, males showed higher values in self-perception, self-confidence, self-expression and communication with others, and knowledge and understanding. While statistically significant, these findings warrant cautious interpretation given their consistently trivial-to-moderate effect sizes, suggesting practical applications would require holistic, sustained interventions rather than isolated adjustments. However, no significant differences were found in PPL9 —I am aware of the health-related benefits of sports. The absence of gender differences in this item carries significant pedagogical implications. While gendered disparities persist in motivational and behavioral domains [9,11], this finding suggests that school-based health education, when delivered through standardized curricula and evidence-based public health messaging, can effectively transcend sociocultural gender barriers to knowledge acquisition. This aligns with competency-focused pedagogical models in Spain's educational framework, where health literacy constitutes a cross-cutting objective in secondary education. The finding suggests that cognitive outcomes in health education are more equitably achievable than attitudinal or behavioral outcomes, highlighting structured pedagogy's potential to mitigate gender gaps in Science, Technology, Engineering, Mathematics (STEM)-related health knowledge. Along these lines, other authors have also found that males aged 8 to 12 report higher total PPL and greater life satisfaction than females [12], indicating that such findings are also present at lower educational levels. Despite geographical diversity among participating high schools, these results suggest that

Spain's standardized public school system and national policies drive consistent outcomes. Nevertheless, Tremblay et al. [17] did not find such sex-based differences in PPLtotal in a study involving 10,034 Canadian participants aged 8 to 12. These discrepancies could be partially explained by cultural factors and the specific sample involved, such as prevailing gender norms, traditional views on physical activity, or educational priorities in Spanish society. In the current Spanish context, for instance, physical activity may still be influenced by gendered expectations or limited by institutional constraints within the school system. However, due to the scarcity of specific empirical studies on these cultural dimensions, further research is needed to clarify their exact influence. Based on the aforementioned findings, it could be interesting to promote physical activity programs tailored to the interests of females, moving away from traditional sports that may be sexualized and/or carry an exclusive cultural weight. This would help girls feel more comfortable and confident when engaging in physical activity, enabling them to more strongly adhere to the physical activity and fitness practices proposed in school and extracurricular programs, thereby improving their healthy lifestyle habits and their overall relationship with physical activity. No between-gender differences were obtained when subscales were analyzed, suggesting that is necessary to perform item-by-item analyses in order not to overlook significant differences.

PPL analysis highlights how adolescents relate to physical activity and healthy lifestyle habits, which may have a direct influence on their behaviors and routines in adulthood. [19]. The ENERGYCO study [20] associated high levels of PPL not only with greater physical activity, but also with better sleep patterns and less screen time. In the present study, age was found to be an influential factor in adolescents' PL, as Baccalaureate students reported higher scores in PPL8 and PPL9 compared to early compulsory secondary education students, and higher PPL8 scores than late compulsory secondary education students. In this regard, it could be that older students are more mature and better able to cope with challenges and identify the benefits of engaging in physical activity [21]. Also, in the second year of Baccalaureate, Physical Education lessons are voluntary, so it is possible that most interested students have chosen this, related to higher values of PPL. Likewise, future studies could incorporate differential item functioning analyses to ensure the measure's reliability and validity across diverse adolescent age groups. On the other hand, no significant differences were found in the PL domains between early and late compulsory secondary education students. These results may be explained by the standardized curricula possibly not matching advancing neuromotor skills, while the shift from skill acquisition to specialization and peer conformity can stabilize perceived competencies. Therefore, it would be advisable to include learning situations in the physical education curriculum [22] that enable younger students to effectively resolve challenges and develop greater awareness of the benefits of physical activity. In addition, no significant differences were found when subscales were analyzed, suggesting the relevance of perform item-by-item analyses. Similarly, no significant differences were obtained when simultaneously examining gender and age group, reinforcing the initial idea of doing so in isolation, due to the marked and differentiated characteristics between male and female adolescent students, to avoid biasing the information and ignoring between-gender differences masked by the influence of age. Future research should adopt longitudinal designs to examine how PPL changes over time and investigate potential mediating factors that might explain the observed sex and age differences.

This study has several limitations. First, a more balanced distribution of participants across age groups and involving more than three public schools would have provided more accurate and generalizable data for comparison. Second, the absence of information on participants' extracurricular physical activity levels, an important factor influencing

adolescents' PPL [13,14,20], limits the interpretation of results. Additionally, future research should adopt a longitudinal design to assess PPL domains throughout adolescence, enabling better alignment of both curricular and extracurricular physical activity programs with developmental needs. Third, we acknowledge that BMI and certain physical fitness profiles may be related to certain components of PPL [23], and future research could incorporate these data to more comprehensively understand the factors influencing physical literacy development. Finally, an important limitation is the homogeneity of the sample, composed exclusively of public-school students from three Spanish regions, predominantly representing middle-class socioeconomic status. Socioeconomic factors significantly influence both access to physical activity opportunities and the development of physical literacy competencies [24]; therefore, these findings should be interpreted with caution when considering their applicability to other populations. This limits the generalizability of the findings to students from private schools, other regions, or significantly different socioeconomic contexts. However, this focus provides a context-specific understanding of the reality within public schools in these regions under these prevailing conditions.

5. Conclusions

The findings of this study showed that males presented higher scores in PPL domains compared to females, highlighting better self-perception, self-confidence, self-expression and communication with others, and knowledge and understanding. In addition, while Baccalaureate students reported higher scores in knowledge and understanding compared to early and late compulsory secondary education students, there are no significant differences between early and late secondary education students. These results provided valuable insights for professionals in charge of designing and adjusting the educational curriculums in physical education, such as integrating more student-centered activities, promoting inclusive teaching strategies, or emphasizing physical literacy development based on students' diverse needs and experiences. Future research could explore the long-term effects of school-based research interventions on PPL through longitudinal designs. In practical terms, given females' lower physical literacy levels identified in this study, we recommend integrating gender-tailored physical activity programs into school curricula through three approaches: activity diversification by replacing traditional sports with non-competitive alternatives (e.g., dance, martial arts, adventure circuits) aligned with female adolescents' interests; pedagogical adaptation through educator training to create psychologically safe environments using single-gender sessions, body-neutral language, and student-co-designed challenges; and curricular embedding by allocating approximately 30% of mandatory physical education time to these tailored modules, complemented by flexible after-school activity hubs where students select a non-traditional physical option. This framework moves beyond theoretical suggestions to provide implementable pathways for reducing gendered barriers while advancing physical literacy development.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data would be available after request to the corresponding author due to privacy reasons.

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children

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Article

Influence of Screen Time on Physical Activity and Lifestyle Factors in German School Children: Interim Results from the Hand-on-Heart-Study ("Hand aufs Herz")

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Abstract: Background/Objectives: Today, digital technologies are integral to children's lives; their increasing use, however, may raise health concerns. This study aims to examine the effect of screen time on physical activity and lifestyle factors in German school children. **Methods**: As part of the prospective hand-on-heart-study ("Hand-aufs-Herz"), a comprehensive cardiovascular system check-up examination was conducted on 922 German schoolchildren. The pupils were asked for a self-report on their daily physical activities and club sports. The examinations on-site contained measurements of the pupils' weight and height as well as their physical fitness, which was assessed by a stair-climbing test. **Results**: A large proportion of pupils had a screen time of more than 2 h daily, regardless of the day of the week (63–76%). In fact, pupils with a screen time $\geq$ 2 h were more likely to achieve poor grades in school (weekday ORs 3.23, 95% CI 1.76, 5.95; weekend ORs 3.28, 95% CI 1.53, 7.00) and not be members of a sports club (weekday ORs 2.35, 95% CI 1.68, 3.29; weekend ORs 2.13, 95% CI 1.44, 3.14). Pupils who did not meet both recommendations for physical activity and screen time walked <5000 steps daily (60%), had a high proportion of overweight/obesity (40%), were non-swimmers (38.5%), spent $\geq$7 h sitting (35.8%), and slept fewer hours than recommended (30%). It has also been shown that longer screen time has a negative impact on the lifestyle of children and young people. **Conclusions**: Our results show that excessive screen time in children is linked to higher weight and an unhealthy lifestyle, increasing long-term cardiovascular risks. Public health initiatives aimed at reducing screen time, promoting physical activity, and encouraging healthier habits are essential to improve children's overall health and prevent future chronic diseases.

Keywords: physical activity; screen time; BMI; adolescents; sports clubs; hand-on-heart-study ("Hand aufs Herz")

1. Introduction

Cardiovascular diseases (CVDs) remain the number one cause of death in industrialized countries and account for about 11% of health expenses in Europe [1]. Cardiovascular diseases not only affect adults but can also originate in childhood, even if they do not manifest themselves at that time [2,3].

The risk factors for future CVDs can exist during childhood [4] but are modifiable [5]. The importance of physical activity (PA) in preventing CVDs has been widely recognized

and regular exercise helps improve cardiovascular health by lowering blood pressure, reducing cholesterol levels, improving blood circulation, and preventing obesity, all of which are key risk factors for heart disease [6,7]. It has already been shown that overweight and obese adolescents have significantly lower cardiorespiratory fitness than their normal-weight peers [8]. In fact, lower physical fitness is a proven independent risk factor for all-cause mortality, regardless of weight status [9].

Despite the known benefit of physical activity [10], 81% of adolescents aged 11–17 years worldwide are physically inactive [11]. In Germany, most children and adolescents are inactive [12], with studies revealing that only 22% of girls and 29% of boys aged 3–17 meet the World Health Organization's (WHO) recommendation of being active for at least 60 min a day. The proportion of children who fulfil the recommendations decreases continuously with age [3,4]. The rising levels of inactivity are concerning, particularly in relation to the growing amount of screen time, which has become a major factor in promoting sedentary behavior among young people [1]. Children and youth today are growing up in a world where both traditional and modern digital media are an integral part of everyday life [13]. Traditional media, such as television, coexist with newer formats like apps, video games, YouTube, and vlogs. Televisions, smartphones, computers, laptops, and internet access are now standard in almost every household [14,15].

Over the past decade, young people have increasingly spent more time using digital media [14]. A large study from 22 countries has found that more than 1 in 10 adolescents (11%) have signs of problematic social media behavior, struggling to control their use and experiencing negative consequences [16]. In 2022, a survey conducted in Germany with 1219 children aged 6 to 13 years found that 81% of 12- to 13-year-olds already owned their own smartphone. Television remained one of their favorite leisure activities, with 92% of children watching television regularly, and 67% even watched it every day [15]. Just two years later, almost every child between the ages of 12 and 19 years owned a smartphone [17]. A more recent German survey showed that screen time increases with age: 10–12-year-olds spent an average of 87 min per day online, 13- to 15-year-olds spent 140 min, and 16- to 18-year-olds spent 166 min [18]. These figures exceed the recommended screen time limits, which suggest a maximum of 45 to 60 min for children between the ages of 9 and 12 and 120 min for adolescents aged 12 to 16 years [19]. Not only might media consumption have an impact on children's physical activity and fitness; participation in club sports also plays a decisive role. Young people who regularly took part in organized sport activities, whether in clubs or at school, showed a higher overall level of activity and better physical fitness than their peers who did not participate [8].

In addition to the alarming trends in screen time and physical activity among children and adolescents, studies also show worrying results concerning sleeping habits. A study of German schoolchildren aged 9 to 18 found that only half of them were getting the recommended amount of sleep. If the recommendations for screen time and exercise are also taken into account, only 9.7% of children met all three guidelines [20].

To summarize, there is a worrying trend about sleeping habits, lack of exercise, and increasing screen time. Obesity and a lack of physical activity are among the main risk factors for cardiovascular disease. This raises the question of the extent to which increased media consumption not only reduces daily exercise but also contributes to weight gain and has a negative impact on other lifestyle habits. In the present study, we investigated the influence of screen time on physical fitness and lifestyle by combining the results of a self-report on daily physical activities with a standardized fitness test.

2. Materials and Methods

2.1. Study Population

In this ongoing study, a total of 922 pupils at a secondary school in the rural Munich area, including siblings, were enrolled between April and July 2024. The consent of both parents was required for participation in our study. For the current analysis, young adults (aged 18 to 20 years) were excluded, and the data of 883 children and adolescents aged between 8 and 18 years were analyzed.

2.2. Procedure

The study presented here bases itself on data collected with the project hand-on-heart ("Hand-aufs-Herz", German Clinical trial register DRKS00033999), a prevention project of the Department of Pediatric Cardiology of the University Hospital Munich [21]. Ethical approval to perform this study was granted on 15 April 2024 with the project number (24-0147) by the Ethics Committee of the Ludwig-Maximilians-Universität.

At the beginning, the project was presented to the parents in a letter and with information flyers handed out to school management and supervising teachers. This was followed by a parents' evening at which the parents were informed again in detail. The project was presented to all pupils on a class-by-class basis. Registration was carried out via a written form; the signature of both parents was required for participation. The tests were carried out by our study team in the school. All participants presented themselves once, and parents were informed of the dates in advance by email. The examinations lasted 45 to 60 min per participant, of which 15 to 20 min were needed to answer the questionnaire on a tablet.

The study team consisted of three doctors and a total of ten students from the healthcare sector. Two doctors and three to four students were present per day. The doctors are members of the Pediatric Cardiology Department of the University Hospital Munich and are experienced in the diagnostic methods used. The students received a detailed briefing from the doctors, initially carried out the assigned tasks under supervision, and were allowed to work independently if they performed satisfactorily.

2.3. Instruments

All pupils underwent a detailed cardiovascular examination, including a questionnaire comprising items on their health status, physical activity, and sedentary behavior. The survey was created with REDCap 14.6.7. Comprehensive data were collected on health and fitness: frequency of daily and weekly physical activity, school grade in Physical Education, swimming ability, steps during the day, sedentary behavior, and screen time during the week and on weekends. The questionnaires were answered under pseudonyms without the presence of parents and teachers to ensure the honesty of the children.

Firstly, the participants were asked whether they would describe themselves as fit. This question could be answered with yes or no. With regard to physical activity, the students were first asked how long they were physically active per day in a typical week; the activities were categorized into moderate to vigorous intensity, vigorous intensity, and those that reinforce muscle strength, in accordance with the WHO guidelines [22]. The answer options were less than an hour, one hour, one to two hours, or more than two hours for moderate to vigorous activity and less than once a week, once a week, two to three times a week, and more than three times a week for vigorous activity and those that strengthen the muscles. According to the WHO guidelines, at least 60 min of moderate to vigorous activity per day as well as performing vigorous activity and those strengthening the muscles at least three times a week were defined as being in line with the recommendations. The pupils were also asked if they were members of a sports club. If the answer was yes, the

type of sport should be indicated. In the questionnaire, the students were also asked to indicate the sports grade of their last school report: the possible answers were 1 to 6, with 1 being the best and 6 the worst grade in the German school system. They were also asked whether they could swim, with the answer options ranging from yes very well to a little to no. The students were also asked whether they could swim 100 m at a stretch. The students who measured their daily step count with their mobile phone should indicate whether they take less than 5000 or less or more than 10,000 steps a day. If daily step count was not measured, the answer option "do not track" was to be chosen. Screen time was to be given in full hours, once for weekdays and once for weekends, with possible answers ranging from 1 to 8 h. In addition, the daily sitting time was surveyed; here, the participants could choose between less than three, 3–5 h, 6–7 h, or more than 7 h. Finally, the students were asked whether they have sleep problems and how many hours they sleep per night during the week or at the weekend (<5, 5–6, 6–7, 8–9, >10 h). The questionnaires were analyzed by a team of three people according to the four-eyes principle using a fixed scheme.

The weight and height of the participants was measured on-site by our study team. The participants were asked to remove shoes, heavy clothing, jewelry, and any items in their pockets. The weight was assessed with portable electronic scales. The children were asked to stand in the center of the scales and let their arms hang loosely beside their bodies. They were instructed to stand still to enable an accurate measurement. The weight was recorded in kg to one decimal place when the scale showed a fixed value on the display. For height measurement, the participants were asked to stand up straight against a wall, making sure that their shoulders were at the same height, their knees were together, and their arms were hanging beside their bodies. The head, buttocks, or heels should touch the wall in at least two places. The children were asked to stand still and fixate on a point straight in front of them. The height was measured using a board which was placed on a right angle to the measuring stick. The values were measured to the nearest half a centimeter and rounded down if necessary.

The following formula was used to calculate the body mass index (BMI). Overweight and obesity were defined as recommended by the German obesity society (overweight weight percentile > 90–97, obesity if weight percentile > 97) [23].

Physical fitness was measured using a stair-climbing test, a standardized exercise test that was further developed and adapted by the Department of Pediatric Cardiology at the LMU [24]. The test was carried out on-site by the study team and subsequently evaluated. The test consists of running up and down four floors as quickly as possible, where each step must be taken individually. All participants were cheered on with the same phrases. The time required was measured in seconds using a stopwatch. Age- and gender-dependent cut-off values were used for the test. Based on the time achieved, the fitness of the participants was rated as good (males <10 y 40–55s, males >10 y 40–50s, females all ages 40–55s), moderate (males <10 y 55–75s, males >10 y 50–65s, females <10 y 55–75s, females >10 y 55–70s), or poor (males <10 y >75s, males >10 y >65s, females <10 y >75s, females >10 y >70s).

Physical activity was defined as the number of hours spent engaging in sport according to the questionnaire completed by the students, while physical fitness was the result of the stair-climbing test, which was carried out on-site.

2.4. Statistical Analysis

The characteristics of the study population, such as sex, age, BMI, and school level, were compared between the categories of screen time (within recommendations, $\leq$2 h versus exceeding recommendations, >2 h) during the weekday and weekend [19]. The key outcome variables, including sports grade, self-assessed fitness, swimming ability,

and PA behaviors (steps per day, time spent on PA per day, and time spent on high-pulse and muscular PA per week), were summarized and compared between males and females. To examine group differences for continuous variables, Student's *t*-tests were performed, and to evaluate differences between proportions of categorical variables, chi-square tests were used. Univariate logistic regression models were employed to explore the relationship between sex and binary outcomes and to quantify changes in mean BMI by sport club membership. Multivariable logistic models were adjusted for age. Effect sizes were reported where relevant (odds ratios with 95% confidence intervals). Statistical significance was set at an alpha level of 0.05. All analyses were conducted using R version 4.4.2 (2024-10-31 ucrt) [25].

3. Results

Of the total number of pupils enrolled in this ongoing study (n = 922), 883 pupils aged between 8 and 18 were included in the analysis. The characteristics are shown in Table 1. The mean (SD) age of the children was 13.1 (2.4) years, and the proportion of girls was 46% (n = 406). The mean (SD) BMI of the included pupils was 19.4 (3.7) kg/m^2. Most of the children and adolescents (68.4%) attended secondary school.

Table 1. Characteristics of the hand-on-heart-study population.

Characteristics	All Children	Screen Time During Weekday			Screen Time During Weekend		
		≤2 h	>2 h	*p*-Value	≤2 h	>2 h	*p*-Value
Number of pupils, N	883	324	559		213	670	
Sex				0.292			0.805
Male	477 (54.0)	167 (51.5)	310 (55.5)		113 (53.1)	364 (54.3)	
Female	406 (46.0)	157 (48.5)	249 (44.5)		100 (46.9)	306 (45.7)	
Age, years	13.1 (2.4)	11.7 (2.2)	13.9 (2.1)	<0.001	11.3 (2.2)	13.6 (2.1)	<0.001
Body mass index (BMI), kg/m^2	19.4 (3.7)	18.0 (3.2)	20.2 (3.7)	<0.001	17.6 (3.1)	20.0 (3.7)	<0.001
School level				<0.001			<0.001
Primary school	100 (11.3)	81 (25.0)	19 (3.4)		63 (29.6)	37 (5.5)	
Middle school	58 (6.6)	10 (3.1)	48 (8.6)		9 (4.2)	49 (7.3)	
Secondary school	604 (68.4)	189 (58.3)	415 (74.2)		111 (52.1)	493 (73.6)	
High school	121 (13.7)	44 (13.6)	77 (13.8)		30 (14.1)	91 (13.6)	

Data are mean (SD) or *n* (%) and tested with regard to screen time per weekday or weekend using Student's *t*-test for continuous and $\chi 2$ test for categorical variables.

In terms of media consumption, 324 children spent 2 h or less in front of a screen during the week, whereas 559 children spent 3 h or more. On the weekend, nearly 3 in 4 children (670/883) indicated >2 h of screen time, while 24.1% (213/883) indicated ≤2 h.

Regarding differences in screen time, no significant differences were found between males and females, regardless of day of the week. However, compared to children with ≤2 h of screen time during the week, children who had screen time >2 h during the week were older (mean [SD]: 13.9 [2.1] years versus 11.7 [2.2]), had a higher BMI (mean [SD]: 20.2 [3.7] kg/m^2 versus 18.0 [3.2] kg/m^2), and were more frequently in secondary school (74.2% versus 58.3%). The results were similar for screen time on weekends.

3.1. Influence of Screen Time on Sport Outcomes

As shown in Table 2, children who had >2 h of screen time (versus ≤2 h) during the week were 3.23 (95% CI 1.76, 5.95) times more likely to receive a grade of 3 or worse in sports and 2.35 (95% CI 1.68, 3.29) times more likely not to be a member of a sports club. The association remained significant after adjusting for age. We found similar results for

screen time on weekends, although the association between sports club membership and weekend screen time disappeared after adjusting for age.

Table 2. Sports grade and sports club membership by screen time.

Outcome		Screen Time During Weekday		Screen Time During Weekend	
	N	Unadjusted	Age-Adjusted	Unadjusted	Age-Adjusted
Sports grade at school					
1	524	Reference	Reference	Reference	Reference
2	288	**2.14 (1.57, 2.92)**	**1.80 (1.27, 2.54)**	**1.93 (1.35, 2.76)**	**1.52 (1.03, 2.25)**
≥3	71	**3.23 (1.76, 5.95)**	**2.82 (1.46, 5.42)**	**3.28 (1.53, 7.00)**	**2.69 (1.20, 6.01)**
Sports club membership					
Yes	639	Reference	Reference	Reference	Reference
No	244	**2.35 (1.68, 3.29)**	**1.75 (1.22, 2.53)**	**2.13 (1.44, 3.14)**	1.48 (0.97, 2.25)

Values are odds ratios and 95% confidence intervals based on logistic regression. The influence of screen time ≥ 3 (test) versus ≤2 h (control) was assessed for each outcome. Bold font indicates $p < 0.05$.

3.2. Adherence on Screen Time and Physical Activity Recommendations

The evaluation of the pupils' physical fitness revealed that 30% showed moderate to poor fitness and 70% showed a good fitness level (Figure 1A). Regarding the recommendations for screen time, only about 17.9% of the children met the recommendations (Figure 1B). Considering both physical activity and screen time together, it was found that only about 11.9% of the study participants met the recommendations for both, about 61.6% met one of the two, and 26.5% did not follow either recommendation (Figure 1C).

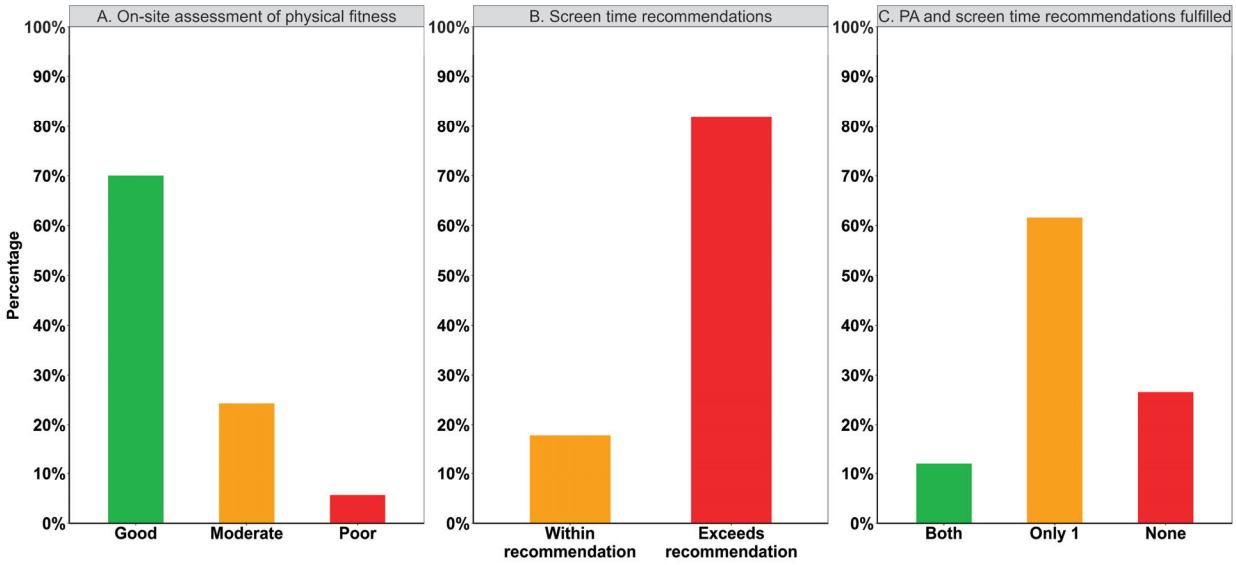

Figure 1. Proportion of children adhering to screen time and physical activity recommendations. (**A**) shows the results of the physical fitness assessment on-site. (**B**) shows proportion of pupils within or exceeding screen time recommendations. (**C**) shows proportion of children who fulfill both, only 1, or none of the recommendations.

3.3. Lifestyle Indicators and Adherence to Screen Time and Physical Activity Recommendations

Lifestyle indicators and adherence to physical activity and screen time recommendations are depicted in Figure 2. Approximately 56.3% of children who self-reported that they were not fit did not meet either the recommendations on screen time nor the ones for physical activity (Figure 2A). A large proportion of the children who did not fulfil both of the two recommendations for physical activity and screen time were not members of a sports

club (53.3%, Figure 2B), had a school grade of ≥3 in Physical Education (52.1%, Figure 2C), walked <5000 steps per day (60%, Figure 2D), spent ≥7 h sitting (35.8%, Figure 2E), had a high proportion of overweight or obese (40%, Figure 2G), were non-swimmers (38.5%, Figure 2H), and slept for less than the recommended hours (30%, Figure 2I).

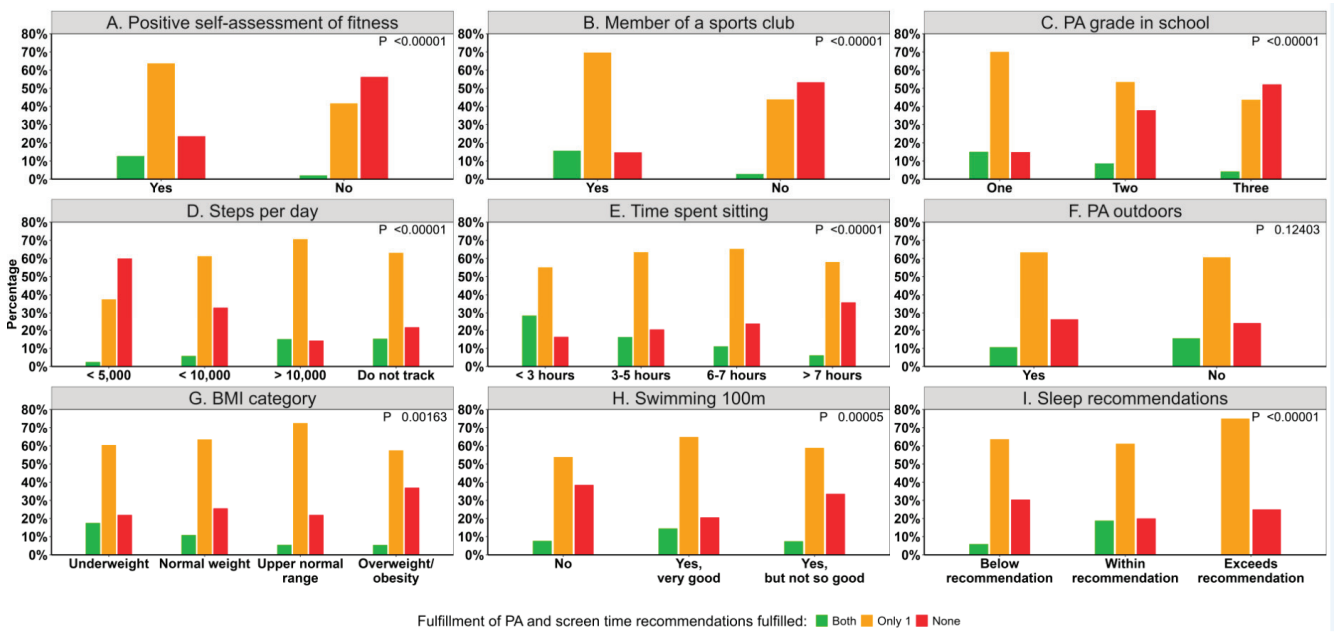

Figure 2. Lifestyle indicators according to adherence to screen time and physical activity recommendations. *p*-values are based on χ2 test.

4. Discussion

The prevention project hand-on-heart ("Hand-aufs-Herz") is an ongoing project that has collected data from almost 900 German school children. The children and adolescents completed a questionnaire which included questions on media consumption, daily step count, membership in a sports club, and a self-assessment of their daily physical activity. Biometric data such as height, weight, and BMI were measured on-site. This study aimed to investigate the influence of screen time on children's lifestyle and physical fitness.

The results of our study raise concerns. Only around 20% of children complied with the recommended limit of, depending on age, 1–2 h of screen time per day. If the daily recommended minimum duration of physical activity is also considered, the proportion of children who followed both recommendations fell to only 10%. In a comparable study, higher adherence to the recommendations was found, but the results were still worrying: only around a third of the 15,000 included children met the recommendations for screen time and physical activity [20]. The recommendations are based on the guidelines of the Federal Centre for Health Education (BzgA) and the WHO and are supported by several German medical associations like the German Society for Paediatric Cardiology [19,22,26].

Children today grow up with the daily use of media [14]. Our study found that almost 3 out of 4 children spend 3 h or more in front of a screen on the weekend. Other studies confirmed these results. In more than 100,000 children aged 6 to 14, a similar average screen time of almost 3 h per day was found, a value that is considered too high at any age according to the guidelines [19,27]. These studies clearly demonstrate that high media consumption is prevalent. It should be kept in mind that excessive use can have negative consequences on health and behavior. Obesity can be a consequence of media consumption and is encouraged by it [28]. Excessive media use can also lead to sleep disorders, poorer school performance, and behavioral problems [29].

In the present study, the consequences of excessive digital media use were identified: children spending more hours in front of a screen are more likely to be physically inactive. These results were confirmed by another study, which linked screen time to physical activity in everyday life [30]. In addition, this study found that children's BMI was positively correlated with screen time. Children who spent less than two hours in front of a screen at weekends had an average BMI of 17.6, while children with more than two hours of screen time had an average BMI of 20.

This was further validated by a study that also showed a correlation between BMI, the amount of digital media consumption, and physical activity. Children who were overweight tended to exercise less and spend more time in front of screens. The screen time of children with a BMI of <90. Pzt. was 12.6 $\pm$ 9.7 h/week vs. the screen time of those with a BMI of >90. Pzt., which was 18.3 $\pm$ 15.7 h/week. A total of 57% of normal-weight children also took part in sport outside of school, compared to only 32% of overweight children [31].

It was additionally observed that non-compliance with the recommendations for physical activity and screen time can have an impact on lifestyle. A large proportion of the children who did not meet either recommendation did not attend a sports club, walked less than 5000 steps per day, sat for more than 7 h per day, scored 3 or worse in sports, and were overweight or obese. Research has also previously demonstrated that there is a correlation between exercise behavior, dietary habits, and smoking status [3]. Digital media consumption increases with age [18]. The results of this study also show that older children were more likely to have screen time that exceeded the recommendations.

In summary, it can be said that this study produced similar results to preceding studies. Children with too much screen time also displayed sedentary behavior and had a higher risk of becoming overweight. They were also less likely to be members of a sports club and had a lower daily step count. The special feature of this study is that, in addition to the self-assessment, physical fitness was analyzed on-site using a stair-climbing test [24].

Exercise has many positive effects on the body and the mind. However, less active lifestyles have increased the rate of obesity and associated health problems [32]. Physical activity has important health benefits, including lower blood pressure, lower BMI, and improved triglyceride levels [3]. Fitness is an independent risk factor for cardiovascular disease and should be given special consideration [3]. The fitness of children and adolescents decreases with increasing media consumption, which underlines the need to take preventive measures at an early stage. At the same time, it is evident that the younger generation's interest in digital media is growing steadily, and their daily use of it has become indispensable in everyday life.

Considering the results of this study, it is crucial to develop preventive measures and continue to implement existing ones. Parents are cautioned and asked to consider media use according to the age, health, and developmental stage of each child [14]. Further studies show how important it is to develop a health promotion program that includes promoting the recommended amount of physical activity and screen time [20,33]. In addition, the focus should be directed towards more physical activity for children and adolescents in schools [3].

With regard to the problem of overweight children, it was found that simply increasing physical activity only brings about limited benefits. Rather, it was shown that reducing sedentary behavior is a much more effective strategy for preventing and reducing obesity [3]. In contrast, a meta-analysis showed that although interventions on media consumption could reduce children's screen time, no effect on BMI was achieved [34]. For our study, this means that although a link between high media consumption, obesity, and lack of exercise was found, the solution does not lie in reducing screen time alone. Rather,

lifestyle, especially sedentary behavior, should also be considered. In this regard, holistic lifestyle interventions and their impact on obesity in children and adolescents should be further studied, preferably with larger sample sizes [34].

It also became clear that the real-life effects of measures to promote physical activity can only be determined if sufficient previous comparative data are available [30]. In order to obtain better data, fitness should be measured in an objective manner, and the result should then be compared to the children's statements. Therefore, we included a dedicated and standardized fitness test in our screening process. As fitness is an independent risk factor for cardiovascular disease, the focus should not only be on surveying the media consumption of children and adolescents but be, in particular, on the objective and meaningful recording of fitness in order to develop targeted preventive measures on this basis.

Despite efforts to create a standardized setting, our study has some limitations.

Daily and weekly physical activity and screen time were collected using a questionnaire that required a certain sense of time. This ability may not yet be fully developed in younger children. Questionnaires were also used in other studies to assess these aspects, although age dependency could play a role, such as in a study with 9- to 18-year-olds [20].

In addition to a basic sense of time and understanding, the value of the data collected was based on the honesty of the answers collected. However, children may have concealed their actual habits for fear of consequences. One study tried to circumvent this by having parents fill out the questionnaires, but this could lead to bias as they often do not know their children's media consumption and activity in detail [31].

In addition to the steps already taken, as outlined in the Methods Section, better documentation of screen time without being dependent on the subjective assessment of the children could be made possible by recording the time using the electronic devices themselves, which already record screen time.

5. Conclusions

Our results confirm the negative effects of too much screen time on the lifestyle of children and adolescents, which have already been investigated. We show that pupils showing excessive media consumption are more likely to consider themselves as not fit and conducted a standardized fitness test to objectify this finding.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the medical faculty of the Ludwig-Maximilians-University Munich (protocol code 24-0147 and date of approval: 15 April 2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study. For minors, a declaration of consent was obtained from parents and children.

Data Availability Statement: Data cannot be shared publicly because the participants did not provide explicit consent for data sharing in accordance with the European Union's General Data Protection Regulation and relevant German privacy laws. However, data can be made available to researchers who meet the criteria for access to confidential information through the Research

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Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body mass index
ORs	Odds ratio
PA	Physical activity
SD	Standard deviation
WHO	World health organization

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Active Minds, Healthy Bodies: Investigating Physical Activity, Barriers, and Health Outcomes in Saudi Adolescent Females

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Abstract: Background: Physical inactivity among adolescents, particularly females in conservative societies like Saudi Arabia, poses significant risks to both physical and psychological health. Cultural norms, environmental constraints, and limited access to gender-appropriate sports facilities further exacerbate the problem. Understanding these factors is essential for developing effective, context-sensitive interventions. **Aim:** This study aimed to examine the relationship between daily physical activity behaviours and health outcomes, both physical and psychological, among adolescent females in Saudi Arabia. This paper also explores the impact of socio-environmental variables such as income, household size, and urban/rural residence on activity levels and wellbeing. **Methods:** A cross-sectional survey of 636 adolescent females aged 13–21 was conducted using validated instruments. The Physical Activity Questionnaire for Adolescents (PAQ-A) measured physical activity levels, and the Self-Rated Health (SRH) assessed psychological wellbeing and health-related quality of life. The analysis employed an Ordinal Logistic Model (OLM) guided by the Social Ecological Model (SEM) to assess predictors of physical activity participation. **Results:** The OLM results indicated that higher income levels, smaller household size, urban residence, and older age categories were significantly associated with higher levels of physical activity ($p < 0.05$). Participants with higher PAQ-A scores reported better psychological health and quality of life. The model showed a good fit, with a pseudo-R^2 of 0.36. Cultural and environmental barriers, particularly in rural areas, were identified as significant deterrents to participation. **Conclusions:** The findings highlight the urgent need for culturally adapted, gender-sensitive health promotion programs that target both individual and structural barriers to physical activity among adolescent girls in Saudi Arabia. Enhanced societal support and accessible sports infrastructure could significantly improve health outcomes and quality of life.

Keywords: adolescents; physical activity; Saudi Arabia; PAQ-A; SEM; Ordinal Logistic Model (OLM); Self-Rated Health (SRH); environmental barriers

1. Introduction

Regular physical activity is a critical determinant of physical, psychological, and social wellbeing among children and adolescents. It supports healthy growth and development, reduces the risk of non-communicable diseases, and enhances mental health and quality of life [1–5]. However, global trends show a marked decline in activity levels among youth, with adolescent girls particularly at risk of physical inactivity due to intersecting social, environmental, and cultural barriers [6].

In Saudi Arabia, these challenges are exacerbated by unique sociocultural dynamics, including restrictive gender norms, limited access to female-friendly sports facilities, and the inconsistent implementation of physical education programs for girls [7,8]. Although national initiatives such as Saudi Vision 2030 are promoting inclusive and health-oriented lifestyles, adolescent females still face substantial structural and cultural obstacles to regular physical activity [9]. These realities highlight the urgent need for context-specific research to understand how social support, environmental access, and cultural attitudes intersect to influence the physical and psychological wellbeing of young Saudi females.

While the international literature consistently links physical activity with improved health outcomes, including better mood, reduced anxiety, higher self-esteem, and improved cardiovascular fitness [10–18], such relationships remain underexplored in the Saudi context—particularly among adolescent girls. Evidence from other regions shows that sports participation supports not only physical and mental health, but also social skills, discipline, and a sense of accomplishment [13–18]. Nevertheless, Saudi-specific research remains limited in scope, often lacking in-depth exploration of the sociocultural factors that inhibit or facilitate adolescent girls' participation in physical activity.

The gender gap in physical activity is particularly pronounced in Saudi Arabia, where cultural expectations around femininity and modesty restrict opportunities for girls to engage in public or organized sports [7,19]. Structural barriers such as the scarcity of girls-only facilities, safety concerns, and lack of supportive school programs further reduce participation levels. Guthold et al. [6] reported that more than 80% of adolescents worldwide fail to meet WHO recommendations for daily activity, with girls consistently reporting lower engagement than boys. These disparities are compounded by familial and community attitudes that may discourage girls from engaging in physical activity, leading to reduced psychological wellbeing and lower perceived quality of life [19,20].

Given these multifaceted influences, researchers increasingly recommend mixed-methods approaches that combine the statistical rigor of quantitative tools with the contextual depth of qualitative inquiry [21,22]. This study follows that approach, employing both systematic surveys and semi-structured interviews to capture not only the frequency of activity but also the lived experiences, perceptions, and cultural narratives that shape participation. The Social Ecological Model (SEM) [23] provides a guiding framework, organizing the inquiry across multiple levels: individual (e.g., motivation and perceived health), interpersonal (e.g., family support), environmental (e.g., access to facilities), and societal (e.g., gender norms and policy context).

The SEM is particularly suited to the Saudi context, where personal choices are often embedded within strong familial, educational, and community structures. Applying the SEM allows for a nuanced analysis of how these factors interact to shape behaviour and offers insight into potential leverage points for culturally sensitive interventions. For example, at the individual level, Self-Rated Health (SRH)—a validated and widely used single-item measure of perceived health—has proven predictive of both physical activity engagement and long-term health outcomes [24–29]. At the interpersonal and community levels, variables such as parental education, family encouragement, and urban residence can either support or constrain girls' activity levels.

To quantify these relationships, this study used the Physical Activity Questionnaire for Adolescents (PAQ-A) [10], a validated self-report instrument widely used across cultural contexts, including the Middle East. It categorizes respondents into low, moderate, and high activity levels over a 7-day period. Using this instrument, an *Ordinal* Logistic Model (OLM) was applied to assess how SEM-informed variables predict activity frequency. Complementing this, qualitative interviews explored adolescents' perceptions of barriers and supports, adding depth to the quantitative findings and enhancing cultural relevance.

Building on the national momentum of Vision 2030—which explicitly emphasizes women's empowerment and increased physical activity—this study aims to contribute empirically grounded recommendations to policymakers, educators, and public health leaders seeking to enhance adolescent girls' wellbeing through active living.

Research Aim and Questions

The overall aim of this study is to investigate the key factors influencing physical activity participation and wellbeing among adolescent females in Saudi Arabia. Guided by the Social Ecological Model and using the validated PAQ-A instrument, the study explores how individual, social, cultural, and environmental factors relate to activity behaviours and perceived quality of life. The study addresses the following three research questions:

1. What individual, social, and environmental factors significantly influence physical activity participation among adolescent females in Saudi Arabia?
2. How do cultural attitudes, family support, and access to facilities relate to the psychological wellbeing and quality of life of physically active and inactive adolescent females?
3. How can the findings inform culturally sensitive interventions to promote physical activity and enhance quality of life among young females in Saudi Arabia?

By addressing these questions, this research aims to generate evidence-based insights to support culturally tailored strategies that promote physical activity and health equity for adolescent girls across the Kingdom.

2. Methodology

2.1. Study Area

This study targeted adolescent females aged 13–21 in the Kingdom of Saudi Arabia, with the aim of capturing diverse physical activity behaviours across varying sociocultural contexts. A total of 636 participants were recruited from both urban and semi-urban areas across four major regions: Riyadh, Jeddah, Dammam, and their surrounding towns. These locations were strategically selected to reflect different levels of access to physical activity infrastructure, cultural attitudes towards female sports participation, and socioeconomic diversity. The selection criteria ensured the inclusion of students from public and private schools, community centres, and health programs, enabling a broad representation of educational, economic, and geographic backgrounds. The age range was chosen to encompass middle to late adolescence and early adulthood, a period critical for identity formation, lifestyle development, and health behaviour establishment.

Participants were selected using stratified purposive sampling to ensure proportional representation from each selected region, taking into account school type, area classification (urban vs. semi-urban), and socioeconomic indicators.

2.2. Study Design

This study adopted a mixed-methods design to thoroughly explore physical activity behaviours, perceived social and cultural supports and barriers, and related physical and psychological health outcomes among adolescent females in Saudi Arabia. The design is guided by the Social Ecological Model (SEM), which provides a framework for understanding how individual behaviour is influenced by a constellation of factors across interpersonal, organizational, community, and policy levels [23]. Rooted in Bronfenbrenner's ecological systems theory [30] and adapted for public health [23], the SEM enables the study to capture the complex interplay between personal attributes (e.g., age and motivation), social relationships (e.g., family and peer support), environmental conditions (e.g., access to recreational facilities and school programs), and broader cultural norms. These layers

were examined across five domains: individual, interpersonal, organizational, community, and policy.

By applying the SEM, this study identifies multiple levels at which interventions can be implemented to support adolescent girls' engagement in physical activity. This comprehensive framework shaped the design of the survey instrument and guided the analysis of how barriers and facilitators operate across various settings. The Physical Activity Questionnaire for Adolescents (PAQ-A) was used to assess physical activity levels, capturing self-reported behaviours over a seven-day period, while the Self-Rated Health (SRH) instrument provided a measure of perceived physical and psychological wellbeing. This integration allowed for deeper insight into how contextual and personal determinants intersect to influence physical activity in a culturally specific setting.

Importantly, SRH contributed to identifying at-risk individuals and aligned with the SEM by linking personal health perception with broader ecological influences [24–29]. Its cultural adaptability and simplicity enhance its value as a public health tool, especially where standardized instruments like the Pediatric Quality of Life Inventory (PedsQL) are not feasible [31].

To quantitatively assess the relationship between physical activity and its predictors, an Ordinal Logistic Model (OLM) was employed. The dependent variable captured three ordered levels of physical activity: Level 1 (physically inactive or rarely active), Level 2 (occasionally active), and Level 3 (regularly active). Independent variables were derived from the conceptual framework and included age group, cultural barriers (low, medium, or high), family support (present or absent), access to facilities (adequate or inadequate), safety concerns (high or low), socioeconomic status (SES), parental education level, psychological health status, and urban vs. rural residence. SRH was modelled as an ordinal predictor to reflect respondents' perceived health and its role in shaping behaviour.

The OLM estimated the log odds of being at or below each physical activity level, allowing the study to identify how various multilevel factors influence participation. Model calibration was based on the log-likelihood, Akaike Information Criterion (AIC), and pseudo R^2 values to evaluate the model fit and predictive strength [32]. This modelling approach supports a nuanced, context-specific understanding of adolescent females' physical activity behaviours and informs culturally responsive strategies for intervention in Saudi Arabia.

The model is specified as follows:

$$\text{Logit}\,[P(Y \leq d)] = \alpha d - \sum \beta n Xn$$

where

Y is the ordinal dependent variable representing the level of physical activity participation (Level 1, 2, or 3);

d indicates the cutoff points between these ordered levels;

Xn are the independent variables (predictors);

βn are the estimated coefficients for each predictor;

αd are the intercepts (threshold parameters) for each cumulative logit.

2.3. Data Collection Procedures

The study population consisted of female adolescents aged 13 to 21 years enrolled in public and private colleges located in urban and suburban areas of Saudi Arabia. To ensure diverse representation across institutional types and socioeconomic backgrounds, a stratified random sampling strategy was employed. The target sample size for the quantitative component was approximately 636 participants, providing adequate statistical

power for the analyses. In addition, a purposive subsample of 30 participants was invited to participate in qualitative, in-depth interviews to gain richer contextual insights.

Data collection was conducted using a structured, self-administered online questionnaire designed to investigate physical activity behaviours, psychosocial determinants, and health-related quality of life among adolescent females. The questionnaire incorporated validated instruments, most notably the Physical Activity Questionnaire for Adolescents (PAQ-A), which assesses the frequency and intensity of physical activity over a seven-day period. The instrument was structured into four main sections:

1. Demographic Information—including participants' age, type of educational institution, urban or rural residence, socioeconomic status (SES), and parental education level.
2. Physical Activity Patterns—assessing the types of physical activity undertaken, daily and weekly frequency, and indicators of sedentary behaviour.
3. Social and Environmental Influences—measuring perceived support from family and school, access to recreational or sports facilities, and perceptions of neighbourhood safety.
4. Cultural and Psychological Factors—evaluating attitudes toward female participation in physical activity, mental wellbeing, and cultural barriers identified through the prior literature and expert consultations.

For analytical purposes, data were categorized into key variables that informed the model estimation:

- Age Group: 13–15, 16–18, and 19–21 years.
- Cultural Barriers: High, medium, or low (based on self-reported perceptions of sociocultural limitations).
- Family Support: Yes or no (reflecting the presence of encouragement or logistical support from family members).
- Access to Facilities: Adequate or inadequate (based on participants' assessment of facility availability and suitability).
- Safety Concerns: High or low (based on perceived safety of the local environment for physical activity).
- Socioeconomic Status (SES): High, medium, or low (derived from reported household income or related indicators).
- Parental Education Level: University, secondary, or other (based on the highest level attained by either parent).
- Psychological Health Status: Good, moderate, or poor (measured through self-reported mental wellbeing).
- Residence Type: Urban or rural (defined by geographic classification).

The survey was administered in Arabic to ensure cultural and linguistic relevance. Trained female researchers facilitated data collection and conducted qualitative interviews where applicable, ensuring a respectful and culturally sensitive approach. Interviews were audio-recorded with participants' consent and transcribed verbatim to support detailed thematic analysis.

2.4. Ethical Considerations

The study protocol was approved by the Institutional Review Board at Princess Nourah bint Abdulrahman University in Saudi Arabia. Informed consent and assent procedures ensured participants' understanding and voluntary participation. Ethical approval was obtained through Princess Nourah bint Abdulrahman University, and parental consent was secured for all participants under the age of 18. Confidentiality was maintained by

anonymizing data, and participants were informed of their right to withdraw at any time without penalty.

3. The Results

The data presented in Tables 1–3 provide a comprehensive overview of the physical activity patterns, barriers, and health outcomes among adolescent females in Saudi Arabia, shedding light on critical factors influencing their engagement in physical activities. Table 1 shows the physical activity frequency among adolescent females. Table 2 shows the prevalence of barriers by physical activity frequency. Table 3 presents the psychological and physical health outcomes reported. Table 4 presents the coefficient estimates of independent variables, odds ratios, and goodness-of-fit statistics of the Ordered Logit Model. These results are discussed in the next section (Section 5).

Table 1. Physical activity frequency among adolescent females.

Physical Activity Frequency	Percentage (%)
Daily (≥5 days/week)	15
Several times per week (3–4 days/week)	25
Occasionally (1–2 days/week)	35
Rarely/Never	25

Table 2. Prevalence of barriers by physical activity frequency.

Barrier	Daily (%)	Several Times/ Week (%)	Occasionally (%)	Rarely/ Never (%)
Cultural Restrictions	70	80	85	90
Lack of Family Support	65	72	78	85
Inadequate Facilities	55	62	70	80
Safety Concerns	40	45	55	70

Table 3. Psychological and physical health outcomes reported.

Health Outcome	Percentage Reporting (%)
Improved Mood	60
Reduced Stress	55
Increased Physical Fitness	50
Experience of Fatigue	30
Experience of Pain	20

Table 4. Coefficient estimates of independent variables, odds ratios, and goodness-of-fit statistics of the Ordered Logit Model.

Predictor	Coefficient (β)	Std. Error	z-Value	*p*-Value	Odds Ratio (Exp(β))
Intercept (Level 1 vs. 2 and 3)	−1.812	0.410	−4.42	<0.001	—
Intercept (Level 1 and 2 vs. 3)	0.935	0.390	2.40	0.016	—
Age Group (13–15)	0.482	0.210	2.30	0.021	1.62
Age Group (16–18)	0.235	0.190	1.24	0.213	1.27
Cultural Barriers (High)	−0.785	0.225	−3.49	<0.001	0.46

Table 4. *Cont.*

Predictor	Coefficient (β)	Std. Error	z-Value	*p*-Value	Odds Ratio (Exp(β))
Cultural Barriers (Medium)	−0.312	0.200	−1.56	0.119	0.73
Family Support (Yes)	0.841	0.195	4.31	<0.001	2.32
Access to Facilities (Adequate)	0.710	0.180	3.94	<0.001	2.03
Self-Rated Health	0.925	0.128	7.23	<0.001	2.521
Safety Concerns (High)	−0.552	0.205	−2.69	0.007	0.58
Socioeconomic Status (High)	0.630	0.210	3.00	0.003	1.88
Socioeconomic Status (Medium)	0.318	0.200	1.59	0.111	1.37
Parental Education (University)	0.527	0.185	2.85	0.004	1.69
Parental Education (Secondary)	0.189	0.180	1.05	0.294	1.21
Psychological Health (Good)	0.676	0.190	3.56	<0.001	1.97
Psychological Health (Moderate)	0.312	0.200	1.56	0.118	1.37
Urban Residence (Yes)	0.402	0.180	2.23	0.026	1.50
Log-likelihood	−298.12				
AIC (Akaike Information Criterion)	628.24				
Pseudo R^2 (Nagelkerke)	0.36				
Sample Size (n)	636				
Significance Level	$p < 0.05$ (statistically significant)				

4. Analysis of the Results

4.1. General Analysis

The study surveyed 636 adolescent females regarding their physical activity frequency and perceived barriers to participation. The data presented in Tables 1–3 provide a comprehensive overview of the physical activity patterns, barriers, and health outcomes among adolescent females in Saudi Arabia, shedding light on critical factors influencing their engagement in physical activities. Table 1 shows the distribution of physical activity frequency and reveals that only 15% of adolescent females meet the recommended daily exercise threshold, while the majority (60%) engage in physical activity sporadically or rarely. This low adherence aligns with global trends of insufficient physical activity among adolescent girls, particularly in conservative cultural contexts, and underscores the urgent need for targeted interventions to promote regular activity. Table 2 shows that cultural restrictions emerge as the most pervasive barrier across all activity levels, increasing from 70% among the most active group to 90% among the least active. This finding highlights the substantial influence of sociocultural norms in limiting physical activity opportunities for

females. Additionally, lack of family support significantly contributes to inactivity, suggesting that family attitudes and encouragement are pivotal in shaping adolescent behaviour. Environmental barriers such as inadequate facilities and safety concerns also exhibit a clear gradient, with higher prevalence reported among less active participants. These results indicate that multifaceted barriers, spanning cultural, social, and environmental domains, interact to discourage consistent physical activity.

Finally, Table 3 indicates that positive health outcomes such as improved mood (60%) and reduced stress (55%) were reported by a substantial portion of participants, reinforcing the well-established psychological benefits of regular physical activity. Increased physical fitness was noted by half of the respondents, illustrating tangible physical benefits. However, the presence of fatigue (30%) and pain (20%) among some participants may reflect challenges related to inadequate preparation, overexertion, or lack of proper facilities, suggesting the importance of safe and guided physical activity programs. These findings highlight a strong inverse relationship between physical activity frequency and the perceived intensity of sociocultural and environmental barriers. Participants with lower activity levels consistently reported higher prevalence of all barriers, suggesting that these factors play a significant role in limiting physical activity among adolescent females in Saudi Arabia. Together, these findings emphasize the complex interplay between behavioural patterns, contextual barriers, and health outcomes. Interventions aiming to increase physical activity among Saudi adolescent females must address cultural sensitivities, enhance family and community support, and improve infrastructure and safety measures. Moreover, promoting awareness of the mental and physical health benefits could motivate greater participation and adherence.

The adoption of the Ordinal Logistic Model (OLM) in this study is well justified by the nature of the dependent variable, physical activity frequency, which was categorized into ordered levels (i.e., never, occasionally, regularly, daily). Unlike continuous or binary outcomes, this ordinal structure necessitates a statistical approach that accounts for the inherent order without assuming equal spacing between categories. The OLM provides cumulative odds ratios, which offer intuitive and interpretable results about how changes in each independent variable affect the odds of an adolescent engaging in more frequent physical activity. This is particularly valuable in public health research, where understanding the direction and magnitude of influence across ordinal levels informs targeted intervention design. In this study, the OLM allowed for the calibration of a multifactorial model that aligned with the Social Ecological Model (SEM), capturing individual, interpersonal, and environmental determinants simultaneously. The model's goodness-of-fit statistics indicated satisfactory model performance, and key predictors such as cultural barriers, family support, and psychological wellbeing were found to be significant, supporting the validity and utility of the OLM in this context.

The Ordinal Logistic Model (OLM) was calibrated to examine the levels of physical activity participation among adolescent females in Saudi Arabia and their association with cultural, social, and environmental factors. Table 4 provides the coefficient estimates of the independent variables, odds ratios, and goodness-of-fit statistics of the Ordered Logit Model.

4.2. General Interpretation of OLM Results

The results of the Ordinal Logistic Model (OLM) revealed several statistically significant predictors of physical activity frequency among adolescent females, providing strong support for the theoretical application of the Social Ecological Model (SEM). Notably, Self-Rated Health (SRH) emerged as the strongest individual-level predictor. With a coefficient of 0.925 and a p-value of <0.001, each one-level increase in SRH (e.g., from "Fair" to "Good")

more than doubled the odds of reporting more frequent physical activity (OR = 2.52). This underscores the critical role of perceived health in motivating physical engagement. At the interpersonal level, family support was also highly significant (β = 0.841, $p < 0.001$, OR = 2.32), indicating that adolescents who received encouragement from family were over twice as likely to be more physically active. Environmental factors also had strong effects. Access to adequate facilities significantly increased the odds of higher activity (β = 0.710, $p < 0.001$, OR = 2.03), while high cultural barriers (β = −0.785, $p < 0.001$, OR = 0.46) and high safety concerns (β = −0.552, $p = 0.007$, OR = 0.58) were significant inhibitors. These findings highlight how physical and sociocultural environments can either facilitate or restrict physical activity among adolescent females, particularly in conservative settings. Additionally, adolescents from high socioeconomic backgrounds (β = 0.630, $p = 0.003$, OR = 1.88) and those whose parents had a university education (β = 0.527, $p = 0.004$, OR = 1.69) were significantly more likely to engage in frequent activity, indicating that social capital and educational attainment play important roles. Good psychological health was also associated with higher activity (β = 0.676, $p < 0.001$, OR = 1.97), further reinforcing the interplay between mental wellbeing and physical behaviour.

Among demographic controls, younger adolescents aged 13–15 were significantly more active (β = 0.482, $p = 0.021$, OR = 1.62) than those aged 19–21, suggesting that physical activity declines with age. Living in urban areas was also positively associated with activity frequency (β = 0.402, $p = 0.026$, OR = 1.50), likely reflecting better access and fewer cultural restrictions. Other variables, such as medium SES, moderate psychological health, and secondary parental education, were not statistically significant, although their directional effects were consistent with theoretical expectations. Overall, the model demonstrated a good fit (Nagelkerke $R^2 = 0.36$), and the significance of predictors across multiple SEM levels supports the need for integrated, multilevel strategies to promote physical activity among adolescent girls.

4.3. Specific Interpretation of OLM Results

The OLM shows that a one-unit increase in the "age group (13–15)" variable results in a 0.482 increase in the log odds of being in a higher category of physical activity (e.g., occasionally active or regularly active), holding all other variables constant. The corresponding odds ratio is 1.62, indicating that adolescent females aged 13–15 are 62% more likely to be more physically active than those aged 19–21 (reference group). This finding may reflect the stronger integration of physical activity in younger adolescents' routines or school environments. A one-unit increase in reported high cultural barriers corresponds to a 0.785 decrease in the log odds of being in a higher activity level. The odds ratio is 0.46, meaning that participants facing high cultural barriers are 54% less likely to be active compared to those reporting low barriers. This underscores the restrictive impact of societal norms and expectations on young females' engagement in physical activity in conservative environments.

Participants reporting family support have a 0.841 increase in the log odds of being more physically active. With an odds ratio of 2.32, they are more than twice as likely to engage in physical activity compared to those without family support. This emphasizes the critical role of family encouragement and permission, especially in contexts where external social support may be limited. Having adequate access to facilities increases the log odds by 0.710, with an odds ratio of 2.03. This suggests that participants with adequate access are twice as likely to be more active, highlighting the importance of investment in female-friendly sports infrastructure. A high level of safety concern leads to a 0.552 decrease in log odds of being more active, with an odds ratio of 0.58. Adolescents concerned about safety are 42% less likely to participate in physical activity. This could reflect concerns about

personal security, transportation, or privacy in facilities, which are especially relevant in the Saudi context. Those from high-income families show a 0.630 increase in log odds, with an odds ratio of 1.88. They are 88% more likely to participate in higher levels of physical activity. This may be due to greater access to private facilities, transportation, and paid programs.

Higher parental education (university level) increases the log odds of activity by 0.527, corresponding to an odds ratio of 1.69. This suggests that educated parents may be more aware of the health benefits of physical activity and more likely to encourage their daughters. A good level of psychological health corresponds to a 0.676 increase in log odds, with an odds ratio of 1.97. This means adolescents reporting good mental health are nearly twice as likely to be active, highlighting the bidirectional link between mental wellbeing and physical activity. Urban dwellers are 1.5 times more likely to participate in physical activity ($\beta = 0.402$, OR = 1.50). This is likely due to better availability of facilities, more social acceptance, and higher exposure to health campaigns in cities compared to rural areas. The model results show that the strongest positive predictors are family support, access to facilities, and psychological health. The greatest barriers are high cultural restrictions and safety concerns. Therefore, interventions should focus on improving access, addressing safety and cultural norms, and enhancing psychological support to promote greater participation in physical activity among adolescent females.

Estimating psychological health parameters in adolescent populations requires careful selection of reliable and validated tools that are age-appropriate and culturally sensitive. In the context of this study, psychological health was assessed through dimensions such as emotional wellbeing, self-esteem, and perceived stress, which are critical indicators of mental health in adolescence. To ensure robust estimation, responses were analysed using psychometric techniques (in this case, factor analysis and reliability testing) to confirm internal consistency (typically with Cronbach's alpha > 0.70). Data were then integrated into multivariate analyses (which was the Ordinal Logistic Model) to examine how psychological health outcomes correlate with physical activity levels, sociodemographic variables, and environmental factors.

Additionally, attention was given to contextual influences, such as family support and college environments, which are particularly relevant in conservative societies like Saudi Arabia. This multi-layered approach ensures a more nuanced understanding of psychological health and its interaction with physical activity and societal support structures, strengthening the credibility and relevance of the findings. The urban/rural residence coefficient in the model captures the influence of geographic context on adolescent physical activity and related health outcomes. Its estimation is crucial because the living environment often dictates access to recreational facilities, school sports programs, transportation, and community safety, factors that significantly shape physical activity behaviours, especially among young females. In this study, urban and rural residence was treated as a categorical independent variable within the Ordinal Logistic Model (OLM). The coefficient reflects the odds of being in a higher physical activity category (e.g., active, club member, or event attendee) based on residence status. A positive and statistically significant coefficient for urban residence would suggest that adolescents in urban areas are more likely to be active, potentially due to greater infrastructure and social support for sports. Conversely, a negative or non-significant coefficient may highlight persistent barriers in urban environments, such as safety concerns or restrictive social norms, or the possible presence of informal activity opportunities in rural areas.

5. Discussions, Conclusions, and Limitations

This study examined the individual, social, and environmental determinants of physical activity among adolescent females in Saudi Arabia using a mixed-methods approach guided by the Social Ecological Model (SEM). The findings address the three research questions by identifying key predictors of physical activity (RQ1), exploring how cultural and psychosocial factors relate to wellbeing (RQ2), and outlining implications for culturally appropriate interventions (RQ3).

RQ1: Determinants of Physical Activity Participation

The results of the Ordinal Logistic Model (OLM) revealed that multiple factors across all SEM levels significantly influence physical activity participation. At the intrapersonal level, Self-Rated Health (SRH) emerged as the most influential predictor ($\beta = 0.925$, $p < 0.001$, OR = 2.52), indicating that adolescents who perceived themselves as healthier were more likely to be physically active. Psychological wellbeing ($\beta = 0.676$, $p < 0.001$, OR = 1.97) and a younger age (13–15 years) ($\beta = 0.482$, $p = 0.021$, OR = 1.62) were also significant, highlighting the interconnected nature of mental health and age in shaping activity patterns. These findings confirm previous evidence suggesting that physical activity tends to decline with age during adolescence [33,34].

At the interpersonal level, family support was a critical enabler ($\beta = 0.841$, $p < 0.001$, OR = 2.32). Adolescents with familial encouragement were over twice as likely to engage in regular physical activity. This reinforces the importance of social networks, particularly in cultural contexts where gender norms may restrict female mobility or public visibility [5,23,31,34].

At the environmental and societal levels, access to facilities ($\beta = 0.710$, $p < 0.001$, OR = 2.03) had a strong positive effect. In contrast, high cultural barriers ($\beta = -0.785$, $p < 0.001$, OR = 0.46) and high safety concerns ($\beta = -0.552$, p = 0.007, OR = 0.58) were negative predictors. These findings suggest that even when individual motivation exists, structural and societal constraints may prevent regular participation in physical activity.

Additional significant predictors included high SES ($\beta = 0.630$, p = 0.003, OR = 1.88), university-educated parents ($\beta = 0.527$, p = 0.004, OR = 1.69), and urban residence ($\beta = 0.402$, p = 0.026, OR = 1.50), indicating that socioeconomic advantage and geographic location can enable or constrain access to resources that facilitate physical activity.

RQ2: Cultural, Family, and Facility Access in Relation to Wellbeing

The strong associations between SRH, mental health, and physical activity levels demonstrate that psychological wellbeing is both a determinant and an outcome of physical activity. Participants who faced fewer cultural and safety constraints were more likely to report both higher activity levels and better psychological health. These findings highlight the burden of sociocultural restrictions and inadequate infrastructure on adolescent females' mental and emotional wellbeing.

Family support not only promoted physical engagement but also correlated with improved self-perceptions of health, underscoring the role of emotionally and logistically supportive environments. Similarly, accessible and safe recreational spaces appear to mitigate psychological distress by enabling physical expression and peer interaction. These results support the growing consensus that mental wellbeing and physical health are mutually reinforcing and must be addressed together in youth-focused public health efforts [31–34].

RQ3: Implications for Culturally Sensitive Interventions

The findings offer clear guidance for designing multilevel, culturally sensitive interventions. At the individual level, strategies should promote mental wellbeing alongside

physical activity by integrating health education and psychological support into school curricula. At the family level, programs should engage parents, particularly mothers, as advocates and facilitators of physical activity.

At the community level, investments in safe, female-friendly recreational spaces are critical, especially in suburban and rural areas. At the policy level, addressing gender-based restrictions and reforming school and municipal planning policies to include inclusive sports programming can create systemic support for adolescent girls.

Given the cultural sensitivities and structural limitations identified, effective interventions must go beyond education and awareness campaigns. They should be embedded in culturally appropriate delivery models, such as through schools, mosques, or family-oriented community centres, and emphasize safe, supportive, and gender-sensitive environments.

Several limitations should be acknowledged. First, the cross-sectional design limits causal inference. Longitudinal studies are necessary to understand how physical activity patterns and barriers evolve over time. Second, the study relied on self-reported data via the PAQ-A, which may be subject to recall and social desirability bias, particularly in a context where female physical inactivity is socially discouraged. The inclusion of objective measures like wearable trackers in future research would enhance data accuracy.

Third, although the sample was stratified by institution type and region, it may not fully capture the experiences of adolescents in remote rural areas, where barriers may differ significantly. Fourth, the qualitative subsample of 30 participants, while valuable for contextual insights, limits the generalizability of those narratives.

In conclusion, this study provides a comprehensive, evidence-based understanding of the multifactorial influences on physical activity among adolescent females in Saudi Arabia. By addressing the interplay of individual, social, and environmental factors, the findings affirm the relevance of the Social Ecological Model in culturally specific contexts. Public health efforts must target multiple levels, including health education, family engagement, facility access, and cultural transformation, to effectively promote adolescent female physical activity and overall wellbeing.

Future research should expand to underrepresented regions, include male perspectives, and evaluate the role of schools and health policies as systemic facilitators. The development and testing of culturally grounded interventions will be crucial to shifting societal norms and improving long-term health outcomes for adolescent girls across Saudi Arabia.

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children

MDPI

Article

Sex-Specific Physical Activity and Weight Status in German Schoolchildren: Interim Results from the Hand on Heart Study

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Abstract: Background/Objectives: physical activity (PA) in children offers lifelong benefits, yet nearly four in five children are insufficiently active. We examined sex-specific differences in sport participation by sport type and its association with weight status. Methods: in the ongoing hand-on-heart-study ("Hand-aufs-Herz"), comprehensive data on sociodemographic profiles, PA, and anthropometry were collected from 922 school-aged children, adolescents, and young adults (8–20 years) in Germany. Sex-specific differences in sport participation, sport types, and weight status were analyzed using descriptive statistics and logistic regression models. Results: based on the eligibility criteria for analysis (ages 8–18 years), 883 pupils were included (mean age 13.1 ± 2.4 years), 406 (46%) were females. Compared to females, males had a 43% higher chance of being members of a sports club and were more likely to spend more days/week on sports (44–85%). Males participated more in football, martial arts, and basketball while females favored gymnastics and volleyball. As age increased, males had a 30% higher likelihood of not being sports club members (females: 13%). Overweight/obese males had twice the risk of lacking sports memberships. The largest body mass index (BMI) difference was found in males and females participating in athletics, with −4.64 kg/m^2 (males) and −1.99 kg/m^2 (females) compared to their counterparts without club memberships. Conclusions: in conclusion, sports participation should be encouraged especially among females and overweight/obese males. Targeted strategies should focus on promoting inclusive and non-competitive activities that cater to their interests.

Keywords: physical activity; sex differences; sports participation; BMI; adolescents; sports clubs; Hand-on-heart-study ("Hand-aufs-Herz")

1. Introduction

Physical activity (PA) is vital for promoting healthy growth, improving cardiovascular health, and developing motor skills [1,2]. Children who engage in sports are more likely to continue participating in physical activities during adulthood, forming habits that contribute to long-term health and well-being [3]. Interestingly, participation in sports during childhood is linked to 148–191% increased levels of vigorous PA in adulthood [4].

Engaging in sports during childhood not only supports physical development but also plays a crucial role in the mental and emotional growth of children, enhancing self-esteem, teamwork, and discipline [5].

This early exposure to PA can potentially reduce the risk of chronic diseases such as obesity, type 2 diabetes, and cardiovascular conditions later in life [6]. A longitudinal study found that children and adolescents (3–18 years) who were persistently active had a significantly lower risk of adult clustered cardiometabolic risk (33% reduction), high glucose levels (23% reduction), low HDL cholesterol levels (22% reduction), obesity (24% reduction), high waist circumference (18% reduction), high insulin levels (42% reduction), and high triglyceride levels (40% reduction) compared to those who were persistently inactive, highlighting the long-term benefits of sustained PA [7].

To promote consistent PA from a young age, PA recommendations aim to establish healthy habits. Guidelines on PA for children are designed to help caretakers, schools, and communities to promote PA, ensuring children lead active lives and develop essential physical and social skills [8]. The World Health Organization (WHO) defines PA as any bodily movement produced by skeletal muscles that requires energy expenditure [8,9] and recommends that children aged 5–17 engage in at least 60 min of moderate-to-vigorous PA daily, including activities that strengthen muscles and bones at least three times a week [9]. In Germany, children aged 4–6 years should engage in 180 min of PA daily, while those aged 6–11 years and 12–18 years should aim for at least 90 min of moderate-to-vigorous activity, with 60 min from daily activities like walking 12,000 steps [10].

Despite the presence of PA guidelines in children, over 80% of school-going adolescents aged 11–17 years do not meet the WHO recommendations for daily PA, putting their current and future health at risk [11]. Evidence from Europe shows regional variations, with Italy, France, and Portugal having the highest proportions of adolescents (up to 96%) who do not engage in moderate-to-vigorous PA daily [12]. In Germany, the Global Matrix 4.0 grading rubric [13] assigned a grade of D– to adolescents for their overall PA levels, indicating that only one in four (20–26%) meet the global PA recommendations [14].

Research gaps remain in understanding the sex differences in adolescent PA, since a French study of 8084 adolescents [15] and data from the International Children Accelerometry Database (ICAD) involving 15,461 individuals across nine countries [16] revealed that boys were fitter, engaged more in sports club activities, and exhibited higher levels of moderate-to-vigorous PA, with greater variability, while no significant sex differences were found in sedentary or light-intensity activity. Sex-specific differences in PA are also apparent on weight outcomes as higher PA levels in boys are linked to lower rates of overweight and obesity, while girls' lower PA participation is associated with higher rates of overweight and obesity [17].

Therefore, differences between sexes need to be studied further in order to explore participation rates for a variety of sports over time and how these preferences evolve with age. Furthermore, it is important to identify which specific sports are related to better weight outcomes in males and females because different sports offer varying levels of physical intensity, endurance, and muscle engagement, which can influence weight management.

Using the comprehensive hand-on-heart-study ("Hand-aufs-Herz"), we aimed to evaluate the prevalence of PA among school-going males and females. Our analysis focused on the engagement in various types of sports and compared participation rates between the sex groups. Additionally, we assessed sex-specific weight status in relation to the different sport types, examining how certain activities may impact the weight outcomes of both boys and girls. By considering both participation levels and weight status, our study provides valuable insights into the role of sports in children's health across different sex groups.

2. Materials and Methods

2.1. Study Design and Participants

The hand-on-heart-project (German clinical trial register DRKS00033999) is an ongoing study of school-aged children, adolescents, and young adults (8–20 years). The study project aims to develop a reliable, effective, and comprehensive cardiovascular screening test that is simple to perform and cost-effective. Each participant completes a detailed questionnaire, undergoes a physical examination, the collection of biometric data and vital parameters, an ECG, an echocardiography, the determination of physical strength and a standardized fitness test. The goal is to establish this test as a preventive measure in both general and pediatric practices, as well as in clinics, and eventually integrate it into routine healthcare.

The study is based on data from the Orlando Heart Health Weeks questionnaires, which are named after the school where the research was conducted. This school was the first to take part in the hand-on-heart project, a prevention initiative by the Department of Pediatric Cardiology at LMU, supported by the Nicolas May Foundation [18]. The children, adolescents, and young adults (ages 8 to 20 years) from the selected school were allowed to take part in the project on a voluntary basis. The majority of the approximately 1000 students took up the offer. Ethical approval for the study was granted on 15 April 2024 (project number 24-0147) by the Ethics Committee of Ludwig-Maximilians-Universität.

Initially, the project was introduced to parents via a two-sided letter and informational flyers for the school management and teachers. This was followed by a detailed parents' evening. The project was then presented to all students in their respective classes, with registration completed using a written form. The consent form contains a detailed information leaflet explaining the examination process over six pages. The consent of parents and children was required for participation.

Comprehensive data on health, PA, fitness, and nutrition is collected using a REDCap based survey that was designed for the project by our department. The pupils completed the questionnaire on a tablet on site. Information on the current state of health, daily step count, daily PA, membership to sports club and type of sports club, frequency of attending sports club per week, eating habits, and risk behavior was requested. For the evaluation of nutritional behavior, we use the published KidMed 2.0 score [19]. The included items with the corresponding answer options are listed in the Section 3.

2.2. Inclusion Criteria for Analysis

All children and adolescents aged between 8 and 18 years were included in the present study. Young adults (ages 18 to 20 years) were excluded from this analysis. In this manuscript, we refer to the study population as "pupils", which encompasses the children and adolescents involved in the study.

2.3. Exposure Variables

Sex was used as the main exposure variable. In order to assess the role of sport activities on body mass index (BMI in kg/m^2), sport club membership and type of sport were also considered as exposure variables.

2.4. Outcome Variables

The outcome variables in this study encompass various aspects of PA, fitness self-assessment, school-related factors, BMI, and BMI categories according to the German cut-offs [20,21]. These included the school grade in physical education, which reflected the pupil's performance in physical education. A key variable was positive self-assessment of fitness, where participants indicate whether the pupils considered themselves fit (yes or no). Additionally, swimming ability for 100 m was assessed, with categories including

"Yes, but not so good", "Yes, very good", or "No". Steps per day, an indicator considered relevant to measure daily PA in children [22], was used in our study to classify participants in categories such as "Do not track", "<5000 steps", "<10,000 steps", and ">10,000 steps". The study also evaluated the time spent on PA per day and included categories including <1 h, 1 h, 1–2 h, and >2 h. For high-intensity PA, time spent on high-pulse PA per week was categorized by frequency (<1 time, 1 time, 2–3 times, and >3 times), as was time spent on muscular PA per week (with similar frequency groupings). These outcome variables provide a comprehensive view of participants' PA levels, fitness perceptions, and their involvement in physical education and sports.

2.5. Statistical Analysis

The characteristics of the study population such as age (in years), school level, and BMI was compared between sex categories. Key outcome variables, including sports grade, self-assessed fitness, swimming ability, and PA behaviors (steps per day, time spent on PA per day, and time spent on high-pulse and muscular PA per week) were summarized and compared between males versus females. To examine group differences for continuous variables Student's *t* tests were performed and to evaluate differences between proportions of categorical variables chi-square tests were used. Univariate logistic regression models were employed to explore the relationship between sex and binary outcomes. Linear regression was used to quantify changes in mean BMI by sport club membership and type of sports club versus membership to no sports club. Multivariable logistic models were adjusted for age. Effect sizes were reported where relevant (odds ratios with 95% confidence intervals). Statistical significance was set at an alpha level of 0.05. All analyses were conducted using R version 4.4.2 (2024-10-31 ucrt) [23].

3. Results

3.1. Study Population

Of the total enrolled pupils as of 31 December 2024 (n = 922), 883 pupils aged 8 to 18 years were included. The characteristics of the included pupils is summarized in Table 1. The mean (SD) age of the included pupils was 13.1 ± 2.4 years. Around 46% (n = 406) were females and 54% (n = 477) were boys. Included pupils had a mean (SD) BMI of 19.4 ± 3.7 kg/m^2. Weight status based on BMI categories did not differ by sex. The average school grade in physical education was 1.5 and 5.4% of the pupils did not consider themselves fit.

Table 1. Characteristics and sport activities of the Hand-on-Heart-study population.

Characteristics and Sport Activities	All Pupils	Female	Male	*p*-Value
	***N* (%)**	***n* (%)**	***n* (%)**	
Number of pupils	883	406	477	
Age, years	13.1 ± 2.4	13.0 ± 2.3	13.1 ± 2.4	0.704
Age categories, years				0.323
8	27 (3.1)	15 (3.1)	12 (3.0)	
9	38 (4.3)	21 (4.4)	17 (4.2)	
10	61 (6.9)	29 (6.1)	32 (7.9)	
11	117 (13.3)	69 (14.5)	48 (11.8)	
12	133 (15.1)	68 (14.3)	65 (16.0)	
13	101 (11.4)	59 (12.4)	42 (10.3)	
14	137 (15.5)	62 (13.0)	75 (18.5)	
15	121 (13.7)	72 (15.1)	49 (12.1)	
16	94 (10.6)	50 (10.5)	44 (10.8)	
17	39 (4.4)	21 (4.4)	18 (4.4)	
18	15 (1.7)	11 (2.3)	4 (1.0)	

Table 1. *Cont.*

Characteristics and Sport Activities	All Pupils	Female	Male	*p*-Value
	N (%)	*n* (%)	*n* (%)	
Body mass index (BMI), kg/m^2	19.4 ± 3.7	19.4 ± 3.5	19.4 ± 3.8	0.901
BMI categories				0.487
Underweight	301 (34.2)	137 (33.8)	164 (34.5)	
Normal weight	411 (46.7)	198 (48.9)	213 (44.8)	
Weight in the upper normal range	91 (10.3)	36 (8.9)	55 (11.6)	
Overweight/Obesity	77 (8.8)	34 (8.4)	43 (9.1)	
School grade in physical education	1.51 ± 0.70	1.53 ± 0.70	1.49 ± 0.70	0.442
School level				0.258
Primary School	100 (11.3)	43 (10.6)	57 (11.9)	
Middle School	58 (6.6)	21 (5.2)	37 (7.8)	
Secondary School	604 (68.4)	290 (71.4)	314 (65.8)	
High School	121 (13.7)	52 (12.8)	69 (14.5)	
Positive self-assessment of fitness				0.670
Yes	835 (94.6)	382 (94.1)	453 (95.0)	
No	48 (5.4)	24 (5.9)	24 (5.0)	
Swim for 100 m				<0.001
Yes, but not so good	253 (28.7)	141 (34.7)	112 (23.5)	
Yes, very good	578 (65.5)	234 (57.6)	344 (72.1)	
No	52 (5.9)	31 (7.6)	21 (4.4)	
Steps per day				<0.001
Do not track	477 (54.0)	211 (52.0)	266 (55.8)	
<5000	40 (4.5)	29 (7.1)	11 (2.3)	
<10,000	240 (27.2)	121 (29.8)	119 (24.9)	
>10,000	126 (14.3)	45 (11.1)	81 (17.0)	
Time spent on PA/day				<0.001
<1 h	145 (16.4)	88 (21.7)	57 (11.9)	
1 h	246 (27.9)	126 (31.0)	120 (25.2)	
1–2 h	368 (41.7)	154 (37.9)	214 (44.9)	
>2 h	124 (14.0)	38 (9.4)	86 (18.0)	
Time spent on high-pulse PA/week				<0.001
<1 time	84 (9.5)	48 (11.8)	36 (7.5)	
1 time	178 (20.2)	107 (26.4)	71 (14.9)	
2–3 times	425 (48.1)	188 (46.3)	237 (49.7)	
>3 times	196 (22.2)	63 (15.5)	133 (27.9)	
Time spent on muscular PA/week				0.085
<1 time	226 (25.6)	100 (24.6)	126 (26.4)	
1 time	274 (31.0)	141 (34.7)	133 (27.9)	
2–3 times	284 (32.2)	128 (31.5)	156 (32.7)	
>3 times	99 (11.2)	37 (9.1)	62 (13.0)	

Data are mean ± SD or *n* (%) and tested with regard to the sex using Student's *t* test for continuous and $\chi 2$ test for categorical variables.

3.2. Sex Differences in Physical Activity

Regarding sex differences, no significant differences were found in age, BMI, sports grade, school level, or positive self-assessment of fitness. However, PA indicators differed by sex (Table 1). For example, a lower proportion of females (57.6%) could swim 100 m as compared to males (72.1%). Interestingly, nearly 6% of all pupils (females: 7.6%, males: 4.4%) could not swim. We found that one in two pupils tracked their daily steps and 17% males had more than 10,000 steps per day (females: 11.1%). With regard to PA per day, females were twice as likely to spend less than 1 h per day on PA than males (females: 21.7%, males: 11.9%). Females were half as likely to spent more than 2 h on PA than males (females: 9.4%, males: 18%). Time spent on high-pulse PA per week was also different

between sex. While 27.9% males did high-pulse PA three times a week (females: 15.5%), 11.8% females spent less than 1 h per week on such activity (males: 7.5%). Although not statistically significant, a similar trend was observed in the time spent on muscular PA per week, with a lower proportion of females compared to males engaging in it.

Next, it was assessed whether there were differences between sex groups and membership in sports clubs. The proportion of membership at sports club ($p = 0.021$) and more days spent at sports club ($p = 0.0014$) was higher in males than females (Figure 1).

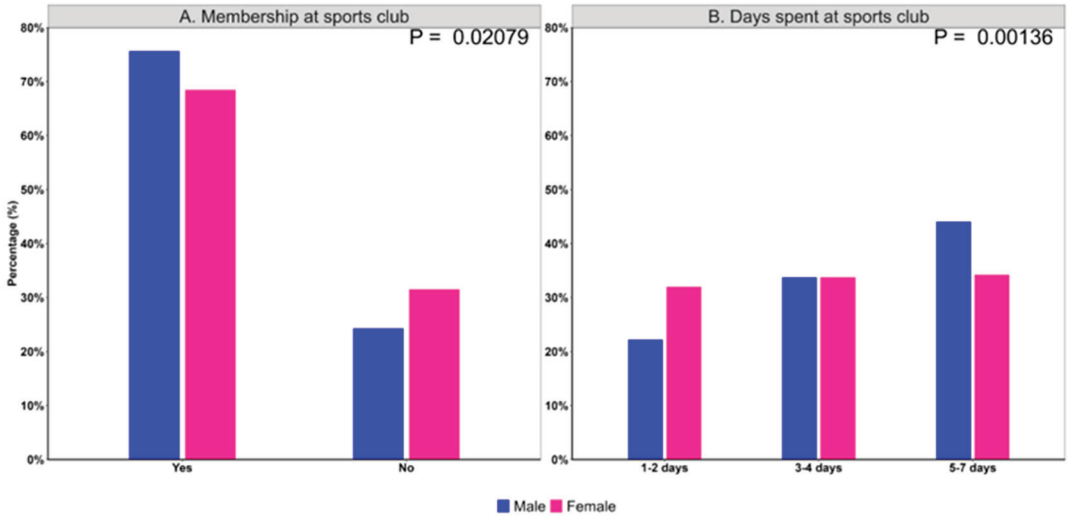

Figure 1. Sports club membership and attendance stratified by sex. Differences between sex groups were tested using χ2 test. (**A**) Proportion of sports club membership in males and females. (**B**) Proportion of days spent at sports club by males and females.

In fact, as compared to females, males had a 43% higher chance of being members of a sport club (Table 2). Even after adjusting for age, this association remained significant (OR [95% CI]: 1.47 [1.09, 1.99]). Furthermore, males (compared to females) had a 44% higher chance of spending 3–4 days at the sports club and an 85% higher chance of spending 5–7 days there. After adjusting for age, these associations increased to 59% and doubled, respectively.

Table 2. Club membership and activity by sex.

Outcome	*N*	Unadjusted	Age-Adjusted
Sports club membership			
No	244	Reference	Reference
Yes	639	**1.43 (1.07, 1.93)**	**1.47 (1.09, 1.99)**
Days spent at sports club			
1–2 days	236	Reference	Reference
3–4 days	298	**1.44 (1.02, 2.03)**	**1.59 (1.11, 2.26)**
5–7 days	349	**1.85 (1.33, 2.59)**	**2.00 (1.37, 2.91)**

Values are odds ratios and 95% confidence intervals based on logistic regression. The influence of sex (Control versus Test: females versus males) was assessed for each outcome. Bold text indicates $p < 0.05$.

3.3. Differences in Sports Types Participated in by Sex

We further assessed proportion of males and females participating in different sports. As shown in Figure 2, a significantly higher proportion of males were involved in football (males versus females: 39.4% versus 8.6%, $p < 0.00001$), martial arts (males versus females: 8.2% versus 5.7%, $p = 0.0265$), and basketball (males versus females: 6.1% versus 2.7%, $p = 0.02524$). On the other hand, females were more involved in other sports, which

included tennis and horse riding (males versus females: 37.4% versus 30.4%, $p = 0.0327$) than males. A higher proportion of females than males were also involved in gymnastics (males versus females: 1.0% versus 11.1%, $p < 0.00001$), volleyball (males versus females: 1.3% versus 8.6%, $p < 0.00001$), and athletics (males versus females: 1.9% versus 4.7%, $p = 0.0302$). No significant differences by sex were found in sports such as swimming, handball, or running.

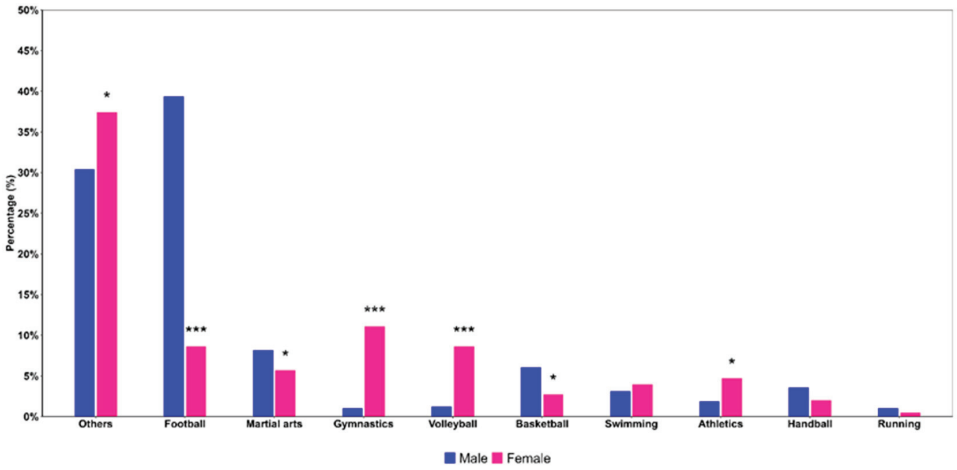

Figure 2. Sport activities stratified by type and sex. Differences between sex groups within each sport type were tested using the chi-square test. Statistically significant results are shown as *** ($p < 0.001$) and * ($0.01 \leq p < 0.05$).

3.4. Differences in Sports Types Participated in by Age

In the next step, the proportion of males and females participating in different sports by age was assessed (Figure 3). Differences in sport types participated in by age were not apparent for most of the sports. However, a drastic difference over age was found in football as the participation was always higher in males than females. While at 8 years of age, 60% males versus 8.3% females played football, the proportion reduced to 9.1% in males versus 5.6% in females by 18 years of age. Among males, a steep decline in football was noticed after age 16 years. An increasing age was associated with a 30% increased chance of absence of sports club membership in males (OR 1.30, 95% CI [1.18, 1.43]).

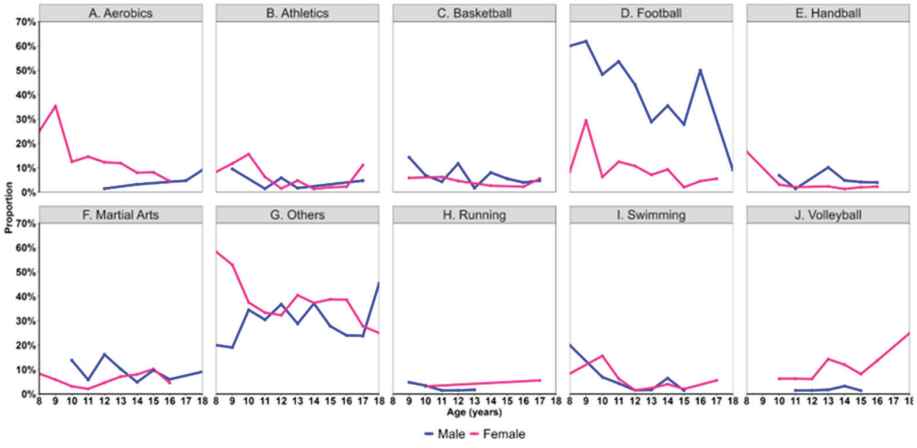

Figure 3. Sport activity participation by age and sex. (**A**) Participation in aerobics. (**B**) Participation in athletics. (**C**) Participation in basketball. (**D**) Participation in football. (**E**) Participation in handball. (**F**) Participation in martial arts. (**G**) Participation in other sport activities. (**H**) Participation in running. (**I**) Participation in swimming. (**J**) Participation in volleyball.

Among females, the uptake of aerobics already started before or at 8 years of age (25%) and slowly decreased to 4.5% by age 16 years. In contrast, a very low proportion of males were involved in aerobics after age 12 years. Starting at 10 years of age, a few females also played volleyball (6.3%). The proportion of males playing volleyball was ranged from 1 to 3.2% between ages 11 and 15. Already, at 8 years of age, nearly 58.3% females were involved in other sport activities (males: 20%). At 10 years of age, the proportion of uptake of other sport activities became similar in males (34.4%) and females (37.5%). However, at 18 years of age, more males (45.5%) were involved in other sport activities than females (25%). We observed that with age, females had a 13% higher likelihood of not being members of a sports club (OR 1.13, 95% CI [1.03, 1.24]).

3.5. Influence of Weight Status on Sports Club Membership

To evaluate the influence of weight status on sports club membership (yes versus no), we calculated the odds ratio of the club membership according to the different BMI groups and considered normal weight pupils as control (Figure 4). The likelihood of sport club membership did not differ between pupils who were a normal weight or underweight or had a BMI in the upper normal range, regardless of sex. However, pupils who were overweight or obese had a 2-fold increased risk of absence of sports membership as compared to normal weight pupils (OR [95% CI]: 2.16 [1.31, 3.57]). Even within the subgroup of males, pupils who were overweight or obese were at a 2.5-fold chances of having no sports club membership as compared to their counterparts who were normal weight. Such association was not found in the subgroup of females (OR [95% CI]: 1.91 [0.91, 4.01], $p = 0.0889$).

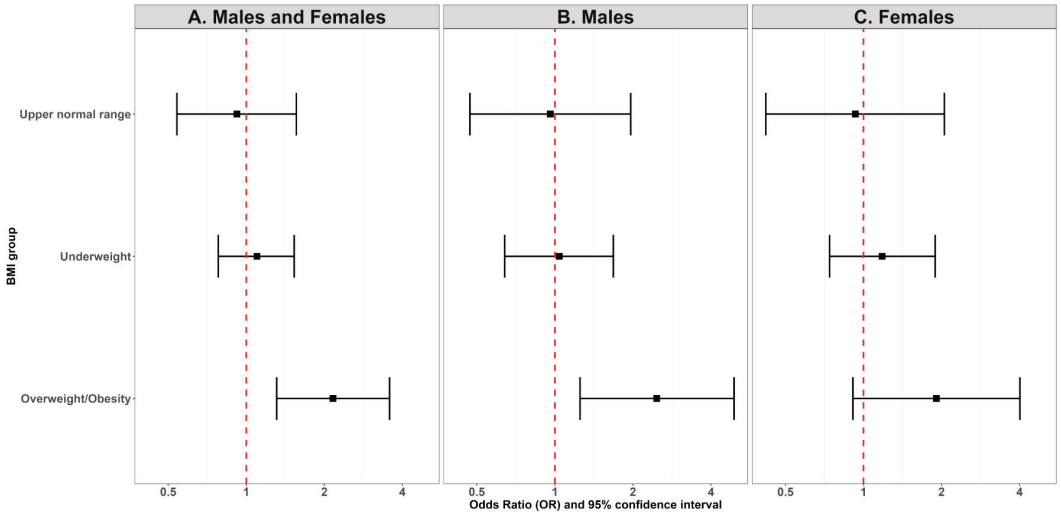

Figure 4. Membership to no sports club and weight status in pupils. Values are odds ratios (OR) and 95% confidence intervals based on univarite logistic regression, where normal weight pupils were considered as control group. The dashed line on the forest plots represents the point of no effect (OR = 1). (**A**) Odds ratios in males and females. (**B**) Odds ratios in males. (**C**) Odds ratios in females.

3.6. Type of Sports Club Membership and Weight Status

As the final step, we assessed the change in BMI based on type of sport club membership compared to absence of sport club membership (Figure 5). Among all pupils who did not have a membership to sports club, the mean BMI was 19.1 kg/m^2 (95% CI 18.9, 19.3 kg/m^2) which was not statistically different from pupils who were members of volleyball, martial arts, handball, swimming, basketball, or running sports clubs. However, compared to non-members, a significant lower mean BMI was observed in pupils who were members of athletics (mean 17.1 kg/m^2, 95% CI [15.9, 18.3 kg/m^2]), gymnastics

(mean 17.8 kg/m^2, 95% CI [17.0, 18.6 kg/m^2]), football (mean 18.8 kg/m^2, 95% CI [18.4, 19.2 kg/m^2]), and other (mean 19.0 kg/m^2, 95% CI [18.6, 19.4 kg/m^2]) sport clubs. The highest difference in mean BMI was observed in all pupils who engaged in athletics versus pupils who did not perform any sports (mean difference in BMI in kg/m^2: −2.98 [95% CI: −4.43, −1.53]).

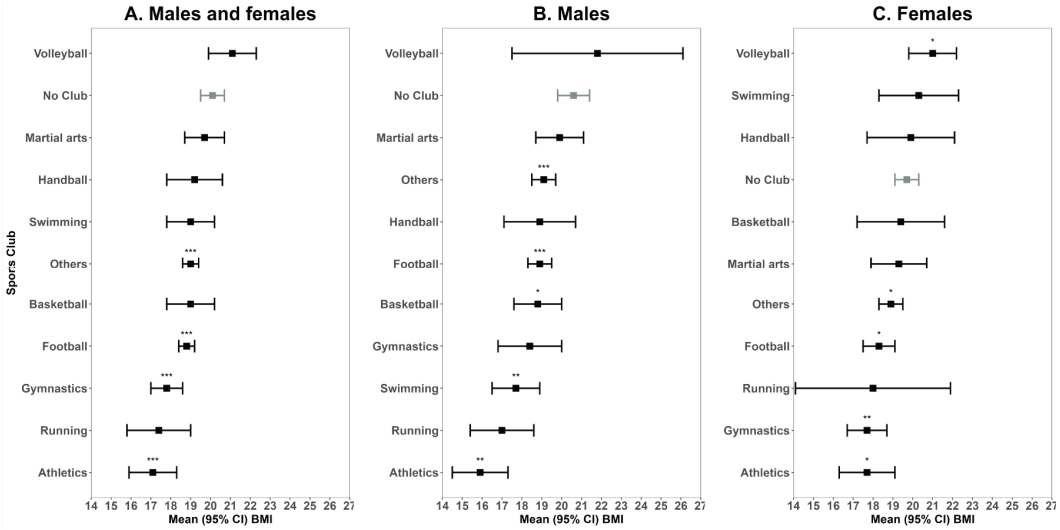

Figure 5. Mean (95%) BMI in pupils by type of sport club membership. Mean values are compared against the control group "No Club" (gray) indicating no membership to any sports club. Significant differences are shown as $p < 0.0001$ (***), $p < 0.001$ (**), or $p < 0.05$ (*) and are based on univariate linear regression models. (**A**) Odds ratios in males and females. (**B**) Odds ratios in males. (**C**) Odds ratios in females.

We repeated the analysis in subgroups of males and females. Among males, we found that the mean BMI for pupils who did not have any sport club membership was 20.6 kg/m^2. Compared to male non-members, lower mean BMI levels were found in counterpart males who played football (mean 18.9 kg/m^2, 95% CI [18.3, 19.5 kg/m^2]), basketball (mean 18.8 kg/m^2, 95% CI [17.6, 20.0 kg/m^2]), swimming 17.7 kg/m^2, 95% CI [16.5, 18.9 kg/m^2]), or athletics (mean 15.9 kg/m^2, 95% CI [14.5, 17.3 kg/m^2]). The largest mean BMI difference was observed between males who participated in athletics and those who did not engage in any sports, with a mean difference of −4.64 kg/m^2 (95% CI: 7.31, −1.98).

In the subgroup of females, those who did not participate in any sports had a mean BMI of 19.7 kg/m^2, 95% CI [19.1, 20.3 kg/m^2], which was even lower than females who played volleyball (mean 21.0 kg/m^2, 95% CI [19.8, 22.2 kg/m^2]). Additionally, in contrast to females who were not members of sport club, a higher mean BMI was found in females who engaged in football (mean 18.3 kg/m^2, 95% CI [17.5, 19.1 kg/m^2]), gymnastics (mean 17.7 kg/m^2, 95% CI [14.5, 17.3 kg/m^2]), athletics (mean 17.7 kg/m^2, 95% CI [16.3, 19.1 kg/m^2]), or other sport (mean 18.9 kg/m^2, 95% CI [18.3, 19.5 kg/m^2]) activities. The most significant mean BMI difference was also found between females who took part in athletics and those who did not participate in any sports, with a mean difference of −1.99 kg/m^2 (95% CI: −3.65, −0.36).

4. Discussion

In this large study of more than 800 school-aged children and adolescents, we examined the participation rates of males and females in various sports. Our study reveals notable sex-based differences in sports involvement. Male pupils were 50% more likely to be members of sports club and spend more time on sport activities than their female

counterparts. Furthermore, males were largely involved in contact sports such as football, martial arts, and basketball while females engaged more often in gymnastics, athletics, volleyball, and other sports activities including horse riding. Although the uptake of sports generally varied with age, involvement in sports was related to better weight status in pupils as opposed to pupils who did not perform any sports. The highest impact on weight status was observed when pupils were engaged in athletics, regardless of sex.

Engagement in sport activities is a crucial factor of physical health and overall well-being. Several previous studies have shown that early participation in sports has a lasting impact on PA levels, mental health, and social development [24,25]. However, sport participation can vary between sex and across age. A recent study of 123,809 adults from 28 European countries showed that a number of persons not fulfilling PA guidelines increased over the past 17 years and there were no major differences in males and females [26]. Another study comparing the distribution of PA levels between 15,461 boys and girls aged 5–18 years in nine different countries found that boys were engaged in greater activity levels than girls, which aligns with the findings of our study [16]. Nonetheless, the type of sport activity performed was not evaluated in this study. A comparatively smaller study including 364 Spanish children aged 7–11 years evaluated the sex-specific engagement in different sports [27]. This study aligns with our findings, showing that males are consistently more likely to engage in organized sports, especially contact sports like football and basketball. One possible reason is that contact sports are often more popular and accessible for boys, due to societal norms that link masculinity with physicality and competition [28], which we hypothesize could influence behaviors from childhood onwards. On the other hand, females tend to prefer non-contact sports or those seen as more "feminine", such as gymnastics, volleyball, and dance, as shown in a recent study [29]. We assume that from a young age, girls are taught to value qualities like grace, flexibility, and coordination, which are often associated with sports such as gymnastics, volleyball, and dance.

The gender gap in sports participation becomes especially evident during adolescence, as social pressures, changing interests, and developmental shifts impact children's involvement in physical activities [30]. In our study, apart from engagement in volleyball in females and other sports in males, we observed a reduction in sport activities over age, regardless of gender. As also noted previously, adolescents may reduce sports participation due to physical changes during puberty [31], which can affect self-esteem and coordination [32]. Social pressures, particularly around body image, discourage girls from engaging in physical activities [33]. It may also be possible that academic demands and extracurricular activities can often take precedence over sports during adolescence.

Recent studies have examined the relationship between weight status and sports club membership among children, highlighting significant associations. A recent study on more than 9000 adolescents examined the impact of health club membership on cardiovascular health and sedentary behavior. The study found that participants with health club memberships had lower resting heart rates, improved cardiorespiratory fitness, and reduced sedentary time compared to non-members [15]. While engaging in sports can influence better weight status in children and adolescents [34,35], present weight status can also influence participation in sports. In our study, we found that pupils with overweight/obesity were twice as likely to not be members of sport club as opposed to normal-weight counterparts. Another study found that there was a 16–19% increased chance of non-membership to sports club among overweight/obese subjects aged 6 to 15 years [36]. Children with overweight and obese children face several barriers to sports participation, including physical, psychological, and social factors [37,38]. Physically, overweight/obese children may have lower endurance and fear of injury, reducing their confidence in sports. Psychologically,

body image issues and fear of stigma discourage participation. Socially, a lack of support from peers or family can lead to feelings of exclusion, further lowering participation and worsening obesity-related health risks [39]. In order to encourage sports participation in overweight and obese children, public health programs should prioritize fun, body positivity, and inclusivity. Activities should cater to various fitness levels, with family and peer involvement offering support [40,41].

The analysis of weight (BMI) changes based on different sports club membership reveals important insights into the relationship between PA and weight status in children. While no significant differences were found in BMI between pupils who were members of volleyball, martial arts, handball, swimming, basketball, or running sports clubs and those who did not participate in any sports, notable reductions in BMI were observed among pupils involved in athletics, gymnastics, football, and other sport clubs. Specifically, an athletics membership was associated with the most significant reduction in BMI, with a mean difference of 2.98 kg/m^2, suggesting that high-intensity, endurance-based sports might have a more pronounced impact on weight status compared to other activities. These findings are consistent with previous research indicating that aerobic exercises, such as those performed in athletics, contribute to greater calorie expenditure and fat reduction, leading to lower BMI [41]. Gymnastics, football, and other team-based sports also showed reduced BMI, though the differences were smaller compared to athletics, which could reflect the varying levels of intensity and energy expenditure inherent in different sports. While sports participation generally has a positive effect on BMI, it is clear that the type of sport matters. This underscores the importance of encouraging children to engage in a variety of physical activities, particularly those with a higher intensity, to achieve the best outcomes in terms of weight management and overall health.

This large German study, which includes boys and girls aged 8–18 years in a school setting, provides valuable insights into the relationship between BMI and sports participation. Its strengths lie in the large sample size, which enhances the reliability and generalizability of the findings, as well as the inclusion of both genders, allowing for gender-based comparison. The study's focus on different sports and BMI measurements in both males and females offers a comprehensive view of how PA influences weight status across various groups. Understanding these differences helps in promoting the most effective sports for each gender, ensuring better health outcomes for both. However, there are limitations, including the lack of consideration for factors such as socioeconomic status, family support, or psychological barriers that could also influence sports participation. Additionally, the study does not differentiate between the types of sports in terms of intensity or frequency, missing the opportunity to explore how various sports might affect BMI differently. Furthermore, the absence of longitudinal data limits the ability to assess the long-term effects of sports participation on BMI changes over time. Lastly, children below the age of 8 years were excluded, as fluent reading was required to complete the questionnaire. Future studies should focus on exploring the impact of different types of sports, accounting for socioeconomic, psychological, and environmental factors, and include longitudinal data to assess long-term effects on BMI and overall health, while also examining strategies to increase participation among underrepresented groups.

5. Conclusions

In conclusion, addressing gender gaps in sports participation is crucial, with a particular focus on encouraging females and overweight/obese males to engage more in physical activities. Both traditionally male and female sports, in general, should be made accessible to all children and adolescents, promoting inclusivity. Offering a diverse range of activities can lead to increased sports participation, resulting in long-term health benefits.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. In the case of minors, a declaration of consent was obtained from parents and children.

Data Availability Statement: Data cannot be shared publicly because participants did not provide explicit consent for data sharing in accordance with the European Union's General Data Protection Regulation and relevant German privacy laws. However, data can be made available to researchers who meet the criteria for access to confidential information through the Research Ethics Board of Ludwig-Maximilians-Universität Munich, Germany. Requests should be directed to: ethikkommission@med.uni-muenchen.de.

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Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body mass index
OR	Odds ratio
PA	Physical Activity
SD	Standard deviation
WHO	World health organization

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children

MDPI

Article

Association Between Food Habits with Mental Health and Executive Function in Chilean Children and Adolescents

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Abstract: Objective: To determine the association between foods habits with mental health (i.e., anxiety, depression, and stress) and executive function (i.e., attention, inhibition, working memory, and cognitive flexibility) in Chilean children and adolescents. Methods: A cross-sectional study with 498 children and adolescents (52.6% female) aged 10–17 years participated. The Krece Plus questionnaire (Food habits), Depression Anxiety Stress Scales (DASS-21, metal health), and the CogniFit (executive functions) test were used to assess the study variables. Results: The poor and moderate food habits groups reported higher prevalence of extremely severe anxiety (poor, 40.8%; moderate, 41.4%; good, 21.6%; $p = 0.013$) and extremely severe depression (poor, 20.4%; moderate, 21.3%; good, 5.7%; $p < 0.001$). The food habits were linked inversely to anxiety (β −0.07, 95%CI −0.11 to −0.03, $p = 0.001$), depression (β −0.08, 95%CI −0.12 to −0.04, $p < 0.001$), stress (β −0.07, 95%CI −0.11 to −0.02, $p = 0.004$), and total score of negative mental health (β −0.03, 95%CI −0.04 to −0.01, $p < 0.001$). Conclusions: The food habits were inversely associated with negative metal health in Chilean children and adolescents, where the good food habits group reported better mental health in all dimensions.

Keywords: children; foods habits; depression; anxiety; stress; cognitive flexibility

1. Introduction

Childhood and adolescence are crucial life stages characterized by significant physiological and psychological changes [1], where humans develop new cognitive skills (including abstract thinking capacities), a clearer sense of personal and sexual identity, and a degree of emotional and personal growth. Hence, adolescence is increasingly recognized

as a life period that poses specific challenges for treating disease and promoting health. Mental health and cognitive development, particularly executive functions (EFs) [2], are critical determinants of later life outcomes. Mental health is widely recognized as a key component of well-being [3], while EFs play a central role in learning, decision-making, and academic success [4]. They allow you to solve problems and manage emotions; research suggests that strong executive functioning skills make a difference in your mental and physical health and quality of life.

These functions are essential not only for mental health but also for academic achievement and overall [5]. Good mental health fosters the development of life skills, acts as a protective factor against stress, and contributes positively to relationships with peers and family [6]. Additionally, mental health is strongly linked to both social and psychological functioning [7]. However, mental health issues during the school years (i.e., childhood and adolescence) represent a significant global public health challenge [8]. Consequently, promoting positive mental health among adolescents has become a priority in health and educational policies across Latin American countries [9]. Moreover, EFs have been identified as strong predictors of academic performance [6]. Among the core EFs, inhibitory control, working memory, and cognitive flexibility are the primary areas of focus in scientific research [10]. Studies suggest that emphasizing EFs such as attention, inhibition, working memory, and cognitive flexibility may facilitate targeted interventions that enhance self-regulation skills, ultimately fostering resilience.

Children's food habits are crucial determinants of mental health. Evidence has shown that fruit and vegetable consumption is associated with better mental health in adolescents, whereas lower frequencies of fruit intake and breakfast consumption have been identified as significant risk factors for mental health issues, particularly among females [11]. Accumulating scientific evidence highlights the role of food habits in mental health promotion and prevention. Healthy dietary patterns have been inversely associated with depression incidence [12]. A nationally representative study examining the associations between adolescent eating habits and mental health—while accounting for age, sex, and socioeconomic factors—across five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) found that healthier food habits, such as regular family meals and breakfast consumption, were linked to improved mental health outcomes [13]. Furthermore, adherence to the Mediterranean diet has been associated with positive health outcomes, including a reduced incidence of mental health disorders. Thus, the Mediterranean diet may serve as a protective factor for mental health among children and adolescents [14]. Additionally, evidence supports a strong association between healthier food habits and improved psychosocial well-being, with high-quality dietary patterns being significantly linked to lower levels of depressive symptoms [15].

Healthy food habits have been linked to better executive functions (EFs). In contrast, unhealthy dietary patterns, such as frequent consumption of processed snacks, have shown an inverse association with EFs in children and adolescents [16]. Furthermore, life satisfaction in children and adolescents has been positively associated with healthier food habits, including a higher frequency of breakfast consumption among individuals aged 10 to 17 years across 42 different countries [17]. Additionally, in Chilean children and adolescents, greater adherence to the Mediterranean diet (i.e., healthy eating habits) has been linked to improved cognitive and academic performance [18].

Given these findings, it is crucial to examine food habits in relation to the Mediterranean diet and their effects on mental health and EFs in children and adolescents. However, to the best of our knowledge, limited information exists regarding the association between food habits, mental health, and EFs in Chilean children and adolescents. Therefore, this study aimed to determine the relationship between food habits and mental health (i.e.,

anxiety, depression, and stress) as well as executive function (i.e., attention, inhibition, working memory, and cognitive flexibility) in this population. We hypothesize that better food habits are related to mental health (i.e., anxiety, depression, and stress) and executive function (i.e., attention, inhibition, working memory, and cognitive flexibility) in Chilean children and adolescents.

2. Materials and Methods

2.1. Participants

In this cross-sectional study, 498 Chilean students aged 10 to 17 years from various schools in the city of Temuco, Chile, participated actively. The sex distribution was nearly equal, with 249 males and 262 females. A total of 53 students were excluded during the selection process. Reasons for exclusion included female students who did not meet the inclusion criteria or had personal circumstances preventing participation (n = 30), and male students who similarly did not meet the inclusion criteria or faced other barriers to participation (n = 23). It is important to note that the sample selection was intentional and non-probabilistic, meaning that participants were chosen deliberately based on predefined research objectives and criteria established by the researchers.

The inclusion criteria for this study were rigorous and designed to ensure the integrity of the research. These criteria included (i) obtaining informed consent from participants and their parents or guardians, thereby ensuring their understanding and voluntary participation in the study, and (ii) being a student, to clearly define the target population. Similarly, the exclusion criteria were detailed to ensure the suitability of participants for the assessments. These included (i) any medical contraindication that could impair normal performance in the assessments, thus ensuring that the results accurately reflected the capabilities of the student population under study, and (ii) absence during the assessments or failure to provide informed consent, thereby maintaining the validity and ethical standards of data collection. This study strictly adhered to the ethical principles outlined in the Declaration of Helsinki (2013), ensuring the protection of participants' rights in scientific research. Additionally, it received approval from the Ethics Committee of Universidad Autónoma de Chile, Chile (ACTA; No. CEC 11-23), affirming the study's methodological validity and ethical integrity. Student participation was contingent upon obtaining their signed consent, along with the informed consent of their respective parents or guardians.

2.2. Main Outcomes

2.2.1. Food Habits

The Krece Plus questionnaire was used to assess food habits and determine dietary quality based on adherence to the Mediterranean Diet [19]. This test is a valuable tool for predicting and preventing nutritional imbalances in children and adolescents. It allows for the rapid and effective detection of nutritional and physical risks that may contribute to obesity. The instrument consists of 15 dichotomous questions (answered with "yes" or "no"), each scored as either +1 or −1 according to established guidelines. The total score is classified based on previous recommendations as follows: (i) 8 to 12: good food habits; (ii) 4 to 7: moderate food habits (indicating a need for dietary improvement); and (iii) 0 to 3: poor food habits (indicating very low diet quality) [19]. The Krece Plus instrument has been previously validated and applied to Chilean students [20]. The questionnaire items used are presented in Table 1.

Table 1. Questions related to Mediterranean diet adherence.

1	Skips breakfast
2	Consumes a dairy product for breakfast (yogurt, milk, etc.)
3	Consumes cereals or grains (bread, etc.) for breakfast
4	Has commercially baked goods or pastries for breakfast
5	Takes a fruit or fruit juice every day
6	Consumes a second fruit every day
7	Consumes a dairy product > 1 time/day
8	Consumes fresh or cooked vegetables regularly 1 time/day
9	Consumes fresh or cooked vegetables > 1 time/day
10	Consumes fish regularly (2–3 times/week)
11	Eats at a fast food restaurant $\geq$ 1 time/week
12	Eats pulses (lentils, beans, more than once a week)
13	Consumes sweets and candy several times every day
14	Consumes pasta or rice almost every day ($\geq$5/week)
15	Uses olive oil at home

2.2.2. Mental Health

The abbreviated version of the Depression Anxiety Stress Scales (DASS-21) was used to assess mental health problems [21]. This three-dimensional self-report scale is designed to evaluate the presence and severity of emotional states or symptoms related to depression, anxiety, and stress [22–24]. The questionnaire consists of 21 items divided into three subscales: depression (assessing dysphoria, hopelessness, devaluation of life, self-hatred, lack of interest, and anhedonia), anxiety (evaluating physiological arousal, situational anxiety, and general anxiety), and stress (measuring irritability, feelings of being overwhelmed, difficulty relaxing, and excessive thinking). Each item is rated on a scale from 0 to 3 based on symptom intensity over the past week, ranging from "It does not describe anything that happened to me or how I felt during the week" (0) to "Yes, this happened to me a lot, or most of the time" (3). The total score ranges from 0 to 21. This instrument is advantageous due to its brevity, ease of administration and interpretation, and its effectiveness as a self-report tool [25]. The DASS-21 has been previously validated and applied to Chilean student populations [26] demonstrating adequate psychometric properties [25].

2.2.3. Executive Function

To assess executive functions (EFs), including inhibition, working memory, cognitive flexibility, and attention, the CogniFit neurocognitive assessment battery (San Francisco, CA, USA) was utilized [27]. This 40 min evaluation provides both an overall cognitive score and specific scores for individual EFs. The CogniFit battery has demonstrated good reliability and has been successfully implemented with school-aged children [28].

The neuropsychological test was administered online and required approximately 30 to 40 min to complete. Upon completion, a comprehensive results report was automatically generated, outlining the user's neurocognitive profile. Previous studies have confirmed that this cognitive profile exhibits high reliability, consistency, and stability [29].

2.2.4. Procedure

The research team responsible for evaluating the adolescent participants was trained in the study protocols and assessment procedures prior to data collection. Assessments

related to mental health, lifestyle, and active commuting were conducted during a morning class session in a laboratory setting with computers provided by the schools. Participants completed the questionnaires and evaluations individually under the supervision of researchers, who were available to address any questions or concerns. Data collection took place between April and November 2023, aligning with the academic calendar of the adolescents.

2.3. Statistical Analysis

Statistical analyses were performed using SPSS® v23.0 software (SPSS Inc., Chicago, IL, USA). The normality of the data was assessed using the Kolmogorov–Smirnov test. Continuous variables are presented as mean and standard deviation (SD), while categorical variables are expressed as frequency and percentage using the Chi-square test. Differences between sexes were analyzed using the Student's *t*-test, while group comparisons were conducted using ANOVA with the appropriate post hoc analysis. To examine the association between mental health, executive functions (EFs), and food habits, a simple linear regression analysis was performed, with results reported as beta coefficients (β) and their 95% confidence intervals (CIs). All analyses were adjusted for sex and age. A p-value < 0.05 was considered statistically significant.

3. Results

Table 2 presents the characteristics of the study sample and a comparison by sex. Males reported better mental health outcomes than females in anxiety (Male: 6.31 ± 5.09 vs. Female: 9.42 ± 5.80, $p < 0.001$), depression (Male: 6.78 ± 4.99 vs. Female: 9.33 ± 5.78, $p < 0.001$), stress (Male: 8.37 ± 4.93 vs. Female: 10.98 ± 5.24, $p < 0.001$), and overall mental health (total score: Male: 21.45 ± 13.48 vs. Female: 29.73 ± 15.60, $p < 0.001$). Regarding executive functions (EFs), significant differences were observed in attention (Male: 445.01 ± 148.99 vs. Female: 399.14 ± 154.06, $p = 0.001$) and cognitive flexibility (Male: 392.96 ± 248.50 vs. Female: 313.05 ± 236.84, $p < 0.001$).

Table 2. Characteristics of the study sample and comparison by sex.

	Male (*n* = 243)	**Female (*n* = 255)**	**Total (*n* = 498)**	***p* Value (F Value)**
Age (y)	13.63 ± 1.58	13.72 ± 1.71	13.68 ± 1.65	$0.561_{(0.34)}$
Mental health				
Anxiety (score)	6.31 ± 5.09	9.42 ± 5.80	7.90 ± 5.68	$p < 0.001_{(41.37)}$
Depression (score)	6.78 ± 4.99	9.33 ± 5.78	8.09 ± 5.55	$p < 0.001_{(28.42)}$
Stress (score)	8.37 ± 4.93	10.98 ± 5.24	9.71 ± 5.25	$p < 0.001_{(33.71)}$
Mental Health (total score)	21.45 ± 13.48	29.73 ± 15.60	25.69 ± 15.17	$p < 0.001_{(41.01)}$
Executive Functions				
Attention (score)	445.01 ± 148.99	399.14 ± 154.06	421.10 ± 153.23	$0.001_{(11.25)}$
Inhibition (score)	286.80 ± 217.76	286.82 ± 235.29	286.81 ± 226.82	$0.999_{(0.00)}$
Working Memory (score)	219.18 ± 218.55	197.33 ± 197.43	207.81 ± 207.90	$0.245_{(1.36)}$
Cognitive Flexibility (score)	392.96 ± 248.50	313.05 ± 236.84	351.38 ± 245.53	$p < 0.001_{(13.33)}$

The values are presented as mean ± SD; a p-value < 0.05 was considered statistically significant.

Table 3 presents the comparison of mental health and executive functions according to food habits categories (poor, moderate, and good). Significant differences were observed between the poor–moderate and good food habits groups in anxiety ($p < 0.001$), depression ($p < 0.001$), stress ($p = 0.014$), and DASS total score ($p < 0.001$). However, no significant differences were found in executive functions.

Table 3. Comparison according to food habits category in mental health and executive functions.

	Poor Food Habits (*n* = 142) A	**Moderate Food Habits (*n* = 268) B**	**Good Food Habits (*n* = 88) C**	***p* Value (F Value)**
Mental health				
Anxiety (score)	8.15 ± 5.56 ^{C}	8.41 ± 5.89 ^{C}	5.58 ± 4.74 ^{A,B}	$p < 0.001_{(8.78)}$
Depression (score)	8.58 ± 5.49 ^{C}	8.50 ± 5.76 ^{C}	5.68 ± 4.31 ^{A,B}	$p < 0.001_{(9.86)}$
Stress (score)	10.15 ± 5.02 ^{C}	9.87 ± 5.41 ^{C}	8.19 ± 4.94 ^{A,B}	$0.014_{(4.30)}$
Mental Health (total score)	26.88 ± 14.55	26.78 ± 15.83	19.45 ± 12.65 ^{A,B}	$p < 0.001_{(8.78)}$
Executive Functions				
Attention (score)	421.95 ± 165.68	421.06 ± 148.64	428.12 ± 149.82	$0.935_{(0.07)}$
Inhibition (score)	280.93 ± 230.87	284.17 ± 220.84	310.05 ± 245.61	$0.616_{(0.48)}$
Working Memory (score)	217.42 ± 220.36	200.73 ± 197.70	217.63 ± 217.06	$0.679_{(0.39)}$
Cognitive Flexibility (score)	336.87 ± 254.95	354.97 ± 237.44	377.66 ± 257.83	$0.493_{(0.71)}$

The values are presented as mean ± SD; a *p*-value < 0.05 was considered statistically significant. Superscript letters A, B, or C indicate significant differences between groups: A = poor food habits, B = moderate food habits, and C = good food habits.

Table 4 presents the frequency of mental health problems, including anxiety, depression, stress, and total mental health score, according to food habits categories. The poor and moderate food habits groups exhibited a higher prevalence of extremely severe anxiety compared to the good food habits group (poor: 40.8%; moderate: 41.4%; good: 21.6%, $p = 0.013$). Similarly, the poor and moderate food habits groups had a higher prevalence of extremely severe depression (poor: 20.4%; moderate: 21.3%; good: 5.7%, $p < 0.001$). However, no significant differences were observed between groups regarding stress levels.

Table 4. Frequency of mental health problems according to food habits category.

		Category of Food Habits						
		Poor A		**Moderate B**		**Good C**		
		n	**%**	***n***	**%**	***n***	**%**	***p* Value**
Anxiety	Absence	38	26.8% ^{C}	69	25.7% ^{C}	38	43.2% ^{A,B}	0.013
	Mild	6	4.2%	16	6.0%	9	10.2%	
	Moderate	22	15.5%	47	17.5%	13	14.8%	
	Severe	18	12.7%	25	9.3%	9	10.2%	
	Extremely severe	58	40.8% ^{C}	111	41.4% ^{C}	19	21.6% ^{A,B}	
	Total	142	100.0%	268	100.0%	88	100.0%	
Depression	Absence	40	28.2% ^{C}	83	31.0% ^{C}	36	40.9% ^{A,B}	<0.001
	Mild	15	10.6%	26	9.7%	23	26.1%	
	Moderate	34	23.9%	62	23.1%	17	19.3%	
	Severe	24	16.9%	40	14.9%	7	8.0%	
	Extremely severe	29	20.4% ^{C}	57	21.3% ^{C}	5	5.7% ^{A,B}	
	Total	142	100.0%	268	100.0%	88	100.0%	
Stress	Absence	48	33.8%	92	34.3%	42	47.7%	0.270
	Mild	17	12.0%	32	11.9%	12	13.6%	
	Moderate	23	16.2%	49	18.3%	16	18.2%	
	Severe	36	25.4%	66	24.6%	13	14.8%	
	Extremely severe	18	12.7%	29	10.8%	5	5.7%	
	Total	142	100.0%	268	100.0%	88	100.0%	

Data are presented as *n* and proportions (%). A *p*-value of less than 0.05 was considered statistically significant. Superscript letters A, B, or C indicate significant differences between groups: A = poor food habits, B = moderate food habits, and C = good food habits.

Table 5 presents the association between food habits, mental health, and executive function. Food habits were inversely associated with anxiety (β = −0.07, 95% CI: −0.11 to −0.03, p = 0.001), depression (β = −0.08, 95% CI: −0.12 to −0.04, $p < 0.001$), stress (β = −0.07, 95% CI: −0.11 to −0.02, p = 0.004), and the total score of negative mental health (β = −0.03, 95% CI: −0.04 to −0.01, $p < 0.001$). However, no significant associations were found between food habits and executive functions.

Table 5. Association between food habits with mental health and executive function.

β Mental variables	β (95%CI)	Beta	SE	*p* Value
Anxiety	−0.07 (−0.11; −0.03)	−0.15	0.02	0.001
	−0.21 [&] (−0.39; −0.02) [&]	−0.10	0.09	0.026
Depression	−0.08 (−0.12; −0.04)	−0.17	0.02	$p < 0.001$
	−0.27 (−0.45; −0.09) [&]	−0.13	0.09	0.003
Stress	−0.07 (−0.11; −0.02)	−0.13	0.02	0.004
	−0.15 (−0.32; 0.02 [&])	−0.08	0.09	0.083
Mental Health	−0.03 (−0.04; −0.01)	−0.16	0.01	$p < 0.001$
	−0.63 (−1.11; −0.14) [&]	−0.11	0.25	0.012
Executive functions				
Attention	0.00 (0.00; 0.00)	0.05	0.00	0.314
	0.43 (−4.71; 5.57) [&]	0.01	2.62	0.869
Inhibition	0.00 (0.00; 0.00)	0.05	0.00	0.314
	3.59 (−4.19; 11.36) [&]	0.04	3.96	0.365
Working Memory	0.00 (0.00; 0.00)	0.02	0.00	0.681
	−0.10 (−7.08; 6.89) [&]	0.00	3.56	0.978
Cognitive Flexibility	0.00 (0.00; 0.00)	0.08	0.00	0.078
	3.79 (−4.26; 11.83) [&]	0.04	4.10	0.356

Data shown represent beta and 95% confidence interval β (95%CI). [&] represents values adjusted by sex and age.

4. Discussion

The main aim of this study was to examine the association between food habits and mental health (i.e., anxiety, depression, and stress) as well as executive function (i.e., attention, inhibition, working memory, and cognitive flexibility) in Chilean children and adolescents. The key findings indicated that poor and moderate food habits were associated with a higher prevalence of extreme anxiety and depression compared to good food habits. However, no significant differences were observed in stress levels across the different food habit categories. Furthermore, no significant associations were found between food habits and executive functions.

Poor and moderate food habits were significantly associated with a higher prevalence of extreme anxiety in children and adolescents, as demonstrated by the study findings. This aligns with prior research, such as a study on dietary patterns among Chinese adolescents, which found that unhealthy food habits, particularly those high in snacks and animal-based foods, were linked to higher odds of anxiety symptoms [30]. Similarly, the CASPIAN-V study reported that skipping breakfast and consuming high amounts of sugary snacks and soft drinks were significantly associated with anxiety and other mental health challenges in children and adolescents [31]. Other studies have shown that adherence to healthier dietary patterns, including a high intake of fruits and vegetables, is associated with lower anxiety levels [32]. These findings highlight the potential impact of unhealthy eating behaviors on mental well-being and emphasize the need to promote healthier food habits as a strategy to mitigate rising anxiety levels among children and adolescents.

A significant association was also found between poor and moderate food habits and a higher prevalence of extreme depression in children and adolescents, according to the findings of this study. These results are supported by previous studies indicating that unhealthy dietary patterns are linked to a greater risk of depression in young people [33,34]. For instance, a study on dietary patterns and mental health in adolescents demonstrated that adherence to unhealthy diets, such as those high in processed foods and snacks, was associated with increased depressive symptoms [35]. Additionally, the CASPIAN-IV study, mentioned earlier, also highlighted that frequent consumption of junk food, such as sweets and fast foods, significantly increased the likelihood of experiencing psychiatric distress, including depression [36]. Additionally, the systematic review published by O'Neil et al. [37] demonstrated a decade ago that adherence to healthy dietary patterns reduces the risk of depressive symptoms, possibly due to the anti-inflammatory and neuroprotective properties of certain nutrients such as omega-3 fatty acids, folate, and antioxidants. Biologically, these nutrients may regulate brain function by modulating neurotransmitter activity, reducing oxidative stress, and promoting neuroplasticity [38].

In our study, no significant differences were found in stress levels based on food habits among Chilean children and adolescents. These results differ from recent studies that have documented associations between dietary habits and perceived stress. For instance, the study conducted by Park et al. [39] on Korean adolescents demonstrated that frequent consumption of unhealthy foods, such as fast food and soft drinks, is associated with higher stress levels, while a higher intake of fruits, vegetables, and milk correlates with better perceptions of general and mental health. Similarly, the study by Michels et al. [40] highlighted that stress can lead to emotional eating patterns, which promote the consumption of foods high in fats and sugars, exacerbating mental health issues. The lack of association could be explained by the limited sample size and cultural differences in how stress is perceived in this specific population. Additionally, contextual factors, such as access to healthy foods and family influence, might have mitigated the impact of stress on dietary habits. Lastly, the cross-sectional design of this study may hinder the ability to capture causal relationships, underscoring the need for longitudinal research.

The present study showed an inverse relationship between food habits and mental health problems according to the DASS-21 scale, where better food habits were associated with a lower prevalence of anxiety, depression, and stress. This finding is supported by recent research such as de Caamaño-Navarrete et al. [15] in which it was observed that a healthy diet was significantly associated with fewer symptoms of anxiety and depression in children and adolescents. Additionally, a study carried out by Geraets and Heinz [41] claimed that adolescents who followed a healthy eating pattern experienced better mental health compared to those with less balanced diets. Furthermore, evidence indicates that healthy diets, rich in fruits, vegetables, and essential nutrients, promote a healthier emotional balance thanks to the anti-inflammatory and neuroprotective effects of nutrients such as omega-3 fatty acids, B complex vitamins, and antioxidants, which reduce oxidative stress and improve brain function [42].

In our study, no significant associations were found between food habits and executive functions, such as attention, inhibition, working memory, and cognitive flexibility. This contrasts with previous research that has shown relationships between a healthy diet and better executive function performance. For example, the study published by Cohen et al. [16] found that healthy dietary patterns, characterized by higher consumption of whole grains, fruits, and vegetables, were positively associated with better executive function, while less healthy foods, such as processed snacks and sugary drinks, showed an inverse association. The HELENA study highlighted that higher dietary quality, measured through healthy diet indices, was related to better attentional control in European adolescents [43].

The lack of association could be explained by methodological factors, such as sample size, sensitivity of the tools, or cultural differences, as well as the cross-sectional design of this study, which limits the ability to establish causal relationships and underscores the need for longitudinal research.

Promoting healthy food habits is essential to improving the mental health of children and adolescents, given the positive impact of a balanced diet on reducing issues like anxiety and depression [14]. These findings highlight the importance of incorporating educational programs and awareness campaigns in schools and communities, as well as developing public policies that facilitate access to healthy foods, especially for vulnerable populations. In the context of Chile, these initiatives could play a key role in preventing mental health problems and promoting overall well-being, serving as a model for implementing similar strategies in other countries.

This study contributes to the field of mental health and food habits research by providing evidence of the inverse relationship between the quality of food habits and mental health issues, such as anxiety and depression, in Chilean children and adolescents. However, no significant associations were identified with executive functions, raising questions about potential underlying mechanisms that remain unexplored. This study has several limitations, including its cross-sectional design, which prevents establishing causal relationships, and the non-probabilistic sampling method, which limits the generalizability of the findings. Additionally, the self-reported assessments of food habits and mental health may be subject to reporting biases. Future studies should include longitudinal designs and more precise assessment tools to investigate causality and consider contextual factors such as family influences, access to healthy foods, and cultural differences.

5. Conclusions

Food habits were inversely associated with negative metal health in Chilean children and adolescents, where the good food habits group reported better mental health in all dimensions. Hence, food habit modification could be a cost-effective strategy for the prevention and treatment of mental health problems among children and adolescents.

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children

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Article

Association Between Screen Time and Lifestyle Parameters with Executive Functions in Chilean Children and Adolescents: Potential Mediating Role of Health-Related Quality of Life

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Abstract: Background/Objective: This study aimed to (i) investigate the association between lifestyle parameters (i.e., screen time [ST], food habits, and physical activity [PA]) and health-related quality of life (HRQoL) with executive functions (EFs, i.e., attention, inhibition, working memory, and cognitive flexibility) in Chilean children and adolescents, and (ii) determine the potential mediating role of HRQoL in the relationship between ST and EFs. **Methods**: A total of 511 children and adolescents (51.3% female) aged 10–17 years participated. Lifestyle parameters and EFs were evaluated. **Results**: Attention was inversely associated with ST ($\beta = -19.51$, $p < 0.001$) and positively associated with HRQoL ($\beta = 4.17$, $p < 0.001$). Inhibition was negatively linked to ST ($\beta = -25.17$, $p < 0.001$) and positively associated with HRQoL ($\beta = 3.23$, $p = 0.041$). Working memory was inversely related to ST ($\beta = -28.89$, $p = 0.001$) and positively associated with PA ($\beta = 34.01$, $p < 0.001$) and HRQoL ($\beta = 4.22$, $p = 0.003$). Cognitive flexibility was associated with ST ($\beta = -26.76$, $p = 0.001$), PA ($\beta = 23.23$, $p = 0.047$), and HRQoL ($\beta = 4.91$, $p = 0.004$). The indirect effect confirmed that HRQoL partially mediated the relationship between ST and EFs, including attention (5%), inhibition (3.18%), working memory (3.82%), and cognitive flexibility (5.3%). **Conclusions**: ST was inversely associated with all EFs assessed, and HRQoL showed a potential mediating role in these relationships.

Keywords: cognitive function; physical activity; schoolchildren; screen time; health-related quality of life

1. Introduction

Childhood and adolescence are critical periods for cognitive development, particularly for executive functions (EFs) [1]. EFs are high-level cognitive processes primarily associated with the prefrontal cortex, enabling attention, self-regulation, and goal-directed behavior [2–4]. These processes play a central role in learning, decision-making, and academic success [5]. Furthermore, EFs are essential for various aspects of life, including mental and physical health, as well as academic and overall success [4]. Similarly, EFs have been identified as strong predictors of students' academic achievement [6]. Among the core EFs, inhibitory control, working memory, and cognitive flexibility are the primary focus of scientific research in this context [6].

In recent years, screen time (ST) has increased significantly among children and adolescents, encompassing activities such as watching television, using mobile phones, and playing video games [7]. Evidence increasingly links excessive ST with adverse physical, psychological, social, and neurological outcomes [8]. For example, one study demonstrated that sedentary behaviors like ST negatively impact brain structure and intelligence [9]. Excessive ST has also been shown to impair EFs and academic performance in young people [10]. A systematic review of cross-sectional and longitudinal studies found that excessive ST is negatively associated with EFs in children and adolescents [11]. Moreover, a two-year follow-up study reported that prolonged ST has a long-term negative impact on the neuropsychological development of preadolescent schoolchildren [12]. A recent narrative review further emphasized the detrimental relationship between ST and cognitive function [13]. On the other hand, adherence to ST guidelines is associated with better EF outcomes in schoolchildren [14].

Conversely, physical activity (PA) is a strong, modifiable factor that can positively influence brain function [15]. PA has been associated with various dimensions of cognitive development, including EFs, which are particularly relevant for schoolchildren [16]. Complementary research suggests that lifestyle factors, such as PA, are closely linked to EFs and the ability to learn in school settings [17]. Numerous studies have shown that PA enhances EFs [18], whereas physical inactivity negatively affects these cognitive processes [17,19]. Additionally, research indicates that low ST combined with high levels of PA is associated with better EF development [20]. Therefore, insufficient PA represents a significant risk to cognitive health.

Promoting subjective well-being and health-related quality of life (HRQoL) among children and adolescents remains a critical public health challenge [21]. The World Health Organization (WHO) defines quality of life as "individuals" perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns" [22]. HRQoL is recognized as a key measure for the young population [23]. Studies have shown a positive association between EFs and HRQoL [24]. For instance, one study conducted among schoolchildren found that HRQoL indirectly affects cognitive functions [25].

However, limited information is available regarding the potential mediating role of HRQoL in the relationship between ST and EFs. Therefore, the present study aims to (i) investigate the associations between lifestyle parameters (i.e., ST, food habits, and PA), HRQoL, and EFs (i.e., attention, inhibition, working memory, and cognitive flexibility) in Chilean children and adolescents, and (ii) determine whether HRQoL mediates the relationship between ST and EFs. This study hypothesizes that increased ST is inversely associated with EFs, and that this relationship is mediated by HRQoL.

2. Methods

2.1. Participants

The present study employed a quantitative, cross-sectional, and descriptive-associative design. A total of 511 Chilean children and adolescents aged 10 to 17 years (mean age 13.68 ± 1.65 years) from Temuco, Chile, participated in this cross-sectional study (male, n = 249; female, n = 262). A total of 53 students were excluded, including 30 females and 23 males who did not meet the inclusion criteria or were excluded for other reasons. The sample was intentional and non-probabilistic.

The sample size was calculated considering the following factors: (1) enrollment of students in educational institutions appropriate for their age group (10–17 years), (2) a significance level of 5%, (3) an absolute precision of 5%, (4) a statistical power of 95%, (5) the statistical test (*T*-test), (6) the number of measurements (x1), and (7) an effect size of 0.2. Based on these parameters and accounting for an expected response rate of 80%, a sample size of 400 participants aged 10 to 17 years was determined.

The Inclusion criteria were the following: (i) participants had to be enrolled in school and (ii) be aged between 10 and 17 years. The exclusion criteria included the following: (i) any medical contraindications that would prevent normal performance in the assessments and (ii) absence during the assessment period.

The research adhered to the principles outlined in the Declaration of Helsinki, year 2013, and was approved by the Ethics Committee (Universidad Autónoma de Chile) with the approval number CEC 11-23. Participation in this study required signed assent from the schoolchildren themselves as well as informed consent from their parents or guardians.

2.2. Main Outcomes

2.2.1. Lifestyle

A Krece Plus instrument was used to assess the students' eating habits [26]. This tool consists of 16 dichotomous questions, which must be answered affirmatively or negatively (yes/no). Each item is scored as either +1 or −1 based on the established guidelines. The total score was classified according to previous recommendations as follows: (i) 8 to 12 points indicate optimal adherence to a Mediterranean diet (MD), (ii) 4 to 7 points suggest a need for improvement in eating habits, and (iii) 0 to 3 points reflect a diet of very low quality [26]. The Krece Plus instrument has been previously validated and used with Chilean students [27].

Physical activity (PA) was measured by asking participants how many hours per week they spent engaging in physical activity, following the recommendations from previous studies [28]. The results for PA were recorded and quantified in hours per week. Screen time (ST) was assessed using the following questions: "How many hours a week do you watch videos?" and "How many hours a week do you play video or computer games?" [26].

2.2.2. Executive Function

To evaluate executive functions (EFs), including inhibition, working memory, cognitive flexibility, and attention, the CogniFit neurocognitive assessment battery (San Francisco, CA, USA) was used [29]. This 40 min assessment provides both a general cognitive score and specific scores for EFs. The CogniFit battery has been reported to exhibit good reliability and has been successfully used with school-aged children [30].

The neuropsychological test was administered online and required approximately 30 to 40 min to complete. At the conclusion of the assessment, a comprehensive results report was automatically generated, detailing the user's neurocognitive profile. This cognitive profile has demonstrated high reliability, consistency, and stability in previous studies [31].

2.2.3. Health-Related Quality of Life

Health-related quality of life (HRQoL) for participants was evaluated using the KIDSCREEN-10 questionnaire. KIDSCREEN-10 is a validated and widely used tool designed to monitor global HRQoL in children and adolescents aged 8 to 18 years. It comprises ten items, which include the following questions: Have you felt fit and well? Have you felt full of energy? Have you felt sad? Have you felt lonely? Have you had enough time for yourself? Have you been able to do the things that you want to do in your free time? Have your parent(s) treated you fairly? Have you had fun with your friends? Have you got on well at school? Have you been able to pay attention? [32].

Each item is answered on a five-point Likert scale, reflecting the frequency of a specific behavior or feeling (1 = never. . . 5 = always) or the intensity of an attitude (1 = not at all, 2 = slightly, 3 = moderately, 4 = very, 5 = extremely). Responses to negatively formulated items (questions 3 and 4) were reverse scored on a scale from 1 to 5. The raw scores were used for analysis, with higher values indicating better HRQoL [32].

2.3. Statistical Analysis

The data are presented as means and standard deviations (SDs). The assumptions of normality and homoscedasticity were evaluated using the Kolmogorov–Smirnov test and the Levene test, respectively. Differences between sexes were determined using Student's *t*-tests.

To examine the associations between executive functions (EFs) and lifestyle parameters, a multivariable regression analysis was conducted, with results reported as beta coefficients (β) and their corresponding 95% confidence intervals (95% CIs). Two statistical models were applied: Model 1 was unadjusted, while Model 2 was adjusted for sex and age. A *p*-value of <0.05 was considered statistically significant.

Regression analyses were also performed to examine the mediating effect of health-related quality of life (HRQoL, denoted as M), with screen time (ST) as the independent variable (X) and EFs as the dependent variables (Y). The analysis included the calculation of the total effect (c), direct effect (c′), and indirect effect (a*b, IE) for the sample. These were computed along with their 95% confidence intervals using the PROCESS macro (version 3.3) for SPSS software version 23, applying a bootstrapping method with a resampling rate of 5000 [33]. The indirect effect was considered statistically significant if zero was not included within the 95% confidence interval.

The percentage of mediation was estimated as the proportion of the direct effect to the total effect, calculated as $1 - (c'/c)1 - (c'/c)1 - (c'/c)$. All statistical analyses were conducted using SPSS statistical software version 23.0 (SPSSTM Inc., Chicago, IL, USA), with the alpha level set at $p < 0.05$ for significance.

3. Results

The participants' characteristics in lifestyle parameters and executive functions (EFs) according to sex are presented in Table 1. Significant differences were observed in lifestyle parameters, including food habits (male: 5.42 ± 2.61 vs. female: 4.23 ± 2.63, $p < 0.001$), screen time (ST) in hours per day (male: 3.66 ± 1.58 vs. female: 3.23 ± 1.40, $p = 0.001$), physical activity (PA) in hours per week (male: 1.94 ± 0.97 vs. female: 1.55 ± 0.92, $p < 0.001$), and health-related quality of life (HRQoL) (male: 26.55 ± 6.27 vs. female: 21.21 ± 6.34, $p < 0.001$).

Table 1. Participants' characteristics in lifestyle parameters and executive functions according to sex.

	Male (n = 249)	**Female (n = 262)**	**Total (n = 511)**		
				***p* Value**	**(f-Value)**
Age (y)	13.63 ± 1.57	13.72 ± 1.71	13.68 ± 1.65	-	-
Lifestyle Parameters					
Food Habits (score)	5.42 ± 2.61	4.23 ± 2.63	4.81 ± 2.69	$p < 0.001$	26.42
Screen Time (h/day)	3.66 ± 1.58	3.23 ± 1.40	3.43 ± 1.50	$p = 0.001$	10.61
Physical Activity (h/week)	1.94 ± 0.97	1.55 ± 0.92	1.74 ± 0.96	$p < 0.001$	20.89
HRQoL (score)	26.55 ± 6.27	21.21 ± 6.34	23.81 ± 6.84	$p < 0.001$	91.82
Executive Functions					
Attention	445.01 ± 148.99	399.14 ± 154.06	421.10 ± 153.23	$p = 0.001$	11.25
Inhibition	286.80 ± 217.76	286.82 ± 235.29	286.81 ± 226.82	$p = 0.999$	0.00
Working Memory	219.18 ± 218.55	197.33 ± 197.43	207.81 ± 207.90	$p = 0.245$	1.36
Cognitive Flexibility	392.96 ± 248.50	313.05 ± 236.84	351.38 ± 245.53	$p < 0.001$	13.33

The values shown are presented as mean ± SD; *p*-value < 0.05 is considered statistically significant. HRQoL: Health-related quality of life.

Regarding executive functions, differences were also found in attention (male: 445.01 ± 148.99 vs. female: 399.14 ± 154.06, $p = 0.001$) and cognitive flexibility (male: 392.96 ± 248.50 vs. female: 313.05 ± 236.84, $p < 0.001$).

Attention showed an inverse and significant association with screen time (ST) (β = −19.51, $p < 0.001$) and a positive association with health-related quality of life (HRQoL) (β = 4.17, $p < 0.001$). Regarding executive functions (EFs), inhibition was inversely and significantly associated with ST (β = −25.17, $p < 0.001$) and positively associated with HRQoL (β = 3.23, $p = 0.041$).

Working memory was inversely associated with ST (β = −28.89, $p = 0.001$) and positively associated with physical activity (PA) (β = 34.01, $p < 0.001$) and HRQoL (β = 4.22, $p = 0.003$). Cognitive flexibility was significantly related to ST (β = −26.76, $p = 0.001$), PA (β = 23.23, $p = 0.047$), and HRQoL (β = 4.91, $p = 0.004$) (Table 2).

Table 2. Association between executive function with lifestyle parameters.

Attention				
Model		**β (95%CI)**	**Standardized Beta (SE)**	***p*-Value**
1	Food Habits (score)	−1.48 (−6.74; 3.78)	−0.03 (2.68)	$p = 0.580$
	Screen Time (h/day)	−19.51 (−28.36; −10.67)	−0.19 (4.50)	$p < 0.001$
	Physical Activity (h/week)	12.42 (−1.76; 26.60)	0.08 (7.22)	$p = 0.086$
	HRQoL (score)	4.17 (2.12; 6.23)	0.18 (1.05)	$p < 0.0001$
2	Food Habits (score)	−2.05 (−7.26; 3.17)	−0.04 (2.66)	$p = 0.441$
	Screen Time (h/day)	−19.50 (−28.35; −10.65)	−0.19 (4.51)	$p < 0.000$
	Physical Activity (h/week)	9.02 (−5.10; 23.14)	0.06 (7.19)	$p = 0.210$
	HRQoL (score)	3.31 (1.16; 5.46)	0.15 (1.10)	$p = 0.003$
Inhibition				
1	Food Habits (score)	0.81 (−7.12; 8.74)	0.01 (4.04)	$p = 0.841$
	Screen Time (h/day)	−25.17 (−38.51; −11.83)	−0.17 (6.79)	$p < 0.001$
	Physical Activity (h/week)	4.78 (−16.59; 26.16)	0.02 (10.88)	$p = 0.660$
	HRQoL (score)	3.23 (0.13; 6.33)	0.10 (1.58)	$p = 0.041$

Table 2. *Cont.*

Model		β (95%CI)	Standardized Beta (SE)	*p*-Value
		Attention		
2	Food Habits (score)	1.13 (−6.84; 9.11)	0.01 (4.06)	$p = 0.780$
	Screen Time (h/day)	−23.57 (−37.10; −10.03)	−0.16 (6.89)	$p = 0.001$
	Physical Activity (h/week)	4.64 (−16.94; 26.22)	0.02 (10.98)	$p = 0.673$
	HRQoL (score)	3.54 (0.24; 6.83)	0.11 (1.68)	$p = 0.035$
		Working memory		
1	Food Habits (score)	−5.20 (−12.23; 1.83)	−0.07 (3.58)	$p = 0.147$
	Screen Time (h/day)	−28.89 (−40.71; −17.06)	−0.21 (6.02)	$p < 0.001$
	Physical Activity (h/week)	34.01 (15.07; 52.96)	0.16 (9.64)	$p < 0.001$
	HRQoL (score)	4.22 (1.47; 6.96)	0.141.40)	$p = 0.003$
2	Food Habits (score)	−4.98 (−11.99; 2.03)	−0.06 (3.57)	$p = 0.164$
	Screen Time (h/day)	−26.76 (−38.66; −14.86)	−0.20 (6.06)	$p < 0.001$
	Physical Activity (h/week)	32.57 (13.60; 51.53)	0.15 (9.65)	$p = 0.001$
	HRQoL (score)	4.30 (1.41; 7.20)	0.14 (1.47)	$p = 0.004$
		Cognitive flexibility		
1	Food Habits (score)	1.47 (−7.01; 9.96)	0.02 (4.32)	$p = 0.733$
	Screen Time (h/day)	−26.07 (−40.34; −11.79)	−0.16 (7.26)	$p < 0.001$
	Physical Activity (h/week)	23.23 (0.36; 46.09)	0.09 (11.64)	$p = 0.047$
	HRQoL (score)	4.91 (1.59; 8.22)	0.14 (1.69)	$p = 0.004$
2	Food Habits (score)	0.59 (−7.66; 8.83)	0.01 (4.20)	$p = 0.889$
	Screen Time (h/day)	−24.71 (−38.70; −10.71)	−0.15 (7.12)	$p = 0.001$
	Physical Activity (h/week)	16.10 (−6.21; 38.41)	0.06 (11.35)	$p = 0.157$
	HRQoL (score)	3.37 (−0.03; 6.78)	0.09 (1.73)	$p = 0.052$

Data shown represent β (95% CI) and Standardized Beta (SE), *p*-Value. Model 1: not adjusted, Model 2; adjusted by sex and age. $p < 0.05$ denotes significant statistics. HRQoL: health-related quality of life.

The mediation analysis results are presented in Figure 1 for the total sample (n = 511). Health-related quality of life (HRQoL) emerged as a mediating variable in the relationship between screen time (ST) and executive functions (EFs), including attention (Panel A), inhibition (Panel B), working memory (Panel C), and cognitive flexibility (Panel D).

In the first regression step (a), ST was significantly associated with HRQoL (β = 0.21, $p = 0.05$). In the second step, the regression coefficients of ST for attention (β = 4.36, $p < 0.001$), inhibition (β = 3.51, $p = 0.05$), working memory (β = 4.81, $p < 0.001$), and cognitive flexibility (β = 5.72, $p = 0.001$) indicated significant associations (c′). In the third step, the potential mediator, HRQoL, was positively associated with the dependent variables of EFs (b) ($p < 0.001$). When both ST and HRQoL were included in the model (c), the regression coefficients remained statistically significant across all outcomes ($p < 0.001$).

Finally, the indirect effect confirmed that HRQoL partially mediated the relationship between ST and EFs. Specifically, the mediation effects were as follows: attention (indirect effect = 0.98; SE = 0.95; 95% CI = −0.68, 3.04, %Med; 5%), inhibition (indirect effect = 0.75; SE = 0.85; 95% CI = −0.65, 2.74, %Med; 3.18%), work memory (indirect effect = 1.03; SE = 1.03, 95% CI = −0.88, 3.27, %Med; 3.82%) and cognitive flexibility (indirect effect = 1.23; SE = 1.27, 95% CI = −1.07, 4.00, %Med; 5.3%).

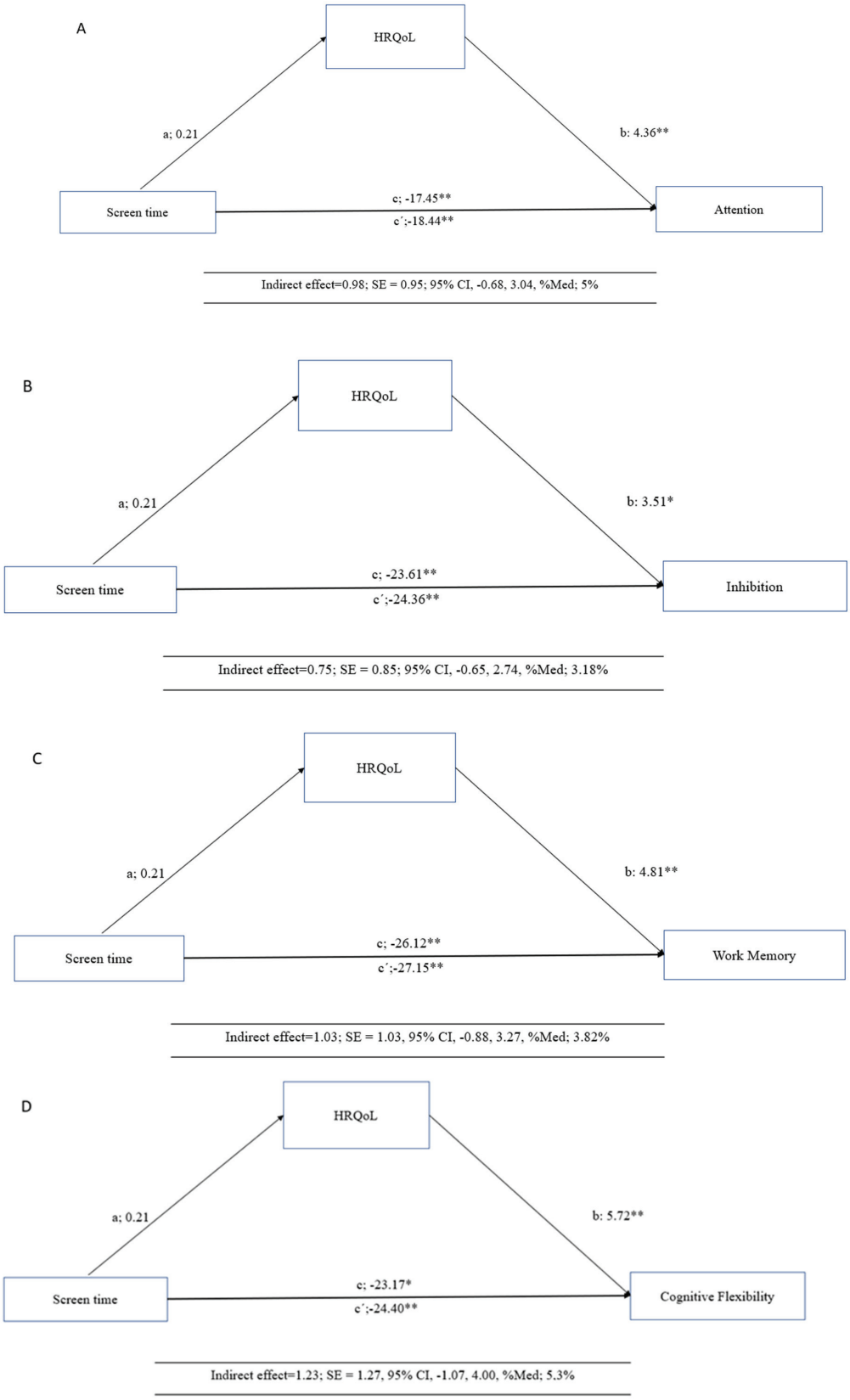

Figure 1. Mediation model testing whether the association between screen time with executive functions was mediated by health-related quality of life (HRQoL). * $p < 0.05$; ** $p < 0.001$. (**A**) including attention; (**B**) inhibition; (**C**) working memory; (**D**) cognitive flexibility.

4. Discussion

The main findings of this investigation were as follows: (i) attention was significantly associated with screen time (ST) ($\beta = -19.51$, $p < 0.001$) and health-related quality of life (HRQoL) ($\beta = 4.17$, $p < 0.001$); (ii) inhibition was inversely associated with ST ($\beta = -25.17$, $p < 0.001$) and positively associated with HRQoL ($\beta = 3.23$, $p = 0.041$); (iii) working memory was inversely related to ST ($\beta = -28.89$, $p = 0.001$) and positively associated with physical activity (PA) ($\beta = 34.01$, $p < 0.001$) and HRQoL ($\beta = 4.22$, $p = 0.003$); (iv) cognitive flexibility was significantly associated with ST ($\beta = -26.76$, $p = 0.001$), PA ($\beta = 23.23$, $p = 0.047$), and HRQoL ($\beta = 4.91$, $p = 0.004$). The mediation analysis confirmed that HRQoL partially mediated the relationship between ST and executive functions (EFs), with mediation percentages as follows: attention (%Med; 5%), inhibition (%Med; 3.18%), working memory (%Med; 3.82%), and cognitive flexibility (%Med; 5.3%).

In recent years, numerous studies have focused on examining children's ST exposure. We found that attention, inhibition, and working memory were significantly and negatively associated with ST. Like our results, another study reported that high ST was linked with poorer EFs [34]. Complementary to the above, a cohort study indicated that meeting ST guidelines was associated with better EFs [14]. Similarly, a recent finding has shown an inverse correlation between ST exposure and EFs. In this vein, Veraksa et al. [35] studied the relationship between ST exposure and EFs, finding that in children aged 5 to 6 years, reduced ST significantly improves cognitive flexibility and inhibitory control compared to those with higher ST. In addition, our results align with those of McHarg et al. [36], who observed in a longitudinal study that ST at age 2 years is negatively associated with the development of EFs in those same children from ages 2 to 3 years. This effect is also observed in adolescents. Marciano et al. [37] emphasized in their systematic review and meta-analysis that prolonged use of digital devices is linked to lower efficiency in the cognitive control system in adolescents, particularly in brain areas related to EFs, such as working memory and cognitive flexibility. Contrary to our results, a meta-analysis indicated that ST showed no effects on EFs [38]. On the other hand, data from schoolchildren indicated a relationship between ST and EF difficulty [39]; therefore, the relationship between screen time and cognition should continue to be studied.

In this study, EFs (i.e., inhibition, working memory, and flexibility) were linked positively to health-related quality of life (HRQoL). Currently, the relationship between EFs and HRQoL has been studied, primarily in adults, highlighting the role of these cognitive skills in daily well-being and mental health. The results of published studies on this topic align with those obtained in the present study. Similarly to our results, a cross-sectional study found that poorer EFs were associated with poorer HRQoL in adolescents [40]. Complementary to the above, another study conducted in children reported that EFs were positively associated with HRQoL [41]. Similarly, another study found that lower levels of EFs were closely linked to lower HRQoL [42]. Complementary to the above, working memory was identified as a key predictor of HRQoL, suggesting that improvements in EFs could lead to a better quality of life for these young individuals. These findings are in line with those obtained in this study, but it would be interesting to compare or relate them to data from healthy populations.

In the case of adolescents, we know that self-management contributes to HRQoL during this developmental stage. Therefore, assessing EFs and health management could help identify those at risk of low HRQoL [24]. Furthermore, incorporating EF assessments as part of adolescent health measures could enhance early identification of those needing support to strengthen HRQoL. Studies suggests that focusing on cognitive skills such as working memory, inhibition, and cognitive flexibility may allow for tailored interventions that reinforce self-management abilities, ultimately fostering resilience and overall

HRQoL [42,43]. Such an approach could also facilitate the development of targeted strategies in educational and clinical settings to improve mental health outcomes. Comparing findings across both healthy and clinical populations could deepen our understanding of how EFs impact HRQoL across diverse groups, emphasizing the potential benefits of early intervention and cognitive support [44].

We found that PA was associated with the EFs (working memory and flexibility). Similarly to our findings, a systematic review concluded that PA is linked with cognition [45]. Likewise, data from a meta-analysis showed a positive relation between PA and EFs in children [46]. Moreover, focusing on the field of PA, improvements in EFs—specifically in working memory and cognitive flexibility—are associated with PA. Recent studies indicate that both acute and chronic PA can have positive effects on these cognitive abilities. In this line, positive effects of PA on EFs have been reported, particularly on attention and academic performance in youth [47]. In addition, the findings by Liu et al. [48] align with those found in this study, showing that both short-term and long-term PA result in a moderate improvement in working memory and a small improvement in cognitive flexibility among youth. Additionally, focusing on children aged 8 to 12 years, it is known that higher amounts of sedentary behavior are associated with poorer EFs [49]. Furthermore, Shi et al. [50] conducted a systematic review that analyzed the impact of PA in real-world settings on EFs in typically developing children and adolescents. The results indicated that both short-term and long-term PA positively impact EFs, particularly improving working memory and cognitive flexibility when open or sequential motor skills are used. In this sense, a systematic review indicated a positive effect of physical exercise on working memory and attention [51]. These findings emphasize the importance of including physical activities in young people's daily routines to promote the development of essential executive skills for academic achievement and adaptation in daily life.

In this study, HRQoL presented a potential mediating role in the relation between ST and EFs. Some recent studies have found that HRQoL might mediate the relationship between ST and EFs of young people. For example, with Chilean schoolchildren, it has been observed that both ST and abdominal obesity harmfully affect HRQoL, where it is shown that the quality of the muscular index mediates the relation, and some health factors could be indirectly affecting the effects of ST on HRQoL and, in turn, cognitive abilities [52].

This is further supported by the findings of a study that found certain sedentary behaviors, such as the excessive use of screen-based devices, to be related to poorer HRQoL among adolescents, possibly mediated by emotion regulation and core cognitive skills including working memory and cognitive flexibility in the context of poor general well-being [53]. Such findings underline that HRQoL is an important factor to consider in understanding the relationship between ST and EFs; therefore, improving HRQoL could buffer the negative effects of ST overuse on the cognition of children and youth.

Limitations and Strengths

In the present study, the main limitations include its cross-sectional design, the reliance on self-reported questionnaires, and the use of a convenience sample. However, this study also has notable strengths, such as the simplicity of the assessments, which facilitates their use and application in healthy lifestyle interventions targeting children and adolescents.

5. Conclusions

ST was inversely associated with EFs. In contrast, lifestyle parameters, such as PA, and HRQoL showed positive and significant associations with EFs, including attention, working memory, and cognitive flexibility. Furthermore, HRQoL demonstrated a potential mediating role in the relationship between ST and EFs.

However, future research should consider employing advanced technologies to more accurately measure and assess ST.

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Institutional Review Board Statement: This investigation complied with the Declaration of Helsinki (2013) and was approved by the Ethics Committee of Universidad Autónoma de Chile, Chile (approval number: CEC 11-23 Act).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to Privacy.

Conflicts of Interest: The authors declare no conflicts of interest.

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Article

Effects of a 12-Week Mixed-Method Physical Exercise Program on Physical Fitness, Stress, Anxiety, and Quality of Life in Adolescents with Cerebral Palsy: A Case Series Study

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Abstract: Background/Objectives: Although the health benefits related to physical exercise for adolescents with cerebral palsy (CP) have been recognized, studies indicate that individuals with CP at school age are less involved in physical activities than their typical peers and are twice as likely to engage in sedentary behaviors. Therefore, our study aims to investigate the effects of a physical exercise program on physical fitness, stress, anxiety, and quality-of-life variables. Methods: A total of 15 teenagers with ambulatory CP (n = 8 boys, n = 7 girls, between 12 and 18 years old; M = 14.35; SD = 1.76) completed a 12-week program based on a mixed-method approach with face-to-face and live online activities. The outcome measures were physical fitness, stress, anxiety, and quality of life. Results: The 12-week exercise program resulted in gains in muscular strength, flexibility, and aerobic endurance tests, characterized by an increase in average walking speed and average VO_2 max. There was also a significant change in the perception of emotional states of depression, anxiety, and stress reported by the participants. Conclusions: The program proved to be effective in physical fitness tests and perception of emotional states. Given the positive effects produced by the program, its design appears to meet the demands of adolescents with cerebral palsy.

Keywords: physical exercise program; well-being; neurodevelopmental disorders; teenagers; rehabilitation

1. Introduction

Cerebral palsy (CP) is one of the most common neurodevelopmental disorders caused by non-progressive damage to the immature brain [1]. Its estimated incidence is 1.4 to 1.8 in 1000 live births in industrialized countries [2]. The degree of motor impairment varies from those who have an almost normal function to others who have a significant disability. The clinical characteristics and comorbidities of CP are also varied. About 75% of children experience pain, 50% have an intellectual disability, at least 25% have epilepsy, and about 20% to 25% have behavioral or sleep disorders [3]. In addition to clinical comorbidities, the occurrence of stress and anxiety in adolescents with CP has been identified [4]. Impacts on quality of life were identified in the physical, psychological, and social domains [5].

Although CP is a non-progressive condition, it results in primary and secondary disabilities, such as muscle changes, decreased range of joint movement, impaired balance function, and reduced cardiorespiratory endurance [1,6]. Consequently, children

and adolescents may also present worse performance in daily activities and restricted participation [7].

One of the main therapeutic goals for children and adolescents with CP is improving motor function [8]. Over the past decade, the benefits of physical activity (PA) have become progressively clear [9]. Research shows that being physically active benefits everyone, regardless of personal and environmental factors [10,11]. It has been reported that a minimal increase in PA could improve overall health [12]. The practice of PA is also related to better mood, better mental health, well-being, and less stress [13,14]. Historically, the recommendations and benefits of physical activity/exercise for individuals with CP have not been clearly defined [15]. However, research suggests that individuals with CP who participate in sports or exercise experience the health benefits reported in the general population [15]. The effects may depend on the proposed activity and the training parameters to achieve the objectives. Specific interventions are aimed at improving muscular strength [16], balance [17], and aerobic capacity [18]. The relationship between physical exercise and the quality of life of children and adolescents with CP has also been investigated [19]. Unfortunately, evidence suggests that school-aged children with CP are 30% less involved in PA than their typical peers and twice as likely to engage in sedentary behavior [20]. Adherence to exercise programs is challenging, especially in children and young people with more significant motor impairments, which limit independent mobility. Success in adhering to the activity depends on the commitment and availability of both the patient and the caregiver [15]. Many barriers that make physical exercise difficult justify a sedentary lifestyle [21]. In this population, intellectual impairment, the presence of pain during exercise, and the daily challenges of managing a child with disability are some reported barriers to participating in PA [22,23].

Home exercises began to be studied to improve exercise adherence. Exercising at home was considered a facilitating strategy for those who had difficulty accessing sports halls or gyms or who were embarrassed to exercise in public [24]. Due to protective measures and restrictions, home exercise has been encouraged, especially during the COVID-19 pandemic [25]. In these extreme circumstances, the disruption of access to healthcare and community support services has also affected people with disabilities and their families, resulting in increased stress and anxiety and decreased PA [26,27]. Technological advances have opened up new possibilities for home exercise programs. Online exercise prescription websites and apps have seen significant improvements. Telemedicine, in particular, has made great strides in the face of the COVID-19 pandemic. It is now possible to conduct home exercises online, with the live supervision of a specialized professional, offering a promising alternative to traditional in-person programs. Following the COVID-19 pandemic, these programs may be synchronous (e.g., video conferencing with a professional), asynchronous (e.g., exercises with digital images and videos), or hybrid (e.g., a combination of synchronous and asynchronous). Studies describe the positive effects of home exercises for older adults and consider them a viable and acceptable alternative to face-to-face programs [28]. They showed that Internet-based programs can offer an alternative for participants who cannot attend regular face-to-face physical activity programs. However, another study raises the limitations of home-based PA in terms of social participation, recreation, and leisure programs for children with CP [25]. Another study suggests that online or hybrid exercise programs incorporating interactive methods (i.e., competition and cooperation) can improve social interaction and quality of life among school-aged children with CP who use wheelchairs [29].

Given the recent changes in exercise programs and the lack of comprehensive answers in the literature, we aim to investigate the potential effects of a 12-week intervention based on physical exercise (PE) in a mixed-method program that alternates face-to-face and live online activities on physical fitness, stress, anxiety, and quality of life of adolescents with cerebral palsy.

2. Materials and Methods

2.1. Participants

Fifteen participants with ambulatory CP (n = 15), eight boys and seven girls, between 12 and 18 years old (M = 14.35; SD = 1.76), met the criteria to participate in the final analysis. Most adolescents had CP GMFCS level I (60%, n = 9) and the most common topography was diplegia (53%, n = 8).

2.1.1. Inclusion Criteria

Eligibility criteria for participation included the following:

(i) A medical diagnosis of CP (information collected in electronic medical records).
(ii) An age between 12 and 18 years.
(iii) CP classified as level I, II, or III by the Gross Motor Function Classification System (GMFCS) and an ability to walk, even if the assistance of a device is required [30].
(iv) The ability to be monitored in a rehabilitation center.
(v) Live in Fortaleza, Brazil, or nearby cities to enable face-to-face monitoring.

2.1.2. Exclusion Criteria

Adolescents with selected age and diagnosis who met the following criteria were excluded from the study:

(i) Those who did not agree to participate in the PE program or whose parents or legal representatives did not authorize their participation in this study.
(ii) Those who had clinical contraindications for participation in the proposed PE program or were using any corticosteroid medication that could confuse the study results (information in electronic medical records).
(iii) Those who had undergone neurological surgery or invasive/non-invasive orthopedic intervention in the last six months (information in electronic medical records).
(iv) Federated athletes.
(v) Those who were unable to provide sufficient cooperation in intervention and testing sessions.

The program was 50% face-to-face and 50% online, and to evaluate the intended effects, we established a 75% attendance rate for the activities. The data evaluated corresponded to data from 60% of the sample since 40% of the adolescents missed more than 25% of the program. The absence was usually in face-to-face activity due to financial difficulties in traveling to the rehabilitation center or the illness of the primary caregiver. Two adolescents dropped out of the program due to a lack of interest in physical activity.

2.2. Ethic

This research was conducted following the recommendations of the ethical guidelines for research with human beings and the Resolution of the National Health Council. An information session was held with the adolescents and their parents or legal representatives to explain the study's objective, data collection, and the characteristics of the intervention program; those who agreed to participate provided written informed consent according to the Declaration of Helsinki. The research was approved by the Rede Sarah Ethics Committee on 6 April 2023 (CAAE 63680022.5.0000.0022).

2.3. Study Design and Procedures

A case series study was conducted in a rehabilitation center (Sarah Network of Rehabilitation Hospitals—Sarah Fortaleza) between August and November 2023.

Participants were invited to face-to-face sessions once a week in the rehabilitation center and online, also once a week, during regular opening hours. Training sessions lasted 45 min and were separated by at least 48 h. The intervention program lasted 12 weeks (24 sessions). Adolescents were grouped by motor ability. Each group had up to 6 adolescents and two mediators, from the research team.

Attendance was recorded and, in the case of two consecutive absences, an institutional employee called or sent a message to the legal guardian to identify the reasons related to the absences. Participants who attended at least 75% of the 24 sessions (at least 9 face-to-face sessions and at least 9 online sessions) were included in the study and considered for data analysis.

The exercise program was based on the program described by Ferreira et al. (2018) [31] in their study protocol with children and young people with autism spectrum disorder (ASD), which aimed to improve physical fitness in the dimensions of aerobic endurance and muscular strength [31]. A third dimension was added to this study—flexibility.

Regarding the intensity of the exercises, the patients were monitored by heart rate, based on the initial assessment. The exercises ranged from moderate to intense intensity (maximum 75% of HR). During face-to-face training, patients wore a smartwatch with GPS to monitor their heart rate. Adolescents and caregivers were instructed to measure heart rate at home using the stopwatch on their own watch or mobile phone. The exercises were moderate to intense.

The muscle-strengthening training with elastic bands was progressive, with each teenager improving in resistance and, therefore, changing the elastic band individually. The muscular resistance training, with one's own body weight, was progressive in terms of the number of repetitions, also on an individual basis, respecting the possibilities of each teenager.

Each training session began with a preparatory phase (5 min) in which the adolescent was prepared for the exercise session, including a brief conversation and warm-up.

In the development phase (30 min), the teenager performed cardiorespiratory endurance, muscular endurance, and strength exercises. At this stage, the exercises were diversified and organized in a progressive sequence of difficulty to maintain the teenagers' interest and fun. Motivational strategies included different materials, different locations within the rehabilitation hospital, and music. Such strategies have been used to help encourage adherence and reduce barriers.

In the return to the calm phase (10 min), the teenager performed stretching and relaxation exercises.

A physiotherapist with a complete understanding of the training protocol supervised all sessions. Considering the possibility of cognitive impairment, participants were taught how to perform every exercise face-to-face and online.

To carry out the activities at home, the adolescents needed a cell phone (with a camera), Internet access, a mattress, a ball, and a regular chair. The online groups comprised six teenagers, supervised by a physiotherapist and a physiotherapy intern. If necessary, a family member was requested to be present. The sessions were held in a live-streaming format, so both staff and patients could see each other and staff could monitor patient exercise performance. An overview of the physical exercise program is given in Table 1. Due to the large volume of exercises, it was not possible to describe how each exercise was performed. The exercises were alternated. For example, in some sessions, there were yoga classes, and in others, there was stretching.

Table 1. Overview of the physical exercise program.

Exercise Type/(Duration)	Workout	Description	Category
Warm-up (Three minutes)	March on the spot	The teen raises each foot alternately two inches off the ground. Teens may need support.	Face-to-face and online
Warm-up (One minute)	Shoulder rolls	Teens should shrug and raise both shoulders without bending their head or neck then rotate their shoulders in a circle, bringing their shoulder blades together and releasing them to propel themselves forward. This should be repeated in the other direction.	
Warm-up (One minute)	Torso rotation	The teenager should place their hands in front of them with their elbows bent and turn their upper body to the left and right, keeping their knees forward without twisting their legs. Their cadence should be adjusted according to their preference.	
Warm-up (Five minutes)	Stationary cycling	Stationary cycling.	Face-to-face
Aerobic Exercise (Five minutes)	Step box with target	The teenager should climb one step, perform plantar flexion of the ankle, and try to reach the target fixed to the wall above their head to score points. Teens may need support.	Face-to-face and Online
Aerobic Exercise (Five minutes)	Circuit with basketball	The teenager will walk as fast as possible, deviating from five cones and through five bars on the floor. At the end of the circuit, they will receive a ball and try to throw it into the basket, earning a point if they get it in the basket.	
Aerobic Exercise (Ten minutes)	"Burned"	This is a popular local game. To play, it is necessary to divide the group into two teams. The player with the ball must throw it, trying to hit (burn) a person on the other team. Whoever is burned leaves the game. The team that manages to burn the entire opposing team first wins.	Face-to-face
Strength Training	Elastic band workout	Leg extesion (seated), glute bridge, clamshell, plantar flexion, lateral band walk, seated abduction, standing bicep curl, overhead tricep extension, pull apart, lying pull over, forward raise, and lateral raise (2 sets of 10 repetitions, progressively increased by changing the elastic band).	Face-to-face and online
Strength Training	Strength training	Plank, low squat, wall sit, isometric push-up, bridge, and calf stretch against the wall (1 to 3 sets of 10 to 15 repetitions of each of the exercises (progressively increased)).	
Flexibility/Relaxation (Ten minutes)	Yoga class	Downward dog on a chair (Uttana Shishosana), child's pose (Balasana), bound angle pose (Baddha Konasana), and cat–cow (Marjaryasana-Bitilasana).	Face-to-face and online
Flexibility/Relaxation (Ten minutes)	Stretching	Triceps stretch, arms and abs stretch, standing quad stretch, hamstring and calf stretch, and figure four stretch.	

2.4. Data Collection Procedures

A multidisciplinary team that included physiotherapists, a pediatrician, and a biomedical practitioner with professional experience in CP services formed the intervention team.

The evaluations were meticulously planned and executed by the main investigator and the research team members. To ensure consistency, the same evaluators collected data at both assessment moments. Adolescents evaluated by a specific physiotherapist underwent the intervention program with another physiotherapist to further minimize the risk of bias.

An accredited biomedical practitioner performed the salivary collection four times: shortly before (8 a.m.) and shortly after (9 a.m.) the first PE session, and shortly before (8 a.m.) and shortly after (9 a.m.) the last PE session.

The remaining measures were collected twice, one week before the first PE session and one week after the last PE session.

2.5. Outcome Measures

The effect of the exercise program on physical fitness, stress, anxiety and quality of life of adolescents with CP was assessed using pre-test and post-test measures, which were crucial in determining the program's impact.

The primary outcomes are related to physical fitness and body structure and function. Secondary outcomes are related to stress and anxiety levels and the perception of health-related quality of life.

2.5.1. Anthropometric Measurements

All anthropometric/body composition measurements were taken by a single experienced observer following standardized procedures [32].

Anthropometric measurements were performed following standardized procedures. Measurements were taken individually. A portable stadiometer model P200C-LD105 Lider (Araçatuba, São Paulo, Brazil), measured body mass and height. The participant stood barefoot on the stadiometer platform, looking straight ahead with their arms at their sides. The body mass index from the formula weight (kg)/height (m^2) was then calculated. Waist circumference was also measured halfway between the iliac crest and the tenth rib, directly on the skin, using a flexible measuring tape. The methods are viable, reliable, and accurate for the population.

2.5.2. Functional Capacity

Physical fitness assessment was based almost entirely on applying a set of tests selected from the Brockport Battery Physical Fitness Test—BBPFT [33]. The tests were chosen according to the need to respond to the proposed intervention and the possibility of reliable performance by the participants. The BBPFT is validated for the study.

According to the objective, we assess physical fitness in cardiorespiratory endurance, muscular endurance/strength, and flexibility. The following tests were selected:

Modified Curl-Up [33]

The objective of this test is to estimate the degree of abdominal strength.

Repetitions are performed with a cadence of 1 to 3 s (cadence can be provided by clapping). The subject performs the repetitions until exhaustion or up to 75.

Trunk Lift [33]

The test aims to measure the trunk and neck extension capacity.

This test evaluates the distance from the floor to the chin. Two attempts are allowed, and the best score is recorded. The maximum score is 12 inches (30.48 cm).

Back-Saver Sit and Reach Test [33]

The test measures the flexibility of the lower back and hamstring muscles. The score is the farthest point (in centimeters) reached with your fingertips. The score corresponding to the best of three attempts is recorded.

Shoulder Stretch Test [33]

The aim is to test the flexibility of the shoulder joint.

If the fingers of both hands touch, "Yes" (S) should be recorded. If the subject cannot touch their fingers, the result to be recorded will be "No" (N), and the minimum distance between the hands will be measured. Repeat, changing the position of your arms.

Aerobic Fitness Test—6 min Walk Test (6MWT) [33]

This test assesses aerobic capacity and endurance. The "6 min walk test" is valid and reliable for evaluating the aerobic resistance of the studied population. Participants can stop and rest, then sit down and resume the route if necessary. Average speed and heartbeats per minute were measured (before and after the test) using a smartwatch.

Aerobic Endurance Test—Step Test [34]

This submaximal test aims to provide a measure of cardiorespiratory or endurance fitness. The Queens College Step Test was added to the test battery as an alternative to the target aerobic movement test (TAMT–BBPFT), as it is shorter and, therefore, more suitable for the selected population. The test was performed in a fixed surface, and light support was allowed for adolescents due to the risk/fear of falling. The subject moves up and down the platform using a four-step, 'up–up–down–down' cadence for 3 min. Heartbeats are counted for one minute (bpm) before and immediately after the end of the test. An estimate of VO_2 max is calculated from the test results using a specific formula.

2.5.3. Depression, Anxiety, and Stress Scale

The 21-item short version of the Depression, Anxiety, and Stress Scale (DASS-21) was developed by Lovibond and Lovibond [35]. It is a set of three scales designed to measure and differentiate the emotional states of depression, anxiety, and stress. This shortened version of the DASS was developed to reduce administration time and can be used for clinical investigation and research purposes. It is a self-report scale. The literature presents strong evidence that the scales are stable over time [36] and respond to treatment for mood problems. The scale was translated and validated in the context of Brazilian adolescents [37].

Each of the three DASS-21 scales contains seven items. When filling out the DASS-21, the interviewee is encouraged to check for the presence of any symptoms in the previous week. Each item is scored from 0 (does not apply to me) to 4 (applies very much or most of the time). The result for depression, anxiety, and stress is calculated by summing the item scores. According to the score, the symptom classification can be standard, mild, moderate, severe, or extremely severe.

2.5.4. Biological Response of Physical Activity to Stress and Anxiety

Physiological stress markers, such as salivary cortisol levels and heart rate variability, objectively measure changes in the stress response. Salivary cortisol is a valid and reliable reflection of the respective unbound hormones in the blood. It reflects changes in serum cortisol levels, with the advantage of being a minimally invasive procedure [38].

Salivary cortisol measurements were collected as a physiological marker of participants' stress levels. These data were collected on a different day from the other assessments due to the need to collect such data immediately before and after physical exercise. Saliva samples were obtained using the Salivette Cortisol device, Euroimmun (Lübeck, Germany). Participants placed the cotton removed from the Salivette tube in their mouths. The sample absorption time was 2 min. Once recovered, the device was centrifuged at $1000 \times g$ for 2 min.

After centrifugation, the sample obtained was placed in an Eppendorf-type plastic tube for refrigeration (between 2 and 8 degrees Celsius) for 14 days after collection until testing. The measurements were carried out in duplicate implementing the ELISA methodology using the Cortisol in Saliva reagent kit from the manufacturer Euroimmun (Lübeck, Germany). The automatic microplate washer model ION-B-BI, Wuxi Hiwell Diatek Instruments Co., Ltd. (Wuxi, China) was used, and reading was carried out on a microplate reader model TP Reader NM, Thermoplate (Troy, MI, USA). The residual material was treated as standard biological waste.

2.5.5. Health-Related Quality of Life—KIDSCREEN-10

KIDSCREEN is a fully open access questionnaire developed for clinical studies and research projects [39]. The 10-item version, KIDSCREEN-10, is the shortest of the three KIDSCREEN questionnaires and measures overall health-related quality of life (HRQoL). It can be answered in a few minutes by healthy adolescents or those with a diagnosis (self-assessment). A corresponding version is available for parents (proxy trial).

The KIDSCREEN-10 index covers physical well-being, emotions, autonomy, family/friends, and school environment, with two items for each segment. It is recommended that the teenager and family/guardian mention the last week in their answers. The instrument provides a single HRQoL score, with higher scores representing better HRQoL. It has good discriminatory power along the HRQoL trait continuum. Its psychometric properties in adolescents aged 12 to 18 are considered adequate [39]. The questionnaire was translated into Brazilian Portuguese and validated for the Brazilian population [40].

2.5.6. Complementary Questions

A complementary questionnaire was evaluated, following the guidelines of the International Classification of Functioning, Disability and Health (ICF) [41]. It was used to characterize the adolescent's personal factors, use of orthosis, routine, means of transportation to the rehabilitation center, and social situation. A parent or caregiver answered supplementary questions.

2.6. Data Analysis

Descriptive statistics will be presented on the participants' personal and environmental data, such as age, sex, education, use of orthosis, participation in physical activity, recreational activity, and transportation conditions (public/private). Such data were collected through a semi-structured interview research format.

Normally distributed continuous variables are presented as the mean and standard deviation. Variables with non-normal distribution are presented as medians and interquartile ranges. The normality of the outcome variables was tested using the Shapiro–Wilk test. Comparisons between groups were performed using the *t*-test, Pearson's chi-square test, or the Kolmogorov–Smirnov test. A significance level lower than 0.05 was considered statistically significant. The statistical program SPSS version 21 was used for the analyses.

3. Results

Fifteen teenagers with ambulatory CP (14.35 $\pm$ 1.76 years old), 8 boys and 7 girls, successfully completed the mixed 12-week exercise intervention program. No adverse events were identified during the intervention. Table 2 presents the baseline characteristics of study participants, including PA, recreational, and mobility habits.

Table 2. Main characteristics of the CP participants in the study.

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CP Dist.	HR	D	QM	HL	D	HL	D	D	QM	D	D	D	D	QM	QS
GMFCS	I	I	III	I	II	I	I	I	II	I	III	I	I	II	II
AFO	N	N	N	N	N	N	N	N	N	N	N	N	N	Y/R	N
Age	13	15	16	12	15	12	14	16	15	17	15	13	12	13	12
Sex	M	F	F	F	F	F	M	M	M	M	F	M	M	F	M
Total Frequency %	91.6	95.8	83.3	83.3	100	87.5	75	87.5	100	91.6	91.6	75	75	100	100
Frequency Face-to-face/online %	91.6/91.6	91.6/100	83.3/83.3	75/91.6	100/100	83.3/91.6	75/75	83.3/91.6	100/100	83.3/100	91.6/91.6	75/75	66.6/83.3	100/100	100/100
PA	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N	Y
Recreation	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N
Transport	Bus	Car	Car	Bus	Car	Car	Bus	Bus	Bus	Bus	Car	Car	Bus	Bus	Car

CP DIST.: distribution of cerebral palsy; HR: hemiplegia (right); D: diplegia; HL: hemiplegia (left); QM: quadriparetic (mixed); QS: quadriparetic (spastic); GMFCS: Gross Motor Function Classification System levels I to III; AFO: ankle foot orthosis—Y: yes, N: no; AGE: age; Sex—F: female, M: male; Frequency %: frequency of participation in the activity, in percentage; PA: physical activity—Y: yes, N: no; Recreation: included in recreational activity—Y: yes, N: no.

Table 3 presents the mean and standard deviation values, and mean differences pre- and post-intervention with exercise, of the body composition, physical fitness, salivary cortisol levels, and quality of life of participants with CP, calculated with a *t*-test.

Table 3. Mean and standard deviation values, and mean differences pre- and post-intervention with exercise, of the body composition, physical fitness, salivary cortisol levels and quality of life, calculated with a *t*-test.

Outcome	Combined Training Group (n = 15)			Sig. (Two-Way)	
	Pre	Post	$\Delta_{mean} \pm SD$	t	p Value
Body mass (kg)	48.4 ± 12.82	48.4 ± 13.06	0.00 ± 0.86	0.045	0.965
Height (cm)	154.0 ± 0.11	154 ± 0.11	0.00 ± 0.00	−1.000	0.334
BMI ($kg/m^{2)}$	20.1 ± 4.13	20.1 ± 4.15	0.00 ± 1.22	0.101	0.921
WC (cm)	71.1 ± 11.22	70.5 ± 10.76	−0.56 ± 1.91	1.145	0.271
Modified curl (rep)	22.8 ± 17.66	62.1 ± 12.52	39.40 ± 18.53	−8.235	0.000 *
Trunk lift (rep)	23.1 ± 7.52	28.5 ± 6.34	5.36 ± 5.03	−4.126	0.001 *
Seat and reach (cm)	−19.2 ± 9.77	−11.4 ± 9.10	7.86 ± 6.30	−4.836	0.000 *
Shoulder stretch (R)	−12.0 ± 11.34	−8.2 ± 10.73	3.78 ± 5.94	−2.432	0.029 **
Shoulder stretch (L)	−12.1 ± 10.44	−7.7 ± 7.82	4.34 ± 5.35	−2.928	0.013 **
Step test (VO_2 max)	52.6 ± 11.93	56.2 ± 11.85	3.65 ± 3.82	−3.696	0.002 *
6MWT (m/s)	1.10 ± 0.32	1.35 ± 0.34	0.24 ± 0.15	−5.975	0.000 *
Salivary cortisol (μg/dL)	7.7 ± 5.53	6.5 ± 5.34	−1.2 ± 0.19	0.439	0.668
KIDSCREEN (score)	38.6 ± 6.17	37.4 ± 7.73	−1.50 ± 5.13	1.002	0.329
KIDSCREENPROXY	41.6 ± 5.96	41.6 ± 5.96	0.00 ± 0.00	0.569	0.579

** Significant for $p < 0.05$, * Significant for $p < 0.01$. BMI: body mass index; WC: waist circumference; VO_2 max: maximum oxygen volume; 6MWT: six-minute walk test; kg: kilogram; cm: centimeters; kg/m^2: kilogram per square meter; rep: repetition; R: right; L: left; m/s: meters per second; μg/dL: micrograms per milliliter.

3.1. Body Composition

Regarding body mass, weight, height, BMI, and WC variables, no significant statistical differences were found pre- and post-intervention with exercise; however, for WC, there was a small Δ_{mean} variation with a positive overall reduction of about 0.5 cm.

3.2. Physical Fitness Tests

In terms of physical fitness variables, significant statistical differences were found pre- and post-intervention with exercise.

3.2.1. Modified Curl-Up

The average number of repetitions increased from 22.73 to 62.12, respectively, showing a statistically significant increase in abdominal strength ($p < 0.001$). Cohen's d = 2.13 (large effect size, indicating a significant improvement in the number of curl repetitions after training), suggesting a relevant impact of training on muscular strength and endurance.

3.2.2. Trunk Lift

The average value of trunk lift increased from 22.73 to 28.53 cm, respectively, showing a statistically significant increase in upper body strength ($p < 0.01$). Cohen's d = 1.06 (large effect size, indicating a significant improvement in the number of repetitions of trunk lifts), suggesting that the training had a positive impact on core strength.

3.2.3. Back-Saver Sit and Reach Test

The hamstring muscle flexibility improved from an average of −7.86 to a −3.73 cm, showing a statistically significant gain in flexibility ($p < 0.001$). Cohen's d = 1.25 (large effect, indicating a significant improvement in participants' flexibility as measured by the sit and reach test), indicating increased mobility and flexibility after training.

3.2.4. Shoulder Stretching Test

The shoulder muscle flexibility test showed an average improvement from −12.00 to −8.26 cm on the right arm and −12.11 to −7.76 cm on the left arm, showing statistically significant gains in flexibility for both the right ($p < 0.05$) and left shoulder ($p < 0.01$). Cohen's d (R) = 0.64 and Cohen's d (L) = 0.81, and both effect sizes are moderate to large, showing a significant improvement in shoulder flexibility after training.

3.2.5. Aerobic Fitness Test—6MWT

The average gait speed increased from 1.10 to 1.35 m/s, showing a statistically significant increase in gait speed ($p < 0.001$). The use of the ankle foot orthosis was permitted during testing. Cohen's d = 1.60, showing a very large effect size, indicating a significant improvement in performance on the 6 min walk test. This suggests an increase in physical capacity and endurance of the participants.

3.2.6. Aerobic Endurance Test—Step Test

VO_2 max was measured using the step test. The mean VO_2 max value improved from 52.57 to 56.22 mL/kg/min, showing a statistically significant increase ($p < 0.01$). The use of the ankle foot orthosis was allowed during testing. Cohen's d = 0.96, showing a large effect size and suggesting a considerable increase in participants' aerobic capacity after training.

3.3. Depression, Anxiety, and Stress (DASS-21)

Figure 1 shows the values of the initial and final evaluations of the participants with CP on the DASS-21 scale for depression, anxiety, and stress.

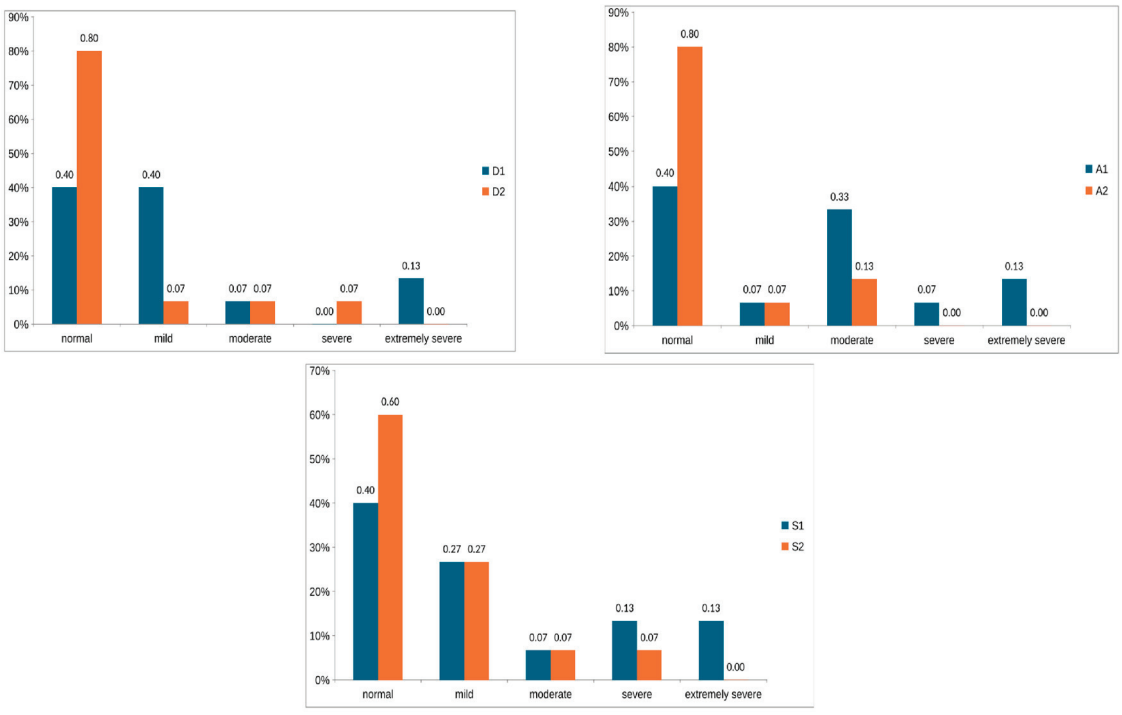

Figure 1. Participants' values for depression, anxiety, and stress from DASS-21 scale. D1, A1, and S1 correspond to the values of the first assessment on the depression, anxiety, and stress scales, respectively. D2, A2, and S2 correspond to the values of the second assessment, after 3 months of intervention, on the depression, anxiety, and stress scales, respectively.

Table 4 presents participant's descriptive values for depression, anxiety, and stress subscales and the mean differences pre- and post-intervention with exercise, calculated with Pearson's chi-square test.

Table 4. Dass-21 scale of depression, anxiety, and stress—Pearson proportion analysis test.

Outcome	Df	*n*	Pearson Value	Likelihood Ratio	*p* Value
Depression	9	15	16.458	13.424	0.058
Anxiety	8	15	17.000	13.827	0.030 **
Stress	12	15	23.229	20.557	0.026 **

** Significant for $p < 0.05$.

3.3.1. Depression

In the first assessment moment (D1) before intervention with exercise, two adolescents presented results suggestive of extremely severe depression, one moderate, six mild, and six within the normal range ($n = 15$). In the second assessment moment (D2), after intervention with exercise, one adolescent presented results suggestive of severe depression, one moderate, one mild, and twelve within the normal range ($n = 15$). A relevant improvement in perceived depression was observed due to exercise intervention; however, this result is statistically seen as marginal ($p = 0.058$).

3.3.2. Anxiety

In the first assessment moment (A1), two adolescents presented results suggestive of extremely severe anxiety, one severe, five moderate, one mild, and six within the normal range ($n = 15$). In the second assessment moment (A2), two adolescents presented results suggestive of moderate anxiety, one mild, and twelve within normal limits ($n = 15$). A statistically significant improvement in anxiety was observed due to exercise intervention ($p < 0.05$).

3.3.3. Stress

In the first assessment moment (E1), two adolescents presented results suggestive of extremely severe stress, two severe, one moderate, four mild, and six within the normal range ($n = 15$). In the second assessment moment (E2), one adolescent presented results suggestive of severe stress, one moderate, four mild, and nine within normal limits ($n = 15$). A statistically significant improvement in stress management was observed due to exercise intervention ($p < 0.05$).

3.4. Salivary Cortisol

Four samples were collected for each adolescent before and after the first day of physical activity (moments 1.1 and 1.2 here) and before and after the last day (moments 2.1 and 2.2). The average values obtained were moment 1.1 = 7.7 pg/mL; moment 1.2 = 5.7 pg/mL; moment 2.1 = 6.5 pg/mL; and moment 2.2 = 4.1 pg/mL. Although there was a reduction in the mean salivary cortisol values, when we compared moments 1.1 and 1.2 and moments 2.1 and 2.2, this reduction was not statistically significant ($p = 0.222$ and $p = 0.091$, respectively). Globally, no significant statistical differences were found for the salivary cortisol biological marker pre- (moment 1.1) and post-intervention (2.1) as a result of exercise ($p = 0.668$). Cohen's d = −6.32, showing a large negative effect, suggesting a reduction in salivary cortisol levels after training. This may indicate a reduction in participants' stress levels.

3.5. Quality of Life

The KIDSCREEN-10 questionnaire was answered by adolescents (self-assessment) and one of their parents or legal guardians. Our sample included eleven mothers, two fathers, and two sisters. Due to difficulty understanding the questions, two teenagers needed help from their family members to answer the questionnaire. The KIDSCREEN and KIDSCREEN proxy test values are provided in Table 3. A small reduction trend in the mean values was observed; however, such reduction was not statistically significant. Cohen's d = −0.29, showing a small, negative effect, indicating that there was a slight reduction in quality-of-life scores. The change is small and may not be clinically relevant. Cohen's d = 0.00 for the proxy test, as there were no changes in the quality-of-life scores reported by the

proxies (observers), indicating that the observers' perception of the participants' quality of life remained unchanged.

4. Discussion

This study allowed us to investigate the effects of a mixed-method exercise program on physical fitness, stress, anxiety, and health-related quality of life in adolescents with CP. Muscle strength, aerobic, and muscle flexibility exercises were offered face-to-face and online in a live exercise program built up for adolescents with CP. No adverse events were reported during the months of intervention.

The most significant results were related to physical fitness tests, showing a direct cause-and-effect relationship with the exercise program in the mixed method. The mixedex-ercise program resulted in gains in strength, flexibility, and aerobic endurance, characterized by an increase in average walking speed and average VO_2 max. These results highlight the importance of the exercise program's specificity, which should be directed toward the predefined set objectives. Furthermore, it can confirm that the frequency and intensity of the training were adequate for the participants.

Baseline results from the DASS-21 scale identified the occurrence of negative emotional experiences of depression, stress, and anxiety in adolescents with CP, but also provided evidence for the positive influence of physical exercise and significant differences found when compared with post-intervention values. The present study also shows a reduction in mean salivary cortisol levels after physical exercise, although this is not statistically significant.

Regarding quality of life, KIDSCREEN-10 classifies values as within or outside the expected range for interpretation purposes. The test presents an international table of values, where the expected average result for the age group of 12 to 18 years would be 47.21 ± 8.98 for girls and 49.97 ± 9.40 for boys [39]. The average results found in the present study, both before and after the intervention, were below the average of the international table. In spite of the physical fitness and reported emotional state improvement, the quality-of-life perception did not change significantly. Quality of life refers to perceptions of one's position in life, functioning, and broad assessment of well-being across multiple domains, where physical and emotional well-being are parts of a wider construct [39]. Possibly, physical and emotional changes achieved with the program were not sufficient to impact the final outcome on the assessment scale.

Physical exercise programs for adolescents with CP are diverse but predominantly face-to-face, and the systematic reviews that investigated the effects of muscle strengthening with adolescents with CP found gains in strength and gait parameters [16,42,43]. Other reviews investigating the effects of aerobic exercise also reported gains in gait parameters [19], with a positive impact on the cardiorespiratory fitness system and increased VO_2 max [44]. All studies included in the systematic reviews were face-to-face and varied in the number of studies included, the number of participants, exercise protocols, and follow-up. Concerning negative emotional experiences assessed using the DASS-21 scale, the results found in this study corroborate previous studies on the identification of the occurrence of negative emotional experiences of depression, stress, and anxiety in adolescents with CP [4] and the positive influence of physical exercise with changes in those emotional experiences [45]. The present study did not show a significant reduction in average salivary cortisol levels after physical exercise. Studies conducted with adolescents without CP indicate that physical exercise does not show significant differences regarding the variation in salivary cortisol levels [46,47]. No studies were found with participants with CP to allow direct comparison and discussion. However, the present study's trend is similar to that found in other studies with adolescents without disability. Additionally, we may also associate the occurrence of significant differences with the length of the exercise program and its relationship with the exercise intensity. Due to the psychomotor characteristics of CP, it is more difficult to reach higher levels of aerobic exercise, close to the anaerobic threshold, for an extended period, so the positive effects of aerobic exercise will probably take more time to become statistically significant, explaining why a 12-week-long program

may not be long enough to maximize the potential effects of exercise in adolescents with CP. Additional studies are needed to answer some of the questions highlighted in the present study. Concerning quality of life, our result is similar to that found in the systematic review by Soares, Gusmão, and Souto (2023) [19], where face-to-face aerobic exercises also did not improve quality of life. The review verified the effectiveness of aerobic exercises, and the results show a significant effect on aerobic capacity, balance, gross motor function, mobility, and participation. However, aerobic exercise did not impact quality of life. In this review, the included studies used varied quality-of-life assessment scales, and the samples were also small. The authors report that definitive conclusions have yet to be reached as this could lead to underestimation of the heterogeneity and, consequently, low uncertainty of the available evidence [19]. On the other hand, the study by Maher, Toohey, and Ferguson (2015) found a positive association between physical activity, social and physical quality of life, and happiness in young people with cerebral palsy [48]. As mentioned previously, quality of life is a broad construct, referring to perceptions of one's position in life [39]. Gains in health-related quality of life may be valued by some and not by others, depending on the position these aspects occupy in each individual's life. A recent scoping review [49] highlighted that systematic reviews and meta-analyses on the effects of physical exercise in adolescents with CP were diverse regarding the exercises studied, the number and type of studies as well as the number of participants in each study. Therefore, we believe that further studies are still necessary.

To our knowledge, no previous studies have evaluated the effects of exercise in adolescents with CP using a mixed-method approach. However, a previous study that evaluated the effectiveness of an online tool replacing a paper-based exercise program indicated that this method was similar to paper for adherence and outcome measures for children and adolescents with CP [24]. A study that compared a face-to-face and online exercise program to relieve neck pain in young adults found a positive result in reducing anxiety in both groups [50]. Another study that implemented an online physical activity program for 12 weeks with obese children showed gains in physical fitness and a reduction in BMI [51]; however, those previous studies did not perform a mixed online and in-person program, as was the case in the present study.

We recognize that it can be challenging for adolescents with CP to follow the exercise guidelines' recommendations, as personal and environmental factors are identified barriers. Some adolescents report being embarrassed to exercise in public places, feeling excluded in gyms, a lack of opportunity, a lack of time, difficulty in transportation, financial problems, and difficulty finding an available companion [22,23]. The companion, who, in turn, needs to have free time, and the frequency of the activity can often be a source of family stress [22,23]. Our study identified financial difficulties and the lack of a companion as the main reasons for missing face-to-face appointments. The literature also describes such factors as barriers to the practice of physical activity in adolescents [23], which is one reason why we believe it is important to study new strategies to facilitate access to physical exercise for this population. On the other hand, although it was greatly encouraged during the COVID-19 pandemic, exclusively online exercise in adolescents with cerebral palsy has not been studied for its long-term effect. We were concerned that exclusively online methods could compromise interaction between adolescents.

This mixed-method exercise program proved to be effective in improving physical fitness. This is a particularly relevant outcome because many patients have a sedentary lifestyle, increasing risk factors for cardiovascular disease [15]. Additionally, this approach allowed activities that encouraged adolescent interaction, which, when combined with exercise, may have contributed to the changes observed in their emotional state. We believe that the mixed method is promising, alternating the use of the online tool and face-to-face interaction, with the advantages of reducing expenses and travel time to the gym and, most importantly, maintaining interaction among adolescents. The mixed method can also be an alternative to encourage adherence to physical activity. However, this study did not aim to characterize adherence to the method due to the difficulties inherent in the study design.

Future studies with a randomized method and larger samples may be more appropriate to test such adherence.

This study has some limitations. Patients were allowed to maintain conventional physical therapy and complete any parallel physical activity in addition to the intervention, which may have impacted the results. However, there were no differences in outcomes between patients who performed additional physical activity and those who did not. Due to the study design (case series) and the corresponding limited sample size, it was not possible to compare the effect of this specific exercise therapy program with other type of interventions or a control group, limiting the generalizability of the results. A randomized controlled trial with long-term outcomes is needed to determine whether this specific program is better than other programs using a control group. Future directions for this type of intervention research include a follow-up to better understand the long-term sustainability of the improvements in physical fitness and emotional well-being variables.

5. Conclusions

The 12-week mixed exercise program (face-to-face and online) resulted in gains in physical fitness, muscular strength, muscular flexibility, and aerobic endurance, characterized by an increase in average walking speed and average VO_2 max in adolescents with ambulatory CP. The participants also reported a positive change in their perception of emotional states of depression, anxiety, and stress on the DASS-21 scale. The present results may contribute to the scope of evidence-based physical exercise guidelines for adolescents with CP, providing healthcare professionals with a clinical tool to help increase physical activity levels in this population.

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Article

Association between Academic Performance, Physical Activity, and Academic Stress in Compulsory Secondary Education: An Analysis by Sex

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Abstract: Objectives: The main objective of this study is to analyze the relationships between academic performance, physical activity, and academic stress in secondary education students, while the secondary objective is to establish differences by gender in the physical activity and academic stress levels of secondary students based on academic performance. Methods: The sample was composed of students from both sexes who attended public institutions. Data collection was conducted applying an ad hoc questionnaire for academic performance, the PAQ-C questionnaire for physical activity, and the QASSE questionnaire for academic stress. Data analysis was performed using descriptive statistics: Spearman's correlation coefficient was used for associations, while comparisons were conducted via the Mann–Whitney U test and Kruskal–Wallis H test. Results: The results show that academic stress is negatively correlated with physical activity and academic performance. Men present significantly higher values in physical activity, while women present higher mean values in general academic stress and the academic overload dimension. Lastly, regarding academic performance, significant differences were observed in the family pressure dimension, with students who perform better academically presenting lower mean values in this dimension of academic stress. Conclusions: In conclusion, the more the general academic stress, the lower the physical activity levels and academic performance. In addition, physical activity appears as a potential coping strategy for academic stress, and its influence on academic performance should be further studied in secondary education.

Keywords: academic stress; academic performance; physical activity; gender; secondary education

1. Introduction

Currently, the health and wellbeing of adolescents have become topics of special interest at the global level [1–3]. The adolescence stage implies significant behavioral changes that may lead to unstable and unhealthy behaviors attributed to adherence to pernicious habits such as alcohol or drug consumption, a poor diet, and sedentarism [4,5]. Therefore, adolescence is a key stage to establish a healthy lifestyle that reflects on other dimensions of life such as education and professional perspectives, which will, in turn, have implications at the physical, psychological, and emotional levels [2,6,7].

Sedentarism has become one of the most widespread risk factors in the world's population [8,9]. It is estimated that more than 50% of adolescents exhibit sedentary behaviors

and have a physically inactive lifestyle [10–12]. In addition, according to Barth et al. [13], physical inactivity in children and youngsters is accompanied by an increase in mental health problems. More than 14% of children in the world present these conditions [14], which can impact their quality of life in the short, medium, and long term, as this is a critical period for their development [5,15–17].

In particular, the transition to secondary education is, for most students, a stage riddled with anxiety and stress due to the academic demands and the new educational, social, and physical environment to which they need to adapt [18,19]. According to Naranjo [20] and Marcial et al. [21], the increase in stress levels can cause students physical, mental, and emotional health problems, reducing their self-esteem and affecting their personal development. In this context, academic stress consists of a reaction of students to school stimuli or demands considered stressors—i.e., exams, homework and task overloads, family pressure, or their own expectations—which affect both their wellbeing and academic performance [22–24].

In this sense, academic stress is recognized as a risk factor and a problem that school centers should prevent by fostering a positive and healthy environment [25]. Furthermore, considering that the sources of academic stress in general cannot be avoided, generating suitable coping strategies becomes necessary [26], mainly because of the relationship between academic stress and academic performance, which is key at the personal, professional, family, and institutional level [27,28]. Academic performance is understood as students' achievement and progress in terms of learning, based on the educational objectives established during the school stage [29]. According to Scrimin et al. [26] and Colunga-Rodríguez et al. [30], the close link between academic stress and academic failure can generate higher levels of frustration and anxiety that, in turn, are related to worse academic performance. This becomes even more evident in higher education stages, as reflected by a higher school failure rate [31,32].

In this sense, the study of factors that affect academic performance, such as academic stress, has gained growing interest at the social and research level, as the influence of parents, teachers, and some sectors of society are decisive [28,33]. In this line, various studies indicate that the practice of regular physical activity (PA) can positively contribute to the academic performance and psychological wellbeing of students [19,34–36]. PA is understood as any body movement produced by the skeletal muscles that implies spending energy and allows for performing daily activities in the environment [37]. More physically active students with high levels of stress have been found to present less stress-induced diseases, while students with a more sedentary lifestyle and high levels of stress are more vulnerable to various diseases [11,38,39]; therefore, PA may have a protective effect against stress and other associated diseases [25].

In fact, Wunsch et al. [24] maintain that PA acts as a moderator variable between stress and academic performance, as it has positive effects on memory, reaction time, creativity, intelligence, and the synthesis process as a consequence of higher levels of oxygen in the brain, and it improves cognitive function [13,40]. In addition, strong factors such as an involvement with teachers and classmates and the possibility of practicing PA at school and outside school are associated with lower stress levels, with PA being an effective coping strategy for frustration that improves the mood and reduces anxiety levels [41], as well as facilitating adherence to healthy life behaviors such as good sleep and diet, which are in turn associated with better academic performance [36,42].

In this sense, considering that adolescents spent a high number of hours at school, and that the stress derived from various demands is a factor that affects academic performance [16], the relationship between stress and the lifestyle choices related to the practice of PA should be identified, as according to Visier-Alfonso et al. [42], the mechanisms behind this influence are still unclear. Contextual factors, such as the academic periods during which stress is assessed, the type of stress, and the nature of the PA interventions (exercise, training, sports, etc.), as well as the bidirectional or tridirectional relationships explored in the investigation of stress and its connection to other psychosocial variables [15,24,36],

highlight the need for further research on this topic at the secondary education level. Therefore, the main objective of this study is to analyze the relationships between academic performance, PA, and academic stress in secondary students, while the second objective is to establish differences by gender in the PA and academic stress levels of students based on academic performance.

2. Materials and Methods

2.1. Participants

The sample was composed of 310 students from mixed public Compulsory Secondary Education (ESO, in Spanish) institutions from the Spanish provinces of Granada, Jaén, and Málaga. The sampling was non-probabilistic and by convenience, as participants were selected according to the characteristics of the study [43].

Regarding the characteristics of the sample, the mean age of the participants was 13.9 years old (SD = 1.22), 169 were men (54.5%), 125 were women (40.3%), and 16 did not specify a sex (5.2%). In addition, 82 participants were in their 1st year of ESO (26.5%), 74 in their 2nd year (23.9%), 96 in their 3d year (31%), 53 in their 4th year (17.1%) and 5 did not specify their year (1.6%).

2.2. Design

The study employed a quantitative research approach with a non-experimental and a descriptive cross-sectional design, as the variables were not manipulated, and the data collection was conducted at a specific time and only once in order to describe the phenomena, contexts, and facts analyzed and explain the trends in the population under study [43].

2.3. Instruments and Variables

A Likert scale was used as it enabled the measurement of different dimensions, such as the beliefs, thoughts, feelings, and behaviors of the participants, through various questions. The variables and measurement instruments validated for the population under study are introduced below:

- Sociodemographic characteristics

An ad hoc questionnaire was employed to collect the following sociodemographic data: age, sex, type of school attended, country of origin, and grade.

- Academic performance

An ad hoc questionnaire was created as in previous studies [13,44]. The mathematics, physical education, language, and English grades of the last term were considered to establish general academic performance. The measurement scale is the same used to grade students at school centers, i.e., ranges from 1 to 10. In addition, the criterion adopted to establish the academic performance level of students was "low" for grades from 0 to 6, "medium" for grades from 7 to 8, and "high" for grades from 9 to 10, as in other studies [30,45].

- Physical activity

The Spanish version of the PAQ-C questionnaire was applied [46]. This instrument calculates the PA of students during the last seven days through 10 questions, of which 9 refer to the level of PA and one to the presence of pathologies or events that impeded conducting PA during the last week. The response scale generates scores from 1 to 5, with higher scores indicating higher levels of PA: The internal consistency of the instrument presented in this study was $\alpha = 0.91$, and it obtained $\alpha = 0.83$ after validation.

- Academic stress

The Questionnaire on Academic Stress in Secondary School (QASSE) was employed [22]. The instrument is composed of 24 items presented on a Likert scale, where 1 equals "no stress at all" and 5 "a lot of stress". The questionnaire measures the following dimensions:

academic overload and school performance (items 1, 4, 5, 7, 10, 16, 18, 20, and 23), interaction with classmates, (items 2, 3, 6, 8, 9, 17, and 24), family pressure (items 15, 19, 21, and 22) and future prospects (items 11, 12, 13, and 14). The internal consistency of the questionnaire after its validation was $\alpha = 0.92$, and in this study, it reached $\alpha = 0.91$.

2.4. Procedure

A literature review was first conducted to have an overview of research on this topic. Then, the objective of the study was established, and the instruments for data collection were selected. Subsequently, the management team from the ESO institutes was contacted and informed about the purpose of the study through an informative letter, as well as about the approval of the same by the Ethics Committee of Universidad de Granada under the code 3324/CEIH/2023. Upon acceptance, schools were requested to send informed consent forms to the guardians or parents of students. In addition, the students' families were informed about the objective of the students' participation, clarifying that this was completely voluntary, anonymous, and confidential, and that students could abandon the study at any time in line with the recommendations of the Declaration of Helsinki [47].

For data collection, participants were given paper questionnaires. When answering them, students were accompanied by members of the research team, who could answer any questions or solve any problems that might arise. Lastly, after data collection, the data were statistically analyzed to obtain the results, discuss them, and establish conclusions based on the objectives of the study.

2.5. Statistical Analysis

The data normality was compared using the Kolmogorov–Smirnov test. Descriptive statistics are presented as mean, standard deviation, frequency, and percentages. The internal consistency of the questionnaires used was calculated via Cronbach's alpha. Based on normality, it was decided that non-parametric tests would be used for inferential statistics. To determine the degree of correlation between academic performance, physical activity, and academic stress, Spearman's correlation test was employed. Subsequently, Mann–Whitney's U test was used to compare means by sex, while Kruskal–Wallis's H test was selected for academic performance, calculating the size effect through Hedges' g and eta squared, respectively. The statistical program used was SPSS V27 (Inc., IBM Corp., Armonk, New York, NY, USA). A significance of <5% was adopted.

3. Results

The results of this work are presented below in the same order as the established objectives and based on the statistical tests mentioned above. The mean and standard deviation values of the variables under study are shown in Table 1.

Table 1. Mean and standard deviation of the variables under study.

	M	SD
Physical activity	2.66	0.77
Academic performance	6.87	1.62
General academic stress	2.88	0.80
Academic overload	3.34	0.90
Interaction with classmates	2.38	0.89
Future prospects	2.87	1.16
Family pressure	2.93	1.04

Note: M = mean; SD = standard deviation.

PA is observed to present an M = 2.66, i.e., moderate PA levels. In academic performance, M = 6.87 is on a "medium" scale value, with an SD = 1.62, which indicates some variability among participants. Regarding general academic stress, an M = 2.88 value is

observed, with participants showing higher academic stress levels in the academic overload dimension (M = 3.34) and lower ones in the classmate interaction dimension (M = 2.38).

In Table 2, a descriptive analysis is presented based on the academic performance levels, i.e., low, medium, and high academic performance.

Table 2. Descriptive analysis of academic performance.

	N	%
Low	93	30
Medium	144	46.4
High	73	23.6
Total	310	100

After analyzing the percentages, 30% of the students present a low academic performance, while most participants (46.4%) have a medium academic performance. In turn, the smallest percentage (23.6%) corresponds to students with a high academic performance.

Table 3 presents the results of the correlation analysis between variables through Spearman's coefficient.

Table 3. Correlation coefficients between the study variables.

		2.	3.	4.	5.	6.	7.
1. Physical activity	Rho	0.087	−0.119	−0.150 *	−0.042	−0.025	−0.115
	Sig.	0.268	0.147	0.049	0.575	0.739	0.138
2. Academic performance	Rho		−0.169 *	−0.069	−0.046	−0.256 **	−0.140 *
	Sig.		0.016	0.293	0.467	<0.001	0.029
3. General academic stress	Rho			0.842 **	0.767 **	0.777 **	0.800 **
	Sig.			<0.001	<0.001	<0.001	<0.001
4. Academic overload	Rho				0.454 **	0.531 **	0.550 **
	Sig.				<0.001	<0.001	<0.001
5. Interaction with classmates	Rho					0.492 **	0.574 **
	Sig.					<0.001	<0.001
6. Family pressure	Rho						0.525 **
	Sig.						<0.001
7. Future prospects							

Note: * = $p < 0.05$; ** = $p < 0.01$; Rho = Spearman's correlation coefficient.

Initially, PA is observed to be negatively related to general academic stress ($p = 0.049$, rho = −0.150), i.e., the higher the PA level, the lower the academic stress levels. In turn, academic performance is negatively correlated to general academic stress ($p = 0.016$, rho = −0.169) and the dimensions of family pressure ($p = <0.001$, rho = −0.256) and future prospects ($p = 0.029$, rho = −0.140). Lastly, general academic stress and each of its dimensions are positively and significantly related with each other ($p = <0.01$).

Table 4 presents the results of the Mann–Whitney U test for calculating the mean differences based on gender. Statistically significant differences were found in PA ($p = 0.005$, g = 0.71), with higher mean values in men. In turn, there are significant differences in general academic stress ($p = 0.007$, g = 0.79) and the dimension of academic overload ($p = <0.001$, g = 0.88), with higher mean scores for women. No significant statistical differences were present in the other variables; however, it is noteworthy that women present higher mean values in all dimensions of academic stress.

Table 4. Statistical differences by gender.

Variables	Gender		p	G
	Man M ± SD	Women M ± SD		
Physical activity	2.77 ± 0.69	2.49 ± 0.74	0.005	0.71
Academic performance	6.86 ± 1.53	6.92 ± 1.73	0.478	1.63
General academic stress	2.75 ± 0.84	3.05 ± 0.71	0.007	0.79
Academic overload	3.15 ± 0.90	3.58 ± 0.84	<0.001	0.88
Interaction with classmates	2.28 ± 0.88	2.46 ± 0.83	0.051	0.86
Family pressure	2.86 ± 1.16	2.92 ± 1.16	0.728	1.16
Future prospects	2.88 ± 1.09	3.01 ± 0.98	0.252	1.05

Note: M = mean; SD = standard deviation; p = significance (<0.05); G = heel effect size.

Lastly, the results of the Kruskal–Wallis H test in Table 5 show significant differences related to academic performance in general academic stress (H = 6.79, p = 0.034, η^2 = 0.02) and in family pressure (H = 21.36, p = <0.001, η^2 = 0.08). After the post hoc analysis using the Games–Howell method, students with high academic performance present significantly lower mean scores than students with a medium (p = 0.002) and lower (p = <0.001) performance in the family pressure dimension. However, general academic stress did not exhibit significant differences according to low, medium, and high academic performance after the post hoc analysis.

Table 5. Statistical differences by academic performance.

Variables	Academic Performance			p	η^2
	Low M ± SD	Medium M ± SD	High M ± SD		
Physical activity	2.54 ± 0.78	2.76 ± 0.73	2.55 ± 0.72	0.117	0.02
General academic stress	3.02 ± 0.80	2.85 ± 0.76	2.69 ± 0.80	0.034	0.02
Academic overload	3.45 ± 0.92	3.29 ± 0.89	3.28 ± 0.95	0.247	0.01
Interaction with classmates	2.30 ± 0.85	2.41 ± 0.86	2.14 ± 0.87	0.144	0.01
Family pressure	3.11 ± 1.07	2.86 ± 1.17	2.18 ± 1.10	<0.001	0.08
Future prospects	3.07 ± 1.10	2.79 ± 0.99	2.78 ± 1.06	0.123	0.02

Note: M = mean; SD = standard deviation; p = significance (<0.05); η^2 = effect size of square eta.

4. Discussion

The main objective of this study was to analyze the relationships between academic performance, physical activity, and academic stress in secondary education students, while the secondary objective was to establish differences by gender of levels of physical activity and academic stress based on academic performance. This study shows an association between the variables analyzed, which provides key information for the acknowledgment of academic stress in the school context as a factor that affects the academic performance of students as multiple factors become stressors [25], for which effective coping strategies are required [26], such as the regular practice of PA [34,36], as students with higher levels of PA present less academic stress, and the lower the academic stress, the better the academic performance. In line with this, the findings of this study can lead to the design of effective coping strategies for school stress, with the goal of improving students' academic performance through the practice of PA, which will contribute to the adherence of ESO students to a healthier lifestyle.

Initially, the descriptive data analysis reveals moderate PA levels in the population under study, a medium academic performance, and higher academic stress levels in the academic overload dimension, but lower ones in the interaction with classmate's dimension. These results agree with those of previous studies showing that PA levels remain moderate–low, as students are a population that does not follow a great percentage of the established

PA recommendations [10,12], due to the fact that they spend most of the day performing low-energy or sedentary activities, such as playing video games, watching television, or using the telephone, to which is added the little interest in encouraging young people to have a healthy and active lifestyle of the media that have a great influence on their behaviors [10,12].

Regarding academic performance, the relative mean of other studies often remains in the "medium" value scale, considering that there are multiple factors affecting this variable (economy, family, gender, sociodemographic characteristics) and that this, in turn, plays a mediating role in terms of healthy lifestyle habits [2,48]. In addition, in the works of Muñoz-Donoso et al. [6] and Borghi et al. [23], high academic stress levels from academic overload were also found, with physically less active students perceiving more stress from homework and assignments, and the exams period being frequently the biggest stressor in this category, mainly due to poor time management. Nevertheless, it is noteworthy that interaction with classmates motivates lower stress, as the pressure of the social environment has been demonstrated to also be a significant source of stress [26,49].

The results of the correlation analysis between variables indicate that both academic performance and PA are negatively associated with general academic stress, i.e., the higher the general academic stress, the lower the PA levels and academic performance. These findings are in line with studies such as that by Zhu et al. [15], which also demonstrates the need to reduce academic stress and increase PA practice, since the higher the academic stress levels, the lower the PA levels and the higher the vulnerability to mental health disorders. In this context, the study by Castro-Sánchez et al. [44] also shows that PA is associated with lower stress and higher academic performance, despite this last association not being significant in this study. This is because the regular practice of PA releases endorphins, which are neurotransmitters that generate feelings of happiness and reduce the perception of pain, which contributes to lower levels of anxiety and stress [44]. In addition, PA improves cognitive function, memory, and concentration, crucial factors for learning and academic performance [13,24].

In contrast, in the work by Castro-Sánchez et al. [44], academic performance also displays a positive relationship with stress; however, the authors warn that these data should be interpreted with caution, as is it understood that students with higher academic stress levels perform worse academically [50]. Regardless, students with medium levels of academic stress have been demonstrated to improve their learning achievements with adequate coping strategies, which can be, to a certain extent, an opportunity to improve performance [51,52]. Students can adapt to stressful situations thanks to a modulation in the production of cortisol, which provides the energy and substrates necessary to cope with the stimuli that give rise to stress [23], taking into account, in addition, its relationship with levels of motivation and resilience [23,44].

Regarding differences by gender, significant differences were found in PA levels, with higher mean values in men, which is in accordance with other studies where men presented the highest PA values [19,53]. In this line, Bobo-Arce et al. [54] and Burton et al. [55] believe that girls often have lower PA levels owing to different social stereotypes inside and outside the school environment that make them be more concerned with academic tasks. In addition, significant differences were observed in the general academic stress and the academic overload dimension, with higher mean values in women. This psychological malaise is attributed to the overload of academic tasks, assessments from teachers, classwork, and lack of time for academic-related activities [56]. In this sense, as indicated by Jones et al. [57], and Gasiūnienė and Miežienė [19], more physically active students—such as men in this case—present lower levels of academic stress. Therefore, the practice of regular PA is suggested to enrich the psychological health of students [58].

Lastly, with respect to academic performance, there are significant differences in general academic performance, and in the family pressure dimension, students who perform well academically present lower levels of academic stress derived from family pressure. In this context, the inverse relationship between family pressure and future prospects and

academic performance found in the correlation analysis should be noted. Pressure from parents and the social environment has been demonstrated to increase the fear of failure, which may generate more anxiety and stress [26,49,59]. According to Naranjo [20], family pressure is classified as an external source of stress, while future prospects is an internal source; these sources increase in specific periods such as exam week, when the family's perfectionist and rigid expectations exceed reality and generate frustration, making students feel incapable and unable to project their ideas for the future, and they arrives at a position of predominant anxiety. This scenario, according to Colunga-Rodríguez et al. [30], is associated with worse academic performance.

Thus, in line with the practice of PA as a potential coping strategy for academic stress, the study of its influence on academic performance should be furthered [60], underscoring the essential role of family in the promotion and adherence to PA, to which are attributed multiple benefits for mental health, such as the reduction of academic stress [61]. The social support provided by the family can significantly affect the motivation, participation, and continuity of young people in physical–sport activities, both positively and negatively, especially from an emotional perspective [20,59,62]. It has been shown that parents who adopt active behaviors and promote a healthy lifestyle tend to have children who also incorporate these habits into their daily lives [63]. Therefore, family support is essential to promote a physically active and healthy lifestyle during this stage, and it is even reflected in academic performance.

One of the main limitations of this study is its non-experimental and descriptive cross-sectional design, which does not allow for establishing causal relationships; therefore, the results should be interpreted with caution. In addition, regarding the measurement instruments, the use of accelerometers could provide more accurate information about the PA of students. Moreover, since all the participants attended public education centers, similar studies could be conducted in the future, but comparing public, state-subsidized, and private schools, expanding the sample size and including upper and lower grades to determine how the results change based on grade and age. Lastly, after analyzing the results of this study, interventions and longitudinal experimental studies should be conducted with a focus on the regular practice of PA, to measure its influence on the stress and academic performance of students.

5. Conclusions

With respect to the objectives proposed, and specifically to the main objective, it is concluded that academic performance, PA, and academic stress have different relationships with one another. In this context, academic performance is negatively associated with general academic stress, while general academic stress and each of its dimensions are positively related.

As for the secondary objective, ESO students see their PA levels and academic performance reduced as academic stress increases. In this scenario, women score higher in general academic stress and academic overload, and present lower levels of PA. Conversely, men present higher levels of PA and less academic stress in all dimensions. Therefore, it can be asserted that PA is an effective coping mechanism for academic stress disorder in secondary education. Lastly, based on academic performance, statistical differences are found in the family pressure dimension as a source of academic stress, with high-achieving students presenting less family pressure compared to students with a medium and low academic performance. Thus, the family plays a key role in the onset of stress. Therefore, encouraging the practice of PA among students should be a priority task for families and schools, proposing spaces and activities that are adapted to the needs and interests of students in order to improve their physical and mental health, which, in turn, can potentially contribute to better school performance.

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children

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Article

Differences in the Development of Motor Skills in Portuguese Children Aged 12 Months after 3 Years of COVID-19 Confinement

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Abstract: (1) Background: The objective of the study was to verify the effects of COVID-19 confinement on motor skills through a longitudinal study in Portuguese children who were one year old at the beginning of the pandemic. (2) Methods: The sample consisted of 88 children of both sexes, in the pre-COVID-19 assessment, they were 13.31 ± 2.4 months old and in the post-COVID-19 assessment, the same children were already 49.31 ± 2.5 months old. Motor skills were assessed using the PDMS-2 scales. For the statistical analysis, the Kolmogorov–Smirnov test was used to test normality, and the Wilcoxon test was used to compare the results of the two assessments in the same sample. (3) Results: There were statistically significant differences in all motor skills assessed, with children presenting, on average, worse results in all global motor skills in the post-COVID-19 assessment, as opposed to fine motor skills, showing better results in the post-COVID-19 assessment. (4) Conclusions: These results show the negative impact of the pandemic on children evaluated with a special emphasis on global motor skills, with the majority demonstrating values considered below average for their age, noting that the pandemic protocols may have had serious consequences on children's motor development, warning professionals who deal daily with children in these age groups about the importance of stimulating global motor skills.

Keywords: COVID-19; motor skills; PDMS-2; children

1. Introduction

The emergence of the new coronavirus infectious disease that began in China in December 2019 caused a state of a Public Health Emergency of International Concern decreed by the World Health Organization (WHO) on 30 January 2020. However, it was only in March 2020 that the COVID-19 outbreak was characterised as a pandemic, spreading across different regions in the world.

The COVID-19 pandemic has caused a series of changes in children's daily routines, impacting processes associated with child development [1]. It constituted the worst public health crisis of the century, disrupting daily life with the closure of daycares, preschools, and schools and, during lockdowns, isolated families in their homes with little outside support [2].

Most scientific evidence has suggested that the COVID-19 pandemic has negatively impacted student learning, disrupting the normal functioning of schools and leading to learning losses. It disrupted the normal functioning of schools and led to learning losses that have yet to be assessed, with the potential to increase inequality in education [3–5].

The Portuguese school system officially closed on 16 March 2020, during the first wave of COVID-19, transitioning to a mixed system of television broadcasting and online home

teaching by June 2020 [6]. This abrupt change required rapid adaptation on the part of both teachers and students, who had to face a number of unprecedented technical and pedagogical challenges [1]. The second lockdown in Portugal took place from January to 15 March 2021 [7], and online teaching once again returned to the daily lives of teachers and students, but this time with higher levels of preparation for primary and secondary education, including improvements to online teaching platforms and greater technical support. On the other hand, and due to its specificities, education in nurseries and pre-schools had been completely neglected [1], significantly reducing the interaction between the school and the child, with children being referred to their parents without proper monitoring of their state of development, since children of daycare age (who were the case in our sample) were in confinement between 2 March and 17 March 2020 without any type of access to learning resources (unlike the other levels of education). On 18 March 2020, when they were able to return to their school environment, they had very strict learning rules with specific and delimited spaces for each child, without toys and without contact with other children and with the mandatory use of masks by educators. The return to daycare centres only lasted until October 2020, as on that date, daycare centres in this geographical area closed again due to an increase in cases per inhabitant until 3 May 2021, leaving children once again isolated in their homes. From 3 May 2021, they were able to return to daycare centres, still with all the previous restrictions, and only from 17 February 2022, they were able to return to their normal routines they had before the pandemic. This lack of educational support for children has raised concerns about the long-term impacts on their social and cognitive development.

From the outset, we heard warnings from experts that the closure of schools, daycares, and preschools, as well as the suspension of various sporting activities and the restriction of outdoor exercise, would have a negative impact on the physical (and mental) condition of the population, including children [8,9]. In particular, the closure of daycares would have a negative impact on children's motor skills [8], compromising their ability to move (such as running, jumping, climbing, descending, etc.) and manipulate objects (such as throwing, catching, kicking, etc.). In this regard, the first reports on the impact of these lockdowns showed a decline in children's motor skills and physical fitness after the first wave of the pandemic in 2020 [10]. In addition, the proposed measures eliminated the possibility of regular contact with other children and deprived babies of an essential part of the stimuli necessary for their development [11]. In this sense, studies on babies' abilities before and after the pandemic are non-existent.

Knowing that children in the first years of life develop through their senses and stimuli from the surrounding environment [12], with confinement inhibiting contact with children and family and prohibiting the use of playgrounds and recreational spaces on the part of the entire population, these stimuli remained closed in each child's home under the influence of parental involvement. It is also known that the socio-economic statuses of families had an impact on stimulation and learning during the pandemic [1]. Homes, particularly in Portugal, are spaces with increasingly smaller rooms, clearly limiting children's mobility and play, favouring video games and digital activities even between parents and children [13]. Even before the start of COVID-19, a survey showed that 47% of parents of children aged four to thirteen played digital games together more often than outdoor games [14].

Although physical inactivity is known to be associated with obesity and delays in motor skills [15], there is a lack of information about the impact of the pandemic protocols on babies. In February 2020, while data were being collected to assess motor skills in 12-month-old children, we were faced with COVID-19 and the consequent isolation and confinement; however, the data already collected before the pandemic served as a starting point and opportunity to check the motor skills of the same children after three years and thus understand the impact of COVID-19 isolation on the motor development of children of these ages. Therefore, the objective of this study was to verify the effects of confinement

on motor skills through a longitudinal study in children who were one year old at the beginning of the pandemic.

We thus intended to understand the impact of the measures imposed on children in these age groups and therefore raise awareness of the importance of more and greater motor stimuli after this confinement.

2. Materials and Methods

2.1. Participants

This longitudinal study involved 88 children (F = 35; M = 53). At the first evaluation (pre-COVID-19, February 2020), the children were 13.31 ± 2.4 months old, and at the second evaluation (post-COVID-19, February 2023), they were 49.31 ± 2.5 months old.

All these children lived in the urban environment of a city in Portugal, and none of them practised any type of physical activity before or after the lockdown. When their parents were asked what kind of activities they did during the pandemic, the answers were that play was limited to the everyday use of toys at home.

For the first data collection, contact had been established with the daycare centre to evaluate the children; subsequently, the same authorisation was requested for the second evaluation. Of the ninety-three children evaluated pre-COVID-19, only eighty-eight were still in the same institution and with the same educators after the pandemic, and only these were re-evaluated.

The following exclusion criteria were considered: children who did not belong to the initial sample of the first assessment before COVID-19, children diagnosed with learning difficulties and/or developmental changes, and children with some type of diagnosed disability.

2.2. Instruments

The scales from the Peabody Developmental Motor Scales–Second Edition (PDMS-2) [16] were used to evaluate children's motor skills. The PDMS-2 are one of the most accurate and valid instruments for assessing motor skills in children from birth to 6 years of age. They were reviewed by Saraiva et al. [17] and Rebelo et al. [18] for the Portuguese population ($\chi 2 = 55.614$; df = 4; $p = 0.06$; $\chi 2/df = 13.904$; SRMR= 0.065; CFI = 0.99, TLI = 0.99; $\alpha = 0.85$, and ICC = 0.98).

The results of the PDMS-2 are indicated in three domains of motor development: the global motor quotient (GMQ), which encompasses postural, locomotion and object manipulation skills; the fine motor quotient (FMQ), which encompasses the skills of fine motor and visuo-motor integration; and the total motor quotient (TMQ) that results from the previous two. With the results of each subtest, we were able to understand whether the child had not yet acquired a certain motor skill, and with the combination of all these factors, it was possible to indicate the motor profile of each child [17].

The items were summed up in each of the tests, and their values are located in the reference table for age, resulting in a standardised value and a percentile value that can be compared between ages. Finally, the standardised values can be converted into a qualitative classification with categories (17–20 Very Good; 15–16 Good; 13–14 Above Average; 8–12 Average; 6–7 Below Average; 4–5 Weak; 1–3 Very Weak) [16]. The scales are standardised for the child population and have a mean value of 10 points (±3) for each test [16].

2.3. Procedures

After approval by the Ethics Committee and the institution for data collection, the Free and Informed Consent Form was sent to the parents who were asked to fill out the child's anamnesis form, which allowed the children to be selected, considering the inclusion and exclusion criteria of the study. All ethical principles, norms, and international standards relating to the Declaration of Helsinki and the Convention on Human Rights and Biomedicine were followed.

According to Folio and Fewell [16], all examiners who use the PDMS-2 must understand the general procedures for applying the test, its interpretation, and classification. In this research, only a single researcher, a specialist in the area of motor development and familiar with the instruments, collected the data.

The administration of PDMS-2 lasts approximately 45 to 60 min, individually and in a room with ample space, with the least possible amount of distracting materials that interfere with the assessment and with stairs nearby, with all routines of the daycare centre itself being respected. When interrupted, the assessments were completed within a maximum period of 5 days, as defined by the scale's authors [16].

The following rules were followed for the correct application of the instrument: to give the opportunity to reach the maximum score on each item, the instructions were repeated three times for each child; the child started the test at a point on the scale established by their age (these points were empirically determined to allow the examiner to start the test on an item that 75% of the children in the normative sample of that age passed), proceeding in the sequence until the test is failed on three consecutive items. The score for each item is 0 to 2 (0 does not perform, 1 performs with difficulty, and 2 performs well) [17]. After the evaluation, the sum of each item is calculated until the final result is established for global, fine, and total motor skills (which is the sum of global and fine skills). Subsequently, the value of the sum of the items in each of the subscales is located in a reference table for age, where a standardised value is obtained (from 1 to 20), which can be converted into a qualitative classification with seven categories (from "Very Good" to "Very Weak"), with values between 8 and 10 being considered "average" for age [16]. These standard scores were used to compare the results in the two different assessment phases since, as the authors state [16], the PDMS-2 standard scores are the most effective way of assessing motor skills over time, because the assessment exercises differ according to age, but are subsequently standardised for the child's specific age in a reference table and can thus be compared over time.

2.4. Statistical Analysis

To process the data, IBM–SPSS–Statistical Package for the Social Sciences SPSS (v.23.0) was used. Initially, the normality of the sample was checked with the Kolmogorov–Smirnov test, and as a non-normal distribution was obtained for all variables under study, the Wilcoxon test was used to compare the results of the two evaluations for the same sample. The method of inferences based on the magnitude of the effects was also performed, using the following scale (d Cohen): 0–0.2, trivial; 0.21–0.6, low; 0.61–1.2, moderate; 1.21–2.0, high; >2.0, very high [19].

3. Results and Discussion

Table 1 presents the results of the comparative analysis of the motor skills of the same children between the first assessment before the COVID-19 pandemic (pre-COVID-19) and after the pandemic (post-COVID-19).

We can observe that there were statistically significant differences in all global motor skills (postural, locomotion, and object manipulation) and in fine motor skills.

For global motor skills, before the pandemic, the children showed normative values considered to be "average" for their age. On the other hand, after the pandemic, especially for locomotion skills (7.44 ± 0.82) and object manipulation (7.15 ± 1.96), they had lower normative values and were considered "below average" for their age.

In terms of fine motor skills, these same children showed better results and abilities after the pandemic (post-COVID-19), particularly in visual-motor integration (11.97 ± 1.19), where they showed above-average values for their age. Since the lockdown gave them greater access to mobile phones, tablets, video games, and televisions, this could be the main reason why visuo-motor integration improved. On the other hand, global motor skills tended not to evolve, with some logic, since the children were deprived of contact with the outside environment and nature and were left to rely solely on their living space

to develop fundamental global motor skills such as walking, running, jumping, kicking, and throwing.

Table 1. Differences in Motor Skills between Pre-COVID-19 and Post-COVID-19.

PDMS-2	COVID-19	N	M ± SD	*p*	Effect Size
Postural skills (PS)	pre-COVID-19 post-COVID-19	88	**10.75 ± 0.58** 8.27 ± 0.98	**0.000** *	≥2.0
Locomotion skills (LS)	pre-COVID-19 post-COVID-19	88	**8.53 ± 0.71** 7.44 ± 0.82	**0.000** *	1.29
Object manipulation skills (OMS)	pre-COVID-19 post-COVID-19	88	**11.27 ± 1.87** 7.15 ± 1.96	**0.000** *	≥2.0
Fine motor skills (FMS)	pre-COVID-19 post-COVID-19	88	**8.72 ± 1.24** 9.37 ± 1.53	**0.000** *	1.24
Visuo-motor integration skills (VMIS)	pre-COVID-19 post-COVID-19	88	10.97 ± 1.53 **11.97 ± 1.19**	0.006	0.97

* $p \leq 0.05$ using the Wilcoxon test; significant *p*-values and their associated effects are in bold. N—number of subjects; M—mean of standard scores; SD—standard deviation.

Also, analysing the Effect Size (η2—Eta squared), we verified a very high effect for postural and object manipulation skills, a high effect for locomotion and fine motor skills, and lower effects for visuo-motor integration skills.

The results for global motor skills clearly indicated that changes in daily routines, stimuli, and children's experiences with confinement and isolation were harmful to their development process [8]. Neuroscience states that until the age of two, the child's brain develops at a unique speed and can make around 1,000,000 new neuronal connections per second [20]. These connections allow the child to develop emotional, cognitive, and social skills. Given this, it is essential to create an environment that encourages the development of these skills, especially for children in this age group, preventing their development from being compromised. Corroborating this point of view, Bonow et al. [21] stated in their study that mothers of babies born and raised during the pandemic were concerned about the socio-affective and motor development of their children due to social isolation.

Silva et al. [22], on the other hand, showed that children after confinement showed changes in behaviour, bringing with them signs and symptoms of anxiety, fear, agitation, stress, and insomnia, these factors being associated with the lack of pleasurable activities such as going to school and playing with friends, thus not having the possibility of spending all their energy at home on a daily basis, which is necessary and fundamental at these ages, and therefore they lacked a greater number of stimuli to improve some fundamental motor skills. For their part, Ferrari et al. [23] and Silva et al. [24] referred to the positive aspects of children spending more time with their parents, in some cases favouring the family environment.

The results verified for global motor skills clearly indicated that changes in daily routines, stimuli, and children's experiences with confinement and isolation were harmful to their development process [1,8], particularly motor development, as mentioned in the study by González et al. [24] who state that in addition to children's cognitive development, motor development was also what suffered most during this pandemic period. Studies with other ages and samples from different nationalities, namely French [25], Austrian [15], and Slovenian [26], also found a decline in motor competence after the first pandemic wave.

As far as we know, our study was the first to report the effects of the pandemic on children in this age group, in which we assessed global and fine motor skills and found that these indicated opposite results. However, it makes sense, since the time of isolation and confinement caused by the pandemic protocols provided more time to play video games [14,24], even though this practise became common even before the pandemic. As

a result, fine motor skills increased, serving as an even greater warning for the future of these children.

The main limitations of this study were the small sample and the fact that it was limited to a small geographical area, so it is not possible to objectively state that these results are only a consequence of the pandemic protocols; the fact that there was no daily characterisation of the children's activities and daily routines may have influenced some of the results, as well as the fact that, although all the children belonged to urban areas, not all of them had the same family and parental involvement, which clearly also has an impact on the development process.

In future studies, we suggest replicating this study with other samples. However, we realise this would be difficult as the data would have had to have been collected before the pandemic. But, following on from the same theme, it would also be interesting to analyse and compare how global and fine motor skill profiles were in studies carried out before the pandemic, compared to studies carried out more recently but with children who had already gone through this process. Another suggestion would be to understand and compare the environment in which the children lived during this period and whether there were any differences in motor development.

4. Conclusions

In our study, we demonstrated that the COVID-19 pandemic protocols clearly affected global development. Activities such as running, jumping, kicking, and throwing seemed to be compromised, and we believe that our research can serve as a warning to institutions, early childhood educators, paediatricians, and sports technicians, for the urgency of intervening with activities and physical activity programs for children who at one year of age were subject to confinement.

Given the characteristic negative changes in the motor development of the children evaluated, our results justify the need to closely monitor the development of the pandemic generation and take systematic corrective measures.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to data protection restrictions for minors.

Conflicts of Interest: The authors declare no conflicts of interest.

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children

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Article

The Mediating Role of Cardiorespiratory Fitness in the Association between a Negative Lifestyle and Poor Mental Health in Chilean Schoolchildren

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Abstract: Background: A negative lifestyle has a reported relationship with psychological problems and deteriorated well-being. However, there is little information regarding the mediating role of cardiorespiratory fitness (CRF) in this relationship. Objectives: The objectives of the present study are twofold: first, to investigate the association between negative lifestyle, physical self-concept (PSC), and depression, and second, to assess the potential mediating role of CRF in this complex relationship. Methods: This cross-sectional study included 612 schoolchildren aged between 9 and 14 years from the Araucanía region (southern Chile). CRF was measured using the Leger test, and lifestyle, depression, and PSC were measured using validated questionnaires. Results: A negative lifestyle reported an inverse association with PSC ($p < 0.001$) and a positive association with depression levels ($p < 0.001$). The mediation analysis showed that CRF was positively related to PSC ($p < 0.001$) and inversely related to depression ($p = 0.001$); besides, the indirect effect CRF acted as a partial mediator in the association between a negative lifestyle and PSC (indirect effect = −1.15; SE = 0.01; 95% CI, −1.87, −0.55) and depression levels (indirect effect = 0.22; SE = 0.08; 95% CI, 0.08, 0.38). Conclusion: In conclusion, CRF in schoolchildren played a potential mediating role in the association between a negative lifestyle and depression and PSC.

Keywords: physical fitness; cardiorespiratory fitness; physical self-concept; depression; mental health; children

1. Introduction

Mental health is a multidimensional state of subjective well-being. Some studies have reported an increase in mental health disorders in youths [1], including internalizing

psychological disorders such as depression and anxiety and externalizing disorders such as conduct problems. In this sense, depression is defined as a mood condition, such as excessive sadness and/or a significantly reduced experience of pleasure. Children and adolescents have a global prevalence of 21.3% for mild-to-severe depression and 3.7% for major depression [2].

Additionally, social, cultural, and negative lifestyles that include high screen time per day (ST) and low physical activity per week (PA) may influence psychological disorders of mental health [3,4]. Therefore, addressing poor mental health among schoolchildren could be considered a public health priority. Existing evidence suggests that the school stage is a crucial period for the development of subjective well-being [5], where previous studies conducted among Chilean youths have reported low levels of subjective well-being [4,6]. Specifically, well-being is a complex and multifaceted concept that encompasses physical, psychological, and social dimensions [7,8].

Physical self-concept (PSC) is essential for mental health and well-being [9,10], and the perception of PSC is significantly correlated with health perception and psychological well-being [11]. Furthermore, higher subjective well-being among youths has been associated with various benefits, such as increased longevity, career success, and better personal relationships [12]. In this regard, a recent study indicated that PSC is negatively associated with anxiety [13]. Another study suggested that improving PSC through exercise participation can contribute to better mental well-being, highlighting PSC as a positive element of a happy life and self-esteem [14]. Indeed, existing research shows a general consensus that developing a positive self-concept is helpful for subjective well-being [15].

Previous data regarding children and young people have indicated an increase in the prevalence of depressive symptoms [16]. In fact, evidence has been reported that 34% of adolescents (aged 10–19 years) globally are at risk of developing clinical depression [17]. Depression is considered one of the most significant health problems, and it is well established that depression has negative consequences for people's daily lives [18]. It has also been shown that a negative self-view can be linked with depressive symptoms [19], and patients with depression are characterized by low PSC [20]. Based on previously reported findings, strategies promoting PSC may have a beneficial impact on the treatment of depressive symptoms in young people [21].

Furthermore, studies have reported a strong association between negative lifestyle and poor mental and psychosocial well-being [22]. This negative behavior leads to the development of clinical and psychological problems in children [23]. The evidence has indicated that excessive ST for schoolchildren is associated with psychosocial problems, where more hours of ST are related to poorer psychological well-being [24], such as low self-esteem [25] and a high risk of increased mental health problems, including depression, anxiety, and dissatisfaction with school life [26] and poor PSC [6].

In addition, numerous studies have consistently provided compelling evidence demonstrating a robust association between a negative lifestyle and diminished mental health status [27]. Specifically, research indicates that inactive young individuals exhibit a higher prevalence of mental health issues, encompassing conditions such as mental disorders, depression, and anxiety [28]. Additionally, a separate investigation revealed that adolescents characterized by physical inactivity were significantly more prone to experiencing psychological distress, depressive disorders, and even bipolar II disorder when compared to their physically active counterparts [29]. Equally noteworthy, physical inactivity has been empirically linked to a reduced quality of life [30].

Intriguingly, a longitudinal study conducted among Norwegian students unveiled a negative correlation between the weekly hours spent on PA during ages 15–16 and emotional as well as peer-related problems at ages 18–19 [31]. In stark contrast, research conducted among European adolescents has reported that engaging in PA and participating in sports are associated with enhanced subjective well-being and reduced levels of anxiety and depressive symptoms [32]. Moreover, a study involving students indicated a direct link between low levels of PA and heightened stress and anxiety problems [33]. Similarly,

another investigation found that a lower level of PSC was prevalent among individuals who engaged in PA [34]. Notably, PA may wield a positive influence on PSC among children and adolescents [35].

It is paramount to acknowledge the complexity of these issues, as poor mental and psychosocial well-being have been found to intertwine with compromised academic performance, impaired social interaction, and familial dysfunction [36–38]. Within this context, cardiorespiratory fitness (CRF), as measured by VO_{2max}, emerges not only as a robust health marker but also as an attribute closely associated with optimism and overall well-being [39]. Substantiated by compelling evidence, a positive relationship between CRF and mental health outcomes, as well as general well-being, has been well-documented [40,41]. Moreover, individuals with higher levels have exhibited a reduced incidence of anxiety and depression symptoms [42]. A recent study underscored the correlation between a subpar PSC and low CRF in schoolchildren [6]. Furthermore, a positive association between elevated CRF and superior mental and psychosocial well-being among youth has been reported [43]. Additionally, improved PSC may positively influence enjoyment and satisfaction in physical education classes [44], and physical education classes can effectively contribute to enhancing youths' CRF [45].

Considering the aforementioned, the hypothesis posits that a stronger PSC among adolescents could promote healthy behaviors, such as physical activity. While there is evidence that CRF positively impacts mental health, specific aspects remain unexplored. Particularly, it is unclear how CRF precisely mediates the relationship between an adverse lifestyle and overall psychological well-being in adolescents. This lack of detailed understanding limits our ability to design effective interventions that could enhance both physical self-concept and mental health in this vulnerable population. Therefore, it is crucial to further investigate these underlying mechanisms to develop more precise and effective health promotion strategies among adolescents. Therefore, the objectives of the present study are twofold: first, to investigate the association between an adverse lifestyle and both PSC and levels of depression, and second, to assess the potential mediating role of CRF in this complex relationship.

2. Materials and Methods

2.1. Participants

In this cross-sectional study, we enrolled schoolchildren aged between 9 and 14 years old (n = 612; n_{girls} = 262) from public and subsidized schools in southern Chile during 2023. The sample was intentional and non-probabilistic.

Participation in the study was contingent upon obtaining signed assent from the schoolchildren themselves, as well as informed consent from their respective parents or guardians. The research adhered to the principles outlined in the Helsinki Declaration (2013) and received approval from the Ethics Committee of Universidad Autónoma de Chile, Chile (ACTA; N° CEC 11–23).

The inclusion criteria encompassed the following conditions: (i) obtaining informed consent from both parents and assent from the participating schoolchild, (ii) enrolment in educational institutions, and (iii) being within the age range of 9 to 14 years. Exclusion criteria were as follows: (i) any musculoskeletal injuries or medical contraindications (i.e., congenital heart disease, fever, diarrhea, or general malaise) that would prevent their average performance in the assessments. Furthermore, children with permanent educational needs mentioned in Decree No.83 of the Chilean Ministry of Education [46], such as visual, hearing, intellectual, or multiple disabilities, dysphasia, or autistic disorder, were excluded from participation in this study.

2.2. Main Outcomes

2.2.1. Lifestyle

Lifestyle assessment was conducted utilizing the PA Krece Plus test as outlined in previous research [47]. This assessment involved the classification of a child's lifestyle based

on daily hours dedicated to activities such as watching television or playing video games (ST) and the amount of PA engaged in after-school hours on a weekly basis. Classification was performed by computing the average for each of these two parameters.

To determine the overall lifestyle classification, the total points assigned for ST were first inverted and then combined with the points allocated for PA after school hours. Based on the resultant combined score, individuals were categorized into one of three lifestyle groups: (i) "Good lifestyle" (for boys with $\geq$9 h and girls with $\geq$8 h of combined ST and PA), (ii) "Regular lifestyle" (for boys with 6–8 h and girls with 5–7 h), or (iii) "Poor lifestyle" (for boys with $\leq$5 h and girls with $\leq$4 h). The questionnaires used for this assessment were administered individually to the children in the presence of the researchers to ensure the accuracy and consistency of responses.

2.2.2. Cardiorespiratory Fitness

CRF assessment was conducted utilizing the progressive 20 m shuttle run test [48]. During this test, participants were instructed to run between two lines positioned 20 m apart while synchronizing their pace with audio signals emitted from a pre-recorded CD. It is noteworthy that this test has undergone validation specifically among Chilean schoolchildren and has been previously employed in the context of the Physical Education National Study. To ensure consistency and comparability of results, the outcomes of the 20 m shuttle run test were standardized according to the protocol established by Leger. Subsequently, the calculation of VO_{2max} was performed employing Leger's equation [48].

2.2.3. Depression

The Children's Depression Inventory (CDI) was employed to assess depression levels in the participants [49]. It was adapted into Spanish by Barrio et al. [50]. This questionnaire comprises 27 sets of three statements that pertain to various aspects of depressive symptomatology. Respondents are provided with three response options: 0, indicating the absence of symptoms; 1, indicating the presence of mild symptoms; and 2, indicating the presence of definite symptoms. The cumulative score generated from the questionnaire can range from 0 to 54, with scores exceeding 18 points indicating a potential presence of depression. It is important to note that higher scores on the CDI are indicative of more pronounced levels of depression.

2.2.4. Self-Concept

The PSC Questionnaire (CAF) was utilized for our study. This questionnaire has psychometric properties that make it suitable for application from preadolescence onwards [51,52]. It consists of a total of 36 items, of which 20 are presented directly and 16 in an inverse manner. Participants evaluate these items using a 5-point Likert-type scale, where a score of 1 represents "false" and 5 signifies "true". The PSC is divided into six distinct dimensions:

(i) "Physical ability", in which students express their thoughts concerning their sporting abilities, such as "I look clumsy in sports activities." This dimension represents one's self-perception regarding their ability to engage in sports;
(ii) "Physical condition" assesses ideas like "I have a lot of physical energy" or "I can engage in prolonged physical activity without becoming tired." It pertains to confidence in one's physical condition and the perception of one's resistance to engaging in strenuous physical activities;
(iii) "Physical appearance" incorporates expressions like "I find it difficult to maintain a good physical appearance" or "I feel confident about the physical image I project". This dimension pertains to one's perception of their physical appearance and their level of satisfaction with the image they present to others;
(iv) "Strength" assesses ideas such as "I am capable of performing activities that require strength" or "I am strong". It relates to one's self-perceived strength and their ability to perform activities that demand physical power, such as lifting weights;

(v) "General PSC" involves statements like "Physically, I am satisfied with myself" or "I feel less capable than others". This dimension represents overall opinions and emotions, including happiness, satisfaction, pride, and confidence, in the physical domain;
(vi) "General subscale self-concept" includes expressions such as "I feel happy" or "I wish I were different". This dimension evaluates subjects' satisfaction levels with themselves and their life in general terms.

The CAF questionnaire provides a comprehensive assessment of various facets of PSC, encompassing both specific attributes and general well-being.

2.2.5. Anthropometric Parameters

To assess the body mass (kg) of the children in the study, a TANITA scale model was employed, Scale Plus UM-028 (Tokyo, Japan). The measurements were taken with the children wearing only their underclothes and without any footwear. For the estimation of their height (m), a Seca® stadiometer model 214 (Hamburg, Germany), which is graduated in millimeters (mm), was utilized.

Subsequently, the Body Mass Index (BMI) for each participant was calculated. BMI was computed as the individual's body mass (kg) divided by the square of their height in meters (kg/m^2) [53]. This standard method provides a valuable indicator of the participant's body composition and is widely used in clinical and research settings to assess health and nutritional status.

2.3. Procedure

Research assistants visited during physical education class day at school. The data were collected over three separate sessions by a team of trained researchers. Physical fitness was evaluated in the first session. In the second session, anthropometric assessments were carried out in a favorable space facilitated by the school with optimum temperature. Finally, lifestyle surveys and well-being instruments were applied in the classrooms and in the presence of researchers (helped with any potential questions).

2.4. Statistical Analysis

Normal distribution was tested using the Kolmogorov–Smirnov test. For continuous variables, values are presented at the mean and standard deviation (SD). Differences between mean values according to sex were determined using the ANOVA and the chi-square test, respectively. The association of PSC and depression with negative lifestyle and CRF was estimated with a simple linear regression adjusted by sex and age. To verify the effect of the mediating variables CRF (M), regression analyses were performed, considering negative lifestyle as an independent variable (X) and PSC and depression as dependent variables (Y). Within the analysis, the total effect (c), direct effect (c′), and indirect effect (a × b, IE) were calculated for the samples as well as the 95% confidence interval (CI) using the macro/interface process v. 3.3 for SPSS v. 23 and the bootstrapping method with a resampling rate of 5000 [54]. All the statistical analyses were performed with SPSS statistical software version 23.0 (SPSS™ Inc., Chicago, IL, USA). The alpha level was set at $p < 0.05$ for statistical significance.

3. Results

Table 1 displays a comparison of study variables according to lifestyle categories (good vs. regular vs. bad). Significant differences were observed in CRF, general PSC, subscale self-concept, and depression. Specifically, the bad lifestyle group reported lower values in these variables compared to the good and regular lifestyle groups.

In terms of the PSC dimension, CRF exhibited positive associations with physical ability (β: 0.04, 95% CI: −0.01 to 0.09, $p < 0.001$), physical appearance (β: 0.07, 95% CI: 0.01 to 0.13, $p = 0.025$), strength dimension (β: 0.15, 95% CI: 0.09 to 0.21, $p < 0.001$), general PSC (β: 0.17, 95% CI: 0.11 to 0.24, $p < 0.001$), subscale PSC (β: 0.12, 95% CI: 0.07 to 0.18, $p < 0.001$), and the overall PSC score (β: 0.69, 95% CI: 0.49 to 0.88, $p < 0.001$). Additionally, CRF was

negatively associated with depression (β: −0.15, 95% CI: −0.22 to −0.08, $p < 0.001$). These significant associations remained even after adjusting for sex and age. In relation to a negative lifestyle, there was an inverse association with strength dimension (β: −0.20, 95% CI: −0.38 to −0.01, $p = 0.034$), general PSC (β: −0.74, 95% CI: −0.93 to −0.55, $p < 0.001$), and the total PSC score (β: −1.40, 95% CI: −1.99 to −0.80, $p < 0.001$). Conversely, a negative lifestyle was positively associated with depression levels (β: 0.72, 95% CI: 0.51 to 0.92, $p < 0.001$). These significant associations remained robust after adjusting for sex and age (Table 2).

Table 1. Comparison of study variables according to lifestyle category.

	Good Lifestyle (*n* = 112) A	**Regular Lifestyle (*n* = 239) B**	**Bad Lifestyle (*n* = 261) C**	***p*-Value (F-Value)**
Age (y)	11.75 ± 1.11	11.64 ± 1.04	11.66 ± 1.08	0.680 (0.39)
Body mass (kg)	52.14 ± 16.20	50.55 ± 12.68	54.20 ± 14.46	0.015 (4.20)
Size (m)	1.54 ± 0.11	1.54 ± 0.10	1.56 ± 0.11	0.107 (2.24)
BMI (kg/m^2)	21.52 ± 5.03	21.08 ± 4.25	22.06 ± 4.71	0.056 (2.89)
VO_{2max} (mL/kg/min)	48.32 ± 9.36	45.74 ± 6.84	44.46 ± 6.56	$p < 0.001$ (11.29)
Physical self-concept (score)	134.74 ± 18.97	128.59 ± 17.05	126.09 ± 19.57	$p < 0.001$ (8.69)
Physical self-concept dimension				
✓ Physical ability (score)	22.21 ± 5.35	21.85 ± 4.83	22.18 ± 5.05	0.707 (0.35)
✓ Physical condition (score)	20.72 ± 5.94	19.81 ± 5.94	20.18 ± 5.66	0.383 (0.96)
✓ Physical appearance (score)	21.91 ± 5.52	21.80 ± 5.92	21.31 ± 5.95	0.540 (0.62)
✓ Strength (score)	20.24 ± 5.93	19.69 ± 5.73	19.11 ± 5.71	0.189 (1.67)
✓ General PSC (score)	25.48 ± 5.22	22.84 ± 5.78	21.02 ± 6.45	$p < 0.001$ (22.67)
✓ Subscale PSC (score)	24.18 ± 5.06	22.59 ± 5.55	22.29 ± 5.28	0.006 (5.14)
Depression (score)	11.46 ± 5.64	12.56 ± 5.94	14.89 ± 7.25	$p < 0.001$ (14.06)

The data are presented as means and standard deviations (M ± SD), with statistical significance set at $p < 0.05$. BMI = body max index. VO_{2max} = maximum oxygen consumption.

Table 2. Association between CRF and lifestyle with psychological variables.

	Cardiorespiratory Fitness (−) → (+)			***p*-Value**	**Negative Lifestyle (+) → (−)**			***p*-Value**
	β (95% CI)	**Beta**	**SE**		**β (95% CI)**	**Beta**	**SE**	
Physical Self-Concept Dimension								
Physical ability								
Model 0	0.04 (−0.01; 0.09)	0.06	0.03	0.137	−0.05 (−0.21; 0.11)	−0.02	0.08	0.551
Model 1	0.06 (0.00; 0.11)	0.08	0.03	0.056	−0.05 (−0.21; 0.11)	−0.03	0.08	0.536
Physical condition								
Model 0	0.13 (0.07; 0.19)	0.17	0.03	$p < 0.001$		−0.04	0.10	0.382
Model 1	0.14 (0.07; 0.20)	0.17	0.03	$p < 0.001$	−0.08 (−0.27; 0.10)	−0.04	0.10	0.375
Physical appearance dimension								
Model 0	0.07 (0.01; 0.13)	0.09	0.03	0.025	−0.15 (−0.34; 0.04)	−0.06	0.10	0.117
Model 1	0.09 (0.03; 0.16)	0.12	0.03	0.006	−0.15 (−0.34; 0.04)	−0.06	0.10	0.124
Strength dimension								
Model 0	0.15 (0.09; 0.21)	0.19	0.03	$p < 0.001$	−0.20 (−0.38; −0.01)	−0.09	0.09	0.034
Model 1	0.15 (0.08; 0.21)	0.19	0.03	$p < 0.001$	−0.20 (−0.38; −0.01)	−0.08	0.09	0.036
General physical self-concept								
Model 0	0.17 (0.11; 0.24)	0.21	0.03	$p < 0.001$	−0.74 (−0.93; −0.55)	−0.29	0.10	$p < 0.001$
Model 1	0.17 (0.10; 0.24)	0.21	0.04	$p < 0.001$	−0.74 (−0.93; 0.55)	−0.30	0.10	$p < 0.001$
Subscale self-concept								
Model 0	0.12 (0.07; 0.18)	0.17	0.03	$p < 0.001$	−0.17 (−0.35; 0.00)	−0.08	0.09	0.051
Model 1	0.13 (0.07; 0.19)	0.18	0.03	$p < 0.001$	−0.17 (−0.35; 0.00)	−0.08	0.09	0.051
Physical self-concept total								

Table 2. *Cont.*

	Cardiorespiratory Fitness (−) → (+)			*p*-Value	Negative Lifestyle (+) → (−)			*p*-Value
	β (95% CI)	Beta	SE		β (95% CI)	Beta	SE	
Model 0	0.69 (0.49; 0.88)	0.27	0.10	$p < 0.001$	−1.40 (−1.99; −0.80)	−0.18	0.30	$p < 0.001$
Model 1	0.74 (0.54; 0.95)	0.29	0.11	$p < 0.001$	−1.40 (−1.99; −0.80)	−0.18	0.30	$p < 0.001$
Psychological Variable								
				Depression				
Model 0	−0.15 (−0.22; −0.08)	−0.16	0.04	$p < 0.001$	0.72 (0.51; 0.92)	0.27	0.10	$p < 0.001$
Model 1	−0.15 (−0.22; −0.08)	−0.17	0.04	$p < 0.001$	0.72 (0.51; 0.92)	0.27	0.11	$p < 0.001$

The presented data represent beta coefficients with their corresponding 95% confidence intervals (95% CI). Two models were used: Model 0 (unadjusted) and Model 1 (adjusted for sex and age). (−) → (+) represents from smallest to largest; (+) → (−) represents from highest to lowest.

Figure 1 displays the results of the mediation analysis for the entire sample, consisting of 617 schoolchildren. In this analysis, CRF emerges as a mediating variable in the relationship between a negative lifestyle and PSC. In the first regression step (a), a negative lifestyle was found to have an inverse relationship with PSC ($p < 0.001$). In the second step, the regression coefficient of lifestyle in PSC remained significant ($p = 0.004$). In the third step, the potential mediator CRF was positively related to the dependent variable PSC ($p < 0.001$). Even when both lifestyle and CRF were included in the model, the regression coefficient remained statistically significant ($p < 0.001$). Finally, the indirect effect analysis confirms that CRF serves as a partial mediator of PSC, with an indirect effect of −1.15 and a standard error (SE) of 0.34. The 95% confidence interval for the indirect effect ranges from −1.87 to −0.55 (Figure 1).

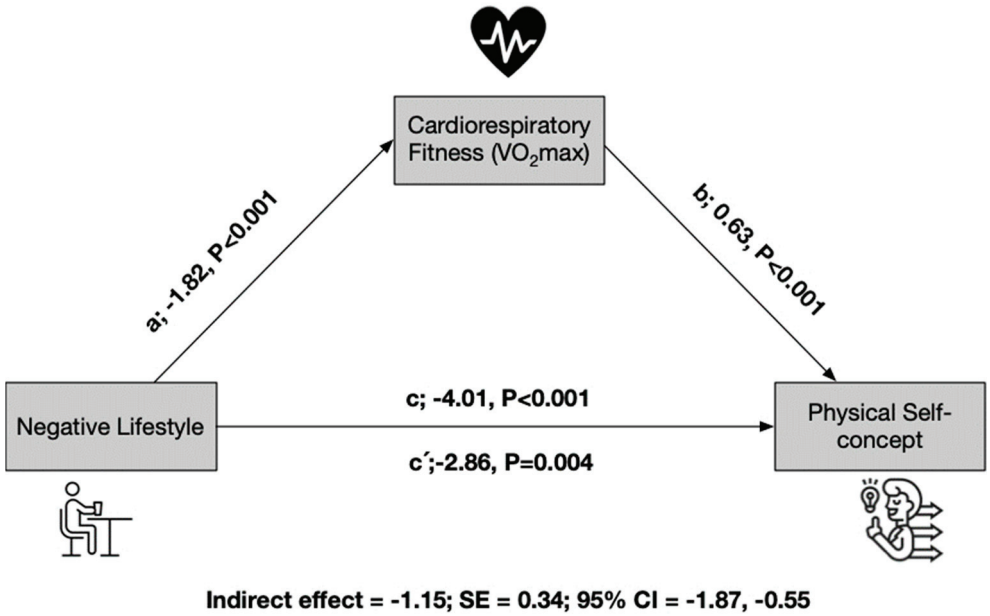

Figure 1. Mediations model testing whether the association between negative lifestyle and negative physical self-concept was mediated by cardiorespiratory fitness.

In Figure 2, CRF is shown to act as a mediating variable in the relationship between a negative lifestyle and depression. The mediation analysis proceeded through several steps: In the first regression step (a), a negative lifestyle was found to have an inverse relationship with CRF ($p < 0.001$), indicating that a negative lifestyle is associated with lower levels of CRF. In the second step, the regression coefficient of lifestyle in depression was also significant ($p < 0.001$), suggesting that a negative lifestyle is associated with higher levels of depression. In the third step, the potential mediator CRF was positively related

to the dependent variable, depression (p = 0.001). This indicates that higher levels of CRF are associated with lower levels of depression. Importantly, even when both lifestyle and CRF were included in the model, the regression coefficient remained statistically significant ($p < 0.001$), indicating that both lifestyle and CRF independently contribute to depression. Finally, the indirect effect analysis confirms that CRF serves as a partial mediator of depression. The indirect effect has a value of 0.22 with a standard error (SE) of 0.08. The 95% confidence interval for the indirect effect ranges from 0.08 to 0.38 (Figure 2). This suggests that part of the relationship between a negative lifestyle and depression is mediated by CRF, highlighting the potential positive impact of improving CRF on reducing depression levels.

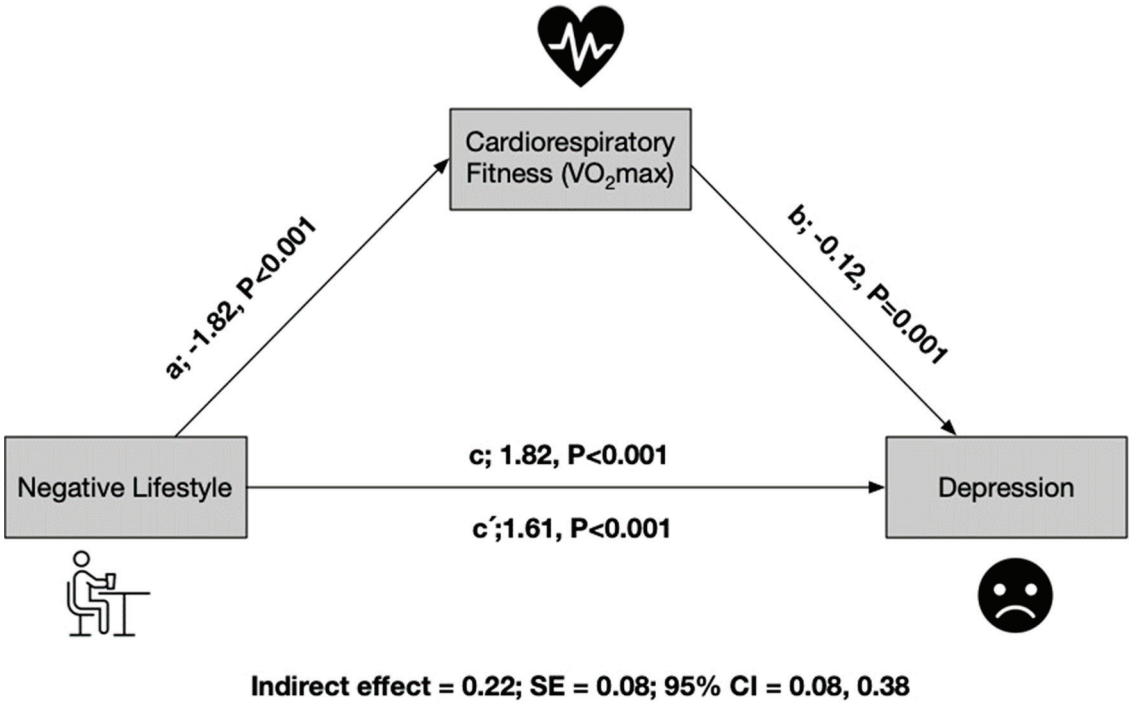

Figure 2. Mediations model testing whether the association between negative lifestyle and depression was mediated by cardiorespiratory fitness.

4. Discussion

The objectives of the present study are twofold: first, to investigate the association between an adverse lifestyle and both PSC and levels of depression, and second, to assess the potential mediating role of CRF in this complex relationship. The main results of this study are as follows: (i) a negative lifestyle is inversely associated with PSC and positively associated with depression levels; (ii) the mediation analysis showed that CRF was positively related to PSC and inversely related to depression (p = 0.001); and (iii) the indirect effect confirms that CRF is a partial mediator in the association between a negative lifestyle and PSC and depression levels.

Negative lifestyle was inversely linked to PSC (i.e., total score) and various dimensions of the PSC. Several studies have highlighted the detrimental role of a negative lifestyle in adolescents' subjective well-being [4,55]. Moreover, a systematic review focusing on HRQoL and children's lifestyle (i.e., PA and low ST) highlighted a negative relationship between ST and HRQoL, as well as lower psychological well-being [56]. In fact, existing evidence suggests that the negative impact of high ST on subjective well-being could be mitigated by high PA [57]. Another study indicated that improvements in physical self-perceptions can positively affect mental health [58]. Other evidence has suggested that prolonged ST has a negative impact on depression and anxiety scores [59] and subjective well-being [60].

A healthy lifestyle has been positively associated with PSC in students [34,35]. Indeed, PA has been proven to be a valuable tool for enhancing subjective well-being [61]. In this context, a recent study conducted among Chilean schoolchildren demonstrated that healthy lifestyle dimensions, such as PA after school and better nutritional habits, were positively correlated with PSC [6]. Similarly, a meditational model reported that PA had a direct effect on PSC and an indirect effect on general self-concept in Spanish adolescents; therefore, improving PA levels could be a promising strategy for promoting subjective well-being [9]. Moreover, previous evidence has indicated that adolescents with poorer PSC are at a higher risk of being physically inactive [62]. Additionally, data from Spanish students have shown that PA and diet quality are positively associated with PSC [34]. Based on previously reported findings, interventions promoting PA in schools can be beneficial for promoting the development of subjective well-being.

It has been suggested that a healthy lifestyle is associated with PSC and self-esteem among Chilean schoolchildren [63]. In this regard, a population-based study indicated that a negative lifestyle characterized by more than 4 h per day of ST was associated with poorer psychological well-being outcomes; furthermore, these relationships were stronger among adolescents than among children [24]. A cross-sectional study conducted with students reported that PSC dimensions were negatively correlated with ST and positively predicted levels of PA [64]. Similarly, a longitudinal study demonstrated the importance of physical self-perceptions in relation to PA patterns; high perceived competence increased the odds of being physically active by 3.8 times [65]. Evidence has also shown that a healthy lifestyle, including PA and the quality of one's diet, improves individuals' self-concept and body image perception [66]. Additionally, an ecological model described significant interpersonal barriers that influence a healthy lifestyle, such as PA patterns and dietary habits, including a lack of self-confidence and motivation [67].

It has also been shown that having higher levels of CRF may help improve levels of PSC and mental health in Spanish adolescents [68]. However, more longitudinal and interventional studies are needed to establish evidence of causation between physical fitness and mental health [69]. In the present study, schoolchildren's CRF was found to be related to the dependent variables of depression and PSC, and it also appeared to have a potential mediating role in the relationship between a negative lifestyle and psychological well-being, specifically PSC and depression. This evidence contributes to solidifying the positive association between CRF and subjective well-being in youths [6,40]. Building on previously reported findings, it is suggested that during adolescence, depression may be linked to unhealthy behaviors, such as low levels of physical activity [70,71]. Similarly, it has been demonstrated that high CRF is associated with lower depressive symptoms [72]. In other words, good CRF can promote better mental health [73]. On the contrary, the evidence indicates that lower levels of CRF are associated with a greater risk of depression [74].

Recent studies have shown that fitness parameters, such as the muscle quality index, are related to better well-being in schoolchildren [75], and these fitness parameters play a mediating role in the relationship between a negative lifestyle, including sedentary time and abdominal obesity, and well-being, as measured by health-related quality of life [76]. Similarly, another observational study conducted with preschool children revealed that CRF acted as a mediating variable in the relationship between gross motor competence and well-being, especially physical well-being [77]. In this context, a recent study indicated that poor PSC was related to low CRF in Chilean students [6]. A previous systematic review and meta-analysis demonstrated a longitudinal association between CRF levels and mental health [78]. Another study among Spanish students reported that physical fitness, including CRF and handgrip strength, was positively associated with PSC [79]. Moreover, a cross-sectional study found that peak oxygen consumption was positively associated with all self-concept dimensions. Additionally, this investigation reported a negative association between body fat and PSQ in female adolescents [80]. Likewise, a study conducted with adolescent schoolchildren revealed that physical fitness, including the ALPHA-fitness test, and fatness mediated the association between lifestyle factors, such as physical activity,

sedentary time, and Mediterranean diet adherence, and body dissatisfaction [81]. In this context, previous evidence indicated that cardiovascular endurance mediated the link between physical self-perception and physical activity in adolescents [82].

Although there is limited evidence of a causal relationship between improvements in CRF and mental health, a previous study reported that improvements in CRF could predict a greater reduction in the severity of depression [83]. Physical fitness seems to provide a buffer against stress-related diseases and the inflammatory process, as well as promoting increased positive mood and well-being [84]. Other evidence has suggested that the effects of inflammation on the brain may contribute to the development of various psychiatric disorders beyond depression [85].

4.1. Limitations

The main limitations of the present study were (i) the cross-sectional design, (ii) we used a convenience sample, (iii) CRF was not measured objectively, (iv) PA levels per week and ST per day were evaluated by a questionnaire and not measure objectively, (v) medical variables were not evaluated, and (vi) Cronbach's alpha was not estimated.

Among the strengths, we could express (i) the use of culturally validated questionnaires ensures accurate data for Chilean adolescents, (ii) the simplicity of the assessments (which would allow their use and application in lifestyle interventions focused on youths), (iii) uniquely explore the mediating role of CRF between negative lifestyle and psychological well-being; therefore, they do not evaluate them independently as has commonly been done; and (iv) the findings support the inclusion of interventions aimed at improving CRF in school programs, promoting a holistic approach that addresses both the physical and mental health of adolescents in an integrated manner.

4.2. Practical Applications

The results suggest that school interventions should focus on improving CRF not only as a physical health goal but also as an integral strategy for enhancing psychological well-being and reducing depression. This research provides a foundation for developing school programs that integrate CRF improvement as a key component in addressing mental health issues, proposing a more holistic and multifaceted approach to health promotion among adolescents.

5. Conclusions

In conclusion, a negative lifestyle is inversely associated with PSC and positively associated with depression levels. Likewise, it has been demonstrated that CRF plays a potential mediating role in the relationship between a negative lifestyle and depression, as well as PSC in schoolchildren. Consequently, CRF emerges as a crucial factor for promoting the psychological well-being of children, and it should be considered in educational and healthcare settings to proactively address mental health issues. This study provides a novel perspective on an area that has been less investigated by exploring the mediating role of CRF between adverse lifestyle and psychological well-being. Consequently, CRF not only improves mental health but also has a potential mediating role between an adverse lifestyle and psychological well-being in schoolchildren.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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children

Systematic Review

Effectiveness of Exercise on Sleep Quality in Attention Deficit Hyperactivity Disorder: A Systematic Review and Meta-Analysis

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Abstract: Objective: This study aimed to systematically review the available evidence on the effects of exercise training programs on sleep quality in attention deficit hyperactivity disorder. **Methods**: Studies were searched in five electronic databases until March 2024. The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database and Methodological Index for Non-Randomized Studies scales. **Results**: A total of five randomized clinical trials, two non-randomized comparative studies, and one single-arm trial were included. Self-reported sleep quality (n = 7) and objective sleep status (n = 3) were the main outcomes analyzed. Generally, exercise induced positive effects on self-reported sleep outcomes. The performed meta-analysis with data from 131 participants indicated that exercise showed a non-significant trend towards increasing objective sleep duration (Hedges' g −2.67; 95% CI −11.33; 5.99, p = 0.185). While exercise appears safe for individuals with attention deficit hyperactivity disorder, its efficacy in managing sleep disturbances in this population remains uncertain. **Conclusions**: While there is evidence suggesting a positive impact of exercise on self-reported sleep quality, its efficacy for improving sleep duration could not be confirmed.

Keywords: ADHD; physical activity; sleep duration; sleep status

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that typically begins in childhood and is characterized by developmentally inappropriate and impairing levels of inattention, motor hyperactivity, and impulsivity. These difficulties often persist into adulthood [1].

People with ADHD often experience comorbidities that significantly impact their daily lives, with sleep problems being a prominent issue among them, with an estimated prevalence ranging from 23% to 73% in adolescents [2] and from 43% to 80% in adults [3], respectively. Sleep problems arise from various factors, including inadequate sleep hygiene, behavioral aspects of ADHD itself, side effects of medications used in ADHD treatment, and psychiatric or medical comorbidities [4]. Sleep problems can contribute to the onset

or exacerbation of ADHD symptoms [5]. This bidirectional relationship underscores the importance of addressing sleep issues as part of the comprehensive management of ADHD.

Approaches for managing sleep problems in individuals with ADHD include both pharmacological and non-pharmacological strategies. While the efficacy of pharmacological treatment is considered controversial [6], non-pharmacological treatments stand out as an interesting alternative [7], with sleep hygiene measures being recommended as a first-line management approach for sleep disorders [8].

Sleep hygiene involves practicing strategies that have been proven to be effective in achieving more optimal sleeping patterns, such as engaging in exercise [9]. Exercise exerts positive effects on sleep through a multitude of pathways, engaging with circadian rhythm regulation, metabolic processes, immune function, thermoregulation, vascular health, mood regulation, and endocrine activity [10]. This is corroborated by scientific findings indicating that exercise not only enhances sleep quality but also reduces the time taken to fall asleep and improves subjective sleep experiences [11]. Moreover, the prescription of exercise has proven to be both viable and efficacious in managing sleep disturbances among affected individuals [12].

In this context, promoting exercise training among individuals with ADHD emerges as a promising strategy for addressing sleep problems. However, before offering guidance on exercise practice, psychologists, general practitioners, and sports physicians should have access to the most up-to-date evidence-based guidelines regarding its prescription and potential benefits for this population. Achieving this objective requires conducting systematic reviews that comprehensively synthesize and evaluate the existing scientific literature on this subject.

To the authors' knowledge, no systematic review has been published that specifically explores the efficacy of exercise in managing sleep problems among individuals with ADHD. This study aims to determine whether exercise interventions improve sleep quality and duration in individuals with ADHD and to explore potential mediating factors.

2. Materials and Methods

This systematic review adhered to the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [13]. The review protocol was formally registered with the Open Science Framework (OSF) and is accessible via the following link: https://doi.org/10.17605/OSF.IO/F53JK.

2.1. Search Strategy

A rigorous and systematic search was undertaken across five major electronic databases: MEDLINE/PubMed, Web of Science, EBSCOhost Environment Complete, Dialnet Plus, and Scopus. The search encompassed the entire publication history of each database, spanning from their inception to March 2024. To ensure exhaustive identification of relevant studies, a meticulously structured search strategy was employed, combining key terms and Boolean operators as follows: ("ADHD" OR "Attention Deficit Hyperactivity Disorder" OR "Hyperactivity") AND ("Exercise" OR "Physical Activity" OR "Sport") AND ("Sleep"). The Supplementary Materials Table S1 provides the detailed search strategy employed for each database.

2.2. Eligibility Criteria

An inclusive approach was adopted to ensure a comprehensive understanding of the available evidence on the research topic. Eligible studies for inclusion in this review consisted of peer-reviewed investigations that examined and reported on the effects of exercise interventions on sleep outcomes in individuals diagnosed with ADHD. Specifically,

randomized controlled trials (RCTs) and non-RCTs were considered eligible provided that they met the following criteria: (a) they involved a structured exercise intervention performed by individuals with ADHD; (b) they used a pre-post design; (c) they included a group for comparison; and (d) they provided quantitative outcomes related to sleep parameters. Studies with mixed samples were excluded due to the lack of ADHD-specific data. Single-session exercise interventions were not analyzed as they do not constitute structured programs. Qualitative studies were omitted for lacking quantitative sleep data essential for systematic analysis. Finally, studies without full-text availability were excluded due to insufficient information for outcome evaluation.

2.3. Study Selection

The titles and abstracts of all identified studies were independently screened by two authors to assess their eligibility for inclusion. Following this preliminary review, the selected studies underwent a more detailed evaluation by both authors to confirm their suitability. Any disagreements or discrepancies encountered during this process were resolved through mutual discussion. In cases where uncertainty persisted regarding a study's eligibility, a third author was consulted to provide additional input, and a consensus was achieved. Full-text copies of potentially relevant studies were obtained for further assessment. Additionally, the reference lists of the included articles, as well as studies citing them in Google Scholar, were examined to identify any additional eligible studies.

2.4. Data Extraction

Data were systematically extracted by one researcher from the original reports, including details on participants' characteristics, intervention protocols, sleep-related outcomes, primary findings, adverse events, and drop-out rates. The extracted data were subsequently cross-verified by a second investigator to ensure accuracy. Whenever feasible, missing data were requested directly from the original study authors or marked as "NR" (Not Reported) when it was not possible to obtain them.

2.5. Quality Appraisal

The methodological quality of each RCT was evaluated using the Physiotherapy Evidence Database (PEDro) scoring system. For trials not indexed in the PEDro database, two authors independently assessed their quality following standardized criteria. Any discrepancies between the assessments were addressed through discussion and resolved by consensus. The quality of the included studies was classified based on the following thresholds: excellent (scores of 9–10), good (6–8), fair (4–5), and poor (<3) [14].

The methodological quality of comparative and single-arm studies was assessed by means of the Mixed Methods Appraisal Tool (MMAT) [15], which allows for the critical appraisal of different types of empirical designs. Two reviewers independently used the MMAT to critically evaluate the papers included in the systematic review. If any disagreement came up, they reevaluated the process until they reached an agreement. The MMAT consists of 7 questions, with the first 2 being screening questions that are common to all types of methodologies. The following 5 questions are specific to each of the 5 categories of study designs. Each question is answered in a 'yes', 'can't tell', and 'no' format. Calculating an overall score is discouraged; instead, a color code rating is usually used (i.e., green for 'yes', yellow for 'can't tell', and red for 'no') and a detailed presentation of the ratings is provided if necessary.

2.6. Statistical Analysis

The meta-analysis calculations were conducted using Microsoft Excel (version 2412) in combination with the Meta-Essentials Workbooks [16]. Effect sizes for quantitative depen-

dent variables were calculated using Hedges' g. A random-effects model was applied for all analyses to account for variability across studies, employing the inverse variance method.

To assess statistical heterogeneity and inconsistency, the I^2 statistic was utilized. An I^2 value of 0% indicates no observed heterogeneity, while higher values signify increasing levels of heterogeneity. In addition to calculating 95% confidence intervals (CIs), prediction intervals were determined to provide a more comprehensive representation of both the magnitude and consistency of the observed effects.

3. Results

3.1. Design and Samples

Out of the 908 records initially obtained, a total of 8 studies, 5 RCTs [17–21], 2 non-randomized comparative investigations [22,23], and 1 single-arm trial [24] were finally analyzed (Figure 1). All the investigations were published between 2016 and 2023. A summary of their main characteristics is provided in Table 1.

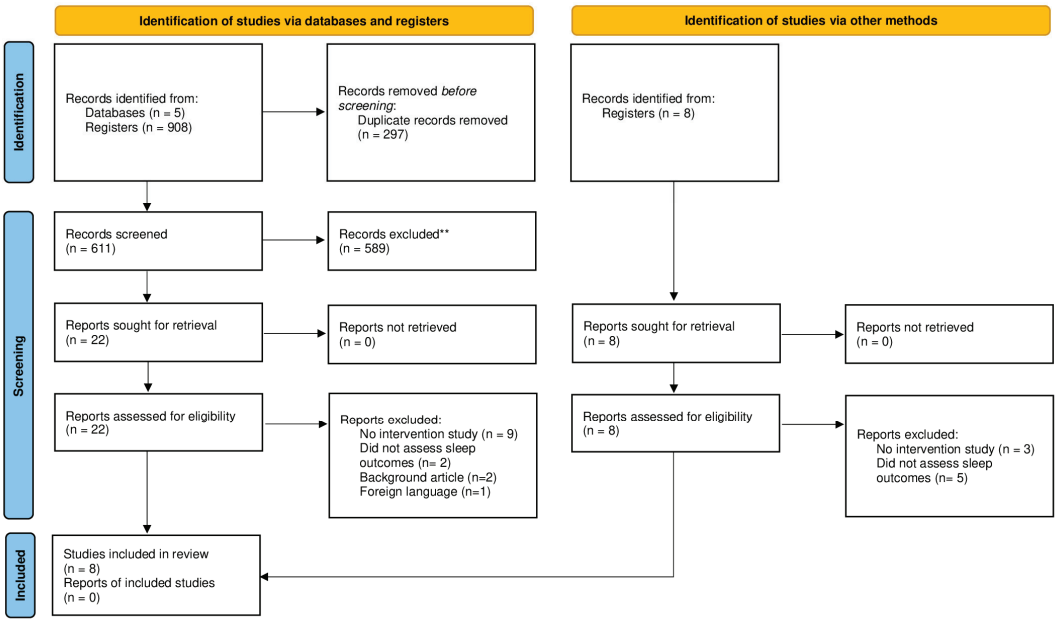

Figure 1. Flow diagram of the search and selection process for the inclusion of articles. ** Studies that were not related to the focus of the review were excluded.

The combined sample size across all reviewed studies amounted to 388 participants. The smallest study involved 14 participants [17], while the largest included 112 participants [20], respectively. The demographic characteristics of the participants varied significantly, with ages ranging from 6 to 54 years. Analysis of the data revealed that approximately 67% of the participants were male, representing a substantial majority. Six studies specifically examined children diagnosed with ADHD [18–20,22–24], one focused on adults [17], and another focused on undergraduates [21].

3.2. Interventions Characteristics

A diverse array of training programs was implemented, including jogging, Tai Chi, and Cooperative High-Intensity Interval Training, while other studies incorporated mixed exercise regimens (Table 1). The duration of exercise interventions ranged from 7 weeks [21] to 12 weeks [17–20,24]. Training frequencies varied between one session per week [18] and three sessions per week [17,19]. Session lengths ranged from 30 min [22,23] to 60 min [19,21,24]. Notably, three studies did not detail the methods used to monitor exercise intensity [18,21,24]. In the remaining studies, heart rate was used for this purpose.

Table 1. Overview of the descriptive characteristics of the included studies.

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Svedell et al. (2023) [17] Design: RCT Country: Sweden	Participants (*n*): 14 adults with ADHD (EG: 9; CON: 5) Gender: EG: 3M + 6F; CON: 2M + 3F Age, years (mean; SD): EG: 33.7 ± 8.1; CON: 43 ± 12.6 BMI, kg/m^2 (mean; SD): EG: 25.3 ± 5.1; CON: 29.1 ± 1.6 Duration of diagnosis, years: EG: 5.7 ± 3.3; CON: 3.4 ± 1.9 Medication, *yes/no*: EG: 5/4; CON: 3/2	Duration: 12 weeks EG Type: Mixed exercise program + treatment. Activities: Warm-up (6 min) light exercises; Cardio (6 min) cycling, running, jumping; Resistance training (23 min) lower body, upper body, core, balance; flexibility (10 min) stretching of large muscle groups; cool-down (5 min) light exercises. Volume: 50 min Frequency: 3 days/week Intensity: 60–90% HR_{max} CON Received treatment as usual	Self-reported sleep quality: • ISI (score)	Intra-group *($p < 0.05$)*—NR Inter-group *($p < 0.05$)* > improvement in sleep quality in EG compared to CON (28.9 ± 16.7 vs. −51.4 ± 9.3%)	Dropouts: EG Drop out: $n = 3$ Participated in less than 60% of treatment sessions: $n = 1$ CON: Missing data: $n = 1$ Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Liu et al. (2023) [18] Design: RCT Country: China	Participants (*n*): 33 children with ADHD (EG: 17; CON: 16) Gender: EG: 14M + 4F; CON: 12M + 4F Age, years (mean; SD): EG: 9.82 ± 1.24; CON: 10.44 ± 0.96 BMI, kg/m^2 (mean; SD): EG: 18.87 ± 2.38; CON: 19.64 ± 2.78 Duration of diagnosis: NR Medication, *yes/no*: EG: 2/15; CON: 2/14	Duration: 12 weeks EG Type: Jogging Activities: Warm-up (10 min): The session began with a warm-up phase lasting 10 min. Jogging exercises (25 min): This segment included a variety of posture and motor learning exercises, such as skipping, high knees, and transitioning from hopping on two feet to one foot. These exercises were integrated into the jogging session to enhance motor skills. Cool-down (5 min): Light exercises were performed during the cool-down phase to gradually reduce physical exertion. Break (5 min) Volume: 45 min Frequency: 1 days/week Intensity: NR CON Received no exercise intervention and were asked to maintain their daily routine.	Self-reported sleep quality (Sleep Log): • Sleep duration (h) • Sleep latency (min) • Sleep efficiency (%) Objective sleep status (Actigraphy Assessment): • Sleep duration (h) • Sleep efficiency (%) • Wake after sleep onset (min)	Intra-group *($p < 0.05$)* ↓ Sleep duration after intervention in CON (Actigraphy: 6.91 ± 0.22 vs. 5.75 ± 0.27 h) but ↑ when assessed with Sleep Log (7.14 ± 0.30 vs. 8.10 ± 0.24 h) ↓ Sleep latency after intervention in EG (Sleep Log: 45.36 ± 4.44 vs. 22.38 ± 2.7 min) ↑ Sleep efficiency after intervention in EG (Actigraphy: 82.64 ± 2.26 vs. 91.66 ± 2%; Sleep Log: 91.08 ± 0.84 vs. 95.64 ± 0.61%) ↓ Wake after sleep onset after intervention in EG (Actigraphy: 87.07 ± 11.20 vs. 39.30 ± 9.74 min) Inter-group *($p < 0.05$)* > Sleep duration in EG compared to CON (Actigraphy: 6.79 ± 0.26 vs. 5.75 ± 0.27 h) < Sleep latency in EG compared to CON (Sleep Log: 22.38 ± 2.7 vs. 39.4 ± 2.26 min) > Sleep efficiency in EG compared to CON (Sleep Log: 95.64 ± 0.61 vs. 91.46 ± 0.86%)	Dropouts: NO Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Liang et al. (2022) [19] Design: RCT Country: China	Participants (*n*): 80 children with ADHD (EG: 40; CON1: 40) + 40 children with typical development as health Control (CON2) Gender: EG: 30M + 10F; CON1: 32M + 8F Age, years (mean; SD): EG: 8.37 ± 1.42; CON1: 8.29 ± 1.27 BMI, kg/m^2 (mean; SD): EG: 16.98 ± 3.14; CON1: 16.37 ± 2.83 Duration of diagnosis: NR Medication, *yes/no*: NR	Duration: 12 weeks + 12 weeks follow-up EG Type: Mixed exercise program Activities: Warm-up (10 min); aerobic exercise (20 min) rope skipping, cardio kickboxing and agility ladder; neurocognitive exercise (20 min) basketball, table tennis, and badminton; cool-down (10 min). Volume: 60 min Frequency: 3 days/week Intensity: 60–80% HR_{max} CON1 Received no exercise intervention and were asked to maintain their daily routine during the first 12 weeks. Thereafter, received intervention in the following 12 weeks. CON2 Received no exercise intervention and were asked to maintain their daily routine.	Self-reported sleep quality: • PSQI (score) ▪ Sleep quality ▪ Sleep latency ▪ Sleep duration ▪ Sleep efficiency ▪ Sleep disturbance ▪ Sleep medications ▪ Day-time dysfunction ▪ Total score Objective sleep status: • Sleep duration (min) • Sleep latency (min) • Sleep efficiency (%)	Intra-group *($p < 0.05$)* ↓ Sleep quality PSQI score after intervention in EG (0.95 ± 1.05 vs. 0.64 ± 0.81) ↓ Sleep latency PSQI score after intervention in EG (1.28 ± 1.10 vs. 0.90 ± 0.88) ↓ Sleep latency PSQI score after intervention in CON1 (1.33 ± 0.98 vs. 0.65 ± 0.71) ↓ Sleep disturbances PSQI score after intervention in EG (1.03 ± 0.49 vs. 1.03 ± 0.54) ↓ Total PSQI score after intervention in EG (6.08 ± 3.38 vs. 5.03 ± 2.28) ↓ Total PSQI score after intervention in CON1 (6.54 ± 3.03 vs. 4.18 ± 3.24) ↓ Sleep latency after intervention in CON1 (25.26 ± 21.40 vs. 16.97 ± 10.41 min) Inter-group *($p < 0.05$)*—NO	Dropouts: EG Discontinued intervention: $n = 1$ Refused test: $n = 2$ CON: Discontinued intervention: $n = 8$ Lost control: $n = 1$ Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Suarez-Manzano et al. (2021) [23] Design: Comparative Country: Spain	Participants (*n*): 80 children with ADHD. Final sample: 52 (EG: 28; CON: 24) Gender: EG: 11M + 17F; CON: 13M + 11F Age, years (mean; SD): EG: 10.92 ± 2.68; CON: 9.46 ± 2.54 BMI, kg/m^2 (mean; SD): EG: 17.44 ± 2.18; CON: 17.06 ± 3.58 Duration of diagnosis: NR Medication, *yes/no*: NR	Duration: 10 weeks EG Type: C-HIIT program Activities: Warm-up (6 min); main (16 min) included a combination of cardiorespiratory, motor, and coordinative exercises carried out in pairs or groups (cooperative context), 4 sets ratio of 30:30 s; cool-down (8 min). Volume: 30 min Frequency: 2 days/week Intensity: 85–100% HR_{max} CON Asked not to change their usual physical activity habits, extracurricular activities, eating habits, or medication.	Self-reported sleep quality: • PSQI (score)	Intra-group *($p < 0.05$)* ↓ Total PSQI score after intervention in EG (7.86 ± 1.01 vs. 2.93 ± 1.76) ↓ Total PSQI score after intervention in CON (8.08 ± 0.93 vs. 6.88 ± 2.64) Inter-group *($p < 0.05$)* < Total PSQI score in EG compared to CON after intervention (2.93 ± 1.76 vs. 6.88 ± 2.64)	Dropouts: No complete cognitive data (*n* = 16) Dropped out during the intervention or attended less than 75% of the sessions (*n* = 12) EG: *n* = 12 CG: *n* = 16 Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Suarez-Manzano et al. (2019) [22] Design: Comparative Country: Spain	Participants (*n*): 30 children with ADHD Final sample: 20 children with ADHD (EG: 10; CON: 10) Gender: EG: 4M + 6F; CON: 6M + 4F Age, years (mean; SD): EG: 11 ± 0.94; CON: 10.7 ± 0.95 BMI, kg/m^2 (mean; SD): EG: 17 ± 2.45; CON: 18.1 ± 2.28 Duration of diagnosis: NR Medication, *yes/no*: NR	Duration: 10 weeks EG Type: C-HIIT program Activities: Warm-up (10 min); main (16 min) included a combination of cardiorespiratory, motor, and coordinative exercises carried out in pairs or groups (cooperative context), 4 sets ratio of 30:30 s; cool-down (4 min). Volume: 30 min Frequency: 2 days/week Intensity: >80% HR_{max} CON Asked not to change their usual physical activity habits	Self-reported sleep quality: • PSQI (score) Objective sleep status: • Sleep duration (min) • Time in bed (min) • Times awake • Times restless	Intra-group *($p < 0.05$)* ↓ Total PSQI score after intervention in EG (7.4 ± 1.17 vs. 3.5 ± 1.08) ↑ Sleep duration after intervention in EG (280.1 ± 34.58 vs. 311.8 ± 24.51 min) ↓ Times awake after intervention in EG (1.7 ± 1.25 vs. 0.7 ± 0.68) ↑ Times awake after intervention in CON (1.1 ± 1.1 vs. 2.8 ± 1.99) ↓ Times restless after intervention in EG (17.2 ± 3.26 vs. 13.4 ± 4.29) ↑ Times restless after intervention in CON (11.4 ± 1.71 vs. 14.4 ± 4.06) Inter-group *($p < 0.05$)* < Total PSQI score in EG compared to CON after intervention (8.5 ± 0.7 vs. 3.5 ± 1.08) < Times awake in EG compared to CON after intervention (0.7 ± 0.68 vs. 2.8 ± 1.99)	Dropouts: Incomplete data (*n* = 2) Did not reach the indicated intensity (*n* = 2) Attended less than 80% of the sessions (*n* = 6) EG: *n* = 5 CG: *n* = 5 Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Geladé et al. (2017) [20] Design: RCT Country: The Netherlands	Participants (*n*): 112 children with ADHD Final sample: 92 (EG: 31; CON1: 33; CON2: 28) Gender: EG: 24M + 7F; CON1: 24M + 9F; CON2: 22M + 6F Age, years (mean; SD): EG: 9.55 ± 1.76; CON1: 9.81 ± 1.86; CON2: 8.97 ± 1.22 BMI: NR Duration of diagnosis: NR Medication, *yes/no*: EG: 14/17; CON1: 12/20; CON2: 21/7	Duration: 10–12 weeks + 6 months follow-up EG Type: Physical activity program Activities: Warm-up (5 min); followed by five 2 min moderate intensity exercises at 70–80% HR_{max}. After a 5 min break, five 2 min vigorous intensity exercises at 80–100% HR_{max}. Volume: 45 min Frequency: 30 sessions/total Intensity: Moderate–vigorous, 70–100% HR_{max} CON1 Type: Neurofeedback. Activities: Theta/beta training was applied with the aim of inhibiting theta activity (4–8 Hz) and reinforcing beta activity (13–20 Hz) at the vertex on a screen. Volume: 45 min Frequency: 30 sessions/total Intensity: NR CON2 Administration of medication, methylphenidate.	Self-reported sleep quality: • Sleep Disturbance Scale (score)—Parent reports	Intra-group *($p < 0.05$)*—NR Inter-group *($p < 0.05$)*—NO	Dropouts: EG Discontinued intervention: *n* = 3 Lost at follow-up motivational reasons: *n* = 3 CON1: Discontinued intervention: *n* = 1 Lost at follow-up motivational reasons: *n* = 5 CON2: Discontinued intervention: *n* = 3 Medical contraindications: *n* = 2 Lost at follow-up motivational reasons: *n* = 5 Adverse events: NR

Table 1. *Cont.*

First Author (Year), Design and Country	Sample	Intervention	Outcomes	Results	Dropouts and Adverse Events
Converse et al. (2020) [21] Design: RCT Country: USA	Participants (*n*): 21 undergraduates with ADHD (EG: 9; CON1: 5; CON2: 7) Gender: 7M + 14F Age, years (mean; SD): 20.7 ± 1.5 BMI, kg/m^2: NR Duration of diagnosis: NR Medication, *yes/no*: 16/5	Duration: 7 weeks Frequency: 2 days/week Volume: 60 min Intensity: NR EG Type: Tai Chi program Activities: Tai Chi principles followed by instruction in the 24-form Yang style sequence CON1 Active control (cardio-aerobic fitness) CON2 Inactive control (no contact)	Self-reported sleep quality: • PSQI (score) ▪ Day-time dysfunction	↑ Day-time dysfunction PSQI score after intervention in EG (1.11 ± 0.60 vs. 1.78 ± 0.67) ↓ Day-time dysfunction PSQI score after intervention in CON1 (1.8 ± 1.3 vs. 1.50 ± 0.58) ↓ Day-time dysfunction PSQI score after intervention in CON2 (1.43 ± 0.98 vs. 1.2 ± 1.2)	Dropouts: CON1: Withdrew prior to intervention, "family emergency": *n* = 1 CON2: Withdrew prior to intervention, "lack of time": *n* = 1 Adverse events: NR
López-Sánchez et al. (2016) [24] Design: Single arm Country: Spain	Participants (*n*): 18 children with ADHD Gender: 18M Age, years (mean; SD): 10.05 ± 1.8; BMI, kg/m^2: NR Duration of diagnosis: NR Medication, *yes/no*: NR	Duration: 12 weeks EG Type: After-school physical activity program Activities: Circuits and exercises aimed at improving their physical condition, especially muscle inhibition and postural control, with an emphasis on relaxation and self-esteem. Volume: 60 min Frequency: 2 days/week Intensity: Moderate to high	Self-reported sleep quality: • PSQI (score)	↑ The number of good sleepers based on the PSQI score (cut-off point 5/21)	Dropouts: *n* = 6 Adverse events: NR

>: Greater; <: Lower; ↑: Increment; ↓: Decrement; ADHD: Attention Deficit Hyperactivity Disorder; BMI: Body Mass Index; C-HIIT: Cooperative-High Intensity Interval Training; CON: Control Group; HR: Heart rate; F: Female; EG: Experimental Group; ISI: Insomnia Severity Index; M: Male; NO: Not Observed; NR: Not Reported; PSQI: Pittsburgh Sleep Quality Index.

3.3. Main Outcomes

3.3.1. Self-Reported Sleep Quality

Seven of the included investigations assessed the effects of exercise on self-reported sleep quality [17,19–24].

According to the intra-group results, significant improvements in this outcome were observed in most of the experimental groups. However, Converse et al. [21] showed an increase in day-time dysfunction after 7 weeks of the Tai Chi program. Five studies assessed inter-group differences following the intervention, with three reporting significant improvements in the exercise groups compared to the control groups [17,22,23]. On the other hand, Liang et al. [19] and Geladé et al. [20] indicated no additional benefits of exercise over standard treatment protocols.

3.3.2. Objective Sleep Status

Three studies utilized accelerometers to measure the objective sleep status as an outcome. Suarez-Manzano et al. [22] observed that exercise increased sleep time and reduced restlessness. In this line, Liu et al. [18] reported that exercise reduced sleep latency and time to wake after sleep onset and increased sleep efficiency. In both investigations, exercise was found to be more effective than usual treatments for decreasing time awake [22] and increasing total sleep duration, sleep latency, and sleep efficiency [18]. Notably, Liang et al. [19] did not observe any significant effect derived from exercising on objective sleep status.

The pooled data from three studies (n = 131) [18,19,22] indicated the absence of a significant impact of exercise on objective sleep duration (Hedges' g −2.67; 95% CI −11.33; 5.99, p = 0.185), with high heterogeneity (I^2 = 96.24%), as shown in Figure 2.

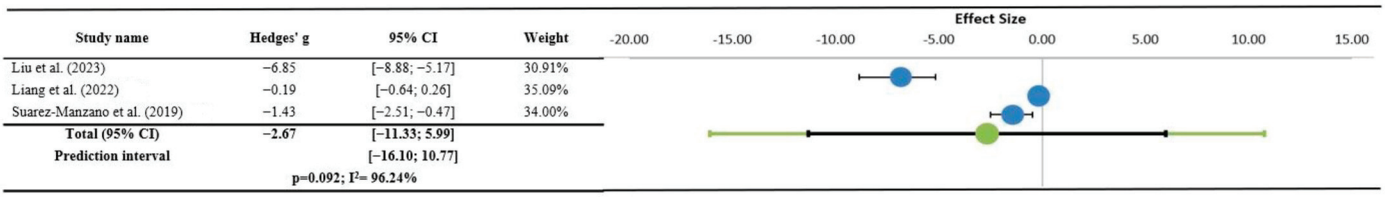

Figure 2. Forest plot on the effects of exercise on sleep duration [18,19,22].

3.4. Dropouts and Adverse Events

A total of 85 dropouts were observed across the seven studies that provided information on this matter [17,19–24], with 36 of them occurring in the intervention group. The primary reasons for dropouts included participants voluntarily withdrawing, discontinuing the intervention, personal reasons, and incomplete data availability. None of the reviewed studies reported adverse effects derived from the training programs.

3.5. Methodological Quality

The methodological quality of the RCTs was considered fair in three studies [17,19,21] and good in two studies [18,20]. A full description of the quality analysis was also provided (see Table 2).

Non-randomized studies generally used appropriate measurements to assess outcomes and interventions, and interventions administered as intended. However, several weaknesses were noted. None of the three studies reviewed [22–24] controlled the confounders accounted for in design and analysis, included participants who were representative of the target population, or showed complete outcome data (Table 2).

Table 2. Methodological quality appraisal of the included studies.

Randomized Controlled Trials (PEDro Scale)	First Author, Year				
	Svedell et al. (2023) [17]	**Liu et al. (2023)** [18]	**Liang et al. (2022)** [19]	**Converse et al. (2020)** [21]	**Geladé et al. (2017)** [20]
1. Random allocation	+	+	+	+	+
2. Concealed allocation	−	−	−	+	+
3. Baseline comparability	+	+	+	+	+
4. Blind subjects	−	−	−	−	−
5. Blind therapists	−	−	−	−	−
6. Blind assessors	+	−	−	+	−
7. Adequate follow-up	−	+	+	+	+
8. Intention-to-treat analysis	−	+	−	−	+
9. Between-group comparisons	+	+	+	−	+
10. Point estimates and variability	+	+	+	−	+
Total score	5/10	6/10	5/10	5/10	7/10

Non-randomized trials (Mixed Methods Appraisal Tool, MMAT)	**Suarez-Manzano et al. (2021)** [23]	**Suarez-Manzano et al. (2019)** [22]	**López-Sánchez et al. (2016)** [24]
1. Participants representative of target population	−	−	−
2. Appropriate measurements of outcome and intervention/exposure	+	+	−
3. Complete outcome data	−	−	−
4. Confounders accounted for in design and analysis	−	−	−
5. Intervention administered (or exposure occurred) as intended	+	+	+

4. Discussion

This study critically examined the scientific evidence on the effectiveness of exercise as a strategy for managing sleep problems in individuals with ADHD. To ensure a comprehensive analysis, the review extended beyond RCTs, considering several methodological factors. Firstly, it has been suggested that when the number of RCTs assessing non-pharmacological interventions is limited, drawing definitive conclusions becomes challenging. Including non-RCTs can thus provide a broader understanding of the evidence and help shape future research directions [25]. Secondly, non-RCTs contribute valuable insights when evaluating the feasibility of novel therapies, offering critical information on safety, adverse effects, and response rates [26]. Lastly, non-RCTs often deliver detailed information about intervention characteristics, such as exercise modality, duration, intensity, and any reported adverse effects. By broadening the scope of the review, this study captures a wider range of findings.

The reviewed literature encompassed a variety of exercise interventions, generally originating from studies with acceptable methodological quality. The findings from these studies contribute valuable insights into the potential role of exercise as a strategy for improving sleep hygiene in individuals with ADHD, enhancing our understanding of its benefits and practical application.

For instance, most of the studies assessed the efficacy of exercise on self-reported sleep quality. This is an important outcome measure given the high prevalence of sleep problems reported by parents of children with ADHD and adults with ADHD [27]. The investigations analyzed showed positive results in both children and adults, which is noteworthy given that pharmacological treatments may not always be effective for sleep problems in individuals with ADHD. Additionally, sleep medications may cause side

effects or have interactions with other medications [28]. Initially, these results point out that exercise can be considered as a potential therapy for managing sleep problems among children with ADHD. These findings align with the positive effect of physical activity on sleep quality observed in children with autism spectrum disorder (ASD) [29], a neurological disorder that shares many similarities with ADHD [30]. It should also be taken into account that most of the studies proposed combined interventions that included exercises aimed at improving fitness levels, a marker of health that has been shown to be positively associated with sleep quality among children and adolescents [31]. However, it should not be overlooked that two of the reviewed investigations did not find exercise to have superior effects over the usual treatment. This aligns with findings from other studies, which have also reported results indicating that exercise may not have significant effects on certain self-reported sleep quality outcomes [9].

When studying sleep quality, it is recommended to use both subjective and objective methods for a comprehensive analysis [32]. In this regard, it has been reported that while subjective sleep problems are common in ADHD, further research is needed to objectively assess sleep alterations in this population [33]. In the present review, three studies provided objective sleep data, including sleep latency and sleep duration. Both outcomes are of interest since they have been found to differ significantly in both children and adults with ADHD [5]. Overall, the results were mixed; two studies indicated a positive effect of exercise on objective sleep, while one study found no significant impact. In this regard, scientific evidence is also controversial. For instance, among breast cancer patients, some authors argue that exercise was shown to be effective in improving subjective sleep problems, but no effect was observed on objective sleep measures [34]. However, other researchers have reported that exercise can positively affect objective sleep in this population [35]. Notably, although a systematic review and meta-analysis performed by Liang et al. [29] indicated that significant effects of exercise on objective sleep were mostly observed among children with ASD, not all investigations yielded positive results.

Previous investigations have suggested that children with ADHD have reduced sleep quantity [36]. In the present review, although the performed meta-analysis showed a positive trend toward the effects of exercise on sleep duration, the impact was not considered statistically significant. In children with TEA, the performance of physical activity was found to be significantly associated with sleep duration [37], while other studies focusing on healthy populations have also noted a lack of significant effect of exercise on this outcome [11]. Our findings suggest that exercise may not be as effective for increasing sleep duration in this population as pharmacological and behavioral interventions [7].

The mechanisms underlying the effect of physical exercise on sleep in individuals with ADHD remain unclear, though several possibilities have been proposed. Exercise may increase melatonin production due to the rise in body temperature it induces, aiding in sleep regulation [38]. Similarly, its benefits have been linked to melatonin secretion and its role in maintaining the circadian rhythm and sleep–wake cycle [18,19]. Another hypothesis is the thermoregulatory effect of exercise, where the body cools down more quickly afterward, promoting sleep induction [23,39]. Zhu et al. [39] also theorized that exercise optimizes vagus nerve function, which inhibits sleep induction, regulates cortisol production, and improves mood, fostering relaxation and better sleep. Additionally, reduced levels of brain-derived neurotrophic factor (BDNF) have been associated with sleep disturbances [40], and Klil-Drori and Hechtman [41] reported that aerobic exercise improved ADHD symptoms by increasing BDNF concentrations, suggesting a role for this protein in enhancing sleep in individuals with ADHD.

Regarding the efficacy of physical exercise for sleep problems compared to other therapies, Geladé et al. [20] found that the use of methylphenidate, neurofeedback, or physical

exercise did not produce statistically significant improvements in any case. There is a lack of solid evidence regarding the effectiveness of pharmacological and non-pharmacological interventions in managing sleep problems in ADHD [7]. However, the same authors have highlighted the efficacy of pharmacological therapies (melatonin) and non-pharmacological therapies (cognitive-behavioral therapy), albeit with limited effects. In this context, Faraone et al. [42] present meta-analytic evidence indicating that stimulant drugs used to treat core ADHD symptoms worsen sleep quality in this population, as do non-stimulant drugs [43]. Therefore, pharmacological therapies should be administered cautiously. Overall, the efficacy of both types of therapies appears to be quite limited and even controversial in the case of pharmacological ones, leaving non-pharmacological options (cognitive-behavioral therapy, physical exercise, etc.) as a more viable alternative for addressing sleep problems in this condition. Ultimately, the literature consistently recommends multidisciplinary therapies (pharmacological and non-pharmacological) to maximize their effectiveness [43–45].

The analyzed studies included diverse exercise interventions in terms of content, intensity, weekly frequency, and participants' age, resulting in significant heterogeneity that complicates the development of standardized exercise guidelines for individuals with ADHD. Despite this variability, the observed findings suggest that clinicians might recommend exercise interventions incorporating aerobic training combined with motor skill tasks aimed at improving coordination and agility for both adults and children. Interventions with a duration of 30–50 min per session, conducted 2–3 times per week, appeared to yield positive outcomes across various studies. Addressing this heterogeneity in future research by standardizing intervention protocols is essential to improve the consistency and reliability of exercise prescription guidelines.

Similarly, further studies are needed to confirm the impact of exercise as an adjunct therapy. Specifically, exploring the outcomes of combining exercise with proven effective approaches, such as cognitive-behavioral therapy, light therapy, or sleep hygiene, could provide valuable insights.

Limitations

This appears to be the first systematic review and meta-analysis on the efficacy of exercise on sleep in individuals with ADHD. The obtained results lay the groundwork for future evidence-based guidelines on managing sleep disturbances in this population. However, there are some limitations that should be acknowledged for an accurate interpretation of the present findings. Firstly, the review included few studies, with most lacking details on ADHD type and severity, which limits the generalizability of the findings to diverse ADHD populations. Secondly, the meta-analysis combined data from three studies with heterogeneity and small sample sizes, resulting in low certainty of evidence and reducing the strength of the conclusions. Thirdly, the limited number of studies comparing different exercise programs made it difficult to determine the most effective regimen, further restricting the applicability of the results in clinical practice. Fourthly, the methodological quality of the studies was evaluated through the MMAT. While this tool is validated and widely used, its checklist is primarily based on generic criteria designed to assess and compare studies with diverse designs. As a result, it may not provide a comprehensive quality assessment for all the studies included in this review Finally, methodological issues, such as reliance on self-reports and cross-sectional designs, introduce potential bias, while the exclusion of grey literature and potential publication bias may have led to an overestimation of positive effects by omitting unpublished or negative findings. Consequently, these limitations weaken the overall robustness and generalizability of the findings.

5. Conclusions

The existing evidence regarding the prescription of exercise for managing sleep problems among individuals with ADHD remains uncertain. Preliminary data from this review suggests a positive effect of exercise on self-reported sleep quality, while its efficacy for improving sleep duration could not be confirmed. Given the small sample sizes, potential biases in self-reported data, and the significant heterogeneity in the exercise interventions studied, these conclusions should be considered tentative. These limitations make it difficult to generalize the results and establish definitive exercise prescription guidelines. As such, further research is needed to further determine whether exercise can be considered an optimal sleep hygiene behavior in this population.

The existing evidence regarding the use of exercise to manage sleep problems in individuals with ADHD remains inconclusive. Preliminary findings from this review suggest a potential positive effect of exercise on self-reported sleep quality; however, its efficacy in improving sleep duration could not be confirmed. Thus, there is still a need to determine whether exercise can be reliably recommended as an effective sleep hygiene practice for individuals with ADHD.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children12020119/s1. Table S1: Full search strategy for each database with arguments presented as they were used (30 March 2024).

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