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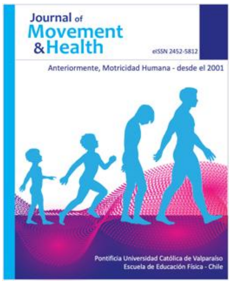

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Protocol

"Play & Cognition": Playground intervention to stimulate physical activity and cognitive function in schoolchildren. Study protocol

Jugar y Cognición: Intervención en el patio de recreo para estimular la actividad física y la función cognitiva en escolares. Protocolo de estudio

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Abstract

Objective: To evaluate the impact of a playground intervention on physical activity and cognitive functions in schoolchildren. **Methods:** A random experimental design will be carried out, considering 300 schoolchildren, with n = 150 per each group, intervention and comparative, and belonging two schools in each arm (NCT05020041, version 1). Parents will complete sociodemographic and lifestyle factors. The schoolchildren will undergo an assessment of their cognitive functions using the TENI test and their physical activity will be measured with accelerometers. Teachers from both the comparative and intervention groups will receive one educational session to promote healthy habits and the benefits of physical activity among schoolchildren. The intervention group will also receive one educational session for schoolchildren, and access to a playground with a painted psychomotor games circuit and a climbing wall. After five months, both schoolchildren's groups will be evaluated. A mixed linear model will be used to analyze the effects of the intervention on physical activity and cognitive function. Statistical significance will be set at $p < 0.05$. **Conclusion:** The intervention is expected to create a more active play environment and stimulate cognitive functions, providing benefits for children in a vulnerable school context through a feasible and low-cost initiative.

Keywords: executive function; moderate-to-vigorous-intensity; school-aged children; active play

Resumen

Objetivo: Evaluar el impacto de una intervención en el patio de recreo sobre la actividad física y las funciones cognitivas en escolares. **Métodos:** Se realizará un diseño experimental aleatorizado, considerando 300 escolares siendo n=150 para cada grupo, comparativo e intervención, y pertenecientes a dos colegios por grupo (NCT05020041, versión 1). Los padres completarán los datos sociodemográficos y de estilo de vida. Los escolares realizarán una evaluación de sus funciones cognitivas mediante el test TENI y de actividad física con acelerómetros. Los profesores del grupo comparativo e intervención recibirán una sesión educativa para promover hábitos saludables y los beneficios de la actividad física en los escolares. El grupo de intervención recibirá además, una sesión educativa para los escolares y un entorno de patio de recreo que incluye un circuito de juegos psicomotores pintados y un rocódromo. Después de cinco meses, se evaluarán ambos grupos-escolares. Los efectos de la intervención sobre la actividad física y las funciones cognitivas se analizarán mediante modelos lineales mixtos. La significación estadística se establecerá en $p < 0,05$. **Conclusión:** Se espera que la intervención genere un ambiente de juego más activo y estimule las funciones cognitivas, brindando beneficios a escolares vulnerables mediante una iniciativa de bajo costo.

Palabras clave: funciones ejecutivas; intensidad moderada-vigorosa; niños en edad escolar; juego activo

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Key points

- Playground is expected to enhance physical activity and cognition in schoolchildren.
- Playground intervention with painted equipment is expected to encourage physical activity in disadvantaged schoolchildren.
- Low-cost playground designs may offer a scalable strategy for Latin American contexts.

Introduction

Cognitive development and motor skill acquisition are dynamically interrelated throughout childhood[1]. Cognitive functions, encompassing perception, memory, attention, executive functions, and reasoning, are crucial for learning and school adaptation[2,3]. Cognitive performance during childhood is associated with brain health, social capital formation, and adaptive behaviors[4], ultimately influencing future opportunities for social and cultural participation. However, recent evidence indicates that a substantial proportion of children exhibit suboptimal executive functions and cognitive performance, particularly in populations with socioeconomic adversity[5].

During childhood, exposure to physical activity positively affects cognitive development by stimulating brain plasticity and may build greater cognitive reserve to protect against future insults[6]. At the molecular level, exercise increases the release of neurotrophic factors, particularly brain-derived neurotrophic factor (BDNF), which enhances neuronal survival, synaptic plasticity, and neuroadaptation[7]. Furthermore, physical exercise stimulates cerebrovascular function by altering regional cerebral blood flow changes[8]. Over time, both acute and chronic moderate-to-vigorous physical activity interventions improve brain function, cognition, and academic outcomes[9,10]. Given that childhood represents a sensitive period for neurodevelopment, reduced physical activity during this window may render individuals more vulnerable to adverse effects on cognitive function compared to similar reductions in adulthood[11–13].

Based on these biological mechanisms, numerous physical activity interventions have been conducted to enhance cognitive function during childhood in school-aged children. However, evidence indicates only a moderate association between moderate-to-vigorous physical activity and improvement in cognition[10,14,15]. Physical activity interventions that yield optimal cognitive benefits appear to be those stimulating creativity, diversity, and complexity in motor actions[16,17]. Additionally, interventions emphasizing moderate-to-vigorous-intensity physical activity have successfully promoted leisure and autonomous play among schoolchildren[18]. Consequently, active games involving jumping movements correlate positively with visuospatial functions, whereas coordination-based activities are associated with improvements in attention[19].

Numerous studies have explored physical activity interventions through classroom-based, pre-class exercise, or extracurricular program strategies; however, outdoor approaches, particularly playground interventions, remain underexplored from the beginning of formal schooling in Latin American countries[14,20,21]. A playground is an area specifically designated for play or recreation. This area is usually outdoors and may include play equipment such as swings and sandboxes, or simply nothing, in vulnerable communities[20]. Likewise, providing attractive designs with colored markings and physical structures in schools has stimulated physical activity during playtime among schoolchildren[21] and has the potential to increase the proportion of the daily recommended moderate-to-vigorous-intensity physical activity[22].

In Chile, children's physical activity levels are particularly concerning. Despite international recommendations of at least 60 minutes per day of moderate-to-vigorous-intensity physical activity for school-aged children (6 years old),[23] only 26% of Chilean schoolchildren aged 5-11 meet these guidelines,

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below the Latin American average[24,25]. Notably, research on physical activity and cognitive function has been predominantly conducted in developed countries, particularly the United States and Australia, with scarce data from South America[26]. This geographic limitation is relevant because several factors that may moderate the relationship between physical activity and cognitive performance—including age, sex, socioeconomic level,[27] physical fitness[28], nutritional status[29], and maternal education[30]—vary substantially across populations. These moderating factors may be particularly salient in contexts characterized by socioeconomic disparities, where children face compounded risks affecting both physical activity opportunities and cognitive development.

Therefore, it is necessary to strengthen the evidence on the impact of physical activity on cognitive function from the beginning of formal schooling[31], particularly in vulnerable communities where children may face cumulative risk factors affecting development[21]. In this context, the aim was to evaluate the impact of playground intervention on physical activity and cognitive functions in schoolchildren. The secondary objective was to explore whether moderate-to-vigorous-intensity physical activity mediates the intervention's effects on cognitive functions. We hypothesized that children exposed to playground intervention would demonstrate improvements in physical activity and cognitive performance compared to a comparative group, and that physical activity would partially mediate the intervention's effects on cognitive outcomes.

Methods

This study is a randomized experimental design conducted in Talca, The Maule Region, Chile. It is the most agricultural community, with 73% of the urban population concentrated in Talca.

Sample size and randomization

Talca has approximately 880 1st-grade schoolchildren enrolled in 23 public schools[32], according to the population, a sample of 300 schoolchildren (n=150 per group) is required to detect small-to-medium-sized effects (i.e. Cohen d=0.3), considering a power of 80%, an alpha error of 5% and 20% of drop-off data.

Schools that meet the inclusion criteria will be invited to participate; those that accept will be randomly assigned to the intervention or comparative arm (Figure 1). Participating in schools will be randomized in a 1:1 ratio (two schools per arm) by the principal researcher using an excel-generated random sequence. Allocation concealment is not feasible due to the school-level intervention; therefore, personnel involved in recruitment and implementation will be aware of group assignments. Schoolchildren will be blinded to allocation by preventing contact between intervention and comparative schools and by not disclosing group assignments. The principal investigator will generate and retain the random allocation sequence. The investigator enrolling schools and participants will not have access to the sequence and will be informed of each school's assignment only after the school has been randomized.

Participants

The inclusion criteria for schools are as follows: being located in an urban area, offering standard primary education, having public administrative dependence, possessing a playground with a solid surface, and maintaining active enrolment of 1st-grade schoolchildren (6 years old).

The inclusion criteria for schoolchildren were as follow: a) being enrolled in the 1st grade, b) having no physical activity, visual or hearing impairments that limit participation in physical activity; c) demonstrating age-appropriate ability to understand simple instructions; d) residing in the city of Talca; and e) maintaining residence in Talca and attendance at the same school throughout the study period. The

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exclusion criteria included any medical condition that could interfere with the assessments, as well as a diagnosis of behavioral disorders, such as autism spectrum disorder.

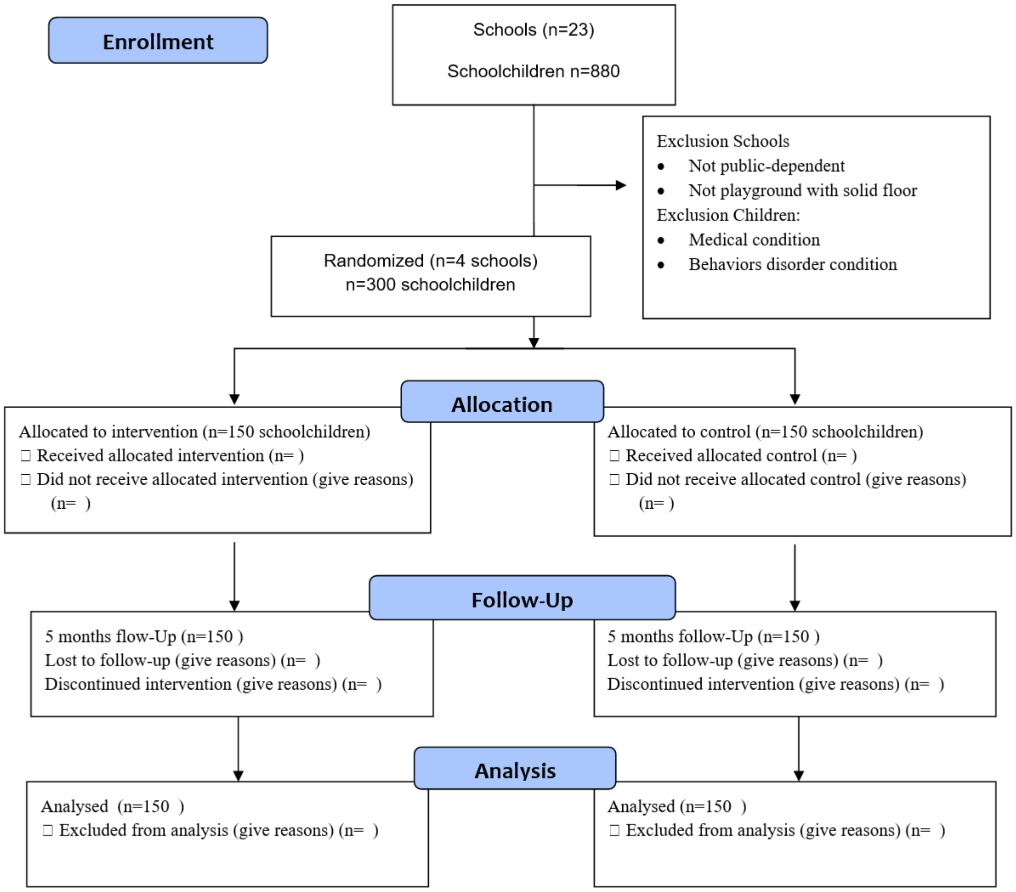

Figure 1. Flow Diagram.

Recruitment

Recruitment has three phases. First, school authorization for access to the children. The research team met with the school principal to explain the study procedures and implementation steps. Second, information about the project for teachers and parents. The research team held either online or face-to-face meetings to present the study objective, potential risks of participation, and the informed consent process, which required a signed agreement from participants. Third, schoolchildren who provided assent proceeded to participate in the data collection.

The fieldwork will be conducted either at the school or at the child's usual place of residence, depending on the polices of each educational institution, while adhering to the current public health and safety measures.

Comparative Group

The school's Physical Education teachers of the comparative group will receive one educational session on promoting healthy habits and the benefits of physical activity among schoolchildren, led by a specialist in physical activity and health. This will take place after the baseline assessments of the participants.

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Intervention Group

The intervention will begin with a single educational session for the school's Physical Education teachers, led by a specialist in physical activity and health, focusing on healthy habits and the benefits of physical activity for schoolchildren. During the following week, schoolchildren will receive one online educational session on healthy lifestyle behaviors, delivered by a physical education teacher from the research team. Additionally, schoolchildren will have access to an enhanced playground environment with colored markings and a physical structure, including painted activity zones and a climbing wall. The painted game's implementation will adapt to the available space and include a psychomotor circuit with a jumping sequence game (i.e., "The Luche" called in Chile), lines designs, and a spiral. The climbing wall will be equipped with climbing pieces along a horizontal circuit, with locations ranging from 20 cm above ground to 150 cm. The painted games and climbing wall involve activities that foster motor skills, such as jumping on different supports, running, or dynamic balance, which does not require contact between peers or manipulating external objects. In both comparative and intervention groups, the evaluations will be performed at baseline and post-5-month of follow-up.

Outcomes measures

All data will be recorded using electronic devices (tablets) and collected in REDCap[33]. The project's database will be generated directly from REDCap. In addition, the database will be automatically stored once a week on a remote hard drive, with the data collected and registered at the time of storage. Data recorded will be monitored by the project's data manager every week. The principal researcher will have full access to all data to oversee monitor study progress.

The data collection process will begin with the sociodemographic and lifestyle questionnaire administered to the parent or legal guardian during an interview. Subsequently, physical health assessments, cognitive function tests, and physical activity assessments using accelerometry will be conducted on the participating schoolchildren (Figure 2). All assessments were performed by trained technical staff members from the research teams.

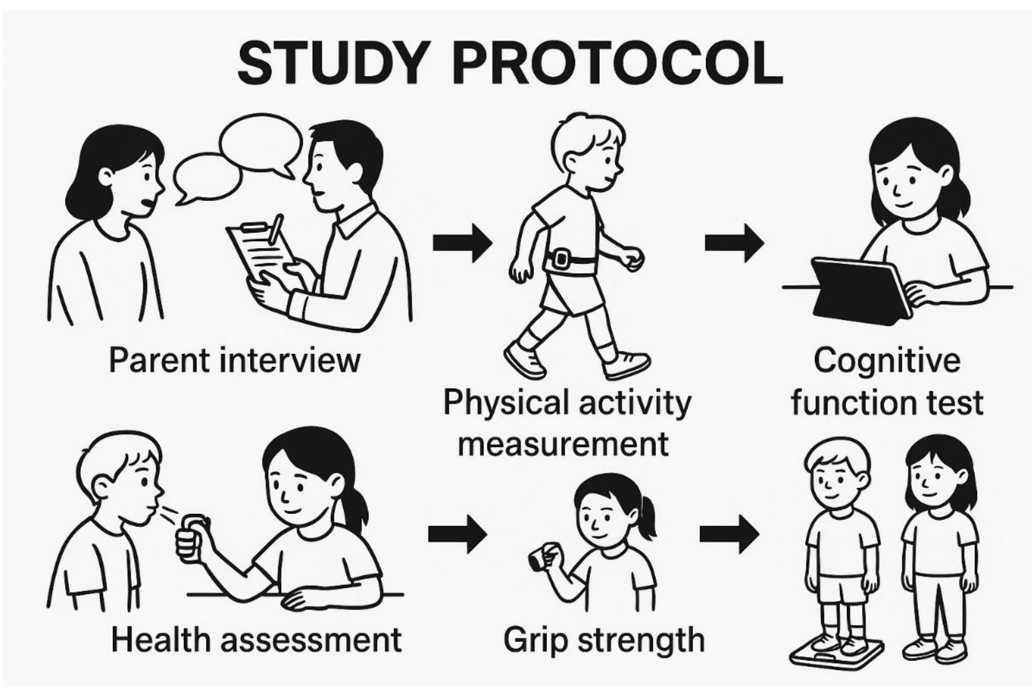

Figure 2. Flowchart of the data collection process and study protocol assessments.

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Primary outcomes

Cognitive function

Cognitive function will be assessed using the Neuropsychological Evaluation Test, TENI[34], which is designed to profiles cognitive strengths and weaknesses in Chilean children. This battery evaluates attention, visuospatial and visuomotor skills, memory systems, language, and executive functions via a tablet for children aged 5 to 9 years (Table 1). The test platform generates individual scores, and the test manual is accessible at www.cedeti.cl. The TENI has been standardized on two samples, one comprising 524 children and another comprising 84 urban children. The TENI demonstrates good validity and reliability indicators (0.7 to 0.9)[34]. The battery lasts 30 minutes; the most extended games have 6 minutes (Duno, The Worms, and Bzz!). Before the execution of the evaluation, the test will be explained together with their demonstration and practice.

Table 1. Description of the cognitive functions evaluated

Cognitive domain	Game	Score
Attention	Alternate Universes Duno and the worms (hits) Duno and the worms (response time) Duno and the worms (errors of omission) Duno and the worms (D prime) Duno and the worms (precision index)	Composite score
Visuospatial	Bzz! Mexican House (copy)	Composite score
Language	Tic-Toc	Score
Memory	Mexican House (recovery)	Score
Executive functions	Torpo the clumsy mole The farm Bzz! Inhibition	Composite score

Physical activity

Schoolchildren's physical activity will be assessed using the Actigraph GT3X and wGT3X-BT accelerometers (www.theactigraph.com). Each participant will receive an accelerometer at the visit, programmed to record the amount of physical activity in epoch of 15 seconds and configured at 30 Hz sampling rate using Actilife software (v 6.13.3)[35]. The accelerometer should be worn for seven consecutive days, located at the right hip level, and secured with an adjustable strap (elastic belt). Participants will be instructed to wear the accelerometer during walking hours throughout the day except when bathing or sleeping. Raw acceleration data will be processed in R using the GGIR package version 3.1.1[36] and physical activity will be defined for Euclidean Norm Minus One (ENMO) metric using 5 s epochs for hip-based cut-off points between ≥95 mg to <325 mg for moderate physical activity, and ≥ 325 mg for vigorous physical activity[37]. Schoolchildren who wore the device for at least ≥ 4 days of measurement with a minimum of 9 h/day of wear time will be considered as valid data to include in the analysis[38].

Secondary Outcomes

Sociodemographic and lifestyle

Each parent or legal guardian of the child will be asked to fill in a survey requesting the following information: affiliation, sociodemographic characteristics, family members, household income level (<350 USD, 350 USD to 911, >911 USD) and gestational history (weeks of gestation, weight in kg and

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height in cm. at birth). Also, data regarding the child's lifestyle and health will be collected: time spent playing per day, participation in organized physical activity (frequency and duration), hours of sleep, and health (diseases). The estimated duration is 20 minutes.

Physical Health Assessment

Body weight will be assessed and accurately measured to the nearest 0.1 kg using a portable electronic scale (SECA 22089, Hamburg, Germany). Height will be assessed with a portable stadiometer to the nearest 0.1 cm (SECA 213, GmbH). According to the Body Mass Index (BMI), the nutritional status will be calculated as weight/height^2. BMI-for-age will be determined according to sex-specific guidelines[39]. Waist circumference will be measured once at the midpoint between the lower costal margin and the iliac crest, using a flexible tape measure (Seca 201); if the measurement is ≥90th percentile of the national reference values, it will be classified as an elevated waist circumference[40].

Peak flow spirometry will be analyzed using three measurements with a Mini wright of 850 l/m (Clement Clarke International Limited, Edinburgh). Manual grip strength will be assessed on the dominant hand three times using a digital dynamometer, T.K.K. 5401 (Takey, Japan). Participants should stand with their feet hip-width apart, arms relaxed at their sides, and palms facing inwards. The mean of the three measurements will be used for analysis. Blood pressure will be assessed three times at intervals greater than 1 minute on the right arm using the M3 HEM-7200 Omron blood pressure monitor (Omron Healthcare Co., Ltd., Kyoto, Japan). The mean between the last two measurements will be obtained[41]; the blood pressure will be classified as hypertension if the mean is ≥95th percentile[42].

No serious adverse events are anticipated. Potential minor adverse events associated with the accelerometer include skin irritation, discomfort from the belt, and participant refusal to wear the device. Study staff will actively inquire about these events during device fitting and collection and will document all occurrence. Adverse events will be summarized descriptively by group.

Statistical Analysis

A normal distribution will be tested using the Kolmogorov-Smirnov test. Continuous variables will be presented as means with standard deviations for normal data and median with range for non-normal data, while categorical variables will be shown as percentages. To compare baseline characteristics between the comparative and intervention groups in terms of cognitive functions, moderate-to-vigorous physical activity, sociodemographic, lifestyle and health assessment variables, Student's t-test for continuous or Chi-square test for categorical variables will be used. If the data are not normally distributed, non-parametric tests will be used. The moderate-to-vigorous-intensity physical activity will be operationalized as average daily minutes at each time point (baseline and post-5-month of follow-up). The moderate-to-vigorous-intensity physical activity will be analyzed as a continuous variable.

To evaluate the impact of the intervention and capture differences in change over time in each cognitive function and moderate-to-vigorous-intensity physical activity, we used linear mixed-effects models incorporating an interaction between groups (Comparative and Intervention) and time (baseline and post). To account for intra-individual variability, the models included a random intercept for each participant. Lastly, we will analyze the associations of moderate-to-vigorous physical activity as a mediator and each cognitive function using linear mixed-effects models. Age, sex, school, and other potential factors will be considered as covariates. Missing data will be handled under the missing at random assumption. Primary analysis will follow the intention-to-treat principle, including all randomized participants in the groups to which they were assigned. Sensitivity analyses will include a per-protocol analysis restricted to participants with valid baseline and post-5-months of follow-up physical activity and

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cognitive functions assessments. The significance differences will be set at $p < 0.05$. The statistical analysis for this study was performed using R Statistical Software version 4.4.2[43].

Ethical Considerations

This study was conducted under the Declaration of Helsinki[44], was approved by the Ethical Guidelines for randomized non-clinical studies of the Institutional Ethics Committee (No. 01-20, dated 3/4/2020), and is registered on ClinicalTrials.gov (NCT05020041, dated 25/8/2021, version 1). The designated researcher responsible for participant recruitment will obtain the required consent and assent form all participants. All physical copies of these documents will be stored in a locked cabinet in the principal researcher's office. Once participants are enrolled in the study, ensuring data anonymity. All schoolchildren enrolled in both the intervention and comparative groups will be evaluated; however, only those who meet the inclusion criteria and do not have exclusion conditions will be included in the final analytical sample.

Study results, regardless of outcome, will be disseminated through publications in peer-reviewed journals and presentations at national and international conferences. School participants will receive an aggregated report of group-level assessments that does not identify individual participants. Parent or legal guardians will receive an individual report summarizing the main results of their child's assessment, in compliance with confidentiality and data protection requirements.

Public involvement

Neither schoolchildren, nor their parents or legal guardians participated in the design, conduct, or reporting of this study.

Data availability

De-identified individual participant data and the corresponding data dictionary will be made available upon reasonable requests and should be made to the corresponding author after publication of the main results. Each request will be assessed according to scientific merit and compliance with ethical approval, and conformity with applicable data protection regulations. For approved requests, a data use agreement will be required to specify the intended use, describe confidentiality safeguards, and delineate restrictions on re-identification and further dissemination.

Discussion

This protocol describes the effects of playground intervention on cognitive function and physical activity in schoolchildren. This playground intervention incorporates colored markings and a physical structure to improve cognitive function and physical activity among vulnerable schoolchildren. Cognitive functions develop rapidly during childhood and enter a dynamic phase that extends into adolescence[3], being particularly amenable to intervention. The developing brain is particularly plastic in response to physical activity, with both acute and chronic activity producing adaptations in cognitive function[26,45,46]. Despite this evidence, limited research has examined how playground interventions can leverage this developmental window to promote cognitive and physical activity in vulnerable educational contexts.

Latin American children demonstrate steadily low rates of meeting physical activity recommendations[24,47]. Simultaneously, there is a recognized need for adequate interventions and objective evaluation methodologies for physical activity among Latin American schoolchildren[48]. Besides, school-aged children in Talca show low levels of physical activity, high sedentary behavior[25], almost 40% of obesity[49] while reported optimal physical fitness levels[50]. In addition, Talca presents over the national average in poverty by income and multidimensional status[51].

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This protocol addresses both gaps by proposing a scalable, low-cost intervention adapted to a vulnerable school context. The proposed intervention is based on the understanding that children enter formal schooling and become increasingly open to peer relationships, typically mediated through play. Free and spontaneous play is essential for stimulating cognitive development, and the playground provides a natural context for promoting physical activity[20,52]. Van Dyck et al. (2022) exposed that attractive playgrounds with high variety encourage physical activity among schoolchildren, and studies have confirmed that availability of physical structure on school playgrounds promotes movement[22]. Primary schools should therefore be designed to actively stimulate play and be accessible throughout different contexts.

The "Play and Cognition" intervention combines game design elements with physical structures (climbing wall) to create an enriched playground environment. Playground interventions are consistent with children's natural play behaviors and promote intrinsic motivation. In addition, it is accessible before the classroom, during recess or other break times, and avoids disruption to the academic curriculum. Also, the infrastructure-based approach affords lasting environmental change rather than involving constant program delivery.

Our study, focusing on vulnerable schoolchildren, contributes to equity in research on this topic. Furthermore, children from disadvantaged communities often have limited access to recreational facilities and organized sports, making school playgrounds a strategic place for promoting physical activity. In addition, considering given the potential mobility restrictions imposed by COVID-19-related health measures in Chile, which could affect the intervention and data collection, we designed outdoor activities compatible with social distancing, as well as assessment options that can be conducted in participants' homes.

Strengths and limitations

Our protocol incorporates several strengths. Among them, we will assess cognitive function using the Neuropsychological Assessment Test (TENI)[34], a tool shown to be reliable and valid in Chilean children. We will objectively measure physical activity using accelerometry. This approach enables us to quantify moderate-to-vigorous physical activity (MVPA) throughout walking hours in schoolchildren. In addition, a low-cost intervention (less than USD 1000 per school, including installing a climbing wall and painting floor games) improves replicability in similar educational contexts. Finally, this playground intervention leverages existing school infrastructure, allowing sustainable implementation without additional staffing.

However, our protocol is not without limitations. First, focusing on a single country (Chile) could limit its generalizability to other populations. Second, the flexibility in school attendance following the return to normalcy after the COVID-19 pandemic could affect the detection of cognitive changes or improvements in physical activity. Finally, the study does not include monitoring of schoolchildren's attendance records or observations of playground usage time were not collected due to logistical constraints and available resources.

Findings from this protocol are expected to inform public education policies encouraging physical activity and school environment transformation to support active lifestyles and cognitive development[53]. If effective, the "Play and Cognition" intervention offers a feasible, replicable model for reducing barriers to physical activity among disadvantaged children[54] that could be replicated across comparable educational communities[55]. Monitoring school-based physical activity interventions is a potential focus for new public policies that promote children's physical health, emotional well-being, and cognitive development from childhood.

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Conclusion

This protocol describes a designed study evaluating a prospective playground intervention to improve cognitive function and physical activity among vulnerable Chilean schoolchildren. The low-cost, scalable approach tackles major gaps in the literature while generating evidence directly applicable to educational policy and practice in Latin American contexts.

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Author Contributions

NB-A conceived the study. NB-A, PVC, YC and EM-N designed the study. PVC, YC, EM-N, JC, and CG-M made substantial intellectual contributions to design of the study. PVC, EM-N and JC made substantial contribution preparation of material and protocols. PVC, JC and CG-M substantial logistical contribution for the acquisition of data. All authors contributed intellectually and approved the final manuscript of this study protocol.

Conflict of Interest

None.

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