https://doi.org/10.6063/motricidade.43783

Original Article

Effects of a Psychomotor and Road Safety Program on Motor Competence and Safety Knowledge in Preschool Children from Cuenca, Ecuador

Short title: Psychomotor and Road Safety Effects in Preschoolers

Helder Aldas-Arcos (https://orcid.org/0000-0002-8389-5473)[1]*, Jorge Barreto-Andrade (https://orcid.org/0000-0001-6239-316X)[1], Nelson Cobos-Bermeo (https://orcid.org/0000-0002-5372-6732)[1], Ana Delgado-Espinoza (https://orcid.org/0000-0002-2620-9852)[1], Johanna Matute-Farez (https://orcid.org/0009-0007-0694-0705)[1], José Moncada-Jiménez (https://orcid.org/0000-0001-9807-5163)[2]

[1] University of Cuenca, EDFIDYS Research Group. Cuenca-Ecuador.
[2] University of Costa Rica, Human Movement Sciences Research Center(CIMOHU), Costa Rica.

***Corresponding author:**
University of Cuenca, EDFIDYS Research Group. Ecuador. **E-mail:** helder.aldas@ucuenca.edu.ec

DECLARATIONS

Conflicts of Interest:

There is no conflict of interest on the part of the authors.

Funding:

This project was funded by the Vice-Rectorate for Research of the University of Cuenca under the code VIUC_XX_2024_14

CRediT authorship contribution statement:

Helder Aldas-Arcos: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Project administration, Funding acquisition

Jorge Barreto-Andrade: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Project administration, Funding acquisition
Nelson Cobos-Bermeo: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Project administration, Funding acquisition
Ana Delgado-Espinoza: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Project administration, Funding acquisition
Johanna Matute-Farez: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision, Project administration, Funding acquisition
José Moncada-Jiménez: Formal analysis, Writing - Review & Editing.

EDITORIAL INFORMATION

Received: 22 October 2025.
Accepted: 4 April 2026

Edited by:
Luís Branquinho (https://orcid.org/0000-0001-9000-5419)
Polytechnic Institute of Portalegre, Portugal

ABSTRACT

This study examined the effects of a school-based psychomotor and road safety education program on motor competence and traffic safety knowledge in preschool children. A total of 328 participants (M=4.1±0.4 years) were assigned to control (n=134) and experimental (n=194) groups using a quasi-experimental pre–post design. Psychomotor skills and road safety outcomes were assessed through standardised tests, and data were analysed using a 5-way mixed ANOVA. Results showed significant improvements in the experimental group compared to controls in total psychomotor skills ($p=0.003$; $\eta^2p=0.027$) and overall road safety education scores ($p\leq0.0001$; $\eta^2p=0.273$). The interaction effects showed that improvements varied according to gender, school type, and geographic context. While both groups improved in some motor domains, the experimental group demonstrated consistently greater scores following the intervention. These findings support the effectiveness of integrated, school-based interventions to enhance both motor development and safety-related learning in early childhood.

Keywords: Child development; Road safety; Educational intervention; Psychomotor competence.

INTRODUCTION

Psychomotor development is a fundamental component of early childhood, encompassing the integration of motor, cognitive, and emotional processes that support children's interaction with their environment. It has been conceptualised as a comprehensive approach that promotes the development of motor, creative, and expressive abilities, enabling children to explore, communicate, and construct knowledge through movement. The age range of 4 to 5 years is a critical period for consolidating fundamental motor skills such as running, jumping, and balance, which are essential for overall development. During this stage, high neural plasticity enhances responsiveness to enriched motor experiences, facilitating both motor learning and broader developmental outcomes (Barnett et al., 2016; Lubans et al., 2010).

Beyond physical development, motor competence plays a key role in cognitive functioning. Evidence indicates that motor experiences are associated with improvements in attention, executive function, and academic-related outcomes, as children learn to perceive, interpret, and respond to environmental stimuli through action (Donnelly et al., 2016; Hillman et al., 2008; Marín-Puyalto et al., 2021). This interaction between movement and cognition is particularly relevant in dynamic contexts, where children must process information and adapt their behaviour accordingly. From this perspective, motor competence may contribute to the acquisition of safety-related behaviours by enhancing children's ability to recognise environmental cues and make appropriate decisions.

In parallel, road traffic injuries constitute a major global public health concern. According to the World Health Organisation (2023), approximately 1.35 million people die each year as a result of traffic accidents, with children and young individuals among the most affected populations. Indeed, road traffic injuries are among the leading causes of death in children and adolescents worldwide, underscoring the urgent need for preventive strategies targeting early developmental stages (Peden et al., 2008). This burden is particularly pronounced in Latin America and the Caribbean, where an estimated 110.000 individuals die annually, and more than 5 million are injured, making traffic incidents the leading cause of death among children aged 5 to 14 (United Nations in Ecuador, 2024). In Ecuador, recent national data further illustrate the magnitude of the problem: during the third quarter of 2024 alone, the National Transit Agency recorded 5,308 traffic accidents, resulting in 940 fatalities among individuals under 18 years of age (National Institute of Statistics and Census, 2024). These figures highlight the critical need for early, targeted interventions to reduce traffic-related risks and promote safe behaviours from childhood.

Early childhood has been identified as an optimal period for the acquisition of road safety knowledge and behaviours. Educational interventions at this stage can promote the development of preventive habits, risk awareness, and responsible attitudes toward traffic environments (Rojo-Ramos et al., 2022; Kourmousi et al., 2024). Road safety education involves not only the transmission of rules but also the development of perceptual, cognitive, and motor skills necessary for safe interaction as pedestrians and passengers. In this context, family involvement and environmental exposure also play a relevant role in shaping children's safety behaviours (Zare et al., 2019).

Despite the recognised importance of both psychomotor development and road safety education, limited research has examined their integration within a single intervention framework, particularly in preschool populations. Existing studies have largely addressed these domains independently, leaving a gap in understanding how motor-based educational strategies may enhance safety learning outcomes. Given that motor competence is associated with adaptive developmental trajectories and health-related behaviours (Robinson et al., 2015; Stodden et al., 2008), integrating psychomotor activities into educational interventions may provide an effective pathway for promoting safety-related learning.

From an integrated theoretical perspective, psychomotor activities may facilitate learning about road safety through sensorimotor and cognitive mechanisms. Learning emerges through action–perception coupling, whereby children construct knowledge through movement-based experiences (Glenberg & Gallese, 2012). Improvements in coordination, balance, and spatial awareness may enhance children's ability to perceive and interpret environmental cues, while also supporting cognitive processes such as attention, inhibitory control, and decision-making (Schmidt et al., 2017). These mechanisms are essential for navigating dynamic and potentially hazardous environments such as traffic contexts.

Based on this rationale, the present study was designed to examine the effects of a psychomotor intervention, with an emphasis on road safety education, on motor competence and safety-related knowledge among preschool children aged 4 to 5 years attending public and private educational institutions in the canton of Cuenca, Ecuador. It was hypothesised that participation in this integrated program would lead to significant improvements in both motor skills and traffic safety knowledge. Accordingly, the primary objective of the study was to evaluate the effect of a psychomotor and road safety education program on the development of motor competence and safety knowledge in this population.

METHODS

Participants

This study followed an experimental design with a mixed-methods (quantitative-qualitative) approach. To determine a representative sample, a population of 7,531 preschool children in Early Childhood Education Level II (ages 4 and 5) was considered, comprising 3,643 boys (48.38%) and 3,888 girls (51.62%) from the canton of Cuenca, Ecuador (Ministry of Education, 2024; Ministry of Education of Ecuador, 2024). The Raosoft software (Raosoft Inc., USA) computed a cluster sample size of 363 preschool children (191 boys and 172 girls), with a 95% confidence level and a 5.3% margin of error. For the study design, participants were randomly assigned to an experimental group (EG, n = 205) and a control group (CG, n = 158).

The inclusion criteria for participation in the study were: a) educational institutions with more than 35 students enrolled in Early Childhood Education II, b) regular attendance of 80% or higher, c) parental or guardian consent to participate in the study, and d) absence of physical disability. The study protocol was approved by the Research Ethics Committee for Human Subjects of the University of Cuenca (code: 2024-003EO-VIUC). Prior to the start of the study, the research team obtained informed consent from the legal guardians.

Instruments

The demographic information used to characterise the sample was collected through an ad hoc questionnaire. The level of psychomotor development was measured by the Capón Perceptual-Motor Test. The battery evaluates the areas of body awareness, spatial awareness, balance, general coordination, and eye-hand coordination, and has been previously adapted and validated through expert judgment, demonstrating adequate content validity and sensitivity to developmental differences in motor performance among children, supporting its applicability in school contexts (González et al., 2025). In adapted versions, acceptable psychometric properties have been reported, including internal consistency values ranging from Cronbach's α=0.70 to 0.85, test-retest reliability coefficients between $r = 0.75$ and 0.90, and high inter-rater reliability ($\geq$0.85) when standardised protocols are followed (Ruiz Pérez & Graupera, 2005) (Supplementary file 1). Additionally, evidence of construct validity has been supported by the test's ability to discriminate motor performance according to age and sex, as well as by moderate correlations with other motor development assessments ($r \sim 0.50$ to 0.70), indicating adequate convergent validity (Henderson et al., 2007).

To measure road safety knowledge, an observation checklist was used. This tool enabled the assessment of knowledge of traffic regulations among 4- to 5-year-old children using road safety signs. The instrument was validated through an expert panel review, with three researchers with expertise in the field analysing it at two different times. They identified minor adjustments to the terminology, resulting in a final version of the instrument. The instrument systematically records behaviours, attitudes, interactions, and relevant situations within the research context. The scoring system identifies three options: a) acquired (0-6 pts.), b) in progress (7-12 pts.), and c) not acquired (13-18 pts.). The following road safety signs were used: stop signs, crosswalks, bicycle lanes, pedestrian lanes, and traffic lights for both vehicles and pedestrians. These signs were placed on a wall in front of the child, who was then asked to identify the correct sign when each one was mentioned.

Procedures

The experimental group (EG) completed the psychomotor development and road safety program over 8 weeks. The children executed the program in three 45-minute sessions per week. In these sessions, the children participated in structured, play-based activities, using the balance bike as the primary teaching tool. The program was designed to develop perceptual-motor competence through exercises of static and dynamic balance, coordination, and spatial awareness on a track equipped with road safety signs (i.e., stop signs, crosswalks, traffic lights, bicycle lanes, and pedestrian lanes). The children completed the experimental sessions while identifying and obeying traffic rules. Following the planned routes on the track ensured the systematic acquisition of preventative behaviours. The control group (CG) continued with the activities programmed in the institution's regular curriculum. At the beginning and end of the study, the EG and CG were assessed using the aforementioned instruments, enabling comparison of results.

Statistical analyses

Statistics were performed using IBM SPSS Statistics, version 26. Descriptive statistics for continuous variables are presented as mean and standard deviation (M±SD). Descriptive statistics for categorical variables are presented as percentages (%). For each dependent variable, full-factorial 5-way mixed ANOVA (2 measurements [pre-test, post-test] by 2 groups [control, experimental] by 2 genders [boys, girls] by 2 zones [urban, rural] by 2 school types [pubic, private]) were calculated at a statistical significance set a priori at $p \leq 0.05$. Appropriate follow-up analyses were computed when significant interactions were found. Effect size is reported as partial eta-squared ($\eta 2p$) and interpreted as small (≤0.01), medium (0.06), and large (≥0.14) (Cohen, 1988), and the 95% confidence interval for the difference between means (95%CIdiff) is presented as precision of the estimate.

RESULTS

Of the 363 recruited children, only 328 (90%) provided complete data for the study. Participants were girls (n=151; 46.6%) and boys (n=177; 53.4%), categorised in the control (n=134) and experimental (n=194) groups, from urban (n = 228; 69.5%) and rural (n=100; 30.5%) areas, and public (n=207; 62.3%) and private (n=121; 37.7%) institutions. Descriptive statistics for participants in the control and experimental groups are shown in Tables 1 and 2, respectively.

Of the total participants, 10.7% were born prematurely, and the most frequent delivery method was cesarean section (61%). The majority of participants live with both parents in a single-family unit (73.1%), with only their mother (24.2%), only their father (0.6%), or with other relatives (2.1%). Additionally, 86.3% of participants do not participate in sports or any physical activity. Their modes of transportation to school include parents' or shared cars

(47.9%), public transportation (19.8%), walking (18.0%), school buses (10.4%), and motorcycles (4.0%). Furthermore, the mothers of the participants demonstrated a high level of education, with 58.5% holding higher education, 32.9% having secondary education, and 8.5% having basic education. For the fathers, almost half had higher education (45.4%), 39.0% secondary education, and 15.5% basic education.

The cohort's anthropometric characteristics were as follows: mean age, 4.1±0.4 yr.; mean body weight, 16.5±2.3 kg; mean height, 101.6±6.5 cm; and mean BMI, 15.9±1.6 kg·m². Overall, the majority of participants were of normal weight for their age (93.1%), while a small proportion were classified as underweight (0.7%), healthy weight (1.7%), or severely underweight (0.6%) for their respective ages. Regarding height-for-age, the majority were of normal height (86.2%), followed by short stature (12.7%), with a small number of individuals with severely short stature (0.8%) or good height (0.3%). The BMI for age of the participants was categorised as healthy weight (94.5%), overweight (3.0%), obese (1.4%), wasted (0.6%), and severely wasted (0.6%).

Table 1. Descriptive statistics of the variables of the psychomotor and road safety tests for the control group (n = 134). The values represent the mean and standard deviation.

	Boys (n = 69)								Girls (n = 65)							
	Urban (n = 45)				Rural (n =24)				Urban (n = 52)				Rural (n = 13)			
	Public (n=19)		Private (n=26)		Public (n=15)		Private (n=9)		Public (n=24)		Private (n=28)		Public (n=7)		Private (n=6)	
Variable	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Psychomotor competence																
Body Parts (pts.)	2.2±1.2	3.2±0.9	2.8±1.1	3.0±0.9	2.2±1.0	2.9±0.9	2.6±1.1	3.0±1.1	2.3±1.0	3.3±0.9	2.8±1.2	3.2±0.9	2.7±1.3	3.4±0.5	2.8±1.3	2.8±1.0
Balance Board (pts.)	1.8±0.9	2.6±1.0	1.5±1.0	2.8±1.0	1.9±0.8	2.4±0.8	1.9±0.6	2.7±0.9	1.8±0.8	2.7±0.9	1.9±0.8	3.3±0.9	2.1±0.7	2.4±1.1	2.0±0.6	2.8±1.2
One-Legged Hop (pts.)	2.2±1.2	2.8±1.3	2.5±1.1	2.3±1.1	2.4±1.4	2.6±1.2	2.9±1.2	3.0±1.2	2.4±1.1	2.9±1.2	3.0±1.2	2.7±1.2	2.4±1.3	3.3±1.1	3.0±1.1	2.7±1.2
Jump and Land (pts.)	2.3±1.4	2.6±1.3	2.0±0.8	2.8±1.1	2.3±1.3	2.8±1.1	1.9±0.9	2.7±1.1	2.7±1.2	3.0±1.4	2.0±0.7	3.4±0.9	2.6±1.4	3.4±0.8	2.3±1.0	3.3±1.0
Obstacle Course (pts.)	2.5±1.0	3.3±1.0	3.1±1.3	3.2±1.0	2.9±1.3	3.0±0.9	2.4±1.4	3.9±0.3	3.1±1.1	3.3±0.8	3.3±1.1	3.5±0.7	3.1±1.1	3.3±1.3	1.8±1.3	3.3±0.5
Ball Catch (pts.)	2.3±1.3	2.2±1.4	1.9±1.0	2.9±1.2	2.3±1.2	1.8±1.2	1.8±1.2	2.6±1.4	2.3±1.0	2.1±1.2	2.3±1.3	3.1±1.3	1.0±0.8	1.7±1.7	3.3±1.0	2.8±1.0
Total (pts.)	13.2±4.9	16.7±3.2	13.8±3.4	17.0±3.4	13.9±4.6	15.5±3.2	13.4±4.3	17.8±3.3	14.6±4.0	17.2±3.3	15.2±2.8	19.1±3.6	14.0±4.5	17.6±2.4	15.3±3.8	17.8±2.9
Road Safety Education																
Stop Test (pts.)	2.1±1.0	2.2±1.0	2.7±0.8	2.0±1.0	2.3±0.8	2.7±0.7	2.6±0.7	2.1±1.1	2.2±0.8	2.2±1.0	2.1±0.9	1.7±1.0	2.0±1.0	2.6±0.5	1.0±0.0	2.0±1.1
Crosswalk (pts.)	2.1±0.9	2.5±0.6	2.6±0.8	2.0±0.9	1.9±0.9	2.1±0.9	2.7±0.7	1.9±0.9	1.7±0.8	1.5±0.8	2.3±0.9	2.2±0.9	2.3±0.8	2.7±0.5	2.7±0.8	1.7±0.8
Bicycle Lane (pts.)	2.3±1.0	2.5±0.6	2.9±0.4	1.4±0.8	2.1±1.0	2.2±0.9	3.0±0.0	1.1±0.3	2.6±0.8	2.0±0.8	2.9±0.4	1.4±0.6	2.1±0.9	2.3±0.5	2.3±1.0	1.3±0.5
Pedestrian Lane (pts.)	2.4±1.0	2.2±0.9	2.3±0.9	1.3±0.6	2.0±1.1	2.0±0.9	2.4±0.9	1.1±0.3	2.5±1.1	1.6±0.9	2.2±1.0	1.1±0.3	2.3±1.1	2.1±0.9	2.0±1.1	1.3±0.8
Traffic Lights (pts.)	2.3±1.0	2.8±0.7	2.8±0.6	2.7±0.7	2.3±1.0	2.7±0.8	2.9±0.3	2.4±1.0	2.3±1.0	2.7±0.7	2.7±0.7	3.0±0.0	2.3±1.0	2.7±0.8	2.7±0.8	2.7±0.7
Total (pts.)	13.6±4.3	14.3±3.1	15.6±2.5	11.8±2.9	12.5±4.0	14.0±3.3	15.8±1.9	11.0±1.9	13.4±3.1	11.3±2.9	14.4±2.7	10.5±2.5	12.4±4.2	14.9±2.1	13.0±2.0	11.0±2.8

Table 2. Descriptive statistics of the variables of the psychomotor and road safety tests for the experimental group (n = 194). The values represent the mean and standard deviation.

	Boys (n =108)								Girls (n = 86)							
	Urban (n = 77)				Rural (n = 31)				Urban (n = 54)				Rural (n = 32)			
	Public (n=56)		Private (n=21)		Public (n=24)		Private (n=7)		Public (n=44)		Private (n=10)		Public (n=18)		Private (n=14)	
Variable	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Psychomotor competence																
Body Parts (pts.)	2.4±1.2	3.2±0.8	2.9±1.3	3.6±0.6	2.0±1.2	3.1±0.9	2.7±1.3	3.7±0.8	2.5±1.2	3.5±0.7	2.9±1.2	3.9±0.3	2.7±1.1	3.5±0.7	2.6±1.3	3.6±0.8
Balance Board (pts.)	2.0±0.9	3.2±0.9	1.9±0.7	2.9±0.9	1.5±0.7	3.1±0.7	2.1±1.1	2.7±1.1	2.2±1.0	3.6±0.7	1.6±0.7	2.9±0.7	2.3±0.9	3.1±1.0	1.6±0.8	2.4±0.9
One-Legged Hop (pts.)	2.7±1.2	3.2±0.8	2.8±1.0	3.6±0.7	2.2±1.4	2.9±1.2	2.6±1.5	3.4±1.0	3.0±1.1	3.1±1.0	3.1±1.0	3.7±0.5	2.4±1.2	3.3±0.6	2.9±1.1	3.4±0.9
Jump and Land (pts.)	2.7±1.1	3.3±1.0	2.7±1.1	3.1±0.9	2.5±1.3	3.1±1.1	2.6±1.4	3.6±0.8	2.4±1.1	3.4±0.9	3.0±1.2	3.3±0.9	3.1±1.1	3.6±0.7	2.9±1.2	3.1±0.9
Obstacle Course (pts.)	3.2±1.1	3.5±0.9	3.0±1.2	3.7±0.7	2.5±1.4	3.3±1.0	2.7±1.1	3.7±0.5	3.1±1.1	3.5±0.8	3.0±1.2	3.6±0.7	3.1±1.1	3.7±0.7	2.6±1.4	3.2±1.2
Ball Catch (pts.)	2.1±1.1	2.8±1.1	2.5±1.2	3.4±0.9	2.5±1.0	2.5±1.3	1.6±0.8	2.9±1.1	2.2±1.1	2.5±1.2	2.2±1.0	3.7±0.5	2.3±0.8	2.5±1.2	2.4±0.8	3.0±1.0
Total (pts.)	15.0±3.9	19.2±3.0	15.8±3.6	20.2±2.4	13.3±4.9	18.1±3.7	14.3±3.0	20.0±3.6	15.3±4.0	19.7±2.8	15.8±4.6	21.1±2.5	16.0±3.7	19.5±2.4	14.9±4.3	18.8±2.7
Road Safety Education																
Stop Test (pts.)	1.8±1.0	2.8±0.5	2.1±1.0	3.0±0.2	1.5±1.1	2.8±0.6	2.4±1.0	3.0±0.0	1.7±0.9	2.9±0.5	2.4±1.0	3.0±0.0	2.0±1.0	2.9±0.2	1.9±1.0	2.7±0.7
Crosswalk (pts.)	1.8±1.1	2.8±0.5	2.3±1.0	3.0±0.0	1.8±1.1	2.8±0.6	2.4±1.0	3.0±0.0	2.0±1.0	3.0±0.2	2.4±1.0	2.9±0.3	2.1±1.0	3.0±0.0	2.1±1.0	2.9±0.3
Bicycle Lane (pts.)	2.9±0.5	3.0±0.3	2.8±0.6	3.0±0.2	2.3±1.1	2.9±0.4	2.7±0.8	3.0±0.0	2.7±0.7	3.0±0.3	3.0±0.0	3.0±0.0	2.7±0.8	3.0±0.0	2.7±0.7	3.0±0.0
Pedestrian Lane (pts.)	1.8±1.0	2.7±0.7	2.1±1.0	3.0±0.2	1.7±1.1	2.8±0.6	2.1±1.1	3.0±0.0	2.0±1.0	2.8±0.5	2.6±0.8	2.5±0.7	2.1±1.1	2.8±0.5	1.8±1.0	2.6±0.6
Traffic Lights (pts.)	2.4±0.6	2.8±0.5	2.7±0.6	3.0±0.0	2.4±0.8	2.8±0.4	2.6±0.9	2.7±0.5	2.0±0.8	2.8±0.4	2.2±0.8	3.0±0.0	2.4±0.5	2.8±0.4	2.3±0.8	2.8±0.4
Total (pts.)	13.3±3.2	16.8±2.3	14.2±3.2	17.9±0.4	12.3±3.9	16.8±2.4	14.1±4.0	17.6±0.8	13.0±3.1	17.2±1.4	16.2±2.0	17.3±0.9	13.6±3.4	17.4±1.2	13.8±3.5	16.7±1.5

ANOVA significance and effect sizes for the dependent variables are reported in Supplementary file 2. From these analyses, a significant quadruple interaction was found for the road safety education total score (Measurements by Group by Gender by School type, $p=0.042$; $\eta^2_p=0.013$), as well as a double interaction (Measurements by Group; $p\leq0.0001$; $\eta^2_p=0.273$). Follow-up analyses showed that girls in the experimental groups from public ($p\leq0.0001$; $95\%CI_{diff} = 3.1, 5.3$ pts.) and private ($p\leq0.0001$; $95\%CI_{diff} = 4.9, 7.6$ pts.) schools showed higher mean total post-test scores than their control counterparts. Similarly, boys in the experimental groups from public ($p\leq0.0001$; $95\%CI_{diff} = 1.7, 3.6$ pts.) and private ($p\leq0.0001$; $95\%CI_{diff} = 5.0, 7.6$ pts.) schools showed higher mean total post-test scores than their control counterparts (Figure 1).

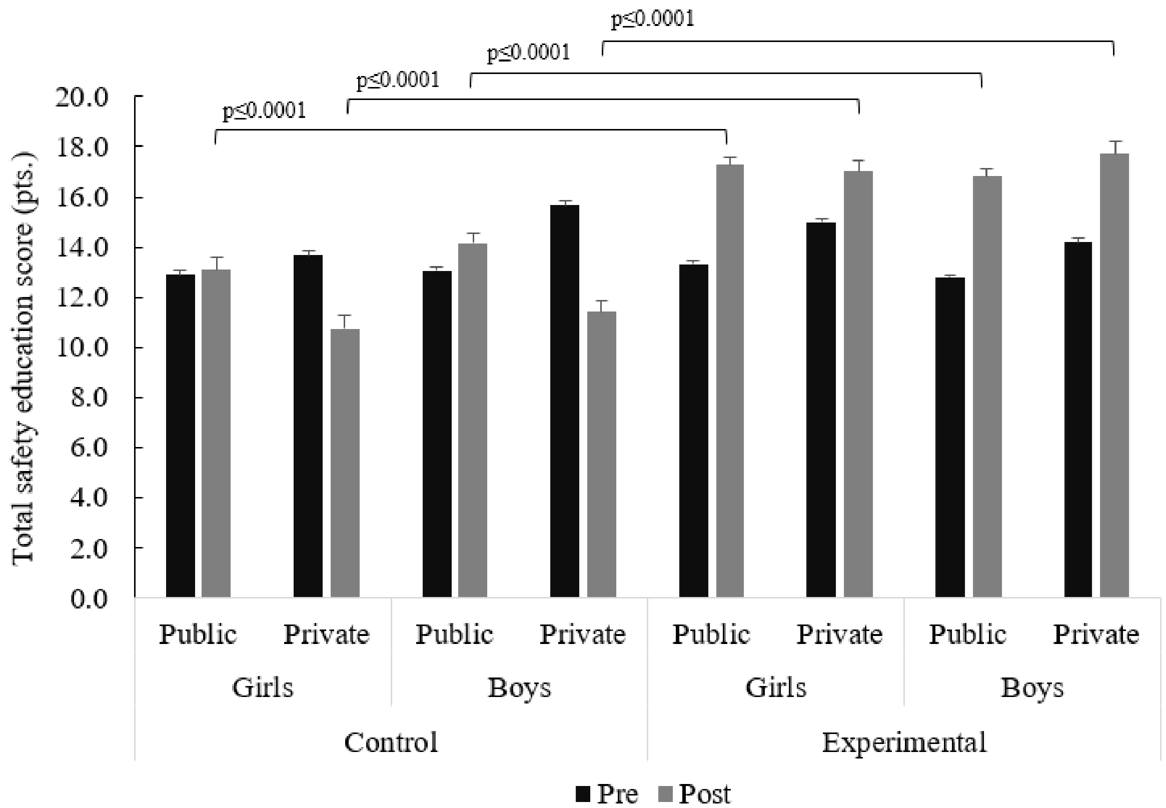

Figure 1. Mean road safety education total score following the experimental protocol in participants from public and private schools.

A significant double interaction (Measurements by Group) was found for the traffic lights test ($p=0.029$; $\eta^2_p=0.015$). The experimental group showed higher mean post-test scores than the control group ($p \leq 0.0001$; $95\%CI_{diff} = 0.3, 0.6$ pts.; Figure 2A) following the experiment. A significant double interaction (Measurements by Group) was found for the crosswalk test ($p \leq 0.0001$; $\eta^2_p = 0.152$). Follow-up analyses showed higher mean post-test scores in the experimental group ($p \leq 0.0001$; $95\%CI_{diff} = 0.7, 1.0$ pts.) compared to the control group. However, both the control ($p = 0.036$; $95\%CI_{diff} = -0.4, -0.0$ pts.) and experimental ($p \leq 0.0001$; $95\%CI_{diff} = 0.6, 1.0$ pts.) groups changed significantly in opposite direction following the experiment (Figure 2B).

A significant triple interaction (Measurements by Group by Zone) was found for the stop test ($p = 0.027$; $\eta^2_p = 0.016$). Follow-up analyses showed higher mean post-test scores in urban ($p \leq 0.0001$; $95\%CI_{diff} = 0.7, 1.1$ pts.) and rural ($p \leq 0.0001$; $95\%CI_{diff} = 0.6, 1.2$ pts.) experimental groups and rural control group ($p = 0.032$; $95\%CI_{diff} = 0.0, 0.8$ pts.), and a significant decrease in mean scores in the urban control group ($p = 0.032$; $95\%CI_{diff} = 0.0, 0.5$ pts.; Figure 2C). A significant double interaction (Measurements by Group) was found for the pedestrian lane test ($p \leq 0.0001$; $\eta^2_p = 0.209$). The experimental group showed higher mean post-test scores than the control group ($p \leq 0.0001$; $95\%CI_{diff} = 1.0, 1.2$ pts.). In addition, the control group decreased scores after the intervention ($p \leq 0.0001$; $95\%CI_{diff} = 0.4, 0.9$ pts.) and the experimental group increased scores following the intervention ($p \leq 0.0001$; $95\%CI_{diff} = 0.6, 1.0$ pts.; Figure 2D).

Two significant quadruple interactions were found for the bicycle lane test (Measurements by Group by Gender by School type, $p = 0.020$; $\eta^2_p = 0.017$; Measurements by Group by Gender by Zone; $p = 0.017$; $\eta^2_p = 0.018$). Mean post-test scores were higher in the experimental group than in the control group for girls from urban ($p \leq 0.0001$; $95\%CI_{diff} = 0.6, 1.1$ pts.) and rural ($p = 0.033$; $95\%CI_{diff} = 0.3, 0.8$pts.) areas and for men from urban ($p = 0.006$; $95\%CI_{diff} = 0.1, 0.5$ pts.) areas (Figure 2E). Follow-up analyses also showed higher mean post-test scores in the experimental group than the control group between girls from public (p≤0.0001; $95\%CI_{diff} = 0.3, 0.9$ pts.) and private (p≤0.0001; $95\%CI_{diff} = 0.3, 1.0$ pts.) schools. Boys in the experimental group from public schools showed higher mean pre-test ($p=0.009$; $95\%CI_{diff} = 0.1, 0.8$ pts.) and post-test ($p=0.001$; $95\%CI_{diff} = 0.2, 0.6$ pts.) scores than their respective counterparts in the control group (Figure 2F).

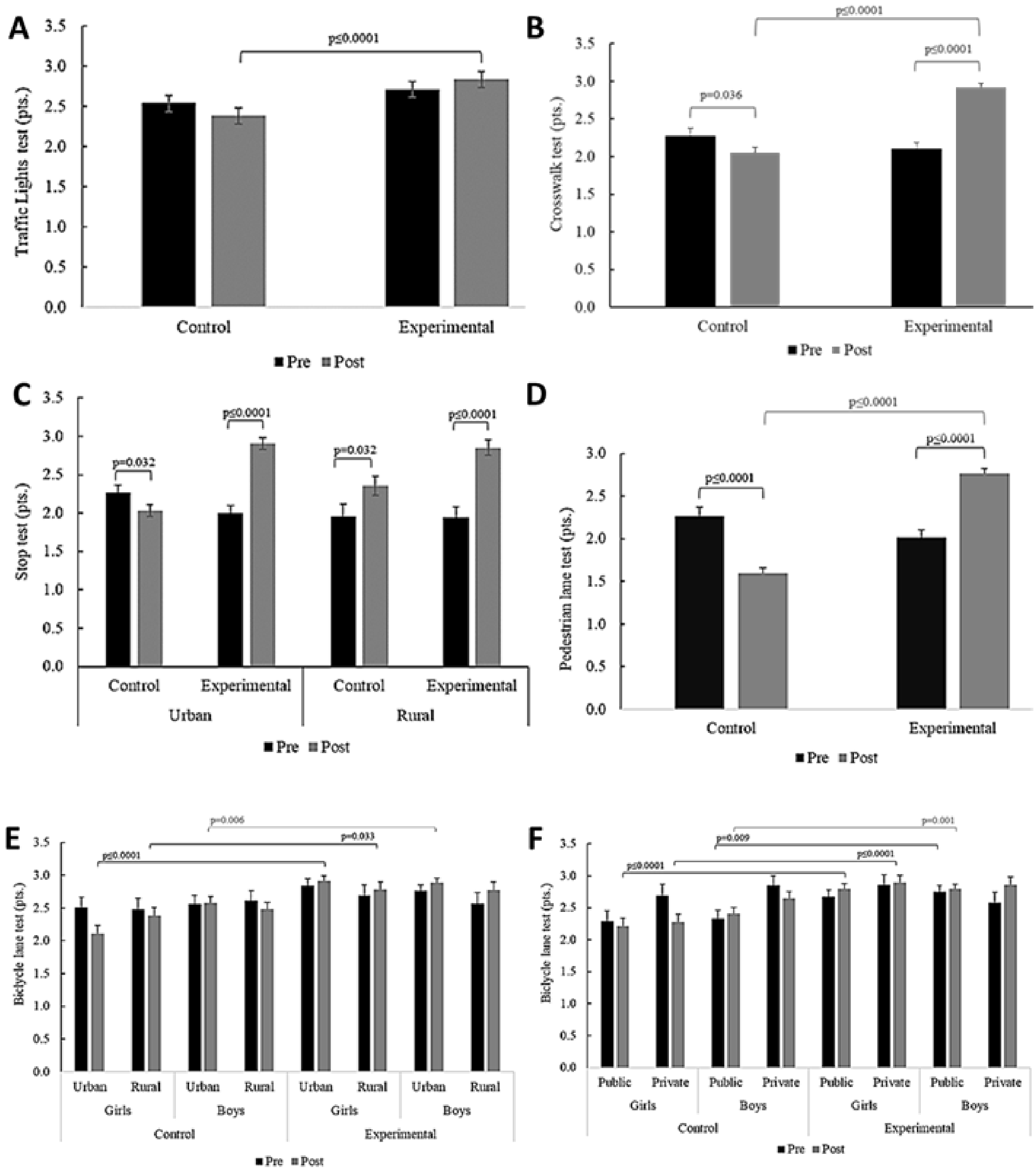

Figure 2. Mean test scores of the road safety education battery following the experimental protocol.

A significant double interaction (Measurements by Group) was found for the total psychomotor skills ($p=0.003$; $\eta^2_p=0.027$). The experimental group showed higher mean post-test scores than the control group ($p\leq0.0001$; $95\%CI_{diff}$ = 1.4, 3.1 pts.). In addition, both the experimental ($p\leq0.0001$; $95\%CI_{diff}$ = 3.9, 5.1 pts.) and control ($p\leq0.0001$; $95\%CI_{diff}$ = 2.5, 3.8 pts.) groups increased the mean post-test scores following the intervention (Figure 3).

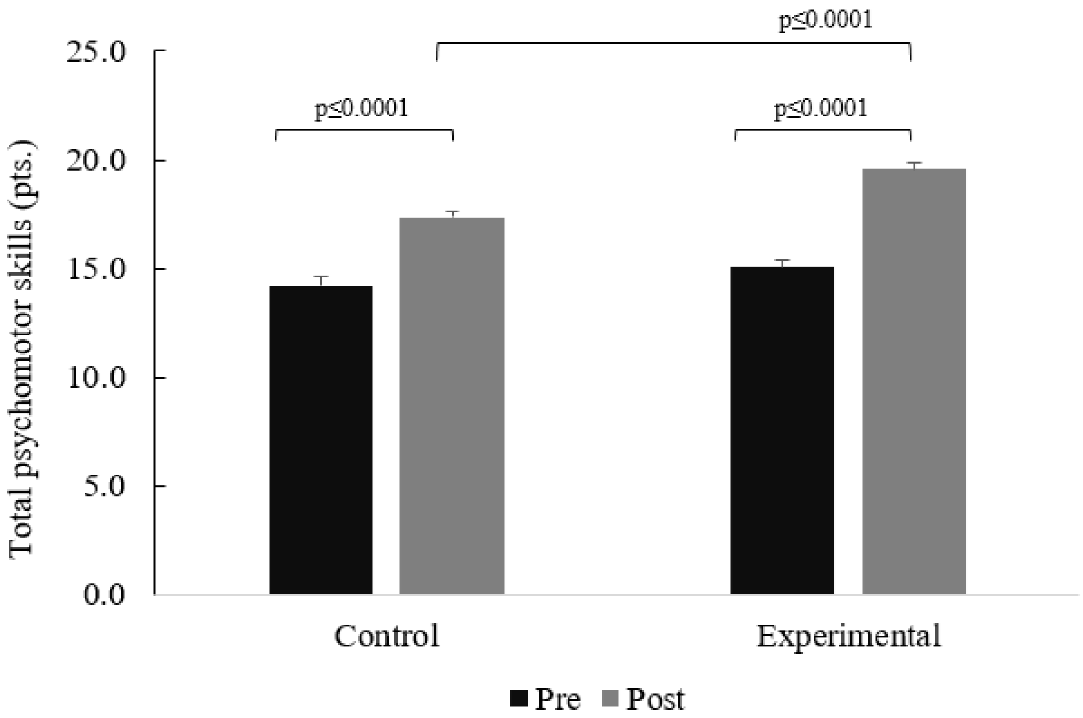

Figure 3. Mean total psychomotor skills scores following the experimental protocol.

A significant double interaction (Measurements by Group) was found for the body parts test ($p=0.029$; $\eta^2_p=0.015$). The experimental group showed higher mean post-test scores than the control group ($p=0.002$; $95\%CI_{diff}$ = 0.2, 0.8 pts.). In addition, the experimental group showed higher mean post-test scores than pre-test scores ($p\leq0.0001$; $95\%CI_{diff}$ = 0.4, 0.9 pts.; Figure 4A). A significant triple interaction (Measurements by Group by School type) was found for the balance board test ($p=0.025$; $\eta^2_p=0.016$). Follow-up analyses showed higher mean post-test scores among individuals in the experimental groups from public institutions ($p\leq0.0001$; $95\%CI_{diff}$ = 0.5, 1.0 pts.) compared to their control counterparts. In addition, all mean post-test scores were higher than the mean pre-test scores in the individuals in the control groups from public ($p \leq 0.0001$; 95%CI_{diff} = 0.3, 1.0 pts.) and private schools ($p \leq 0.0001$; 95%CI_{diff} = 0.7, 1.5 pts.) and individuals in the experimental groups from public ($p \leq 0.0001$; 95%CI_{diff} = 1.0, 1.5 pts.) and private schools ($p \leq 0.0001$; 95%CI_{diff} = 0.6, 1.3 pts.; Figure 4B).

A significant triple interaction (Measurements by Group by School type) was found for the one-legged hop test ($p=0.003$; $\eta^2_p=0.028$). Follow-up analyses showed higher mean post-test scores among individuals in the experimental group from private institutions ($p \leq 0.0001$; 95%CI_{diff} = 0.5, 1.3 pts.) compared to their control counterparts. In addition, the mean post-test scores were higher than the mean pre-test scores in the individuals in the control group from public schools ($p \leq 0.0001$; 95%CI_{diff} = 0.3, 0.8 pts.) and individuals in the experimental groups from public ($p \leq 0.0001$; 95%CI_{diff} = 0.4, 0.8 pts.) and private schools ($p \leq 0.0001$; 95%CI_{diff}= 0.4, 1.1 pts.; Figure 4C). A significant triple interaction (Measurements by Group by School type) was found for the jump and land test ($p=0.048$; $\eta^2_p=0.012$). Follow-up analyses showed higher mean post-test scores among individuals in the experimental groups from public institutions ($p=0.021$; 95%CI_{diff} = 0.1, 0.7 pts.) compared to their control counterparts. In addition, the pre-test scores of individuals in the experimental groups from private institutions were higher ($p=0.003$; 95%CI_{diff} = 0.3, 1.2 pts.) than those of their control counterparts (Figure 4D).

A significant quadruple interaction (Measurements by Group by Zone by School type) was found for the total obstacle course score ($p=0.006$; $\eta^2_p=0.024$). Follow-up analyses showed that individuals in the control group from urban areas attending public schools showed higher mean post-test scores than their pre-test scores ($p=0.015$; 95%CI_{diff} = 0.1, 0.9 pts.). Also, individuals in the control group from rural areas attending private schools showed higher mean post-test scores than their pre-test scores ($p \leq 0.0001$; 95%CI_{diff} = 0.8, 2.1 pts.). Similarly, individuals in the experimental group attending public schools from urban ($p=0.007$; 95%CI_{diff}=

0.1, 0.6 pts.) and rural ($p \leq 0.0001$; $95\%CI_{diff} = 0.4, 1.1$ pts.) areas showed higher mean post-test scores than their pre-test scores, as well as those attending private schools from urban ($p=0.013$; $95\%CI_{diff} = 0.1, 1.1$ pts.) and rural ($p=0.008$; $95\%CI_{diff} = 0.2, 1.4$ pts.) areas (Figure 4E).

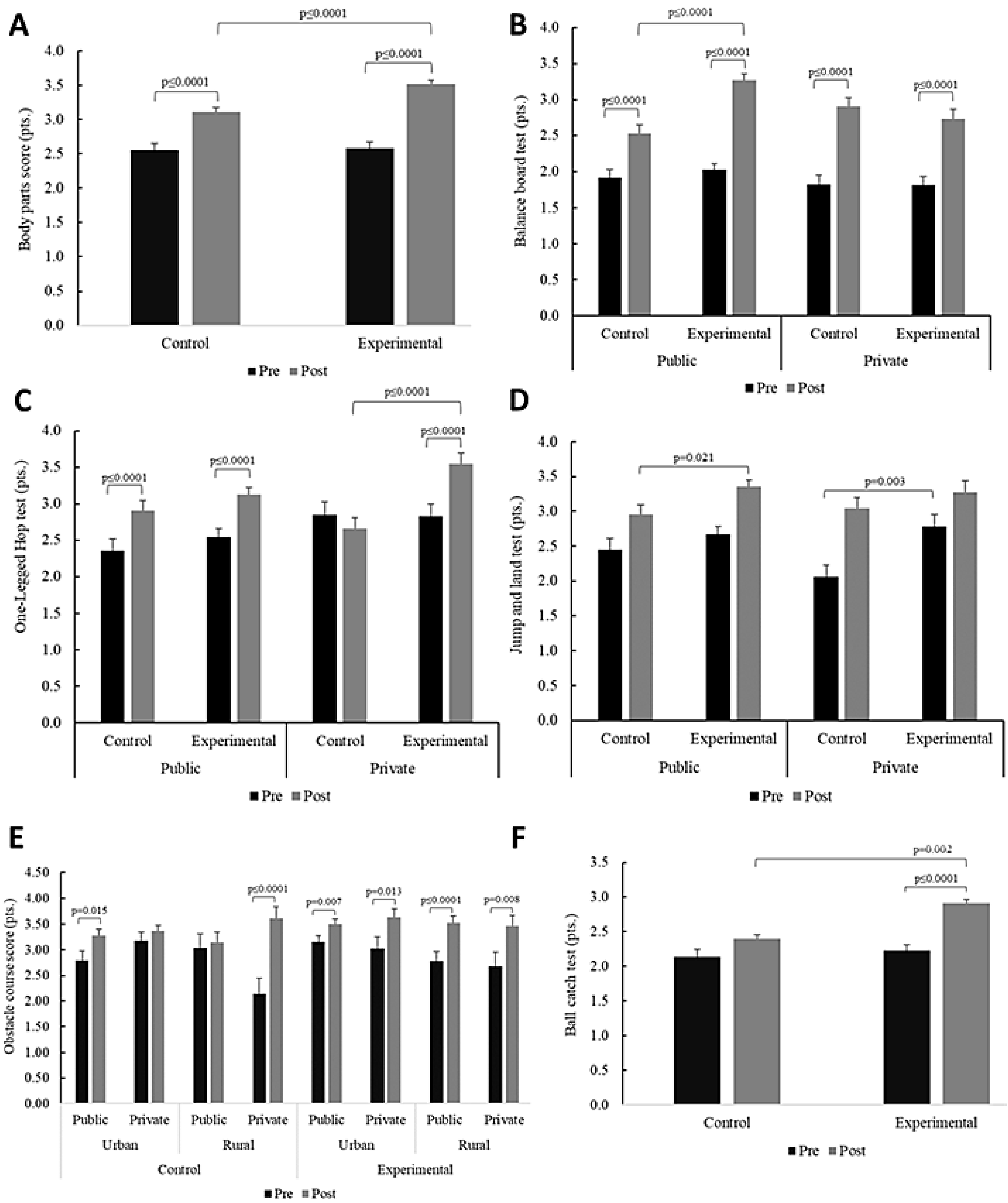

Figure 4. Mean test scores of the psychomotor competence battery following the experimental protocol.

A significant double interaction (Measurements by Group) was found for the ball catch test ($p=0.029$; $\eta^2_p=0.015$). The experimental group showed higher mean post-test scores than the control group ($p=0.002$; $95\%CI_{diff}$ = 0.2, 0.8 pts.). In addition, the experimental group showed higher mean post-test scores than pre-test scores ($p\leq0.0001$; $95\%CI_{diff}$ = 0.4, 0.9 pts.; Figure 4F).

DISCUSSION

The present study examined the effects of a psychomotor intervention with an emphasis on road safety education on motor competence and safety-related knowledge in preschool children aged 4 to 5 years from public and private educational schools in Cuenca, Ecuador. The findings indicate that the intervention produced significant improvements in both psychomotor performance and road safety outcomes, with the experimental group consistently outperforming the control group at post-test. These results reinforce the effectiveness of structured, play-based, and context-specific interventions during early childhood and agree with previous international evidence (Chakma et al., 2025; Chui Betancur et al., 2024; Flores-Ferro et al., 2025; Kourmousi et al., 2024; Marín-Escobar et al., 2022; Morrongiello et al., 2023; Navarro-Patón et al., 2021; Navarro-Patón et al., 2024; Wang et al., 2025) supporting the role of intentional motor programs in enhancing developmental outcomes.

From a developmental perspective, the observed improvements in overall psychomotor competence ($\eta^2p = 0.027$) and specific domains such as balance, object control, and locomotor abilities are consistent with the sensitive period for motor development between ages 3 and 5. During this stage, heightened neural plasticity facilitates motor learning, making children particularly responsive to enriched movement experiences. Previous research indicates that structured and cognitively engaging physical activity promotes motor skill acquisition beyond natural maturation (Barnett et al., 2016; Robinson et al., 2015). Indeed, while both the experimental and control groups showed improvements, likely reflecting natural maturation and incidental physical activity, the greater gains in the experimental group highlight the added value of structured practice, task-specific feedback, and intentional instructional design, as emphasised in motor learning frameworks (Logan et al., 2012; Robinson et al., 2015). This finding agrees with developmental models suggesting that motor competence is shaped not only by biological maturation but also by environmental affordances and opportunities for practice (Stodden et al., 2008). The inclusion of feedback, repetition, and progressively challenging tasks within the intervention likely contributed to these enhanced outcomes.

The intervention also yielded substantial improvements in road safety education, with large effect sizes observed in total scores ($\eta^2p = 0.273$) and specific domains such as pedestrian and bicycle lane tasks, particularly those involving recognition and application of traffic rules. These findings agree with previous studies demonstrating that structured educational interventions, including those based on interactive and experiential methodologies, significantly enhance children's understanding of road safety concepts and promote safer behaviours (Kourmousi et al., 2024; Rojo-Ramos et al., 2022). Evidence from diverse intervention formats, including virtual simulations, active learning environments, and play-based programs, consistently shows that repeated and context-specific exposure facilitates the acquisition and retention of safety-related knowledge in early childhood. In contrast, declines observed in some control-group measures may reflect insufficient reinforcement, variability in attention, or the absence of structured learning opportunities, underscoring the importance of repeated, guided exposure to safety-related content.

The relationship between psychomotor development and road safety learning can be interpreted through an integrated theoretical framework grounded in embodied cognition and motor–cognition interaction. According to this perspective, learning emerges through action–perception coupling, whereby children construct knowledge through movement-based experiences (Wilson, 2002; Glenberg & Gallese, 2012). Improvements in motor competence, particularly in coordination, balance, and spatial awareness, likely enhanced children's ability to perceive, interpret, and respond to environmental cues relevant to traffic situations. In turn, these sensorimotor experiences support the development of cognitive processes such as attention, inhibitory control, and decision-making, which are essential for navigating dynamic and potentially hazardous environments such as traffic settings (Robinson et al., 2015; Schmidt et al., 2017). Thus, the observed gains in road safety knowledge may reflect transfer effects from motor development to cognitive and behavioural domains.

Importantly, the significant interaction effects involving gender, school type, and geographical context indicate that these developmental processes are influenced by environmental and sociocultural factors. Differences in exposure to traffic environments, access to structured physical activity, and educational resources may partially explain variability in outcomes across groups. For instance, children from urban settings may have greater familiarity with traffic systems, while institutional differences between public and private schools may reflect variations in pedagogical practices or resource availability. These findings are consistent with ecological models of development, which emphasise the interaction between individual characteristics and contextual affordances in shaping learning outcomes (Stodden et al., 2008). Moreover, the observed improvements across both boys and girls support evidence suggesting that, when provided with equal opportunities and structured learning environments, motor development progresses similarly across sexes. This highlights the importance of inclusive and well-designed interventions that promote equitable developmental outcomes in early childhood.

From a practical and public health perspective, the high prevalence of physical inactivity observed at baseline (86.3%) in the Ecuadorian children underscores the need for interventions that simultaneously promote physical activity and cognitive development. The present findings suggest that integrating psychomotor training with educational content, such as road safety, can enhance engagement and produce multidimensional benefits. This approach agrees with evidence supporting school-based interventions as effective strategies for improving both health-related and educational outcomes in early childhood (Donnelly et al., 2016).

Finally, we acknowledge that the present study has strengths and limitations. The strengths include the relatively large sample size and the analytical approach, which allowed for the examination of interaction effects across multiple contextual variables. Potential limitations include the quasi-experimental design that limits causal inference. Future research should incorporate randomised controlled designs, longitudinal follow-up, and more robust measurement instruments to further validate these findings and explore their long-term implications.

CONCLUSION

The present study demonstrates that a psychomotor intervention emphasising road safety education effectively enhances both motor competence and safety-related knowledge among Ecuadorian preschool children. The greater improvements observed in the experimental group indicate that structured, play-based interventions provide added value beyond what natural maturation alone offers during a critical period of motor development. The findings support an integrated perspective in which motor competence contributes to cognitive processes such as attention, decision-making, and environmental awareness, facilitating the acquisition of safety-related behaviors. This suggests that psychomotor interventions can extend their impact beyond physical development to domains relevant for everyday functioning and injury prevention.

The influence of contextual factors, including gender, school type, and environment, supports the need for context-sensitive approaches in early childhood education. Additionally, the high levels of physical inactivity observed reinforce the importance of school-based programs that combine movement and learning to promote holistic development. Overall, integrating psychomotor development with road safety education represents an effective strategy to support both developmental and public health objectives in early childhood.

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