Building motor foundations through tennis: a mastery climate intervention enhancing fundamental and sport specific motor skills

Desarrollo de las bases motrices a través del tenis: una intervención basada en un clima de maestría para potenciar las habilidades motrices fundamentales y específicas del deporte.

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RESUMEN

Objetivo: Examinar los efectos de un programa de tenis para jóvenes, basado en un clima motivacional orientado a la maestría, sobre el desarrollo de las habilidades motrices fundamentales (HMF) y las habilidades específicas del tenis en niños pequeños.

Metodología: Este estudio cuasi-experimental incluyó a 26 niños (14 niñas y 12 niños), de entre 5 y 7 años, inscritos en un proyecto social. Las HMF se evaluaron mediante el Test of Gross Motor Development-2 (TGMD-2), mientras que las habilidades específicas del tenis se valoraron utilizando el instrumento HMET. La intervención tuvo una duración de 16 semanas y se estructuró siguiendo el modelo TARGET, con el propósito de promover un clima motivacional y un aprendizaje orientados a la maestría.

Resultados: Se observaron mejoras significativas a lo largo del tiempo tanto en las HMF generales como en las habilidades específicas del tenis ($p < 0,05$), independientemente del sexo. Se identificó una interacción sexo × tiempo en las habilidades locomotoras, con mayores ganancias en los niños, mientras que tanto niños como niñas mejoraron en las habilidades de control de objetos. Todos los participantes presentaron mejoras sustanciales en las habilidades específicas del tenis, sin diferencias significativas según el sexo. Los análisis de correlación mostraron que las asociaciones entre las HMF y el rendimiento en tenis fueron débiles en el pre-test, pero aumentaron hasta niveles de moderados a fuertes en el post-test, especialmente en las habilidades de control de objetos. Además, se observaron asociaciones más fuertes y consistentes entre las niñas.

Conclusión: Los programas de tenis orientados a la maestría pueden favorecer tanto el desarrollo de la competencia motriz como el rendimiento específico en tenis en niños pequeños. Asimismo, este tipo de intervención puede contribuir a fortalecer la relación entre las habilidades motrices fundamentales y las habilidades deportivas específicas durante la primera infancia.

Palabras clave: Actividad física, Suplementos nutricionales, Estudiantes universitarios, Consumidores de suplementos.

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ABSTRACT

Objective: To examine the effects of a Tennis Youth Program grounded in a Mastery Motivational Climate on the development of fundamental motor skills (FMS) and tennis-specific skills in young children.

Methodology: This quasi-experimental study included 26 children (14 girls and 12 boys), aged 5–7 years, enrolled in a social project. Fundamental motor skills were assessed using the Test of Gross Motor Development-2 (TGMD-2), while tennis-specific skills were evaluated using the HMET instrument. The 16-week intervention was structured according to the TARGET framework to promote a mastery-oriented motivational climate.

Results: Significant improvements over time were observed in overall FMS and tennis-specific skills ($p < .05$), regardless of sex. A sex × time interaction was identified for locomotor skills, with boys showing greater gains, while both boys and girls improved in object control skills. All participants demonstrated substantial improvements across all tennis-specific skills, with no significant sex differences. Correlational analyses showed that associations between FMS and tennis performance were weak at pre-test but became moderate to strong at post-test, particularly for object control skills. Stronger and more consistent associations were **observed among girls.**

Conclusion: A mastery-oriented tennis program can enhance both fundamental motor competence and tennis-specific performance in young children. The intervention may also contribute to strengthening the relationship between general motor skills and sport-specific skills during early childhood.
Keywords: Fundamental Motor Skills; Sport Specific Skills; Intervention Program; Tennis; Children Sports.

Introducción

Motor development is a dynamic and nonlinear process emerging from the interaction of individual, task, and environmental constraints[1]. Motor skill acquisition reflects the progressive organization and reorganization of movement patterns as learners adapt to changing context and task demands[2]. Fundamental motor skills (FMS) are the foundational action systems that support the later acquisition of more specialized and sport-specific skills[3]. Recent advances in ecological dynamics have reinforced this perspective, emphasizing perception–action coupling and the role of affordances in shaping motor learning processes across development[4,5].

The development of FMS during early childhood has been consistently associated with increased physical activity participation, sport engagement, and perceived motor competence later in life[6,7,8,9]. More recent systematic reviews and longitudinal studies have strengthened this relationship, highlighting bidirectional associations between motor competence, physical activity, and health outcomes across childhood[6,7,10,11.] Evidence from intervention studies also supports these associations, showing that improvements in motor competence are linked to increased engagement and perceived competence in children[12,13].

Consequently, environmental affordances and structured instructional experiences play a decisive role in determining whether children reach mature and efficient movement patterns. Contemporary evidence underscores the importance of enriched motor environments and guided instruction, particularly in early childhood, where variability of practice and task manipulation enhance skill adaptability[14,15,16]. Research conducted by Valentini and colleagues has consistently demonstrated that children exposed to mastery-oriented and structured environments show superior motor performance compared to those in less structured contexts[12,13,17].

Intervention research demonstrates that structured motor programs can effectively enhance children's fundamental movement proficiency[12]. Meta-analytical evidence confirms that such interventions yield moderate to large improvements in FMS, especially when programs are developmentally appropriate and systematically implemented[16,18,19]. In particular, mastery climate interventions have been shown to produce significant gains in locomotor and object control skills[19,12].

However, much of this literature has examined either fundamental motor skills or sport-specific skills in isolation. Emerging research calls for integrative approaches that bridge fundamental motor competence and sport-specific skill development, particularly during childhood transitions to sport-specific skill[15]. Despite growing evidence on motor competence and sport participation, there is still limited understanding of how structured, theory-driven sport interventions simultaneously influence fundamental and sport-specific skill development. From a constraints-led perspective, sport contexts provide rich task affordances that may accelerate motor development when appropriately structured[20]. Recent developments in nonlinear pedagogy further support the use of modified sport environments to promote adaptive motor behavior and skill transfer[5,21].

Tennis requires object control, perceptual attunement, anticipatory timing, and coordinated segmental action, making it a potentially powerful environment for developing both foundational and specialized movement patterns. However, the acquisition of tennis skills in early childhood can be challenging due to the perceptual-motor demands imposed by equipment, spatial constraints, and timing requirements[22]. Modified equipment and scaled environments (e.g., mini-tennis formats) have been shown to facilitate skill acquisition and engagement in young learners by reducing task complexity[23]. Thus, instructional design becomes a central factor in determining whether sport participation enhances or limits motor development.

Mastery motivational climate interventions[12,13,24] provides a robust theoretical and pedagogical framework for structuring instructional environments that support adaptive learning behaviors. Mastery-oriented climates foster higher engagement, persistence, and motor learning in children, particularly in early childhood contexts[13,17,24,25]. Although mastery climates have demonstrated positive effects on motor learning and motivational outcomes, limited empirical evidence exists regarding their application within structured youth sport programs aimed at simultaneously developing fundamental and specialized motor skills[26,27,28,29].

Furthermore, few studies have examined specifically impact for girls and boys populations, where access to structured motor experiences may be limited and where sport programs often represent a primary context for motor development opportunities. Although there is some evidence supporting sex differences in motor competence during early childhood, findings remain inconsistent across age groups, skill domains, and cultural contexts, with girls often outperforming in locomotor skills and boys in object control skills, but not uniformly across development[30]. Moreover, there is a lack of intervention-based evidence examining sex-specific responses within ecologically valid sport contexts, limiting our understanding of how boys and girls differentially benefit from structured motor programs.

This gap is critical, as sex-related differences in motor competence may influence how children respond to instructional design, task constraints, and motivational climate, potentially leading to distinct developmental trajectories. Therefore, a critical gap remains in understanding whether a mastery climate tennis program for children can effectively promote gains in both fundamental motor skills and specialized sport skills in early childhood. Addressing this gap is theoretically relevant for clarifying how motivational climate interacts with task constraints in shaping motor development, as well as how these processes may operate differently for boys and girls, and practically relevant for informing pedagogical design in youth sport programs.

Accordingly, the objectives of the present study were: a) to examine the effects of a Mastery Climate Tennis Youth intervention on fundamental motor skills and tennis-specific skills in young boys and girls participating in a social project; b) to examine whether the effects of the intervention differed between boys and girls; and c) to investigate the associations between changes in fundamental motor skills and tennis-specific skills from pre- to post-intervention, including whether these associations differed according to sex.

Metodología

Participants

A total of 26 children (14 girls and 12 boys), aged 5 to 7 years, participated in this quasi-experimental study. Participants were enrolled in four public schools in the south of Brazil. Recruitment occurred through schools and the local community. To be eligible for inclusion, children needed to be novices in tennis practice. Children identified with any known physical, neurological, or behavioral disorders reported by the family's pediatrician were excluded from the present study. All participants were from low-income families enrolled in governmental social support programs and lived in peripheral neighborhoods of a large city in southern Brazil. Human subjects´ approval was obtained from the university ethical committee. Consent was obtained from each child's custodial caregiver(s), and each child verbally agreed to participate in the study.

Assessments

The Test of Gross Motor Development – Second Edition[31], validated for Brazilian children[32], was used to assess fundamental motor skills. The TGMD-2 comprises 12 fundamental motor skills organized into two subtests: locomotor skills (running, galloping, hopping, leaping, horizontal jumping, and sliding) and object control skills (striking, dribbling, catching, kicking, throwing, and rolling). Each skill includes three to five performance criteria describing the efficient movement pattern, which are scored as present or absent across two trials. Subtest raw scores are obtained by summing the performance criteria across all skills and were used for analysis in this study.

Specialized tennis skills were assessed using the HMET[33], adapted from Arbeitsmaterialen zur differentiellen Bewegungsanalyse der Grundschläge im Tennis[24]. The instruments evaluates six fundamental tennis strokes: forehand, backhand, forehand volley, backhand volley, smash, and serve. Performance is analyzed using a differential movement approach, in which each stroke is decomposed into technical components (e.g., preparation, execution, and follow-through) and evaluated according to predefined qualitative criteria. Each performance criterion is scored on a three-point scale (0 = not performed, 1 = partially performed, 2 = correctly performed), allowing for the assessment of different levels of skill execution. Total scores reflect overall performance quality across all evaluated components and were used for analysis in this study.

Children were assessed at pre- and post-intervention following by two trained examiners. All performances were video recorded and analyzed without identification of assessment time (pre or post). Two raters (doctoral students) underwent approximately 40 hours of training prior to data collection using standardized training videos. After achieving at least 85% agreement, raters independently coded all performances. Inter-rater reliability was high (TGMD-2 locomotor skills =0.90 and ball skills = 0.93; HMET = 0.91).

Intervention Design

The present study implemented an intervention designed not only to improve fundamental motor skills and tennis-specific skills, but also to promote adaptive developmental pathways through mastery-oriented learning experiences. Figure 1 presents the conceptual, operational, and fidelity framework guiding the intervention design and implementation. The model was adapte[13], conceptual and operational intervention model and contextualized to a Mastery Climate Tennis Youth program implemented within a social project setting. Specifically, the framework proposes that mastery climate strategies operationalizaded through the TARGET structure

(Task, Authority, Recognition, Grouping, Evaluation, and Time)[12,13] may promote motor development by increasing engagement, autonomy support, self-referenced competence experiences, motor exploration, and adaptive learning opportunities during movement participation. Thus, the intervention integrated motor, motivational, pedagogical, and social components within a mastery-oriented climate structured through the TARGET framework, aiming to support both fundamental motor skill development and the transfer of these competencies to tennis-specific skill acquisition.

This approach was systematically integrated into all sessions to promote engagement, autonomy, and motor learning. The Task component involved the design of activities with varying levels of difficulty and multiple possible solutions, allowing children to select tasks that matched their individual skill levels. Activities were progressively structured to promote both fundamental motor skills and tennis-specific skill acquisition. The Authority dimension emphasized shared decision-making between the instructor and participants. Children were encouraged to make choices regarding task progression, equipment use, and participation in different activities, fostering autonomy and intrinsic motivation. The Recognition component focused on valuing individual effort, improvement, and persistence rather than performance comparison. Feedback was provided in a positive and individualized manner, reinforcing personal achievement and engagement. The Grouping dimension involved flexible organization of participants, including individual tasks, pair work, and small-group activities. Grouping strategies were adapted throughout the sessions to encourage cooperation, peer learning, and social interaction. The Evaluation component incorporated both instructor feedback and opportunities for self-assessment. Children were encouraged to reflect on their own performance, identify improvements, and set personal goals, promoting metacognitive engagement in the learning process. Finally the Time component was adapted to individual learning pace, allowing children to spend more time on tasks according to their needs and progression, rather than following a strictly uniform schedule. Overall, the intervention emphasized a mastery-oriented climate, prioritizing skill development, engagement, and positive learning experiences over competitive performance.

Appropriate motor tasks were implemented with sufficient equipment for each child, including variations in task difficulty and equipment size to accommodate different skill levels. Motor skills were modeled using simple verbal cues highlighting key performance criteria and were practiced in every session. At the beginning of each session, children received instruction and demonstration, with verbal cues paired with skill modeling. Throughout the session, children were encouraged to use these cues to guide performance, and augmented feedback was continuously provided. Positive reinforcement of effort and behavior was emphasized for all participants.

The intervention, conducted at a federal university court, lasted 16 weeks and consisted of two weekly sessions of 60 minutes each. All sessions were conducted by the same Physical Education teacher with previous. experience.to ensure consistency in delivery and to minimize variability in instructional approach. Each session followed a structured format, comprising four sequential phases: an initial phase (5–10 minutes), focused on welcoming, organization, and engagement; a preparatory phase (10–15 minutes), involving warm-up activities and general motor activation; a main phase (20–25 minutes), dedicated to the development of fundamental motor skills and tennis-specific skills; and a final phase (approximately 5 minutes), including cool-down activities, reflection, and feedback. All children participated in the 32 sessions. Figure 1 shows the design of the intervention model.

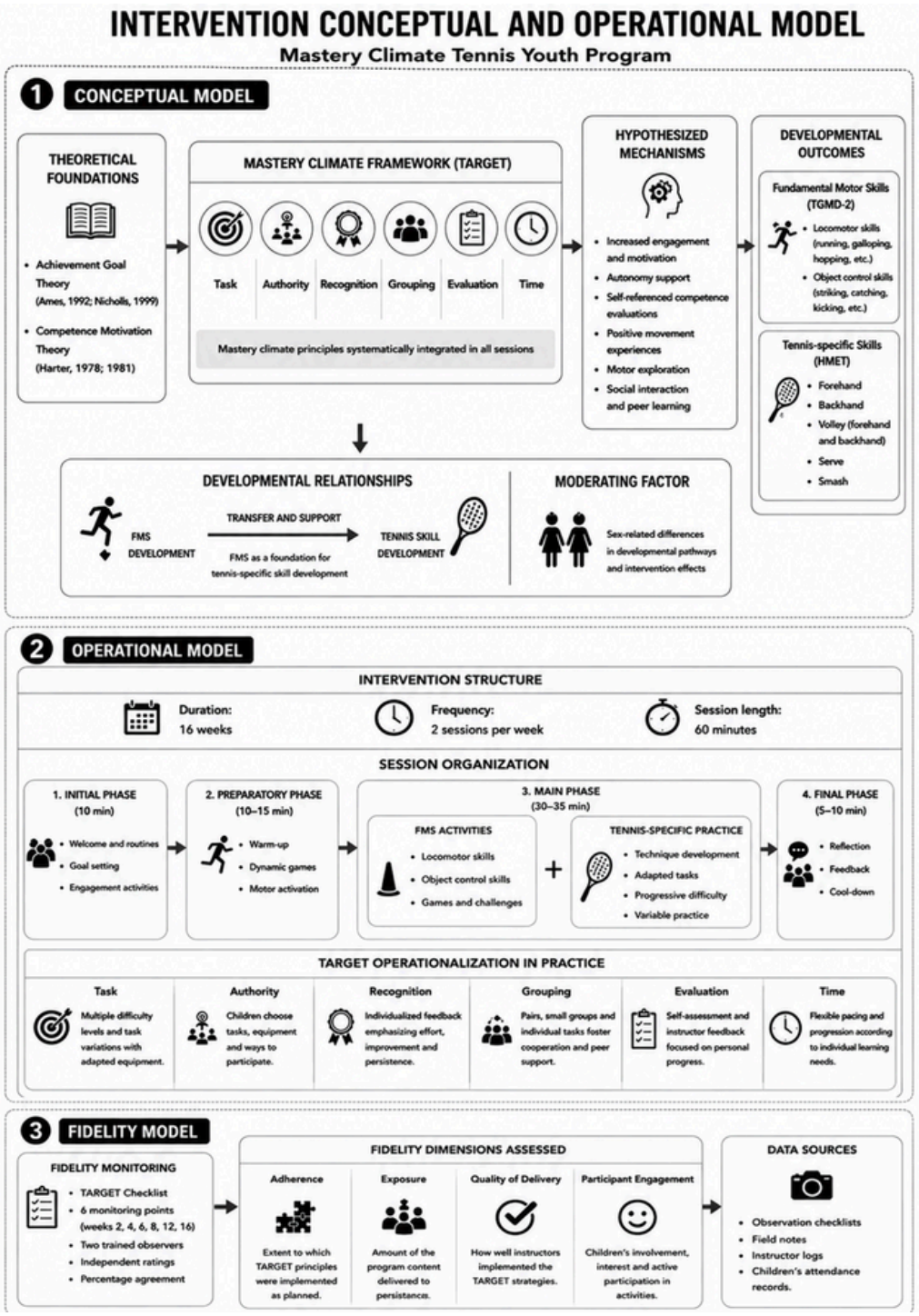


Figure 1. Intervention conceptual and operational model of the Mastery Climate Tennis Youth program.

Intervention Fidelity

Intervention fidelity was monitored using a behavior checklist adapted from previous mastery climate studies[34,35]. The checklist included items related to the presence of each TARGET structure. Two trained researchers independently completed the checklist on six occasions (weeks 2, 5, 8, 10, 13, and 15). Agreement between observers was calculated as percentage agreement. Agreement was superior to 90% for all dimensions in the TARGET structure.

Procedurres

Fundamental motor skills (TGMD-2) were assessed

assessed at two time points: pre-intervention and post-intervention. Assessments were conducted in pairs, with participants performing each skill according to TGMD-2 standardized procedures, following demonstration and verbal instruction, while being recorded using a frontal camera. The evaluator provided standardized demonstrations and verbal instructions to ensure task comprehension. All performances were subsequently analyzed from video recordings. Outcome measures included raw scores, standard scores, percentiles for each subtest, and age-adjusted composite scores. Because the TGMD-2 does not directly provide Z-scores, these were derived from the normative standardized scores provided by the test. For each subtest (Locomotor and Object Control), Z-scores were obtained based on the normative mean of 10 and standard deviation of 3. For the Gross Motor Quotient (GMQ), Z-scores were derived considering its normative mean of 100 and standard deviation of 15. Thus, the Z-scores represented each participant's performance in standard deviation units relative to the TGMD-2 normative reference population.

Specialized tennis skills were assessed at pre-intervention and post-intervention. Assessments were conducted individually, with lateral video recording. Participants performed three attempts for each skill following standardized instructions and two practice trials to ensure familiarity with the task.

Data Analysis

Descriptive statistics (mean, standard deviation, and percentage change [Δ%]) were used to characterize pre- to post-intervention results for boys and girls. A General Linear Model (GLM) with repeated measures was used to examine the effects of time (pre vs. post), sex (boys vs. girls), and their interaction on the investigated variables. Wilks' Lambda criterion was adopted, and Bonferroni post hoc tests were used to identify significant interaction effects. Pearson correlation coefficients were calculated to examine the relationships between fundamental motor skills and tennis-specific skills at pre- and post-intervention. Statistical significance was set at $p \leq 0.05$.

Resultados

Table 1. Total sample FMS and sport skills raw scores

TGMD-2 & Tennis skills - raw scores (N=26)	Pre-intervention		Post-intervention	
	M	SD	M	SD
TGMD-2 total score	59.53	10.42	66.61	6.29
LOC skills subtest	31.04	6.18	34.77	3.74
Ball skills subtest	28.50	6.35	31.85	4.45
TGMD-2 individual scores				
Run	4.27	1.34	5.54	1.73
Gallop	5.27	1.37	6,08	1.20
Jump	5.81	1.85	6.31	1.41
Hop	5.12	2.01	6.12	1.81
Leap	4.62	1.42	4.73	0.96
Slide	5.96	1.31	6.00	0.69
Strike	5.96	1.89	6.15	1.85
Bounce	3.65	2.12	4.88	1.84
Kick	5.12	1.34	6.00	0.40
Catch	4.46	1.27	4.65	1.26
Throw	3.92	1.94	4.04	1.40
Roll	5.38	2.47	6.12	1.11
Tennis skills total scores	120.42	33.65	310.92	76.04

Tennis individual skills				
Forehand	18.73	6.80	52.04	15.59
Backhand	23.31	6.82	62.00	16.40
Right volley	17.65	5.40	43.88	10.31
Left volley	21.81	5.85	47.85	10.41
Smash	19.12	5.61	52.15	15.42
Serve	19.81	7.32	53.00	17.83

Fundamental Motor Skills

Table 2. provided the FMS raw scores and statistical results for the post hoc for boys and girls.

TGMD2 Skills		**Pre-Intervention**		**Post-Intervention**		*Time Comparisons p*
Raw scores		**M**	**SD**	**M**	**SD**	
TGMD-2	Boys (n=12)	57.67	10.43	66.33	4.98	**.003**
	Girls (n=14)	61.14	10.52	66.85	7.42	**.026**
Group comparisons p		.408		.837		
LOC skills	Boys (n=12)	28.25	6.97	34.92	4.34	**< .001**
	Girls (n=14)	33.42	4.36	34.64	3.32	**.382**
Group comparisons p		**.030**		.857		
Ball skills	Boys (n=12)	29.42	5.26	31.42	3.34	.268
	Girls (n=14)	27.71	7.26	32.21	5.32	.022
Group comparisons p		.247		.658		
TGMD-2 Individual Skills						
Run	Boys (n=12)	4.42	1.31	5.58	1.93	**.020**
	Girls (n=14)	4.14	1.41	5.50	1.60	**.004**
Group comparisons p		.614		.905		
Gallop	Boys (n=12)	4.92	1.56	5.92	1.16	**.014**
	Girls (n=14)	5.57	1.16	6.21	1.25	**.079**
Group comparisons p		.233		.538		
Jump	Boys (n=12)	5.00	2.17	6.08	1.50	**.025**
	Girls (n=14)	6.50	1.22	6.50	1.34	**1.00**
Group comparisons p		**.037**		.463		

Hop	Boys (n=12)	4.50	2.24	6.50	1.17	**.016**
	Girls (n=14)	5.64	1.69	5.79	2.22	**.843**
Group comparisons p		.151		.328		
Leap	Boys (n=12)	4.00	1.04	4.83	1.03	.093
	Girls (n=14)	5.14	1.51	4.64	0.93	.267
Group comparisons p		**.037**		.624		
Slide	Boys (n=12)	5.42	1.56	600	95	56
	Girls (n=14)	6.43	0.85			
Group comparisons p		**.047**		1.00		
Strike	Boys (n=12)	6.50	2.07	6.33	1.43	.828
	Girls (n=14)	5.50	1.65	6.00	2.18	.483
Group comparisons p		.183		.739		
Bounce	Boys (n=12)	4.17	2.44	5.50	1.45	.096
	Girls (n=14)	3.21	1.76	4.36	2.02	.122
Group comparisons p		.261		.116		
Kick	Boys (n=12)	5.25	1.21	5.92	.29	.114
	Girls (n=14)	5.00	1.47	6.07	.47	.009
Group comparisons p		.644		.335		
Catch	Boys (n=12)	4.08	1.44	4.42	.99	.389
	Girls (n=14)	4.79	1.05	4.86	1.46	.841
Group comparisons p		.165		.335		
Throw	Boys (n=12)	4.33	2.15	3,50	1.31	.146
	Girls (n=14)	3.57	1.74	4.50	1.34	.083
Group comparisons p		.327		.068		
Roll	Boys (n=12)	5.08	2.19	5.75	.75	.302
	Girls (n=14)	5.64	2.73	6.43	1.28	.192
Group comparisons p		.575		.121		

Regarding TGMD-2 total score a non-significant sex by time interactions were found (λ = .97, F(1, 24) = .69, p = .415, η^2 = .03, power = .13), the group main effect was also non-significant F(1, 24) = .47, p = .500, η^2 = .02, power = .10). However, a significant time main effect was found, F(1, 24) = 16.38, p = < .001, η^2 = .41, power = .97), children improve over time on the

the TGMD-2 total scores regardless of the sex.

Regarding locomotor skills subtests, a significant sex × time interactions were found for locomotor skills subtest ($\lambda = .76$, $F(1, 24) = 7.38$, $p = .0152$, $\eta^2 = .23$, power = .74) as well as a time main effect, $F(1, 24) = 15.41$, $p = < .001$, $\eta^2 = .39$, power = .96); a non-significant group main effect was found $F(1, 24) = 2.28$, $p = .144$, $\eta^2 = .09$, power = .30). The follow up testes for the significant interaction showed that girls had higher scores at pre-test at post-test boys and grills showed similar performance, in addition the locomotor skills increased over time only for boys.

Regarding ball skills, a non-significant sex × time interactions were found $F(1, 24) = 1.10$, $p = .305$, $\eta^2 = .04$, power = .17) as well as for group main effect $F(1, 24) = .06$, $p = .807$, $\eta^2 = .00$, power = .06). However, a significant time main effect was found ($\lambda = .76$, $F(1, 24) = 7.42$, $p = .012$, $\eta^2 = .24$, power = .74); all children improve ball skill regardless of the sex.

Regarding individual skills, significant sex × time interactions were found for leap ($\lambda = 0.85$, $F(1, 24) = 4.23$, $p = 0.050$, $\eta^2 = 0.15$, power = 0.51), slide ($\lambda = 0.79$, $F(1, 24) = 6.52$, $p = 0.017$, $\eta^2 = 0.21$, power = 0.69), and throw ($\lambda = 0.81$, $F(1, 24) = 5.43$, $p = 0.028$, $\eta^2 = 0.18$, power = 0.61). Significant time main effects were observed for running ($F(1, 24) = 15.71$, $p < 0.001$, $\eta^2 = 0.40$, power = 0.97), galloping ($F(1, 24) = 10.15$, $p = 0.004$, $\eta^2 = 0.30$, power = 0.86), hopping ($F(1, 24) = 4.14$, $p = 0.050$, $\eta^2 = 0.15$, power = 0.50), bouncing ($F(1, 24) = 5.58$, $p = 0.027$, $\eta^2 = 0.19$, power = 0.62), kicking ($F(1, 24) = 9.84$, $p = 0.004$, $\eta^2 = 0.29$, power = 0.85), indicating improvement over time regardless of the sex. No significant sex × time interactions, or time main effect, and sex main effects were found for the remaining TGMD-2 skills (all $p > 0.05$).

Overall, these findings indicate that the intervention effectively promoted improvements in fundamental motor skills over time, with some sex-specific responsiveness observed in locomotor development.

Sport-Specific Skills

Table 3 provided the tennis skills raw scores and statistical results for the post hoc for boys and girls.

Table 3. Tennis skills and statistical results for post-hoc tests for boys and girls

Tennis total test & Skills Raw scores		**Pre-Intervention**		**Post-Intervention**		*Time comparisons p*
		M	**SD**	**M**	**SD**	
Tennis skills	Boys (n=12)	127.58	33.47	333.75	65.49	**< .001**
	Girls (n=14)	114.28	31.86	291.36	81.23	**< .001**
Group comparisons p		310		161		
Tennis individual skills						
Forehand	Boys (n=12)	20.50	6.42	56.58	11.07	**< .001**
	Girls (n=14)	17.21	6.97	48.14	18.12	**< .001**
Group comparisons p		.226		.173		
Backhand	Boys (n=12)	25.00	7.15	67.92	15.13	**< .001**
	Girls (n=14)	21.86	6.43	56.93	16.24	
Group comparisons p		.249		.089		

Right volley	Boys (n=12)	17.67	6.00	44.67	12.30	**< .001**
	Girls (n=14)	17.64	5.05	43.21	8.67	**< .001**
Group comparisons p		.991		.728		
Left volley	Boys (n=12)	23.83	6.75	48.83	7.96	**< .001**
	Girls (n=14)	20.07	4.50	47.00	12.38	**< .001**
Group comparisons p		.103		.664		
Smash	Boys (n=12)	20.17	4.91	56.92	14.21	**< .001**
	Girls (n=14)	18.21	6.18	48.07	15.74	**< .001**
Group comparisons p		.387		.148		
Serve	Boys (n=12)	20.42	6.53	58.83	17.71	**< .001**
	Girls (n=14)	19.29	8.15	48.00	16.97	**< .001**
Group comparisons p		.703		125		**< .001**

Regarding tennis skills a non-significant sex × time interactions were found ($\lambda = .97$, $F(1, 24) = 1.92$, $p = 1.78$, $\eta^2 = .07$, power = .26), the group main effect was also non-significant $F(1, 24) = 1.93$, $p = .177$, $\eta^2 = .07$, power = .27). However, a significant time main effect was found, $F(1, 24) = 333.35$, $p = < .001$, $\eta^2 = .93$, power = 1.00), children improve tennis skills over time regardless of the sex

Significant time main effects were observed for forehand ($F(1, 24) = 197.85$, $p < 0.001$, $\eta^2 = 0.89$, power = 1.00), backhand ($F(1, 24) = 204.43$, $p < 0.001$, $\eta^2 = 0.89$, power = 1.00), right volley ($F(1, 24) = 296.11$, $p < 0.001$, $\eta^2 = 0.92$, power = 1.00), left volley ($F(1, 24) = 231.43$, $p < 0.001$, $\eta^2 = 0.91$, power = 1.00), smash ($F(1, 24) = 164.36$, $p < 0.001$, $\eta^2 = 0.87$, power = 1.00), and serve $F(1, 24) = 174.81$, $p < 0.001$, $\eta^2 = 0.88$, power = 1.00), indicating improvement over time regardless of the sex. No significant sex × time interactions or sex main effects were found for the tennis skills (all $p > 0.05$).

These results demonstrate that the intervention was highly effective in enhancing tennis-specific skills, with improvements occurring consistently across all skills and independent of sex.

Correlations Between FMS and Tennis Skills for the Total Sample

Table 4 provided the correlations between TGMD-2 total test, subtests and skills with Tenis skills total test and specific skills for the total sample.

Table 4. Correlations between TGMD-2 and Tenis skills: Total sample

TGMD-2 & Tennis skills	**Correlations (r) at pre- and post-tests**													
	Tennis total test		**Forehand**		**Backhand**		**Right volley**		**Left volley**		**Smash**		**Serve**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
TGMD-2	.15	**.45***	.12	**.43***	.16	**.41***	.12	.34	.11	**.48***	.01	.41*	.33	.32
LOC Skills	.06	.28	.05	.38	-.00	.23	-.05	.14	-.04	.20	.15	.32	.29	.17
Ball Skills	.28	**.60****	.25	**.61****	.26	**.44***	.22	**.49***	.31	.63**	.16	.48*	.34	**.54***
Run	.34	.17	.27	.13	.252	.14	.15	.04	.30	.26	**.39***	.22	**.41***	.10
Gallop	.18	**.44***	.25	**.46***	.15	.33	.10	.34	.06	.36	.28	.53**	.18	.32
Jump	-.05	.04	-.05	.12	-.07	.05	-14	-.07	-.11	-.11	-.04	.10	.19	.03

Hop	-.21	.01	-.32	.14	-.28	.01	-.20	-.01	-.10	-.10	-.06	-.08	-.03	.03
Leap	.18	-.02	.25	-.06	.16	-.07	.09	-.01	-.09	.04	.12	.01	**.46***	-.09
Slide	-.04	.26	-.09	.21	-.03	.29	-.15	.23	-.10	.24	.09	.28	.06	.13
Strike	.27	**.58***	.25	**.63****	.30	**.44***	.29	**.42***	**.42***	**.61****	.07	.45*	.06	**.50***
Bounce	.33	**.44***	.36	.37	.28	.26	.16	**.39***	.32	**.46***	.33	.37	.30	**.51***
Kick	.07	.07	.03	-.03	.05	.04	.01	.07	.11	.21	.06	.02	.15	.12
Catch	.12	**.48***	.13	**.52***	.15	**.48***	.19	.27	.04	.44	.08	.53	.10	.26
Throw	.33	-.07	.34	-.09	.31	-.22	.30	.10	.13	.01	.14	-.14	**.49***	.05
Roll	-.06	.22	-.10	.27	-.08	.31	-.06	.18	-.02	.13	-.09	.14	.13	.10

Note. Significant results *p< .005; **p< .001.

At pre-test, correlations between TGMD-2 total scores and tennis scores were generally weak and non-significant (r = .01 to .33), indicating limited association between those skills prior to the intervention. Similarly, locomotor skills showed negligible relationships with tennis performance (r = -.05 to .29), while ball skills demonstrated small, non-significant associations (r = .16 to .34).

However, at post-test, a different pattern emerged. TGMD-2 total scores were moderately and significantly correlated with overall tennis sores (r = .45), as well as with several individual skills, including forehand, backhand, left volley, and smash (r = .41 to.48). In addition, ball skills showed the strongest associations with tennis performance at post-test, with moderate to strong correlations observed for total tennis scores (r = .60), forehand, backhand, right volley, left volley, smash, and serve (r = .44 to .63). In contrast, locomotor skills remained weakly associated with tennis performance at post-test (r = .14 to .32), with no significant correlations observed.

At the level of individual motor skills, several significant associations emerged at post-test. Object control skills, particularly striking (r = .58 to .63), bouncing (r = .39 to .51), and catching (r = .48 to .52), were positively associated with multiple tennis skills. Galloping was moderately associated with tennis performance, particularly with smash (r = .53). In contrast, locomotor skills such as running, jumping, hopping, and sliding showed mostly weak or non-significant associations with tennis skills at both time points.

Overall, these findings for the total sample indicate that while FMS were not strongly related to tennis scores prior to the intervention, significant and meaningful associations—particularly for object control skills—emerged following the intervention, suggesting a strengthening of the relationship between fundamental motor competence and sport-specific skill performance. These findings suggest that the relationship between fundamental motor skills and sport-specific performance strengthened following the intervention, particularly for object control skills.

Correlations Between FMS and Tennis Skills by Sex

Table 5 provided the correlations between TGMD-2 total test, subtests and skills with Tenis skills total test and specific skills for boys and girls.

Table 5. Correlations between TGMD-2 and Tenis skills: Boys and girls

		Tennis test		Forehand		Backhand		Right volley		Left volley		Smash		Serve	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
TGMD-2	**Boys**	.12	.40	.23	.33	.18	.42	--.08	.14	.11	.52	.13	.43	.07	**.25**
	Girls	.25	**.76***	.12	**.75***	.24	**.76***	.34	**.70***	.29	**.59***	-.01	**.70***	**.55***	**.70***
LOC skills	**Boys**	-.08	.20	-.05	.276	-.18	.22	-.27	.08	-.01	.06	.14	.29	-.01	.08
	Girls	.52	.40	.45	.50	**.55***	.25	.31	.23	.32	.31	.38	.37	**.81***	.28
Ball skills	**Boys**	-.05	**.63***	.06	**.63***	-.00	.40	-.09	.51	.01	**.61***	-.02	.42	-.24	**.63***
	Girls	.47	**.66***	.34	**.66***	.43	**.57***	.46	**.57***	**.58***	**.65***	.23	**.60***	**.61***	**.61***
Run	**Boys**	.15	-.24	.15	-.10	-.01	-.10	-.04	-.24	.12	-.12	.33	-.14	.29	**-.39**
	Girls	.48	.50	.33	.28	.45	.38	.32	.45	.48	.52	.41	**.57***	**.49**	**.61***
Gallop	**Boys**	.02	**.73***	.10	**.79***	.04	**.74***	-.05	.34	.12	.22	.07	**.86***	-.18	**.55***
	Girls	.53	.36	**.58***	.41	.45	.15	.31	.39	.21	.47	**.60***	*	**.57***	.25
Jump	**Boys**	-.10	.27	-.02	.29	-.16	.20	-.35	.10	-.10	.06	.07	.34	.03	**.34**
	Girls	.27	-.06	.18	.17	.34	.03	.19	-.28	.34	-.20	.00	-.01	**.55***	-.17
Hop	**Boys**	-.17	-.05	-.32	-.14	-.39	-.29	-.21	.23	.02	.05	.12	-.23	-.04	.17
	Girls	-.14	-.05	-.21	.16	-.03	.03	-.20	-.18	-.04	-.18	-.12	.11	.02	-.13
Leap	**Boys**	.13	-.11	.39	.13	.21	-.01	.01	-.13	-.10	-.20	.00	-.01	.13	-.31
	Girls	.43	.00	.40	-.02	.35	-.20	.17	.16	.20	.17	.32	-.02	**.73***	.04
Slide	**Boys**	-.19	.27	-.23	.20	-.21	.37	-.33	.16	-.10	.30	.04	.32	-.16	.06
	Girls	.44	.36	.36	.38	**.55***	.28	.15	.47	.31	.30	.38	.32	.44	.32
Strike	**Boys**	.49	.55	.47	.56	.53	.33	.47	.42	**.62***	**.65***	36	.38	.13	.52
	Girls	-.06	**.59***	-.06	**.66***	-.07	.51	.10	.47	-.03	**.60***		.49	-.29	.50
Bounce	**Boys**	-.04	.20	.01	.17	-.06	-.05	-.19	.26	.08	.24	-.00	.01	-.08	.39
	Girls	**.71***	.48	**.68***	.37	.64	.29	**.66***	**.53***	**.59***	**.55***	.60*	.48	**.66***	.50
Kick	**Boys**	-.46	.35	-.41	.64	-.53	.43	-.40	.17	-.32	.35	-.25	.29	-.51	.01
	Girls	.41	.05	.29	-.16	.46	-.04	.35	.03	.51	.19	.20	-.01	.51	.31
Catch	**Boys**	.30	.44	.42	**.63***	.40	**.64***	.24	-.05	.14	.12	.29	**.63***	.09	.17
	Girls	.08	**.61***	.01	**.60***	.02	**.57***	**.13**	**.60***	.15	**.60***	-.00	**.62***	.16	.44
Throw	**Boys**	-.08	.06	-.04	-.10	-.04	-.20	-0.3	.30	-.28	.17	-.22	-.14	.15	.30
	Girls	**.69***	.02	**.65***	.07	**.63***	-.03	**.72***	-.06	**.61***	-.03	.39	.04	**.79***	.08
Roll	**Boys**	-.40	.53	-.32	.49	-.37	**.60***	-.37	.42	-.29	.42	-.21	.45	.54	.30
	Girls	.22	.26	.07	.35	.18	**.43**	.20	.10	.35	.09	.00	.17	.50	.18

At pre-test, correlations between TGMD-2 total scores and tennis scores were generally weak and non-significant for both boys (r = -.08 to .23) and girls (r = -.01 to .55), indicating limited association between FMS and tennis skills prior to the intervention. At post-test, a clear divergence between sexes emerged.

For boys, TGMD-2 total scores showed small to moderate, but mostly non-significant associations with tennis performance (r = .14 to .52), suggesting a modest relationship between general motor competence and tennis skills. Besides, for boys, locomotor skills were weakly associated with tennis scores at both time points (r = -.27 to .29), with no significant correlations observed. In contrast, ball skills showed moderate and significant associations at post-test, particularly with total tennis scores (r = .63), forehand, left volley, and serve (r = .61 to 63).

In contrast, for girls, TGMD-2 total scores were strongly and consistently correlated with tennis scores (r = .59 to .76), including total tennis scores, forehand, backhand, volleys, smash, and serve. Besides, while locomotor skills showed moderate but mostly non-significant associations, ball skills were strongly and consistently correlated with tennis scores at post-

test ($r = .57$ to $.66$, $p < .05$), across multiple skills.

At the level of individual skills, distinct patterns emerged between sexes. For boys, significant post-test correlations were observed primarily for object control skills, including gallop ($r = .73$ to $.86$), striking ($r = .62$–$.65$), catching ($r = .63$–$.64$), and rolling ($r = .60$). In contrast, most locomotor skills showed weak or inconsistent associations with tennis scores. For girls, stronger and more widespread associations were observed. Several object control skills, including striking ($r = .59$–$.66$), bouncing ($r = .53$–$.55$), catching ($r = .57$–$.62$), and ball skills overall, were consistently related to tennis scores. Additionally, some locomotor-related associations were observed, although less consistently.

Overall, the results indicate that the relationship between fundamental motor skills and tennis performance strengthened from pre- to post-intervention, particularly for girls. While boys showed improvements primarily linked to specific object control skills, girls demonstrated stronger and more consistent integration between overall motor competence and tennis-specific performance. These results indicate that the integration between motor competence and sport-specific performance may occur differently across sexes, with girls demonstrating a more consistent and generalized coupling between these domains.

Discussion

Fundamental Motor Skills

Based on the data presented, participants in the Youth Tennis Intervention Program demonstrated significant improvements from pre- to post-intervention in both locomotor and object control fundamental motor skills. Previous research has consistently shown that structured motor interventions are effective in enhancing fundamental motor competence in children[13,16,19], reinforcing the importance of well-designed programs for promoting motor development across domains. Importantly, the present findings extend this body of work by demonstrating that sport-based interventions, such as tennis programs, can simultaneously promote gains in both locomotor and object control skills within ecologically valid contexts

Regarding sex, no statistically significant differences were observed between boys and girls. However, boys showed significant improvements in locomotor skills, whereas girls did not. This pattern may be partially explained by sociocultural influences on early motor experiences, as boys are often encouraged to engage in more vigorous and exploratory activities, while girls may be directed toward more restricted forms of play[8,36].

Conversely, girls demonstrated significant improvements in object control skills, whereas boys did not, contrasting with previous literature suggesting male advantages in these skills[37]. This finding suggests that, within structured and equitable learning environments, traditional sex differences in motor competence may be attenuated or even reshaped. The results highlighting the role of context in motor development and the importance of providing equal opportunities for practice and engagement, similar to previous research[25,34].

The effects of the intervention over time were clearly reflected in the statistical analyses. These findings align with Valentini's work, demonstrating that participation in structured motor programs leads to significant improvements in both locomotor and object control skills. From an ecological dynamics perspective, these results support the view that motor learning emerges through the interaction of individual, task, and environmental constraints[5]. Accordingly, improvements in motor performance depend on the intentional design of learning environments that provide varied practice opportunities, appropriate feedback, and motivational support[13,38].

Sport-Specific Tennis Skills

The results related to tennis performance demonstrated clear improvements across all specialized skills, including forehand, backhand, volleys, smash, and serve. These findings reinforce the effectiveness of structured practice in promoting sport specific skill acquisition. Consistent with previous research, improvement in

tennis performance appear to be strongly influenced by systematic instruction and task organization[24,27]. In addition, research indicates that modifying task constraints—such as equipment scaling and structured practice—can facilitate skill acquisition in children[23], which may help explain the consistent improvements observed in this study.

When analyzed by sex, both boys and girls demonstrated significant improvements, with no differences between groups. This finding reinforced that, when provided with similar learning opportunities and task conditions, children tend to follow comparable development trajectories in sport-specific skills, regardless of sex[24,37]. From a developmental perspective, childhood represents a critical period for motor learning due to high levels of neural plasticity and adaptability[15]. These characteristics support the acquisition of complex movement patterns when children are exposed to appropriately structured learning environments.

Relationship Between FMS and Sport-Specific Skills

The present findings contribute to the limited body of literature directly examining the relationship between fundamental motor skills and sport-specific performance. Studies in soccer have reported strong associations between TGMD-2 scores and sport-specific skills[39], as well as evidence that motor competence mediates the relationship between physical fitness and sport performance[40]. Similarly, research in volleyball has demonstrated associations between motor coordination and sport-specific performance[41] and has shown that higher levels of motor competence facilitate skill learning[42].

Despite these findings, the literature remains fragmented, with most studies examining motor competence and sport-specific performance in isolation. A central contribution of the present study is to demonstrate that meaningful associations between these domains may emerge as a result of structured intervention. At pre-test, weak correlations suggested limited integration between fundamental motor skills and tennis performance. However, at post-test, moderate to strong associations were observed, particularly for object control skills. This pattern indicates that the relationship between motor competence in FMS and sport-specific performance is not static but may develop progressively as children engage in structured and meaningful practice.

In particular, the stronger associations observed for object control skills suggest that transfer between motor domains is influenced by shared movement demands. In tennis, skills such as striking and ball control are closely aligned with object control proficiency, which may explain the observed relationships. From an ecological dynamics perspective, these findings suggest that structured sport environments may facilitate the integration of motor systems, enhancing the coupling between perception and action[4,5].

Sex Differences in the Relationship Between FMDS and Sport-Specific Skills

An additional important finding was the presence of sex-specific patterns in the relationship between motor competence and sport-specific performance. While boys demonstrated more task-specific associations, girls exhibited stronger and more consistent correlations across multiple skills. This pattern suggests that girls may develop a more generalized relationship between fundamental motor skills and sport-specific performance when exposed to structured learning environments, whereas boys may show more domain-specific adaptations.

These findings highlight the importance of considering sex-specific developmental responses when designing sport-based interventions and may contribute to understanding inconsistencies reported in previous literature regarding sex differences in motor competence.

Several strengths of the present study should be highlighted. The intervention was implemented within a real-world social project, increasing its ecological relevance, and was systematically structured according to the TARGET framework. Intervention fidelity was also monitored throughout the program, supporting the consistency of the mastery-oriented climate. In addition, the study simultaneously assessed fundamental motor skills and tennis-specific skills, allowing the examination of changes in

both general motor competence and sport-specific performance, as well as the relationships between these domains.

Nevertheless, some limitations should be considered when interpreting the findings. The relatively small sample size and the absence of a control group limit the generalizability of the results and prevent the observed changes from being attributed exclusively to the intervention. Furthermore, potentially relevant factors such as participants' previous sport experiences, physical activity outside the program, maturation, and differences in opportunities for motor practice were not fully controlled. The short duration of the study and the absence of a follow-up assessment also limit conclusions regarding the maintenance of the observed improvements over time.

From a practical perspective, this program may be applied in social projects, schools, community-based initiatives, and introductory sport programs as a structured approach to simultaneously promote fundamental motor skills and early tennis-specific competence. The TARGET-based mastery climate may also provide coaches and physical education teachers with a useful pedagogical framework for creating inclusive learning environments that emphasize effort, individual progress, active participation, and skill development in young children.

Conclusion

This study examined the effects of a mastery climate tennis intervention on the development of fundamental and sport specific motor skills in children. The findings demonstrated significant improvements in both domains, indicating that structured sport interventions can effectively promote motor development. Importantly, the results suggest that such interventions may not only improve isolated motor skills but also foster the integration between fundamental and sport-specific performance. This highlights the potential of structured sport programs as comprehensive developmental tools.

No differences were observed between boys and girls, reinforcing the importance of providing equitable learning environments that support motor development across sexes. The use of a mastery-oriented climate and a structured instructional approach contributed to increased engagement and improved performance. These findings underscore the importance of pedagogical strategies that promote autonomy, motivation, and meaningful learning experiences.

From a practical perspective, tennis—and sport programs more broadly—can serve as effective contexts for promoting motor development when appropriately structured. Educators play a critical role in designing learning environments that support the development of efficient movement patterns and encourage continued participation. Future research should further investigate how different instructional approaches and sport contexts influence the relationship between fundamental motor skills and sport-specific performance, particularly across developmental stages and between sexes.

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