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The Theoretical and Pedagogical Foundations for Designing a Targeted Physical Activity Program to Develop Motor Abilities Among Third-Year Middle School Students (Aged 14–15)

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Abstract:
This study outlines the foundations of a 16-session physical activity program designed to improve agility, balance, and coordination in 14–15-year-old students experiencing adolescent motor awkwardness due to growth spurts. Grounded in pragmatic philosophy, the program utilizes problem-solving pedagogy to help students discover motor solutions tailored to their developmental changes. The study concludes that this holistic approach to school sports effectively prepares adolescents physically, psychologically, and socially, aligning personal development with broader educational goals.
Keywords: Motor abilities, Peak Height Velocity (PHV), Adolescent Awkwardness, Neural plasticity, Non-linear pedagogy, Physical education.

1. Introduction and Problem Statement:

Introduction and Problem StatementPhysical education has transcended its traditional recreational role, becoming a vital pedagogical tool for the holistic development of the learner. This evolution aligns with Algerian legislative texts (Hezerchi, 2021) that emphasize the necessity of structured and purposeful practice. Within this context, the middle school stage—specifically the 14–15 age group—is exceptionally sensitive due to profound developmental transformations.Biologically, adolescents experience "Peak Height Velocity" (PHV), an asynchronous growth where bone elongation outpaces muscle and tendon adaptation. This disrupts the body's center of mass, causing temporary "Adolescent Awkwardness"—a notable decline in coordination, balance, and agility. Concurrently, the adolescent brain undergoes hyper-neural plasticity and rewiring. This delayed maturation of the prefrontal cortex demands the conscious activation of executive functions (e.g., inhibitory control) to execute complex motor skills.Rather than viewing these challenges as obstacles, neuroscience recognizes this phase as a "Sensitive Window" to reprogram the neuromuscular system. Because traditional linear teaching methods and unstructured practice fail to address these nuanced developmental needs, there is an urgent necessity for targeted programs grounded in modern approaches like non-linear pedagogy and ecological dynamics.Therefore, this theoretical-analytical article aims to provide a comprehensive pedagogical framework to recalibrate the coordinative system and overcome temporary growth obstacles in third-year middle school students. Based on these premises, the primary research problem is formulated as follows: What are the developmental and neurological foundations, alongside modern educational approaches, that can be relied upon to design a targeted and effective physical activity program for developing motor abilities (speed, agility, balance, and coordination) in 14–15-year-old students?

The following sub-questions branch out from this primary question:

- What are the distinctive developmental and neurological characteristics of middle adolescence (aged 14–15), and how do they explain the phenomenon of "Adolescent Awkwardness" and affect their motor learning capacity?
- How can modern educational approaches (such as non-linear pedagogy) and biomechanical principles be employed in designing a targeted motor program that transcends traditional training to address coordination challenges and build autonomy among adolescents?

1.1. Study Objectives This theoretical-analytical article seeks to achieve three primary objectives:

- **Developmental and Neurological Analysis:** Explaining how morphological changes (Peak Height Velocity and motor clumsiness) and neurological transformations (neural plasticity and prefrontal cortex maturation) directly impact the motor performance of 14–15-year-old adolescents.
- **Pedagogical Comparison:** Contrasting traditional linear teaching methods with modern ecological approaches in addressing coordination challenges and fostering student autonomy.
- **Intervention Framework:** Establishing a comprehensive pedagogical foundation for designing a structured school sports program, serving as the theoretical basis for a subsequent field study evaluating agility, balance, and coordination.

1.2. Significance of the Study This study's value lies at the intersection of sports science, neuroscience, and educational psychology, manifesting in two dimensions:

- **Theoretical:** It enriches Arabic literature by bridging neuroplasticity with sports pedagogy, reframing "temporary adolescent awkwardness" from a developmental barrier into a golden learning opportunity.
- **Practical:** It provides a methodological guide for educators to transition toward learning environment engineering using the STEP framework, while establishing the core scientific rationale for the proposed experimental field program of the current doctoral thesis.

1.3. Methodology A descriptive analytical review approach was adopted to deconstruct motor development phenomena within an applied educational context. This approach involved three key steps:

- **Literature Review:** Systematically analyzing recent scientific literature (2019–2025) on motor learning and physical education.
- **Directed Analysis:** Interpreting the limitations of linear competitive training and highlighting the efficacy of ecological dynamics as a pedagogical alternative.
- **Program Synthesis:** Synthesizing these findings to establish a robust scientific foundation for the proposed 16-session field intervention, specifically validating the use of constraint manipulation to enhance motor competence.
- **1.4. Review of Previous Studies and Commentary** Recent literature indicates that traditional linear teaching and unstructured play are inadequate for comprehensive adolescent motor development. Conversely, targeted interventions integrating Fundamental Motor Skills (FMS) within mastery-oriented climates significantly improve coordination and balance compared to traditional physical education (Lorås, 2020; Vasileva et al., 2024). Furthermore, open-skill environments and Small-Sided Games (SSGs) compel dynamic adaptation, substantially enhancing both agility and executive functions—such as working memory and inhibitory control (Condello et al., 2021; Tavakoli et al., 2024; Williams et al., 2020).
- **Commentary and Study Positioning:** While existing research links complex motor performance to executive functions, a distinct methodological gap remains. Most studies either focus broadly on pedagogy without addressing the specific biomechanical disruptions of Peak Height Velocity (PHV), or target neurological outcomes without a clear constraint-led pedagogical structure. The current study bridges this gap by proposing a 16-session ecological design, engineered via the STEP framework, to specifically address "adolescent awkwardness" and leverage neural plasticity for enhanced motor competence and autonomy.

1.5. Study Distinction This study bridges the epistemological gap by presenting a hybrid approach that integrates neuroscience and pedagogy. Rather than a generic sports program, it proposes a 16-session ecological design to capitalize on neural plasticity and mitigate adolescent awkwardness. Its distinction lies in combining the gradual release of joint "degrees of freedom" with Small-Sided Games (SSGs) to challenge cognitive flexibility and inhibitory control. This develops agility and coordination while building the "motor autonomy" needed to adapt to rapid morphological changes.

3. Theoretical and Developmental Foundations (Aged 14–15)

3.1. The Functional Concept of Motor Abilities Motor abilities (agility, balance, coordination) must be understood not as isolated traits, but as an integrated "Motor Competence" system (Henderson & Sugden, 1992). In sports, these abilities are highly interdependent; agility requires lower-extremity power, while balance is crucial for controlling the center of mass during rapid movements. Furthermore, motor coordination acts as the cognitive guide, defined by Bernstein (1967) as the "voluntary control over the degrees of freedom of the joints". Developing this comprehensive competence during middle adolescence requires sequential pedagogical interventions that align with biomechanical and neurological maturation to ensure sustainable neural adaptations.

3.2. Developmental Characteristics and Their Impact on Motor Performance Middle adolescence (aged 14–15) entails rapid morphological and biomechanical transformations that profoundly reshape the adolescent's neuromuscular development.

- **Peak Height Velocity (PHV) and Asynchronous Growth:** Around age 14 (particularly in males), long bones elongate faster than soft tissues can adapt, causing increased muscle tightness and temporary flexibility reduction. This rapid limb growth elevates the body's center of mass (CoM), imposing complex mechanical demands on the nervous system to maintain balance.
- **Adolescent Awkwardness:** This asynchronous growth induces a temporary decline in motor competence known as "adolescent awkwardness". The brain struggles to update its spatial "internal model," compensating through visual overreliance. According to Newell's model, the nervous system attempts to control increasing degrees of freedom by "freezing" certain joints, resulting in rigid, uncoordinated movements that negatively impact agility.
- **The "Sensitive Window":** Despite this decline, researchers view the PHV phase as a golden "sensitive window" to reprogram the neuromuscular system. Engaging adolescents in targeted programs with spatial and environmental constraints compels the nervous system to explore new motor solutions. This structured intervention accelerates the "unfreezing" of joints, transitioning the adolescent from awkwardness to fluid, automated coordination.

3.3. Biomechanical and Neurological Foundations of Motor Learning Motor learning in adolescents (aged 14–15) rests on two interconnected neurological foundations:

- **Neuroplasticity and Neural Maturation:** Middle adolescence is a highly sensitive period for structural brain reorganization. This occurs via *synaptic pruning* (eliminating unused connections while strengthening active motor pathways) and increased *myelination*, which accelerates neural transmission and response speed. Furthermore, brain maturation follows a "posterior-to-anterior" trajectory. The maturation of the prefrontal cortex is crucial for transitioning to precise, voluntary movements (Fandakova

& Hartley, 2020). This "experience-dependent plasticity" makes regions like the cerebellum highly responsive to structured training, directly enhancing coordination and balance.

- **Neurochemical Interactions and Executive Functions:** Motor development is driven by a temporary neurochemical imbalance between the excitatory (glutamatergic) and maturing inhibitory (GABAergic) systems, alongside dopamine/serotonin fluctuations (Arain et al., 2013). This discrepancy often causes impulsive motor decisions. Consequently, "executive functions" (inhibitory control, working memory, and cognitive flexibility) emerge as crucial compensatory mechanisms for complex abilities like agility. Targeted physical activity stimulates neurotrophic factors (e.g., BDNF, IGF-1) that enhance prefrontal synaptic plasticity. Notably, open-skill sports enhance working memory and cognitive flexibility, while closed-skill sports improve inhibitory control (Tavakoli et al., 2024).

3.4. Conclusion of Section One: A structured sports educational program (e.g., a 16-session curriculum) transcends mere neuromuscular adaptation. Rather, it acts as a calibrated intervention leveraging neuroplasticity and dopaminergic recalibration to overcome temporary adolescent awkwardness during this sensitive developmental window. This systematic approach strengthens the neural pathways linking executive functions with motor performance, optimizing the development of complex abilities such as agility, balance, and coordination in 14–15-year-old students.

4.1. The Concept of the Educational Sports Program and Planning Principles Unlike competitive training characterized by "Early Specialization," linear repetition, and potential burnout a targeted educational program adopts "Early Diversification" and non-linear pedagogy. It prioritizes the comprehensive development of Fundamental Motor Skills (FMS) and physical literacy over elite performance. The learner is viewed as a dynamic system that acquires coordination by adapting to changing environments and exploring motor solutions.

To effectively structure a multi-week intervention (e.g., a 16-session curriculum), the planning must rely on four foundational pedagogical principles:

- **Progressive Design:** Moving gradually from stable motor environments (to establish postural control) toward highly variable dynamic environments.
- **Constraint Manipulation (STEP Framework):** Utilizing ecological dynamics to systematically alter Space, Task, Equipment, and People. This purposeful "temporary instability" provokes the nervous system to self-organize and invent agile responses.
- **Holistic Integration:** Incorporating small-sided games to challenge executive functions (working memory, cognitive flexibility) and enhance socio-emotional competence, such as self-regulation. Furthermore, guided group games serve as an ideal environment for enhancing socio-emotional competence, as recent local studies emphasize the critical role of educational physical activity in improving the psychological health of middle school pupils aged 14–15 years (Moussaoui, 2023).
- **Unfreezing Degrees of Freedom & Mastery Climate:** Encouraging the fluid use of biomechanical resources ("unfreezing joints") within a motivational climate that evaluates students on effort and individual improvement rather than pure competitive comparison.

4.2. Modern Educational Approaches in Motor Learning Developing complex motor abilities in adolescents requires a paradigm shift from rote instruction toward learner-centered pedagogies, specifically integrating three crucial approaches:

- **Competency-Based Approach:** Prioritizes "Physical Literacy" and a mastery-motivational climate over pure competitive achievement (Lorås, 2020).
- **Non-Linear Pedagogy (Ecological Dynamics):** Views learning as "self-organization" triggered by teacher-engineered environmental "motor noise" (Rudd et al., 2019).
- **Holistic Physical Education:** Explicitly links physical tasks to the development of cognitive "Executive Functions" (Vasileva et al., 2024).

Fostering Autonomy and Problem-Solving: At ages 14–15, the prefrontal cortex is highly plastic. By systematically manipulating constraints via the STEP framework, educators strip away "ready-made solutions," confronting students with immediate motor problems. This demands cognitive flexibility to inhibit old motor patterns and working memory to generate creative responses, ultimately transforming the adolescent from a mechanical executor into an autonomous, self-regulating problem-solver (Slimani, 2022).

4.3. Foundations for Designing a Targeted Physical Activity Program (Aged 14–15)
Operationalizing theoretical concepts into a calibrated 16-session educational intervention requires grounding the methodological construction in three primary foundations:

- **Progression and Motor Undulation:** To induce sustainable neural adaptations, programming must follow an ascending learning curve. Initial sessions focus on static balance and simple coordination within closed environments to recalibrate the "internal body model" and overcome growth-induced awkwardness. The program then progressively transitions to dynamic balance, agility, and open skills in complex environments.
- **Individualization (Non-Linear Pedagogy):** Recognizing the extreme variance in biological maturation during Peak Height Velocity (PHV), the program discards "motor stereotyping". Instead, it employs differentiated pedagogy by designing "problem-solving scenarios" that afford multiple achievement levels. This allows each student to discover their "individual motor solution" aligning with their specific limb length and center of mass, thereby maintaining motivation.
- **Synergistic Integration:** Balance, agility, and coordination operate as an integrated network guided by the brain's executive functions. Thus, the program avoids fragmenting these abilities into isolated sessions. Instead, learning situations and small-sided games are engineered to require simultaneous recruitment of these motor indicators. This cognitive-motor overlap multiplies neural plasticity and accelerates the pace of holistic learning.

4.4. Applied Structural Model (16 Training Sessions): Translating these foundations into field reality, we propose a 16-session physical activity program (conducted twice weekly for 8 weeks). This model systematically manipulates environmental constraints via the STEP framework to overcome "adolescent awkwardness" and recalibrate the coordinative system through four progressive phases:

Table (1): Structural Phasing of the Proposed Motor Program.

Phase (Sessions)	Targeted Neurological & Motor Objectives	Constraint Manipulation (STEP Framework)
1 : Recalibration (4-1)	Overcome "adolescent awkwardness" and recalibrate sensorimotor perception. Focus: Static balance &	Space :Wide, safe areas (internal focus). Task :Individual tasks, no time pressure. Equipment :Stable, defined tools.

	foundational coordination (Closed Skills).	
2 : Dynamic Balance(8-5)	Gradual joint "unfreezing" and Center of Mass (CoM) shifting. Focus: Limb coordination during continuous movement.	Equipment :Varying ball sizes/weights. Task :Movement combined with coordination. People :Non-competitive pairs.
3: Agility & Flexibility-9) (12	Develop reaction speed and direction change (Open Skills). Focus: Challenging "Inhibitory Control."	Space :Sudden narrowing (spatial pressure). Task :Dynamic rule changes via cues. People :Light competition (1v1).
4: Synergistic Integration (16-13)	Complex integration of balance, coordination, and agility under pressure to achieve "Self-organization."	People :Small-Sided Games (e.g., 3v3). Space/Equip :Mini-courts, multiple tools Task :Compound tasks requiring. rapid decisions.

Source: (The Researchers, 2026)

Analytical Reading and Applied Example of the Structural Model An effective educational program relies on the progressive engineering of "Cognitive Load" rather than the random escalation of physical exertion. Phases 1 and 2 secure a stable environment, allowing the adolescent's nervous system to internalize new morphological body dimensions. Phases 3 and 4 then transition into deliberate "Environmental Noise" via the STEP framework. This progression provokes executive functions (cognitive flexibility and working memory), compelling the adolescent toward autonomy in discovering agile, coordinated motor solutions.

Applied Example of Constraints Manipulation (Small-Sided Games - SSGs): To illustrate the STEP framework's field application for simultaneously developing balance, agility, and coordination, consider a 3v3 mini-handball game:

- **Task & Equipment:** Requiring students to pass balls of varying sizes and weights (handball, tennis, volleyball) breaks automatic expectations, forcing the brain to constantly recalibrate force and hand-eye coordination.
- **Space:** Suddenly narrowing the playing area creates spatial pressure that deprives the adolescent of time. This provokes executive functions to make rapid decisions and execute sudden direction changes (agility) while maintaining dynamic balance to evade opponents.

4.4. Measurement and Evaluation Tools for the Proposed Program (Field Validation) To objectively evaluate the pedagogical intervention's efficacy in inducing neural and mechanical adaptations, a comprehensive battery of standardized psychometric motor tests was selected. These tools are categorized into three pivotal domains:

- **Agility (Inhibitory Control & Direction Change):** The T-Test and Illinois Agility Test evaluate multidirectional speed, reaction time, and continuous motor control (Hachana et al., 2013; Pauole et al., 2000).
- **Balance (Center of Mass Recalibration):** The Stork Stand Test (EUROFIT) and Y-Balance Test (YBT) assess static postural stability via proprioception and dynamic neuromuscular asymmetry, respectively (Adam et al., 1987).
- **Motor Coordination (Joint Unfreezing & Cognitive Integration):** The Alternate Hand Wall Toss and MABC-derived Ball Catch/Control Test measure upper and lower limb perceptual-motor coordination (eye-hand/eye-foot). Additionally, the Four-Limb Coordination Test evaluates the central nervous system's "synergistic integration" to confirm the unfreezing of motor degrees of freedom (Bernstein, 1967; Henderson & Sugden, 1992).

4.5. Rationale for Targeting Male Adolescents (Aged 14–15): While Peak Height Velocity (PHV) is universal, its biological timing differs by sex. Females typically peak around age 12, whereas males experience this acute morphological shift later, at approximately age 14 (Tsutsui et al., 2022). Consequently, "temporary adolescent awkwardness" and the resulting disruption in coordination and balance are most pronounced in third-year middle school males. Therefore, the proposed training program specifically targets male adolescents to ensure sample developmental homogeneity and provide a precise pedagogical intervention during this critical neuro-motor window.

5. Conclusion: This analytical study investigated the theoretical, developmental, and educational foundations of motor development in middle school adolescents (aged 14–15). By intersecting developmental neuroscience with sports pedagogy, the study transcends viewing physical activity as mere energy expenditure, redefining physical education as an integrated neuro-cognitive-motor intervention.

5.1. Fundamental Conclusions and Synthesis

This theoretical analysis yields the following fundamental conclusions:

- **Developmental and Neurological Perspective:** The 14–15 age group is a "highly sensitive temporal window" for motor learning. Despite the "adolescent awkwardness" caused by PHV, peak neuroplasticity allows rapid neural rewiring when provided with appropriate motor stimuli.
- **Educational and Pedagogical Perspective:** Traditional linear training is insufficient for comprehensive development. Thus, "educational sports programs" must adopt non-linear pedagogy and ecological dynamics. By manipulating environmental constraints, these models present problem-solving tasks that challenge executive functions and compel self-organization for agile motor responses.

Synthesis and Rationale for the Applied Field Study: Unstructured practice risks wasting this sensitive window and consolidating poor motor patterns. Therefore, transitioning from theory to experimentation is imperative. A subsequent field study will subject a purposive sample of male adolescents (aged 14–15, aligning with PHV) to the proposed 16-session targeted program. To precisely evaluate the program's efficacy in recalibrating the coordinative system, a battery of seven standardized tests will be utilized. These include the Stork Stand and Y-Balance tests (balance), T-Test and Illinois Agility Test (agility), and three specialized tests for motor competence (Wall Toss, Ball Catch, and Four-Limb Coordination).

The ultimate goal is to demonstrate the program's ability to overcome motor disruption and foster lifelong physical competence.

5.2. Recommendations and Proposals

Based on the conclusions derived from this theoretical analysis, the study recommends the following to maximize field-level benefits:

- **Updating Professional Development:** This transition requires comprehensive training, as the success of implementing non-linear pedagogy relies heavily on the actual level of teaching skills practiced by physical education and sports teachers (Hachani et al., 2025).
- **Considering Developmental Differences:** Raise middle school teachers' awareness regarding Peak Height Velocity (PHV) morphological changes. Rigid assessments must be replaced with individualized diagnostic evaluations for students experiencing "adolescent awkwardness".
- **Cognitive-Motor Integration:** Incorporate Small-Sided Games (SSGs) as core curriculum components due to their proven effectiveness in challenging executive functions (e.g., working memory and inhibitory control) alongside developing agility and coordination.
- **Future Research:** Sports science researchers should conduct longitudinal studies utilizing precise tools, such as biomechanical motion analysis, to measure the neuro-mechanical impacts of educational programs on adolescents.

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