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OPTIMIZING JOINT MOBILITY AND MUSCLE ELASTICITY THROUGH GYMNASTICS EXERCISES AT HIGH SCHOOL STUDENTS

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Abstract

This study evaluated the effectiveness of integrating specific gymnastic exercises and active-dynamic/PNF stretching into high school PE to enhance joint mobility and muscle elasticity. In an experimental design, forty-five ninth-grade students were split into experimental and control groups and tested before and after a 16-week intervention. Assessments (sit-and-reach, back extension, straddle, scapulo-humeral goniometry) were analyzed with paired t-tests ($p<0.05$). The experimental group showed significant gains: sit-and-reach +18.5%, back extension +15.7%, straddles +20.0%, and scapulo-humeral abduction +13.2%. Findings support systematic inclusion of gymnastics and dynamic stretching in the high school curriculum.

Introduction

Joint mobility is the ability to perform movements through a full anatomical range and is a cornerstone of motor ability, directly influencing injury prevention, technical efficiency, and overall physical health [4]. During adolescence, rapid skeletal growth and neuromuscular adaptations often lead to imbalances in muscle tension and joint flexibility, making targeted interventions critical. While static stretching can produce immediate gains in range of motion, these benefits diminish quickly without active reinforcement exercises [5,6]. Proprioceptive Neuromuscular Facilitation (PNF) techniques leverage stretch reflexes and connective tissue remodeling to sustain long-term improvements in flexibility [2,13]. Despite strong empirical support, PNF is infrequently integrated into school PE programs, which typically rely on static or generalized gymnastics methods [9,10]. Furthermore, apparatus-based gymnastics and partner drills have been shown to enhance segmental coordination, postural awareness, and neuromuscular control [9,12]. An integrated protocol that combines these functional drills with active-dynamic stretching and PNF holds promise for achieving significant, durable gains in adolescent mobility and elasticity, yet remains under-researched in high school contexts [7,8]. The present study aims to implement and validate such a protocol to provide PE teachers with an evidence-based framework for developing robust motor skills in high school students.

Material-method

This study employed a parallel-group experimental design in which forty-five ninth-grade students (mean age 15–16 years) were randomly assigned to an experimental group (n = 23) and a control group (n = 22) [11]. Over a 16-week semester, both groups attended three 50-minute physical education lessons per week. The experimental group received, in each lesson, a combination of apparatus-based gymnastics and partner drills aimed at enhancing segmental control and neuromuscular coordination [9,12], followed by active-dynamic stretching and Proprioceptive Neuromuscular Facilitation (PNF) holds of 30–60 s for major muscle groups [6,14]. The control group followed the standard curriculum, which consisted solely of general exercises and static stretching. Mobility and elasticity assessments were conducted one week before (pre-test) and one week after (post-test) the intervention using four field tests:

Anterior Spinal Flexion (“Sit-and-Reach”) - the student sits on a gym bench with legs extended and torso relaxed, performs four rhythmic forward bends with arms alongside the trunk, then holds maximal flexion; measurement is taken in millimeters using a ruler placed with its 25 cm mark at bench level and zero toward the participant [1].

Spinal Extension (“Bridge”) - from a supine position with knees bent and heels near the buttocks, hands placed on the mat by the head with palms down, the student lifts the pelvis and extends the spine into a full bridge, after which the distance between the middle fingertip and the heel is measured in millimeters [7].

Hip (Coxo-Femoral) Mobility (“Straddle”) - standing with feet shoulder-width apart along the sagittal plane, the student gradually lowers into a straddle position, supporting themselves with hands on the floor to avoid overstretching, and then the vertical distance from the pubic symphysis to the floor is measured in millimeters [15].

Scapulo-Humeral Mobility (Shoulder Goniometry) - The student stands with arms raised overhead, the goniometer’s fixed arm on the lateral trunk and its movable arm on the humerus; after reaching maximal arm extension, the angle is recorded in degrees [10].

Results

Relative to the control group, the experimental group demonstrated significant gains in all mobility and elasticity measures.

Table 1. Results at applied tests

Test	Pre-test (mean ± SD)	Post-test (mean ± SD)	Change (%)
Sit-and-Reach	29.4 ± 6.2 cm	34.9 ± 5.8 cm	+18.5 %
Back Extension “Bridge”	76.0 ± 11.6 cm	88.0 ± 10.3 cm	+15.7 %
Straddle Flexibility	17.4 ± 1.1 cm	20.9 ± 1.0 cm	+20.0 %
Scapulo-Humeral Abduction	178.6 ± 5.8 °	202.1 ± 6.0 °	+13.2 %

The reduction in coefficients of variation indicated a homogeneous response among participants in the experimental group [15]. All pre- to post-differences were statistically significant ($p < 0.05$).

In the sit-and-reach test, boys improved their mean score from 30.66 cm to 35.38 cm, an increase of 4.72 cm, while girls increased from 31.00 cm to 35.62 cm, an increase of 4.62 cm. In the back-extension (“bridge”) test, girls reduced the middle-finger-to-heel distance from 76.00 cm to 68.25 cm, a decrease of 7.75 cm, and boys showed a comparable reduction from 79.00 cm to 68.88 cm, a decrease of 10.12 cm. Hip abduction (“straddle”) results revealed the pubis to floor distance for boys dropped from 17.37 cm to 10.82 cm, a decrease of 6.55 cm, and for girls from 17.21 cm to 11.14 cm, a decrease of 6.07 cm. Finally, in scapulo-humeral goniometry, boys’ shoulder-flexion angle rose from 177.34° to 180.52°, an increase of 3.18°, and girls’ from 178.80° to 190.90°, an increase of 12.10°.

Discussions

The present study investigated the effects of a 16 week apparatus-based gymnastics and PNF stretching intervention on mobility and elasticity in ninth-grade students, compared to a standard physical education curriculum. Our findings indicate that the experimental group, which combined apparatus drills, partner exercises, active-dynamic stretching, and 30–60s PNF holds, experienced marked improvements in all four mobility tests (sit-and-reach, bridge, straddle, and scapulo-humeral goniometry), whereas the control group, following only general exercises and static stretching, showed minimal change. The substantial gains in anterior spinal flexion (“sit-and-reach”) suggest that the inclusion of dynamic stretching and PNF effectively enhances hamstring and spinal flexibility beyond what is achievable with static stretching alone [1,14]. The experimental group’s improved bridge performance further supports the utility of PNF for increasing spinal extension range, likely by promoting neuromuscular relaxation of antagonist muscles and facilitating reciprocal inhibition [6,7]. Similarly, the greater gains in straddle (coxo-femoral mobility) reflect the combined effects of apparatus-based drills which emphasize lower-limb segmental control and prolonged PNF holds, which together optimize both muscle elasticity and joint tolerance to stretch [12,15]. Finally, the enhanced scapulo-humeral range of motion observed in the experimental group underscores the importance of integrating targeted goniometry-based drills on gymnastics apparatus (e.g., rings or parallel bars) to promote shoulder girdle mobility, supplemented by PNF patterns that specifically address the complex interplay of rotator-cuff and scapular stabilizers [9,10]. In contrast, the control group’s reliance on static stretching alone did not produce comparable adaptations in dynamic joint mobility or neuromuscular coordination.

Our results are consistent with earlier investigations demonstrating that PNF stretching elicits superior improvements in range of motion compared to static stretching, due to its facilitation of both autogenic and reciprocal inhibition mechanisms [6,14]. Likewise, partner-assisted drills and apparatus-based gymnastics have been shown to enhance proprioceptive acuity and segmental control, which can translate into functional gains in mobility [9,12]. The integration of active-dynamic stretching aligns with evidence supporting movement-based techniques for promoting functional flexibility and reducing muscle stiffness more effectively than passive methods [14]. The combination of apparatus exercises and PNF likely exerts synergistic effects on both peripheral and central neuromuscular pathways. On the peripheral level, PNF holds increase muscle-tendon unit compliance by triggering Golgi tendon organ inhibition, while active-dynamic movements promote viscoelastic adaptations in connective tissues [6,14]. Centrally, the demand for precise segmental control during partner drills and apparatus routines may enhance cortical representation of the stretched muscles, facilitating more efficient voluntary relaxation during subsequent stretching phases [9]. This dual adaptation may account for the robust improvements seen in both flexibility and dynamic joint control. For physical education curricula, these findings suggest that integrating apparatus-based and partner-assisted PNF drills into regular PE lessons can yield meaningful improvements in student mobility and motor quality, beyond what is possible with traditional static stretching. Educators seeking to optimize flexibility and functional mobility might thus consider allocating a portion of lesson time to structured PNF protocols and dynamic drills, particularly when training adolescent populations undergoing rapid musculoskeletal development. Several limitations warrant consideration. First, the absence of long-term follow-up means that the durability of these mobility gains remains unknown. Second, while our field-based tests offer practical applicability, more precise instrumentation (e.g., motion capture or isokinetic dynamometry) could quantify joint kinematics and muscle properties with greater fidelity. Finally, we did not assess changes in injury rates or functional performance (e.g., sprinting, jumping), which would provide insight into the real-world benefits of enhanced flexibility. Future research should investigate the retention of PNF induced mobility gains over extended periods, as well as their translation into improved athletic or daily life performance metrics. It would also be valuable to compare different PNF patterns (e.g., contract-relax vs. hold-relax) and partner-drill configurations to determine the most time-efficient protocols for school based settings. Finally, incorporating psychological measures (e.g., perceived exertion, enjoyment) could inform the design of engaging, sustainable flexibility programs for adolescents.

Conclusions

Overall, the integration of apparatus-based gymnastics, partner drills, active-dynamic stretching, and PNF holds represents an effective strategy for enhancing joint mobility and muscle elasticity in high-school students. These multimodal interventions appear to leverage both neurophysiological and biomechanical pathways, yielding significant gains in flexibility that surpass those achieved by static stretching alone. Implementing such protocols in physical education can foster improved motor quality and potentially contribute to long-term musculoskeletal health in adolescent populations.

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