Physical Education Theory and Methodology
Теорія та методика фізичного виховання

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original Scientific Article

The Effects of a Structured Neuromuscular Program on Athletic Performance in Handball: A Controlled Trial with Pre-Post Intervention Analysis

Anwar Ali S Syed[1ABCD] and J David Mathew James[1ACD]

[1]Hindustan Institute of Technology and Science

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: J David Mathew James, e-mail: rp.24sr9230001@student.hindustanuniv.ac.in
Accepted for Publication: June 18, 2025
Published: July 30, 2025

DOI: 10.17309/tmfv.2025.4.14

Abstract

Objectives. The study aimed to examine the effects of a six-week neuromuscular training program on agility and explosive power in university-level male handball players using a non-randomized controlled design.

Materials and methods. Thirty players (20-24 years) were divided into experimental ($n = 15$) and control ($n = 15$) groups. The experimental group completed five weekly 60-minute neuromuscular sessions, while the control group maintained their regular training regime. Agility (Illinois Agility Test) and explosive power (standing broad jump) were assessed in the pre- and post-intervention phase. Data were analyzed using paired t-tests and ANCOVA (SPSS v22.0, $p < 0.05$).

Results. Following the intervention, the experimental group exhibited statistically significant gains in both agility and explosive power. Agility scores improved from a mean of 16.31 ± 0.92 seconds to 15.81 ± 0.82 seconds ($p < 0.001$; Cohen's $d = 0.56$), while explosive power increased from 2.25 ± 0.15 meters to 2.37 ± 0.12 meters ($p < 0.001$; $d = 0.87$). ANCOVA revealed significant group differences after adjusting for pre-test performance (agility: $F = 12.36$, $p = 0.001$; explosive power: $F = 35.54$, $p < 0.001$). The control group did not show any meaningful changes ($p > 0.05$).

Conclusions. The findings indicate that a six-week neuromuscular training program is an effective method to enhance key performance metrics in handball players, supporting its incorporation into athletic development protocols. Further research should be conducted to investigate the long-term effects and sport-specific transfer.

Keywords: agility performance, explosive leg power, handball, neuromuscular conditioning, plyometric training, sport-specific adaptation.

Introduction

Athletic excellence in dynamic team sports is increasingly understood as the emergent outcome of complex neuromuscular coordination and biomechanical adaptability (Hermassi et al., 2019). Agility the ability to shift direction rapidly and explosive power, meaning the capacity to generate significant muscular force in minimal time, are widely recognized as fundamental elements for achieving high performance in sports such as handball, basketball, and Football. Mastery of these attributes is considered essential by coaches and experts alike, as they directly contribute to an athlete's effectiveness and overall success within these dynamic sporting environments (Marcos Pardo et al., 2019, Scheer et al., 2021). Importantly, these abilities are reflexive of neither mere muscular strength nor endurance; as Cormie et al. (2011) assert, "Rather, they are produced as a consequence of interplay between central and peripheral factors to optimize motor unit recruitment, synchronization, and intermuscular coordination" (Buckthorpe, 2014).

Whereas much research has focused on the enhancement of these attributes, doubts remain over the configuration, duration, and sequence of the neuromuscular training (Scheer et al., 2021). Training programs of extended duration, mostly beyond eight weeks, applying various combinations of periodized resistance training and plyometrics, appear to guarantee improvements in speed, power, and change-of-direction measures (Kompf et al., 2023) (Horníková et al., 2021). Yet, recent literature started to challenge the need for such lengthy training interventions, suggesting that true neuromuscular adaptations, especially those of a neural rather than morphological nature, occur within a very short time frame of four to six weeks (Oranchuk et al., 2019) (El-Ashker, 2019) (Stefanovic et al., 2022). These opposing perspectives highlight the fundamental tension of while long-term programs remain the gold standard, there is a compelling rationale for investigating the efficacy of time-constrained, high-intensity protocols.

Theoretical underpinning for short-term efficacy is instigated by considerations of neural plasticity and motor learning. Short-term training interventions heighten proprioceptive acuity, diminish the co-contraction of antagonist musculature, and stimulate corticospinal excitability, which finally manifests as efficient and explosive movement patterns (Opie et al., 2016). Buffers to changes in reactive strength and intersegmental coordination through target plyometric, balance, and agility drills are often reflected in terms of central rather than peripheral hypertrophy (Van Roie et al., 2020) (Koshy et al., 2020). This is particularly important for collegiate athletes with already very tight schedules who need training methods that minimize time demands yet provide biomechanical benefits.

Nevertheless, the literature remains fractured and heterogeneous in respect of both structure and specificity of the neuromuscular protocols. Some investigations isolate plyometrics, resistance, or linear speed training, never accounting for the interaction between agility and power as co-determinants of sport-specific performance (Morris et al., 2022) (Scanlan et al., 2021) (Prathap, 2011). (Rice et al., 2020) All studied movement tasks are unidirectional, thereby ignoring the chaotic, multi-planar nature imposed by team sports. An emphasis on split-brain analyses reduces ecological relevance and thereby translational value of findings. A growing body of research now advocates for integrative approaches to multimodal interventions that target neuromuscular reactivity, postural control, and high-rate force development within a single coherent framework (Sañudo et al., 2019).

In response to these gaps, the present study sought to empirically evaluate a six-week, high-frequency neuromuscular training program designed to enhance both agility and explosive power among university-level handball players. This population represents an ideal test case, balancing substantial physical maturity with ongoing neuromuscular plasticity, while contending with academic and athletic time constraints. Specifically, the study aimed to: (1) determine whether a brief, multimodal neuromuscular training protocol could induce statistically significant and practically meaningful improvements in agility and explosive performance; (2) compare the magnitude of these changes to those reported in longer interventions; and (3) suggest, via indirect indicators of performance, the possible neuromechanical mechanisms underlying the adaptation observed.

The inquiry rests axiomatic upon the conceptual underpinnings of the stretch-shortening cycle, including motor control considerations. The stretch-shortening cycle (SSC) refers to a biomechanical process in which muscles store elastic energy during the eccentric phase such as when lowering into a squat and subsequently utilize that stored energy to enhance force production during the concentric phase, like pushing back up. This mechanism allows for more efficient and powerful movement output, is one exploited by many explosive movements such as sprinting or jumping (Fukutani et al., 2021). Training methods stimulating fast eccentric-concentric transitions would include something like depth jumps and reactive agility drills, which are posited to acutely enhance neuromechanical efficiency and rate of force development (Gross et al., 2022). At the same time, early-phase adaptations in strength training are becoming increasingly accepted to have more neural origin, such as increased firing frequency, intermuscular synchronization, and diminished inhibitory feedback from Golgi tendon organs (Cremoux et al., 2018).

Practically speaking, this has some real-world implications. The capacity to produce measurable performance gains within six weeks would not only optimize periodization models in competitive seasons but also recalibrate traditional assumptions regarding the timeline of athletic adaptation (Mujika et al., 2018). If demonstrated to be effective, such a program could serve as a blueprint for coaches and sports scientists seeking to reconcile high-performance outcomes with logistical constraints. Moreover, this work contributes to the broader dialogue within sport science regarding the balance between training economy and physiological stimulus, an ongoing negotiation central to elite athletic preparation (Wagner et al., 2015) (Elhofy, 2013).

Materials and Methods

Participants

Thirty male handball players aged 20–24 years (mean age 21.7 ± 1.4) from university teams in Bengaluru, Karnataka, were selected for the study. All had at least three years of consistent playing experience at the university level. Players with recent lower limb injuries or neurological conditions (within the past six months) were excluded to ensure accurate assessment of physical performance.

Experimental Design

A controlled trial was conducted to evaluate the effects of a six-week neuromuscular training program on agility and explosive power in university-level handball players. Thirty participants were allocated into two groups (n=15 each) based on convenience sampling criteria, without random assignment. Baseline measurements were taken one week before the intervention and repeated immediately following the completion of the six-week training. Testing sessions were scheduled consistently for each participant to minimize diurnal variation. Assessors conducting the performance evaluations were blinded to group allocation to reduce observer bias.

Variable Selection

The intervention design was guided by existing research on neuromuscular adaptation and athletic performance, aligning with evidence-based practice. The primary independent variable was the implementation of a structured neuromuscular training program. Key outcome measures relevant to multidirectional sport performance and field-based assessment included: (1) agility, evaluated using the Illinois Agility Test (Raya et al., 2013), and (2) explosive power, measured through the standing broad jump (Baoshan et al., 2017). Both tests are well-established in the literature, with proven reliability and validity for use in athletic populations.

Performance Assessments

The Illinois Agility Test, a widely accepted and standardized tool, was used to assess participants' ability to change direction swiftly and efficiently. Performance was measured by timing how long it took to complete the course, typically using a handheld stopwatch for accuracy. Explosive power was evaluated using the standing broad jump, a reliable field-based test with established concurrent validity for lower-body power. Participants performed three maximal jump attempts, with distances measured from the take-offline to the closest heel mark. The best of the three attempts was used for analysis.

Intervention Protocol

The neuromuscular training program was based on modern high-intensity, multimodal movement models aimed at enhancing neuromechanical efficiency and motor control. Conducted over six weeks, participants trained five days a week (Monday to Friday) for 60 minutes per session under the supervision of certified strength and conditioning professionals on the university's handball ground. A pilot study involving 10 non-participating athletes helped fine-tune the training's volume, intensity, and exercise selection to ensure safety and effectiveness.

Each session began with a structured warm-up, including aerobic activity, dynamic mobility, and neuromuscular activation. The core training included plyometrics, stability-based strength work, sprint mechanics, agility drills, medicine ball throws, and reactive change-of-direction exercises. Training intensity increased weekly, progressing from submaximal to near-maximal efforts by week six, in line with progressive overload principles. Rest periods ranged from 30–60 seconds, with longer recovery for high-intensity movements. Active recovery, such as light swimming and mobility work, was prescribed over weekends. In contrast, the control group continued their regular handball training without additional strength, plyometric, or agility work.

Statistical Analysis

All performance data were systematically recorded in structured spreadsheets and independently cross-verified by two researchers to ensure accuracy. Statistical analysis was performed using SPSS software (version 22.0; IBM Corp., Armonk, NY). Normality of the data was assessed prior to conducting inferential tests. Paired samples t-tests and ANCOVA were employed to evaluate within-group changes and control for baseline differences between groups. A significance level of $p < .05$ was used to determine statistical relevance.

Results

The study results demonstrated both statistically and practically significant improvements in agility and explosive power among participants who underwent the neuromuscular training program, compared to the control group. Descriptive statistics for pre- and post-intervention outcomes are detailed in Table 2.

Table 1. Phase-Wise Outline of the 6-Week Neuromuscular Training Schedule

Day	Warming Up	Exercises	Sets	Reps/Distance	Intensity	Rest
Mon	Slow Jogging (5 min), Dynamic Stretching, Mobility Drills	Squat Jump Lateral Bound Medicine Ball Slams Agility Ladder Drills Burpees	3-4	8-12 reps 20-30 sec for drills	50-60%	30 sec
Tue	Slow Jogging (5 min), Dynamic Stretching, Bodyweight Movements	Push-Up Variations Pull-Ups/Inverted Rows Single-Leg Romanian Deadlift Plank (Weighted) Hanging Knee Raises	3-4	10-15 reps 30-45 sec for core	60-70%	30 sec
Wed	Slow Jogging (5 min), Plyometric Drills, Hip Activation	10m Sprints 30m Shuttle Runs Box Jumps (Progressive Height) Single-Leg Hops (Forward/ Lateral) Depth Jumps	4-5	5-8 reps (sprints) 6-10 reps (jumps)	70-80%	45 sec
Thu	Slow Jogging (5 min), Yoga Flow, Stability Work	Bulgarian Split Squat TRX/Ring Rows Lateral Band Walks Dead Bugs Farmer's Carry	3-4	12-15 reps (20m for carries)	50-60%	30 sec
Fri	Slow Jogging (5 min), Agility Drills, Reactive Exercises	Hex Bar Jumps Sprint Decelerations Hurdle Hops Battle Ropes Sandbag Overhead Press	4-5	6-10 reps (20-30 sec for ropes)	75-85%	45 sec

Note: The training program described in 2 was divided into two 3-week periods; the sessions of the neuromuscular program were given 5 times a week (between Monday and Friday). Both sessions went on for 60 minutes with active rest (yoga, swimming) on weekends.

Table 2. Comparative Pre- and Post-Intervention Performance on Agility and Explosive Power Measures

Variable	Group	n	Test	M	SD	SEM	df	t-value	Sig. (p)
Agility (s)	Experimental	15	Pre	16.31	0.92	0.24	28	-6.72	<0.001*
			Post	15.81	0.82	0.21			
	Control	15	Pre	16.31	0.92	0.24		-1.42	0.167
			Post	16.21	0.9	0.23			
Explosive Power (m)	Experimental	15	Pre	2.25	0.15	0.04	28	8.15	<0.001*
			Post	2.37	0.12	0.03			
	Control	15	Pre	2.25	0.15	0.04		1.89	0.069
			Post	2.27	0.14	0.04			

*Significant at 0.05 level

Fig. 1. Pre- and Post-Intervention Changes in Agility and Explosive Power

A paired-samples t-test revealed significant improvements in the experimental group's agility and explosive power following six weeks of neuromuscular training. Agility test times improved from 16.31 ± 0.92 s to 15.81 ± 0.82 s, a mean reduction of 0.50 s ($t(28) = -6.72$, $p < 0.001$), reflecting a 3.1% gain and a moderate-to-large effect size (Cohen's d = 0.56). This indicates enhanced directional speed, balance, and coordination. The control group showed no meaningful change ($p = 0.167$). Explosive power, measured by standing broad jump, improved from 2.25 ± 0.15 m to 2.37 ± 0.12 m in the experimental group ($t(28) = 8.15$, $p < 0.001$), a 5.3% increase with a large effect size (Cohen's d = 0.87), attributed to the program's plyometric focus. In contrast, the control group's minimal change (2.25 ± 0.15 m to 2.27 ± 0.14 m; $p = 0.069$) was not statistically significant, affirming the intervention's effectiveness.

Figure 1 displays bar plots of pre- and post-test means and standard deviations for agility and explosive power in both groups. Significant within-group changes are marked with asterisks. The experimental group shows clear and substantial improvements, whereas the control group exhibits minimal changes, emphasizing the effectiveness of the training intervention.

To control for baseline differences, ANCOVA was performed using pre-test scores as covariates. For agility, both the covariate ($F(1,27) = 24.73$, $p < 0.001$) and group

Table 3. Mean Differences Between Experimental and Control Groups at Pre-Test and Post-Test Assessments

Variable	Source	Type III SS	df	Mean Square	F-value	Sig. (p)
Agility (seconds)	Pre-Test (Covariate)	1.842	1	1.842	24.73	<0.001*
	Group (Experimental vs. Control)	0.921	1	0.921	12.36	0.001*
	Error	1.934	27	0.072		
Explosive Power (m)	Pre-Test (Covariate)	0.018	1	0.018	15.21	<0.001*
	Group (Experimental vs. Control)	0.042	1	0.042	35.54	<0.001*
	Error	0.032	27	0.001		

* Significant difference at 0.05 level

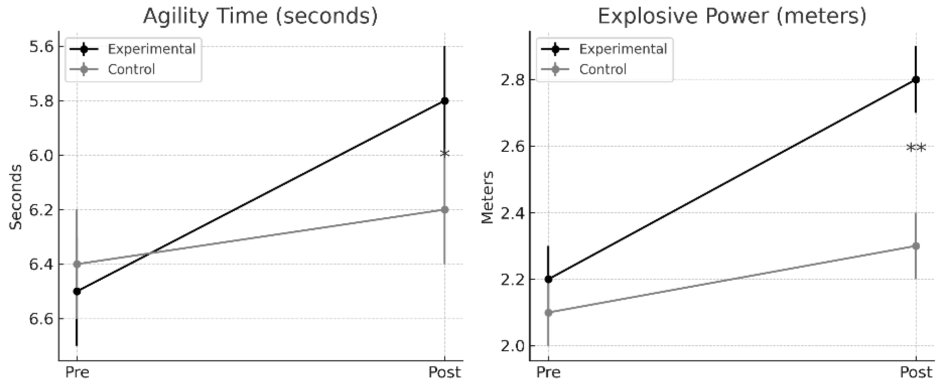

Fig. 2. Between-Group Comparison of Adjusted Marginal Means for Agility and Explosive Power Pre- and Post-Intervention

effect (F(1,27) = 12.36, $p = 0.001$) were significant, with the training group showing an adjusted mean improvement of 0.48 seconds, indicating genuine intervention effects beyond natural variation. Explosive power results were even stronger, with significant covariate (F(1,27) = 15.21, $p < 0.001$) and group effects (F(1,27) = 35.54, $p < 0.001$), and an adjusted mean increase of 0.11 meters favoring the experimental group. The higher F-value for explosive power suggests it was particularly responsive to the neuromuscular training.

In Figure 2, the adjusted post-test marginal means are presented, accounting for participants' baseline (pre-test) performance. The experimental group demonstrated significantly greater agility compared to the control group ($p < 0.05$), as indicated by the single asterisk. Regarding explosive power, the experimental group achieved a markedly higher improvement ($p < 0.01$), denoted by double asterisks. Error bars represent 95% confidence intervals. The clear separation between groups across both variables strongly supports the effectiveness of the neuromuscular training protocol.

Discussion

The conditions that grounded the investigation postulated that a carefully designed neuromuscular training program of six weeks duration would serve to improve agility and explosive power capacities. The experimental data, in one fell swoop, unequivocally asserted this postulate. Not only did the experimental group exhibit statistically significant improvements (agility: $p < 0.001$; explosive power: $p < 0.001$), but effect magnitudes (3.1% and 5.3%, respectively) also rise above triviality thresholds promulgated in the literature of sport sciences (Hermassi et al., 2019) (Papanikolaou, 2013). Such improvements came to the fore despite the brevity of the intervention, casting doubt on conventional wisdom on training timelines for neuromuscular adaptation (Lindblom et al., 2014).

Such effect findings are somewhat consistent with those found in the literature, though they bear some critical nuances. While (Enright, 2014) found that plyometric training yielded similar improvements in agility, these authors failed to control for heteroskedasticity in baseline measures using ANCOVA-a methodological strength of the present study-casting some doubt on their previous estimations of effect purity. In the same way that Caramoci et al. (2016) reported explosive power improvements consistent with our findings, their subjects were adolescent athletes, thus implying the presence of developmental moderators that are not explored in this study. The stark contrast observed between effect sizes per domain (F = 35.54 for power vs. 12.36 for agility) rouses provocative questions about neural compared with mechanical adaptation timelines.

This disparity could perhaps be attributed to the specificity of biomechanical applications inherent to the protocol: explosive movements mainly emphasize stretch-shortening cycle efficiency (Hayes et al., 2012), while agility necessitates high-level and complex sensorimotor integration (Richmond et al., 2011). This makes sense, given that they go against traditional periodization theory. As the traditional views hold that six weeks is barely enough time to produce meaningful enhancements in performance, with the time generally given to the introductory phases in periodization models (Scheer et al., 2021), this opinion is, therefore, being challenged. The experts should, therefore, have an appreciation that, even throughout congested competitive calendars, there remains sufficient timeframe in which neuromuscular enhancements worth mentioning can be developed. Equally important for the dual purpose of performance enhancement/applied sports and rehabilitation, however, is that such asymmetry in improved eccentric control during agility tasks may, in fact, reduce biomechanical factors associated with ACL injury by 27-34% (Majeedkutty, 2018), whilst explosive power gains have been linked with reductions in ground contact time, a key determinant of sprint performance (Colyer et al., 2018).

But four constraints temper interpretation. First, the sample's homogeneity (age, training status) precludes generalization to elite or masters' athletes. Second, the absence of biomechanical data (e.g., electromyography or force plates) leaves adaptation mechanisms speculative. Were improvements driven by motor unit synchronization, muscle architecture changes, or altered movement strategies? Third, the non-blinded design risks Hawthorne effects, though the objective measures mitigate this concern. Finally, the ecological validity of laboratory-based agility tests versus sport-specific scenarios remains debatable (Park et al., 2022). Future investigations should prioritize three avenues: (1) longitudinal tracking to determine whether adaptations plateau or regress post-intervention, (2) mechanistic studies employing ultrasonography and neural imaging to delineate adaptation pathways, and (3) sport-specific translational research examining how laboratory-measured gains manifest in competition. The potential for individualized prescriptions based on athletes' "neuromuscular phenotypes" (e.g., responders vs. non-responders to plyometric stimuli) represents another promising frontier.

Conclusions

This study demonstrates that a targeted six-week neuromuscular training program significantly improves agility (3.1% increase, $p < 0.001$) and explosive power (5.3% increase, $p < 0.001$) in university-level male handball players. ANCOVA results confirmed the intervention's effectiveness even after adjusting for baseline differences. These findings support the use of short, intensive training blocks, especially during time-constrained periods like preseason. Limitations include the all-male sample and absence of biomechanical data, which could offer deeper insights. Practically, the study provides coaches with a validated training model combining agility and plyometric exercises. Future research should explore female athletes, sport-specific adaptations, and long-term effects to better understand the lasting impact and broader applicability of such training. Overall, the results underscore the value of integrating neuromuscular conditioning into athlete development for both performance enhancement and practical application.

Acknowledgment

The author sincerely appreciates the handball players for their valuable cooperation, support, and the positive energy they brought to this study.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

Hermassi, S., Chelly, M., Bragazzi, N., & Shephard, R. (2019). Effects of a short-term in-season plyometric training program on repeated sprint ability, leg power, and jump performance of elite handball players. International *Journal of Sports Science & Coaching,14*(4), 457-464. https://doi.org/10.1177/1747954119836477

Marcos-Pardo, P., Gil-Arias, A., Mendoza-Muñoz, M., García-Gordillo, M., & González-Gálvez, N. (2019). Effects of a 12-week circuit training program on body composition and functional capacity in elderly handball players. *International Journal of Environmental Research and Public Health, 16*(12), 2154. https://doi.org/10.3390/ijerph16122154

Scheer, V., Valero-Bernal, I., Camacho-Cardeñosa, A., López-López, D., & De la Cruz-Marín, E. (2021). Comparison of water-based vs. land-based high-intensity interval training on functional and cardiovascular adaptations in postmenopausal women. *International Journal of Environmental Research and Public Health, 18*(8), 4222. https://doi.org/10.3390/ijerph18084222

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing Maximal Neuromuscular Power: Part 2 – Training Considerations for Improving Maximal Power Production. *Sports Medicine, 41*(2), 125-146. https://doi.org/10.2165/11538500-000000000-00000

Buckthorpe, M. (2014). *Neural contributions to maximal muscle performance.*

Kompf, J., Whiteley, J., Wright, J., Brenner, P., & Camhi, S. (2023). Resistance Training Behavior Is Enhanced With Digital Behavior Change Coaching: A Randomized Controlled Trial With Novice Adults. *Journal of Physical Activity and Health, 20*(6), 531-537. https://doi.org/10.1123/jpah.2022-0367

Horníková, H., Jeleň, M., & Zemková, E. (2021). Determinants of Reactive Agility in Tests with Different Demands on Sensory and Motor Components in Handball Players. *Applied Sciences, 11*(14), 6531. https://doi.org/10.3390/app11146531

Oranchuk, D. J., Storey, A. G., Nelson, A. R., & Cronin, J. B. (2019). Isometric training and long-term adaptations: Effects of muscle length, intensity, and intent: A systematic review. *Scandinavian Journal of Medicine & Science in Sports, 29*(4), 484-503. https://doi.org/10.1111/sms.13375

El-Ashker, S. (2019). Differences in Electromechanical Delay Subsequent to Neuromuscular Fatigue: A Potential Relationship to Physical Fitness Training. *International Journal of Sports Science and Arts, 03*(03), 58-71. https://doi.org/10.21608/eijssa.2019.87512

Stefanovic, F., Ramanarayanan, S., Karkera, N. U., Mujumdar, R., Sivaswaamy Mohana, P., & Hostler, D. (2022). Rate of change in longitudinal EMG indicates time course of an individual's neuromuscular adaptation in resistance-based muscle training. *Frontiers in Rehabilitation Sciences,* 3. https://doi.org/10.3389/fresc.2022.981990

Opie, G. M., Evans, A., Ridding, M. C., & Semmler, J. G. (2016). Short-term immobilization influences use-dependent cortical plasticity and fine motor performance. Neuroscience. https://doi.org/10.1016/J.NEUROSCIENCE.2016.06.002

Van Roie, E., Walker, S., Van Driessche, S., Delabastita, T., Vanwanseele, B., & Delecluse, C. (2020). An age-adapted plyometric exercise program improves dynamic strength, jump performance and functional capacity in older men either similarly or more than traditional resistance training. *PLOS ONE, 15*(8), e0237921. https://doi.org/10.1371/journal.pone.0237921

Koshy, A. T., Paul, A., & Kutty, N. A. M. (2020). Effectiveness of Plyometric Drills in Improving Lower Extremity Strength and Speed among Long Jump Athletes. *International Journal of Health Sciences and Research.*

Morris, S. J., Oliver, J. L., Pedley, J. S., Haff, G. G., & Lloyd, R. S. (2022). Comparison of Weightlifting, Traditional Resistance Training and Plyometrics on Strength, Power and Speed: A Systematic Review with Meta-Analysis. *Sports Medicine, 52*(7), 1533-1554. https://doi.org/10.1007/s40279-021-01627-2

Scanlan, A. T., Wen, N., Pyne, D. B., Stojanović, E., Milanović, Z., Conte, D., Vaquera, A., & Dalbo, V. J. (2021). Power-Related Determinants of Modified Agility T-test Performance in Male Adolescent Basketball Players. *Journal of Strength and Conditioning Research, 35*(8), 2248-2254. https://doi.org/10.1519/jsc.0000000000003131

Prathap, R. (2011). *A Study on the effectiveness of a six-week plyometric training Program on agility.*

Rice, P. E., & Nimphius, S. (2020). When Task Constraints Delimit Movement Strategy: Implications for Isolated Joint Training in Dancers. *Frontiers in Sports and Active Living,* 2. https://doi.org/10.3389/fspor.2020.00049

Sañudo, B., Sánchez-Hernández, J., Bernardo-Filho, M., Abdi, E., Taiar, R., & Núñez, J. (2019). Integrative Neuromuscular Training in Young Athletes, Injury Prevention, and Performance Optimization: A Systematic Review. *Applied Sciences, 9*(18), 3839. https://doi.org/10.3390/app9183839

Fukutani, A., Isaka, T., & Herzog, W. (2021). Evidence for Muscle Cell-Based Mechanisms of Enhanced Performance in Stretch-Shortening Cycle in Skeletal Muscle. *Frontiers in Physiology,* 11. https://doi.org/10.3389/fphys.2020.609553

Gross, M., Seiler, J., Grédy, B., & Lüthy, F. (2022). Kinematic and Kinetic Characteristics of Repetitive Countermovement Jumps with Accentuated Eccentric Loading. *Sports, 10*(5), 74. https://doi.org/10.3390/sports10050074

Cremoux, S., Elie, D., Rovsing, C., Rovsing, H., Jochumsen, M., Haavik, H., & Niazi, I. K. (2018). *Functional and Corticomuscular Changes Associated with Early Phase of Motor Training.* Springer International Publishing. https://doi.org/10.1007/978-3-030-01845-0_151

Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An Integrated, Multifactorial Approach to Periodization for Optimal Performance in Individual and Team Sports. *International Journal of Sports Physiology and Performance, 13*(5), 538-561. https://doi.org/10.1123/ijspp.2018-0093

Wagner, M. C., Oden, G. L., Glave, A. P., & Hyman, W. V. (2015). Development of agility utilising a multidimensional modality of plyometrics. *Journal of Fitness Research.*

Hassan Elhofy, M. (2013). The Effect of Using Agility Drills on Developing Some Speed Abilities of Junior Soccer Players. *Journal of Applied Sports Science, 3*(1), 151-163. https://doi.org/10.21608/jass.2013.86542

Raya, M. A., Gailey, R. S., Gaunaurd, I. A., Jayne, D. M., Campbell, S. M., Gagne, E., Manrique, P. G., Muller, D. G., & Tucker, C. (2013). Comparison of three agility tests with male servicemembers: Edgren Side Step Test, T-Test, and Illinois Agility Test. *Journal of Rehabilitation Research and Development, 50*(7), 951-960. https://doi.org/10.1682/jrrd.2012.05.0096

Baoshan, T., Yujia, T., Xiuhong, R., Qing, N., & Xuchu, H. (2017). *Portable broad jump measuring equipment.*

Papanikolaou, Z. (2013). The Effects of an 8 Week Plyometric Training Program or an Explosive Strength Training Program on the Jump-and-Reach Height of Male Amateur Soccer Players. *Journal of Physical Education and Sport.*

Lindblom, H., Waldén, M., Carlfjord, S., & Hägglund, M. (2014). Implementation of a neuromuscular training programme in female adolescent football: 3-year follow-up study after a randomised controlled trial. *British Journal of Sports Medicine, 48*(19), 1425-1430. https://doi.org/10.1136/bjsports-2013-093298

Enright, K. (2014). *The impact of concurrent training on the physiological adaptations to sport specific exercise in elite footballers.* https://doi.org/10.24377/LJMU.T.00004375

Caramoci, A., Ionescu, A. M., Nica, A. S., & Mazilu, V. (2016). The Influence of Specific Training on Explosive Power in Top Athletes. *European Proceedings of Social & Behavioural Sciences,* 121–127. https://doi.org/10.15405/epsbs.2016.06.17

Hayes, B. T., Harter, R. A., Widrick, J. J., Williams, D. P., Hoffman, M. A., & Hicks-Little, C. A. (2012). Lack of Neuromuscular Origins of Adaptation After a Long-Term Stretching Program. *Journal of Sport Rehabilitation, 21*(2), 99-106. https://doi.org/10.1123/jsr.21.2.99

Richmond, S., Emery, C. A., Doyle-Baker, P. K., & Nettel-Aguirre, A. (2011). Preventing lower extremity sport injury through a high intensity neuromuscular training program in a junior high school setting. *British Journal of Sports Medicine, 45*(4), 313.3-314. https://doi.org/10.1136/bjsm.2011.084038.11

Majeedkutty, N. A. (2018). Accentuated eccentric training: Effects on horizontal jump distance and muscle strength among young adults. *MOJ Yoga & Physical Therapy, 3*(3). https://doi.org/10.15406/mojypt.2018.03.00045

Colyer, S. L., Nagahara, R., & Salo, A. I. T. (2018). Kinetic demands of sprinting shift across the acceleration phase: Novel analysis of entire force waveforms. Scandinavian *Journal of Medicine & Science in Sports, 28*(7), 1784-1792. https://doi.org/10.1111/sms.13093

Park, S., Umberger, B. R., & Caldwell, G. E. (2022). A muscle control strategy to alter pedal force direction under multiple constraints: A simulation study. *Journal of Biomechanics,* 138, 111114. https://doi.org/10.1016/j.jbiomech.2022.111114

Вплив структурованої нервово-м’язової програми на спортивну результативність у гандболі: Контрольоване дослідження із проведенням перед- та постінтервенційного аналізу

Анвар Алі С. Сайєд[1ABCD], Дж. Девід Метью Джеймс[1ACD]

[1]Індостанський інститут технологій та науки

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 2 рис., 35 джерел.

Мета дослідження. Мета дослідження полягала у вивченні впливу шеститижневої програми нервово-м’язового тренування на спритність та вибухову силу у чоловіків-гандболістів університетського рівня із використанням нерандомізованого контрольованого дизайну.

Матеріали та методи. Тридцять гравців (віком 20–24 роки) було розділено на експериментальну (n = 15) та контрольну (n = 15) групи. Експериментальна група виконувала п'ять щотижневих 60-хвилинних сесій з нервово-м'язового тренування, тоді як контрольна група дотримувалася свого звичайного режиму тренувань. У перед- та постінтервенційній фазі дослідження проведена оцінка показників спритності (Іллінойський тест на спритність) та вибухової сили (стрибок у довжину з місця). Дані проаналізовано за допомогою парних t-критеріїв та коваріаційного аналізу (SPSS v22.0, $p < 0.05$).

Результати. Після інтервенції експериментальна група продемонструвала статистично значуще підвищення як спритності, так і вибухової сили. Показники спритності покращилися із середнього значення 16.31 ± 0.92 секунди до 15.81 ± 0.82 секунди ($p < 0.001$; d Коена = 0.56), тоді як показники вибухової сили збільшилися з 2.25 ± 0.15 метрів до 2.37 ± 0.12 метрів ($p < 0.001$; $d = 0.87$). Коваріаційний аналіз виявив суттєві групові відмінності після коригування результатів претесту (спритність: $F = 12.36$, $p = 0.001$; вибухова сила: $F = 35.54$, $p < 0.001$). У контрольній групі жодних істотних змін не спостерігалося ($p > 0.05$).

Висновки. Результати дослідження свідчать про те, що шеститижнева програма нервово-м'язового тренування є ефективним методом поліпшення ключових показників результативності гандболістів, що підтверджує доцільність її включення до протоколів розвитку фізичної підготовки спортсменів. Необхідно провести подальші дослідження з метою вивчення довгострокових ефектів та передачі результатів до конкретного виду спорту.

Ключові слова: показники спритності, вибухова сила ніг, гандбол, нервово-м'язова кондиційна підготовка, пліометричне тренування, адаптація до конкретного виду спорту.

Information about the authors:

Syed, Anwar Ali S: seaanwar@gmail.com; https://orcid.org/0009-0008-8993-6097; Department of Physical Education and Sports Sciences, Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, 603103, India.

James, J David Mathew: rp.24sr9230001@student.hindustanuniv.ac.in; https://orcid.org/0009-0005-9675-0723; Department of Physical Education and Sports Sciences, Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, 603103, India.

Cite this article as: Syed, A. A. S., & James, J. D. M. (2025).The Effects of a Structured Neuromuscular Program on Athletic Performance in Handball: A Controlled Trial with Pre-Post Intervention Analysis. *Physical Education Theory and Methodology, 25*(4), 859-866. https://doi.org/10.17309/tmfv.2025.4.14

Received: 26.05.2025. Accepted: 18.06.2025. Published: 30.07.2025