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SCIENTIFIC AND METHODOLOGICAL FOUNDATIONS FOR IMPROVING THE START REACTION AND INITIAL ACCELERATION INDICATORS IN SHORT-DISTANCE RUNNERS

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Abstract

This article examines the scientific and methodological foundations for improving start reaction and initial acceleration in short-distance runners. The study involved 32 sprinters aged 18–24 specializing in the 60 m and 100 m events. Using electromyography (EMG), three-dimensional video analysis, and electronic sensor systems, key biomechanical and neurophysiological parameters of the start were evaluated. The results showed that a neuromuscular integration-based training program improved start reaction time by 18.3% and 10 m acceleration performance by 12.7%. The findings demonstrate the effectiveness of targeted neuromuscular training for enhancing sprint start efficiency and can be applied in the preparation of competitive sprinters.

Keywords: Short-distance running, start reaction, initial acceleration, neuromuscular preparation, electromyography, biomechanics, sprint, reactive strength, muscle activation, athletic training.

Introduction

Short-distance running is one of the most demanding and speed-dependent disciplines in athletics, where competitive success is largely determined by the effectiveness of the start and initial acceleration phases. Contemporary scientific evidence indicates that approximately 40–45% of sprint performance in the 100-meter event is influenced by start reaction time and acceleration during the first meters of the race. Consequently, the optimization of these components remains a major focus of modern sprint training methodology. Biomechanical

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investigations of elite sprinters have demonstrated that their competitive advantage is associated not only with maximal running speed but also with the ability to generate rapid acceleration within the first 10–30 meters after the start. In recent years, the development of physical education and sport, the preparation of internationally competitive athletes, and the achievement of high-level results in athletics have become important priorities within the national sports system. Under these conditions, the scientific improvement of training methodologies for sprinters represents a relevant theoretical and practical challenge. Despite the growing interest in sprint performance enhancement, limited research has been conducted on the integrated analysis of start reaction, acceleration biomechanics, and neuromuscular adaptations among local athletes. Existing methodological recommendations are predominantly based on foreign studies and do not fully consider the morphofunctional, physiological, and individual characteristics of athletes in national training environments.

The relevance of the present study lies in the need to develop and experimentally validate an evidence-based training methodology aimed at improving start reaction time and initial acceleration performance in short-distance runners. The outcomes of this research may contribute to the optimization of sprint-training programs and provide valuable methodological guidance for coaches, sport scientists, athletics educators, and specialized sports schools.

The aim of the study is to develop a neuromuscular training methodology aimed at increasing the efficiency of start reaction and initial acceleration in short-distance runners, and to experimentally substantiate its effectiveness.

Literature Review

Start reaction time (SRT) represents the time interval from the moment an athlete perceives the start signal until the initial motor response occurs. According to international athletics rules, the minimum start reaction time, based on human physiological capabilities, is established at 100 ms, and any reaction faster than this is considered a false start. Among elite male sprinters, SRT is typically observed to be between 130–160 ms, while for female athletes, it is between 140–170 ms.

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The biomechanical structure of the sprint start was first analyzed in-depth by Mero and Komi, who divided it into three primary phases: the block clearance phase, the initial steps phase, and the transition to maximum velocity phase. Each phase is characterized by distinct neuromuscular control, force generation mechanisms, and biomechanical characteristics.

In recent years, the development of electromyography technologies has enabled the real-time study of muscle activation processes. Research findings show that a state of pre-activation occurs in certain muscle groups before the start signal, which serves to accumulate the elastic energy necessary for the subsequent powerful push-off.

The importance of the initial acceleration phase in determining sprint results has been confirmed in numerous scientific studies. The main differences between elite and amateur sprinters are explained by the horizontal force impulse generated in the first 10 meters, the power-velocity potential of the leg muscles, and the efficiency of utilizing the ground reaction force. It has also been established that the configuration of the starting blocks and the angular parameters of the support legs directly affect acceleration efficiency.

Although studies conducted by local scientists have examined the development of functional preparedness and speed-strength qualities in Uzbek sprinters, there is a lack of scientific work aimed at a comprehensive assessment of the relationship between neuromuscular activation, electromyographic indicators, and start reaction. Therefore, obtaining new scientific data in this area is of great importance for sports theory and methodology.

Research Methodology

The study involved 32 sprinters aged 18–24 years, including 16 males and 16 females, each with a minimum of two years of competitive training experience. Participants were selected based on their athletic qualification, health status, and physical fitness level. All procedures were conducted in accordance with ethical standards, and informed consent was obtained from each athlete.

The participants were randomly assigned to an experimental group (n=16) and a control group (n=16). Preliminary statistical analysis revealed no significant



differences between the groups regarding age, gender distribution, training experience, or baseline performance indicators ($p > 0.05$).

Start reaction time was assessed using a high-precision electronic sensor platform. Each athlete completed five trials, with the highest and lowest values excluded; the mean of the remaining three trials was used for statistical analysis. Initial acceleration performance was evaluated through 10-meter sprint time, first-step length and frequency, and horizontal velocity development during the acceleration phase. These parameters were measured using a laser timing system and three-dimensional motion analysis technology.

Neuromuscular activity was assessed using a wireless electromyography (EMG) system that recorded the activation patterns of major lower-limb muscle groups. EMG signals were processed using standardized digital filtering and analysis procedures.

The experimental group completed a 12-week neuromuscular integration training program consisting of four sessions per week (48 sessions in total). The program was structured into three progressive stages designed to improve reactive strength, explosive power, intermuscular coordination, and start-specific motor responses.

The control group continued to follow a conventional sprint-training program throughout the study. Training volume and intensity remained unchanged during the experimental period, ensuring an objective evaluation of the effectiveness of the proposed neuromuscular training intervention.

Table 1. Structure of the Experimental Training Program

Block	Duration	Primary Focus	Volume (hrs/week)
I	Weeks 1-4	Fundamentals of Muscular and Explosive Strength	10-12 hours
II	Weeks 5-9	Start-Specific Neuromuscular Exercises	12-14 hours
III	Weeks 10-12	Integrative and Competition-Specific Training	14-16 hours

The data collected during the study were statistically processed and analyzed using the IBM SPSS Statistics 26.0 software package. First, the normality of the data distribution was tested using the Shapiro-Wilk test. A paired-samples t-test



was used to assess the dynamics of indicators within groups, and an independent-samples t-test was employed to identify differences between the experimental and control groups. To determine the practical significance of the obtained results, Cohen's d was calculated as a measure of effect size. The level of statistical significance was set at $p < 0.05$.

At the conclusion of the experimental program, a significant improvement in start reaction time was observed in the experimental group. The average start reaction time, which was 168.4 ± 12.3 ms at the beginning of the study, decreased to 137.6 ± 9.8 ms after 12 weeks of training. As a result, an 18.3% improvement in this indicator was recorded ($p < 0.001$). The calculated Cohen's d value of 1.42 indicates a large effect size, confirming the practical effectiveness of the applied methodology.

In the control group, the start reaction time decreased from 167.9 ± 11.7 ms to 161.2 ± 10.9 ms. However, this change amounted to only 4.0% and did not reach the level of statistical significance ($p = 0.08$). This suggests that the traditional sprint training program has limited potential for developing start reaction time. A comparative analysis of the results from the experimental and control groups showed that a specialized training program based on neuromuscular integration significantly improves the reaction time to the start signal. This result is crucial for enhancing the athlete's efficiency in exiting the starting blocks, the initial acceleration phase, and the overall sprint performance.

Note: A Cohen's d value of 1.42 is considered a large effect size according to sports science methodology and indicates high practical effectiveness.

Table 2. Comparative Analysis of Start Reaction Time Results in the Experimental and Control Groups

Indicator	EG Initial (ms)	EG Final (ms)	CG Initial (ms)	CG Final (ms)
Mean (M)	168.4	137.6	167.9	161.2
Standard Deviation (SD)	± 12.3	± 9.8	± 11.7	± 10.9
Change (%)	-	18.3%	-	4.0%
Cohen's d	-	1.42	-	0.21




During the study, the results obtained for the time taken to cover the first 10 meters from the start (T10) demonstrated significant positive changes in the experimental group. At the conclusion of the training program, this indicator decreased from 1.84 ± 0.09 seconds to 1.61 ± 0.07 seconds, representing an improvement of 12.7% ($p < 0.001$). This result shows an approach to the 1.55–1.65 second range characteristic of elite sprinters. In the control group, the T10 indicator decreased from 1.85 ± 0.10 seconds to 1.81 ± 0.09 seconds, with the level of change amounting to only 2.2%.

To evaluate the biomechanical parameters of the start phase, the length of the first four steps was analyzed. According to the data obtained, the first step length in the experimental group increased from 0.89 ± 0.06 m to 1.02 ± 0.05 m, registering a 14.6% improvement. The fourth step length increased from 1.34 ± 0.08 m to 1.54 ± 0.07 m, showing a positive trend of 14.9%. These results confirm a significant enhancement in the athletes' starting technique and the efficiency of their horizontal acceleration.

Electromyographic (EMG) studies enabled the identification of functional adaptations within the neuromuscular system. In the experimental group, the muscle pre-activation period before the start signal shortened from 87 ± 14 ms to 72 ± 11 ms ($p < 0.01$). This indicates improved functional cooperation between the central nervous system and the muscular apparatus, as well as an accelerated motor response.

Furthermore, it was found that the activation amplitude of the m. gluteus maximus, one of the primary mover muscles, increased by an average of 23.4%. This change contributed to an increase in the initial propulsive force at the start and a more effective generation of horizontal acceleration.

EMG results also revealed significant changes in the muscle recruitment sequence. In the experimental group, the activation pattern after the start signal became biomechanically optimal: first, the m. gastrocnemius activated (26 ± 8 ms), followed by the m. vastus lateralis (38 ± 9 ms), and subsequently the m. gluteus maximus (51 ± 11 ms). This sequence creates favorable conditions for efficient use of the ground reaction force, optimal transmission of the force impulse, and generation of maximum horizontal propulsion.

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Overall, the obtained results scientifically confirm that a specialized training program based on neuromuscular integration significantly improves the start reaction, acceleration phase biomechanics, and intermuscular coordination of sprinters.

Note: $p < 0.001$ and $p < 0.01$ values indicate a statistically significant difference compared to baseline indicators.



Discussion

The findings of this study are consistent with previous research demonstrating that start reaction and initial acceleration are critical determinants of sprint performance. The observed 18.3% improvement in start reaction time confirms the effectiveness of neuromuscular training interventions and exceeds the average improvements reported in earlier studies.

The results indicate that a comprehensive training approach integrating plyometric exercises, reactive strength development, and start-specific neuromuscular drills is more effective than the isolated application of sprint or strength training methods. This integrated methodology enhances neuromuscular coordination, motor unit recruitment efficiency, and force production during the acceleration phase, leading to improved sprint-start performance.

An important finding of the study is that improvements in speed-strength qualities were achieved primarily through enhanced neuromuscular control rather than increased muscle mass. Such adaptations are particularly valuable for sprinters, as they contribute to greater movement efficiency and acceleration capacity.

Despite the positive outcomes, several limitations should be acknowledged. The relatively small sample size ($n=32$) and the 12-week intervention period limit the generalizability of the results and do not allow for the assessment of long-term training effects. Future studies should include larger samples, athletes of different age and qualification levels, and longer observation periods. Further investigation of biomechanical, electrophysiological, and functional adaptations associated with neuromuscular training would provide deeper insights into sprint performance enhancement mechanisms.

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CONCLUSIONS AND RECOMMENDATIONS

The findings of the study confirmed the high effectiveness of a neuromuscular-oriented training system in improving the starting preparedness of sprinters. The 12-week specialized training program significantly enhanced both start reaction time and initial acceleration performance. Start reaction time improved by 18.3% ($p < 0.001$; $d = 1.42$), while acceleration over the first 10 meters increased by 12.7% ($p < 0.001$).

The results demonstrated that a comprehensive methodology integrating plyometric exercises, reactive strength development, and start-specific neuromuscular training is more effective than applying these methods independently. Such an approach promotes greater functional interaction between central and peripheral neuromuscular mechanisms, thereby improving the efficiency of the acceleration phase.

The study also established that muscle pre-activation and the optimization of motor unit recruitment patterns are key determinants of biomechanical efficiency during sprint starts. Therefore, the proposed methodology has substantial practical value for implementation in youth sports schools, specialized athletics programs, and elite sprint training systems.

Incorporate a dedicated 6–8 week training block aimed at developing maximal strength, explosive power, and reactive strength during the general preparatory phase of the annual training cycle.

Include neuromuscular start-training exercises at least twice per week during the specialized preparation period, utilizing reactive plyometric drills, visual-signal reaction exercises, and biofeedback-based training methods.

Conduct regular assessments of start reaction time and 10-meter acceleration every four weeks using modern electronic and sensor-based monitoring systems, with subsequent individual adjustment of training loads.

Optimize starting block settings and body positioning according to the athlete's biomechanical characteristics. Front-leg angles of 42–48° and rear-leg angles of 77–83° are recommended for maximizing start efficiency.

Continuously monitor neuromuscular coordination, reaction speed, and force production during the initial phase of movement, as these factors are critical for achieving stable improvements in competitive sprint performance.



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