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Information Article

Neuromuscular and Metabolic Adaptations of Specific Conditioning on Anaerobic Speed Endurance in Deaf 400-Meter Sprinters

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ABSTRACT

This study aims to determine the effect of adapting sport-specific physical capacities on improving speed endurance and 400-meter sprint performance among deaf athletes, while evaluating the correlational strength between explosive power, speed-strength, and digital performance times.

The researcher employed an experimental design with two equivalent groups (experimental and control) comprising ($N = 12$) athletes. A dedicated physical assessment battery was administered, including the medicine ball throw test (measuring explosive power), the 30-meter bounding/hop run test (measuring speed-strength), and the 400-meter sprint performance test.

The findings demonstrated statistically significant differences favoring the post-test assessments, with the experimental group exhibiting superior outcomes across all measured variables. Strong, statistically significant correlations were confirmed between specific physical capacities, speed endurance, and 400-meter sprint achievement. The study concludes that targeted conditioning of specific physical capacities substantially enhances speed endurance and athletic achievement in 400-meter runners, underscoring the necessity of integrating specialized, directed drills into training programs to maximize competitive results.

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1. Introduction

The integration among various sports sciences (such as motor learning, athletic training, and exercise physiology) is considered one of the fundamental pillars contributing to the advancement of athletic achievement across diverse sporting disciplines. These sciences assist researchers and coaches in understanding the mechanisms underlying motor performance enhancement and elevating competitive levels. Athletic training has witnessed remarkable progression as a consequence of continuous scientific advancement, leading to the emergence of modern methodologies that have enhanced athletes' efficiency across various track and field events.

Athletics is regarded as one of the disciplines that has benefited most extensively from this development, achieving prominent records at the Arab, Asian, and international levels. This success is attributed to the adoption of training methods established on rigorous scientific foundations and the selection of appropriate exercises that contribute to developing athletes' specific physical capacities (Ayad Mohammed Abdullah et al., 2011, p. 132).

The 400-meter sprint is an event requiring a delicate equilibrium between maximum sprint velocity and speed endurance, alongside substantial reliance on the efficiency of anaerobic energy systems. Therefore, achieving advanced athletic performance in this event is linked to the degree of adaptation in specific physical capacities, particularly explosive power and speed-strength, which are developed through specific exercises based on jumping and weight training to ensure sustained, high-efficiency muscular performance throughout the race duration (Mohammed Hassan Allawi & Mohammed Nasr El-Din Radwan, 2004, p. 31). The research problem manifests in the researchers' observation of a relative decline in 400-meter sprint performance levels recently. This decline is primarily attributed to deficient adaptation in specific physical capacities, notably explosive power and speed-strength. These capacities represent the foundation for generating the requisite force for acceleration and maintaining high running velocity despite the accumulation of anaerobic fatigue.

Given that the 400-meter event relies on the sprinter's ability to operate within the domain of "speed endurance," insufficient functional adaptation of these capacities leads to performance deterioration during the final phases of the race. Furthermore, reliance on traditional, non-targeted training methods may fail to achieve the required adaptations in these capacities. This necessitates investigating the effect of specific exercises on developing these capacities and their subsequent reflection on speed endurance and digital performance time. Consequently, the research aims to achieve the following objectives:

1. Identify the adaptation level of specific physical capacities (explosive power and speed-strength) among 400-meter sprinters.
2. Determine the effect of adapting these capacities on improving speed endurance among the research sample participants.
3. Identify the relationship between specific physical capacities and the digital performance level in the 400-meter event.
4. Determine the differences between the pre- and post-tests for both groups (experimental and control) across the investigated variables.

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The researchers hypothesize the following:

- There are statistically significant differences between the pre- and post-test results for both groups (experimental and control) in the adaptation of specific physical capacities (explosive power and speed-strength), favoring the post-tests.
- There are statistically significant differences in the post-tests between the experimental and control groups in speed endurance and 400-meter performance, favoring the experimental group.
- There is a statistically significant correlation between the adaptation of specific physical capacities and speed endurance on one hand, and digital performance level on the other.

2. Research Methodology and Field Procedures

2.1Research Design

Based on the nature of the research aimed at investigating the adaptation of specific physical capacities and their effect on improving speed endurance among 400-meter sprinters, the researcher adopted the experimental method due to its appropriateness for identifying the nature of changes occurring in the physical variables under investigation. This method is considered one of the most rigorous approaches for examining causal relationships and demonstrating differences between pre- and post-measurements. To control variables and establish equivalence under experimental conditions, a two-equivalent-group design (experimental and control) was employed. The experimental group underwent targeted specific exercises designed to develop specific physical capacities, whereas the control group continued their conventional training program. This design was adopted to ensure the objectivity of the results and allow the interpretation of observed changes in light of the physical adaptations resulting from the nature of the applied training (Van Dalen, 1985, p. 33).

2.2 Research Population and Sample

The researcher selected the study sample using a purposive sampling method, comprising twelve (N-400 (12=meter deaf sprinters. The athletes were classified and registered by the Diyala Committee Supervising Athletics Events. This sample was selected due to its suitability for the nature of the research, which aims to examine the adaptation of specific physical capacities and their effect on improving speed endurance. Moreover, the participants were in a preparation and conditioning phase for upcoming competitions, allowing for accurate monitoring of their physical and functional adaptations.

2.3 Apparatus and Instruments

- Electronic stopwatches
- Electronic calculator
- SONY video recording camera
- SONY compact discs (CDs)
- Small signaling flags
- Medical weight scale
- Wooden benches (variable heights)
- 2medicine balls (2 kg each)
- -30meter measuring tape
- 12hurdles

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2.4 Pilot Study

The researcher conducted the pilot study on Saturday, November 8, 2025, on a sample of two (n (2=athletes from the Diyala Committee prior to undertaking the main experiment, with the objective of testing the research methods and measurement tools.

Table 1. Equivalence of Participants Between the Experimental and Control Groups

Variables	Control Group Mean (X(¯	Control Group SD (SD(	Experimental Group Mean (X(¯	Experimental Group SD (SD(	Calculated t-value	Significance
Height (m)	1.46	0.07	1.47	0.05	0.526	Not Significant
Age (years)	18.45	1.22	18.67	1.18	0.552	Not Significant
Weight (kg)	68.23	4.10	68.01	3.90	0.178	Not Significant
Performance (s)	52.64	0.63	55.03	0.55	1.04	Not Significant

2.5 Pre-tests

Pre-tests were administered to both the control group (which followed conventional training under their coaches) and the experimental group (which utilized the specific exercise program designed by the researcher). On Monday, November 10, 2025, explosive power was tested. On the following day, Tuesday, November 11, 2025, after allowing for complete recovery, tests for speed-strength were conducted. On November 13, 2025, the 400-meter sprint performance test was administered at 3:00 PM at the Diyala Sports Club Stadium.

The applied tests included:

- **Explosive Power Tests:**
  - Overhead medicine ball throw.
- **Speed-Strength Tests (administered following one recovery day):**
  - -30meter bounding/jump-running test.
- **Performance Test (administered following two rest days to prevent injury and muscle strain):**
  - -400meter sprint performance test.

2.6 Field Procedures and Test Protocols

Explosive Power Tests:

1. **Overhead Medicine Ball Throw (2 kg) from Standing Position (Nouri Ibrahim Al-Shawk, 1996, p. 57):**
   - *Objective:* Measure the explosive power of the arm and shoulder muscles.
   - *Instruments:* 2 kg medicine ball, measuring tape, and recording sheet.
   - *Performance Description:* The participant stands behind the starting line holding the medicine ball overhead with both hands. The participant attempts to throw the ball as far as possible without taking any forward step. Each participant is given three trials, and the best attempt is recorded.

Speed-Strength Tests:

1. **-30Meter Bounding / Jump-Running Test:**
   - *Objective:* Measure the speed-strength of the lower extremities.
   - *Instruments:* Track and field track, measuring tape, and chalk.
   - *Performance Description:* The participant stands at the starting line of the 30-meter distance. Upon receiving the visual starting signal (red flags), the

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participant bounds (jump-runs) to the end of the 30-meter mark. The total number of bounding strides is counted.

- *Scoring:* The score is recorded as the total number of bounding strides executed from the start to the finish line of the 30-meter distance.

-400Meter Sprint Performance Test:

- *Objective:* Measure performance time in the 400-meter sprint.
- *Instruments:* Track and field track, 4 electronic stopwatches, recording sheets, and a visual start flag.
- *Performance Description:* Four athletes were tested simultaneously in heats to foster a competitive environment. Upon observing the red flag visual signal, athletes commenced sprinting along the 400-meter distance, each maintaining their assigned lane. Upon crossing the finish line, the elapsed time for each athlete was recorded on their designated recording sheet.

2.7 Training Program

In accordance with ongoing scientific developments in sports training and the resulting modernization of athletic preparation methods—particularly in track and field events—the researcher designed a training program based on specific exercises aimed at inducing adaptations in specific physical capacities, specifically explosive power and speed-strength, given their direct role in enhancing speed endurance among 400-meter deaf sprinters.

The researcher established this program based on field coaching experience, consultations with experts and specialists in sports training and track and field sciences, and reputable scientific literature emphasizing progressive loading in developing specific physical capacities to achieve optimal functional and muscular adaptations.

The training program was implemented over a duration of 10 weeks, comprising 3 training sessions per week. This aligns with scientific recommendations indicating that specific strength training should range between 3 to 4 sessions weekly to ensure an optimal training response (Mufti Ibrahim Hammad, p. 87). The program focused on inducing progressive adaptation in the muscular and nervous systems to meet the demands of the 400-meter event.

The program included a total of 30 training sessions executed between November 15, 2025, and January 22, 2026. High-intensity interval training (HIIT) was employed at intensities ranging from 80% to 95%, aiming to develop speed endurance by elevating the efficiency of anaerobic energy pathways among sample participants.

Training load intensity was determined based on the actual performance difficulty of the training sessions, whereas repetitions were regulated according to intensity parameters established in modern sports training to ensure functional adaptations tailored to the performance demands of the 400-meter event for deaf athletes.

2.8 Post-tests

The researcher conducted post-tests for both experimental and control groups over two consecutive days, January 23 and 24, 2026, assessing explosive power and speed-strength. On January 27, 2026, the 400-meter sprint performance test was administered. These tests were executed following the completion of the 10-week experimental period. The researcher maintained identical conditions and requirements as the pre-tests in terms of timing, venue, and measurement apparatus.

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2.9 Statistical Analysis

Data processing and statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS).

3. Results and Discussion

3.1Presentation of Results

Table 2. Means, Standard Deviations, and Calculated and Tabulated t-values for the Control Group Post-tests

Tests	Statistical Parameters	Unit	Control		Calculated t-value	Tabulated t-value	Significance
			X(¯	SD(			
Explosive Power Tests	Medicine Ball Throw	m	9.9	0.2	5.7	3.17	Significant
Speed-Strength Tests	30m Bounding	m	11.1	0.7	4.3	3.17	Significant
Performance	400m Sprint Performance	Time (s)	54.9	1.6	3.40	3.17	Significant

Note: Tabulated t-value at degrees of freedom (df (10=and error probability (α (0.01=is.3.17

Table 3. Means, Standard Deviations, and Calculated and Tabulated t-values for the Experimental Group Post-tests

Tests	Statistical Parameters	Unit	Experimental		Calculated t-value	Tabulated t-value	Significance
			(X(¯	(SD(			
Explosive Power Tests	Medicine Ball Throw	m	12.1	0.8	5.7	3.17	Significant
Speed-Strength Tests	30m Bounding	m	9.5	0.5	4.3	3.17	Significant
Performance	400m Sprint Performance	Time (s)	52.3	0.9	3.40	3.17	Significant

Note: Tabulated t-value at degrees of freedom (df (10=and error probability (α (0.01=is.3.17

Table 4. Comparison of Post-test Means and t-test Values Between the Experimental and Control Groups

Tests	Unit	Experimental Group Mean (X(¯	Control Group Mean (X(¯	Calculated t-value	Significance
Medicine Ball Throw	m	12.1	9.9	5.7	Significant
30m Bounding	m	9.5	11.1	4.3	Significant
400m Performance	Time (s)	52.3	54.9	3.40	Significant

Note: Tabulated t-value at degrees of freedom (df (10=and significance level (α (0.01=is.3.17

Table 5. Correlation Coefficients, Significance Values, and Types of Relationships Among Study Variables

No.	Correlated Variables	Correlation Coefficient (r(	Significance Value (p(	Type of Relationship
1	Explosive Power (Legs) and 400m Performance	0.82-	0.01	Strong Inverse Correlation
2	Explosive Power (Arms) and 400m Performance	0.78-	0.02	Strong Inverse Correlation
3	Speed-Strength and 400m Performance	0.89-	0.00	Very Strong Inverse Correlation

Table 5 indicates statistically significant correlations between all anaerobic physical tests and digital performance in the 400-meter event. The correlation coefficients (r (reached high values ranging from 0.78− to ،0.89− which are statistically significant at p .0.05≥This confirms that the observed improvement in digital performance times was not random, but rather an outcome of the development in anaerobic capacities induced by the proposed training program.

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3.2 Discussion of Results

The pre- and post-test results of the control group demonstrated statistically significant differences in explosive power and speed-strength, alongside a noticeable improvement in 400-meter sprint performance. The researcher attributes this improvement to the sprinters' adherence and commitment to the conventional training program prepared by their coaches. This indicates that any programmed physical activity elicits specific physiological and physical adaptive responses; however, this progression remained within standard traditional limits (Al-Mandlawi et al., p. 74).

Conversely, the experimental group demonstrated clear qualitative development and substantial significant differences across all physical variables, in addition to fundamental improvements in 400-meter digital performance. The researcher attributes this superiority to the efficacy of the proposed training program, which was constructed on precise physiological foundations targeting specific adaptations in physical capacities to support speed endurance.

The implementation of specialized exercises—such as jump-running/bounding, variable-height plyometric boxes, resistance and weight training, and hurdles at varied intensities—enhanced neuromuscular coordination and established an equilibrium between both anaerobic energy systems (phosphagen and glycolytic/lactic acid), which is fundamental in the 400-meter event (Abu El-Ela Abdel-Fattah, 1997, p. 88).

Allerheiligen (2021, p. 65) emphasizes that the utilization of modern training methodologies represents a decisive factor in advancing international sports achievement, while Al-Basati (1998, p. 77) highlights the importance of progression and wave-like periodization in training loads to achieve physiological adaptation. From a technical perspective, the development of explosive power and speed-strength directly contributed to enhancing speed endurance, enabling the sprinters to distribute effort more effectively throughout the race, which is consistent with the findings of Al-Mandlawi et al. (p. 87).

.4 Conclusions and Recommendations

4.1 Conclusions

In light of the obtained results, the researcher concluded the following:

1. The application of specific exercises based on scientific and physiological principles demonstrated clear efficacy in inducing positive adaptations in specific physical capacities among experimental group participants, which was reflected in improved physical and functional performance indices.
2. The results demonstrated an inverse relationship between the development of anaerobic physical capacities and 400-meter race time (improved speed endurance index), whereby higher levels of specific physical adaptation corresponded to superior digital sprint performance.
3. The implementation of specific training modalities—such as ballistic exercises, resistance/weight training, and plyometrics—effectively contributed to developing the functional efficiency of the muscular and nervous systems, thereby enhancing sprinters' capacity to resist fatigue across different race phases.
4. The adaptations resulting from the proposed training program exerted a direct impact on elevating speed endurance by improving anaerobic energy production and sustaining mechanical output during the final stages of the sprint.

4.2 Recommendations

Based on the conclusions, the researcher recommends the following:

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1. Emphasize the adoption of training programs established on the development of specific physical capacities as a primary method for enhancing speed endurance among deaf 400-meter sprinters.
2. Adopt the anaerobic fitness assessments utilized in this study as periodic benchmark criteria to evaluate sprinters' conditioning and monitor their physical and functional progression.
3. Direct coaches toward integrating scientifically regulated speed endurance exercises within training curricula due to their effective role in improving digital performance times.
4. Focus on incorporating specific training modalities (ballistic drills, weight training, and plyometric jumps) within training regimens due to their direct effect on inducing physical adaptations and enhancing the functional efficiency of biological systems.
5. Prioritize training periodization structured on progressive loading principles to ensure optimal physiological adaptations without inducing overtraining or performance decrements.

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Appendices: Sample Training Session Plan

Table 1. Sample Training Sessions for the Fourth Week

Week	Day and Date	Training Session	Intensity	Type of Complex Exercise	Repetitions	Number of Sets	Rest: Between Repetitions	Rest: Between Sets	Rest: Between Exercises	Notes
Fourth	Saturday, 6/12/2025	10th (10)	%90	30 .1m Bounding / jump-running. 10 .2Hurdles (distance between hurdles: 1 m). .3Standing decuple jump with landing in the pit. .4Standing triple jump. .5Alternating arm and leg swings with 20 kg weight (forward). .6Alternating arm and leg swings with 32 kg weight (lateral).	4 4 4 4 4 4	2 2 2 2 2 2	130bpm = = = = =	110bpm = = = = =	90bpm = = = = =	
Fourth	Tuesday, 9/12/2025	11th (11)	%92.5	.1Hurdle jumps: 10 hurdles (distance between hurdles: 80 cm). .2Bounding / jump-running over 8 inverted hurdles. .3Alternating step-jumps onto a bench with a barbell on the back (35 kg). .4Jump half-squats with 55 kg weight. .5Weighted walking with 25 kg for 15 m. .6High-knee lifts with 35	4 4 4 4 4 4	2 2 2 2 2 2	130bpm = = = = =	110bpm = = = = =	90bpm = = = = =	

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				kg weight (10 s).						
Fourth	Thursday, 11/12/2025	12th (12)	%90	.1Single-leg hopping over inverted hurdles. .2 Bleacher/stair climbing with high knees. .3Single-leg hopping bleacher climb (right + left). .4Bounding / jump-running with 20 kg weight. .5Drop jump from a bench followed by a five-fold jump (quintuple jump) landing in the pit. .6Drop jump from a bench followed by a triple jump landing in the pit.	4 4 4 4 4	2 2 2 2 2	130bpm = = = =	110bpm = = = =	90bpm = = = =	

Note: bpm = beats per minute (heart rate recovery indicator); (=) indicates the same value as above.