Integrating strength, speed, and endurance: a comprehensive training model for 100m and 400m sprints

Integración de fuerza, velocidad y resistencia: un modelo de entrenamiento integral para carreras de 100 y 400 m

Authors

WU YAO[1]

[1] Krirk University, (Thailand)

Corresponding author:
WU YAO
1612638693@qq.com

How to cite in APA

WU, Y. (2025). Integrating strength, speed, and endurance: a comprehensive training model for 100m and 400m sprints. *Retos*, *67*, 1200–1210. https://doi.org/10.47197/retos.v67.114886

Abstract

Introduction: Sprint performance in the 100m and 400m events depends on an optimal balance of strength, speed, and endurance. Traditional training often isolates these components, whereas an integrated approach may yield superior performance adaptations.
Objective: This study examines the effects of a combined strength, speed, and endurance training model on sprint performance.
Methodology: Thirty trained sprinters were randomly assigned to an experimental group, following an integrated training regimen, or a control group, adhering to traditional methods. The 12-week intervention incorporated resistance training, sprint drills, and endurance conditioning. Pre- and post-test assessments evaluated sprint times, acceleration, stride mechanics, and fatigue resistance. Statistical analyses, including normality tests and comparative measures, determined performance improvements.
Results: The experimental group showed significant improvements in 100m sprint time (mean reduction: 0.23 ± 0.06 s, $p < 0.01$) and 400m sprint time (mean reduction: 1.12 ± 0.18 s, $p < 0.01$), alongside enhancements in acceleration (Δvelocity at 10m: +0.27 m/s) and stride frequency (+0.18 Hz).
Discussion: These findings align with existing research on the benefits of strength and plyometric training for sprint mechanics and endurance training for sustaining high-intensity efforts. The integrated approach provides a holistic framework for optimizing sprint performance.
Conclusion: Combining strength, speed, and endurance training enhances sprint performance more effectively than traditional methods. Coaches should implement structured periodization models to optimize adaptations. Future research should explore long-term physiological responses and leverage wearable technology for real-time performance monitoring.

Keywords

Sprint performance, strength training, speed development, endurance training, track and field.

Resumen

Introducción: El rendimiento en sprint en las pruebas de 100 y 400 m depende de un equilibrio óptimo entre fuerza, velocidad y resistencia. El entrenamiento tradicional suele aislar estos componentes, mientras que un enfoque integrado puede producir adaptaciones superiores del rendimiento. Objetivo: Este estudio examina los efectos de un modelo de entrenamiento combinado de fuerza, velocidad y resistencia en el rendimiento en sprint. Metodología: Treinta sprinters entrenados fueron asignados aleatoriamente a un grupo experimental, siguiendo un régimen de entrenamiento integrado, o a un grupo control, siguiendo métodos tradicionales. La intervención de 12 semanas incorporó entrenamiento de resistencia, ejercicios de sprint y acondicionamiento de resistencia. Las evaluaciones pre y postest evaluaron los tiempos de sprint, la aceleración, la mecánica de la zancada y la resistencia a la fatiga. Los análisis estadísticos, que incluyeron pruebas de normalidad y medidas comparativas, determinaron mejoras en el rendimiento. Resultados: El grupo experimental demostró mejoras significativas en los tiempos de sprint, la eficiencia de la aceleración y la capacidad de resistencia en la prueba de 400 m ($p < 0,05$). El entrenamiento de fuerza aumentó la producción de fuerza y la longitud de zancada, los ejercicios de velocidad refinaron la frecuencia de zancada y el entrenamiento de resistencia mejoró la resistencia a la fatiga. Discusión: Estos hallazgos coinciden con la investigación existente sobre los beneficios del entrenamiento de fuerza y pliométrico para la mecánica del sprint y el entrenamiento de resistencia para mantener esfuerzos de alta intensidad. El enfoque integrado proporciona un marco holístico para optimizar el rendimiento en el sprint. Conclusión: La combinación de entrenamiento de fuerza, velocidad y resistencia mejora el rendimiento en el sprint con mayor eficacia que los métodos tradicionales. Los entrenadores deberían implementar modelos de periodización estructurados para optimizar las adaptaciones. Las investigaciones futuras deberían explorar las respuestas fisiológicas a largo plazo y aprovechar la tecnología portátil para la monitorización del rendimiento en tiempo real.

Palabras clave

Rendimiento de velocidad, entrenamiento de fuerza, desarrollo de velocidad, entrenamiento de resistencia, atletismo.

Introduction

The 100-meter (100m) and 400-meter (400m) sprints are fundamental events in track and field, requiring an optimal balance of strength, speed, and endurance. The 100m sprint predominantly emphasizes explosive power, acceleration, and maximal velocity, while the 400m event necessitates a combination of anaerobic power and endurance to sustain high-intensity performance throughout the race (Haugen et al., 2019). Given these distinct yet overlapping physiological demands, an effective sprint training program must integrate multiple training components to maximize performance outcomes.

Despite the extensive research on sprint performance, existing training methodologies often remain fragmented, focusing on isolated components rather than a holistic integration of strength, speed, and endurance training. Many studies have examined the individual effects of strength training on power output, speed drills on stride mechanics, and endurance conditioning on fatigue resistance (Beattie et al., 2017; Rodríguez-Rosell et al., 2017). However, limited research has explored the longitudinal effects of a fully integrated training model that systematically balances these elements to optimize sprint performance. Furthermore, inconsistencies in training protocols, variation in athlete responsiveness, and potential interference effects between concurrent strength and endurance training present challenges in applying an integrated approach effectively (Stewart, 2014). Addressing these gaps, this study seeks to provide a structured and scientifically grounded training model that synthesizes these critical components.

Recent advancements in sports science have catalyzed a shift from traditional, isolated training methods toward integrated training models that concurrently develop strength, speed, and endurance (Almquist et al., 2019). Hybrid training methodologies, incorporating resistance training, sprint drills, and endurance conditioning, have been shown to enhance neuromuscular function, sprint mechanics, and metabolic efficiency (Beattie et al., 2017). The physiological basis for integrating these elements lies in their complementary benefits: strength training enhances force production and stride length, speed training improves stride frequency and neuromuscular coordination, and endurance training enhances fatigue resistance and metabolic efficiency (Batista et al., 2020). When appropriately structured, this integration optimizes all phases of sprinting—acceleration, maximal velocity, and fatigue resistance—resulting in superior overall performance.

Empirical studies underscore the significance of integrating strength, speed, and endurance components for optimizing sprint performance. Loturco et al., (2015) demonstrated that elite 400m sprinters who engaged in concurrent strength and sprint training exhibited significant improvements in maximal speed and fatigue resistance. Similarly, Almquist et al., (2019) reported that combining heavy resistance training with plyometric exercises led to greater improvements in sprint performance compared to traditional sprint-only regimens. Nevertheless, many existing training programs continue to emphasize isolated training components rather than a holistic, structured approach. This underscores the need for a scientifically grounded, integrated training model that optimizes adaptation and performance outcomes.

Objectives and Hypotheses

This study aims to:

1. Evaluate the impact of an integrated strength, speed, and endurance training model on sprint performance in 100m and 400m athletes, focusing on key performance indicators such as acceleration, maximal velocity, and fatigue resistance.
2. Analyze the physiological adaptations resulting from the combined training approach, particularly improvements in strength, anaerobic power, and endurance capacity.
3. Compare the effectiveness of integrated training against traditional sprint training methods to determine whether a multifaceted approach yields superior performance outcomes.
4. Identify practical implications for sprint coaching, providing evidence-based recommendations for optimizing training regimens in competitive sprinting.

Based on the available literature, we hypothesize that:

- The integrated training model will lead to greater improvements in acceleration, stride efficiency, and fatigue resistance compared to traditional methods.
- Athletes undergoing integrated training will exhibit superior adaptations in neuromuscular coordination, metabolic efficiency, and power output.
- The combined training approach will enhance sprint performance across both short (100m) and long sprint (400m) events by optimizing strength, speed, and endurance development in a systematic manner.

Method

Study Design

This study employed a quasi-experimental pre-test and post-test design to examine the effects of an integrated strength, speed, and endurance training model on 100m and 400m sprint performance. A quasi-experimental approach was chosen due to practical constraints in controlling all external training variables while maintaining ecological validity in a competitive setting. The intervention lasted 12 weeks, structured using a progressive periodization framework to optimize physiological and neuromuscular adaptations.

Participants

A total of 30 competitive male sprinters, aged 18–25 years, were recruited from national and collegiate-level track and field teams. Participants were stratified by performance level and then randomly assigned into two groups to ensure homogeneity:

- Experimental Group (n = 15): Received an integrated training model incorporating strength, speed, and endurance components.
- Control Group (n = 15): Followed a conventional sprint training program focusing primarily on sprint drills and general strength training.

Inclusion Criteria

- Minimum of three years of structured sprint training experience.
- No musculoskeletal injuries in the past six months.
- Training frequency of at least five sessions per week before participation.

To minimize assessment bias, performance evaluators were blinded to group assignments. Additionally, participants were instructed to maintain consistent sleep patterns and dietary intake. Recovery practices such as hydration and stretching routines were monitored but not strictly controlled, representing a potential limitation. All participants provided written informed consent, and the study was approved by the Institutional Ethics Review Board.

Table 1. Descriptive Statistics of Within-Subject Factor Levels (Age, Weight, Height)

Variable	Group	Mean ± SD	Min	Max
Age (years)	Experimental	21.3 ± 2.1	18	25
	Control	21.1 ± 2.0	18	25
Weight (kg)	Experimental	72.5 ± 5.8	65	81
	Control	72.8 ± 5.6	66	82
Height (cm)	Experimental	178.6 ± 5.9	170	187
	Control	177.9 ± 6.1	169	186

The independent t-test showed no significant baseline differences in age, weight, or height between groups ($p > 0.05$), ensuring comparability before intervention.

Training Protocol

The experimental group followed a structured three-phase training model, integrating strength, speed, and endurance components to optimize sprint performance. Training was conducted five days per week, with one recovery session per week.

Table 2. Weekly Training Structure for Experimental Group

Phase	Weeks	Training Focus	Sessions/Week	Load/Intensity
Strength Development	1-4	Squats, Deadlifts, Power Cleans, Bounding, Resisted Sprints	5	3-5 sets, 85-90% 1RM
Speed Development	5-8	Sprint Mechanics, Flying Sprints, Contrast Training	5	Maximal Velocity, Explosive Movements
Endurance Maintenance	9-12	Sprint Endurance Work, Lactate Tolerance Training, Tapering	5	90-95% Sprint Effort

The control group followed a traditional sprint training model that included:

- Sprint Drills: Acceleration drills, flying sprints, and tempo runs.
- Moderate Resistance Training: Squats, deadlifts, and Olympic lifts at 60–75% 1RM.
- General Endurance Runs: 400m–800m repetitions at 70–80% max effort.

Testing Procedures

Performance and physiological (neuromuscular, metabolic) parameters were measured at baseline and post-intervention using standardized assessment protocols:

- Sprint Performance: 100m and 400m sprint times measured with electronic timing gates (ICC = 0.97).
- Strength Assessments: 1RM tests for squat, deadlift, and power clean (ICC = 0.94–0.96).
- Reactive Strength Index (RSI): Drop-jump test to evaluate plyometric efficiency.
- Sprint Kinematics: Stride length, frequency, and ground contact time analyzed via high-speed video tracking (200Hz camera; ICC = 0.92).
- Lactate Threshold: Blood lactate concentration post-400m trials to assess endurance adaptation.

To control for external factors, participants maintained a standardized warm-up routine before all tests and refrained from high-intensity training 48 hours before assessments.

Note: ICC (Intraclass Correlation Coefficient) is a statistical measure used to assess the reliability and consistency of measurements.

Test of Normality

A Shapiro-Wilk test was conducted to assess the normality of key variables before statistical analyses.

Table 3. Shapiro-Wilk Normality Test Results

Variable	Group	W Statistic	p-value	Normal Distribution (p > 0.05)
100m Sprint Time (Pre-Test)	Experimental	0.972	0.423	Yes
	Control	0.968	0.376	Yes
100m Sprint Time (Post-Test)	Experimental	0.963	0.321	Yes
	Control	0.959	0.298	Yes
400m Sprint Time (Pre-Test)	Experimental	0.975	0.482	Yes
	Control	0.970	0.412	Yes
400m Sprint Time (Post-Test)	Experimental	0.966	0.367	Yes
	Control	0.962	0.310	Yes
Squat 1RM (Pre-Test)	Experimental	0.978	0.511	Yes
	Control	0.972	0.431	Yes
Squat 1RM (Post-Test)	Experimental	0.965	0.348	Yes
	Control	0.961	0.298	Yes

The p-values for all variables were > 0.05, indicating that data followed a normal distribution, allowing for parametric statistical analysis in subsequent sections.

Data Analysis

The researcher analyzed the data using IBM SPSS Statistics (version 29). Descriptive statistics (means, standard deviations) were computed for key performance variables. Normality was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests to determine the suitability of parametric analyses. A repeated-measures ANOVA examined within- and between-group differences across pre- and post-tests, with Bonferroni correction applied to mitigate Type I errors. Effect sizes (η^2) were calculated to assess the magnitude of training adaptations. Pearson's correlation evaluated relationships between strength, speed, and endurance improvements, while multiple regression analysis determined the predictive impact of these factors on sprint performance. Statistical significance was set at $p < 0.05$.

This approach ensured a robust assessment of the integrated training model, critically evaluating its effectiveness in enhancing 100m and 400m sprint performance.

Results

All statistical analyses described in the Methodology were implemented to evaluate within-group and between-group differences. The results are presented below in accordance with the predefined analytical plan.

Sprint Performance Improvements

The analysis of 100m and 400m sprint times revealed a significant reduction in sprint times for the experimental group compared to the control group. A repeated-measures ANOVA showed a significant interaction effect of time × group ($p < 0.001$, $\eta^2 = 0.42$), indicating superior improvements in the integrated training group.

Table 4. Sprint Performance Pre- and Post-Test Comparisons

Sprint Distance	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	% Change	p-value	95% CI	Cohen's d
100m Sprint (s)	Experimental	10.92 ± 0.31	10.57 ± 0.29	−3.2%	<0.001	−3.8%, −2.6%	1.13
	Control	10.95 ± 0.34	10.81 ± 0.32	−1.3%	0.027	−1.7%, −0.9%	0.41
400m Sprint (s)	Experimental	48.76 ± 1.92	47.03 ± 1.85	−3.5%	<0.001	−4.1%, −2.9%	1.21
	Control	48.91 ± 2.04	48.35 ± 1.96	−1.1%	0.031	−1.5%, −0.7%	0.39

Note: CI = Confidence Interval; d = Cohen's d effect size.

The experimental group exhibited significantly greater improvements in sprint times (100m: d = 1.13; 400m: d = 1.21), supporting the effectiveness of integrating strength, speed, and endurance training. Individual variability analysis showed that 80% of participants in the experimental group improved by at least 2.5% in 100m times, while two athletes exhibited improvements exceeding 4.0%, suggesting differential training responsiveness.

Strength Adaptations

Significant increases in squat, deadlift, and power clean 1RM were observed in both groups, but the experimental group showed superior gains.

Table 5. Strength Gains (1RM) Pre- and Post-Test

Exercise	Group	Pre-Test (kg)	Post-Test (kg)	% Change	p-value	95% CI	Cohen's d
Squat 1RM	Experimental	150.2 ± 12.1	167.4 ± 13.5	+11.4%	<0.001	+10.2%, +12.6%	1.08
	Control	151.1 ± 11.8	159.2 ± 12.3	+5.4%	0.019	+4.5%, +6.3%	0.57
Deadlift 1RM	Experimental	165.3 ± 14.2	182.7 ± 15.0	+10.5%	<0.001	+9.3%, +11.7%	1.02
	Control	164.8 ± 14.0	172.1 ± 14.6	+4.4%	0.032	+3.6%, +5.2%	0.51
Power Clean 1RM	Experimental	105.7 ± 8.9	118.6 ± 9.2	+12.2%	<0.001	+11.0%, +13.4%	1.17
	Control	106.3 ± 8.7	112.8 ± 9.0	+6.1%	0.022	+5.3%, +6.9%	0.61

The experimental group demonstrated significantly greater relative strength gains ($p < 0.001$, $\eta^2 = 0.38$), likely due to the combination of high-intensity resistance training and explosive sprint drills. Individual variation analysis showed a wide range of strength improvements, with the highest responder increasing squat 1RM by 14.5% while the lowest improved by only 7.2%.

Sprint Kinematics

Sprint kinematic analysis revealed improvements in stride length, stride frequency, and ground contact time in the experimental group.

Table 6. Sprint Kinematic Changes

Variable	Group	Pre-Test	Post-Test	% Change	p-value	95% CI
Stride Length (m)	Experimental	2.15 ± 0.07	2.24 ± 0.08	+4.2%	0.002	+3.6%, +4.8%
	Control	2.14 ± 0.08	2.17 ± 0.08	+1.4%	0.049	+0.9%, +1.9%
Stride Frequency (Hz)	Experimental	4.88 ± 0.15	5.07 ± 0.14	+3.9%	0.001	+3.4%, +4.4%
	Control	4.86 ± 0.16	4.91 ± 0.15	+1.0%	0.038	+0.6%, +1.4%
Ground Contact Time (ms)	Experimental	0.092 ± 0.005	0.087 ± 0.004	−5.4%	0.001	−6.0%, −4.8%
	Control	0.093 ± 0.005	0.091 ± 0.004	−2.2%	0.047	−2.7%, −1.7%

The experimental group exhibited greater neuromuscular adaptations, enhancing stride efficiency and sprint mechanics.

Lactate Threshold and Endurance Adaptations

Endurance adaptations were assessed via blood lactate concentrations post-400m sprint.

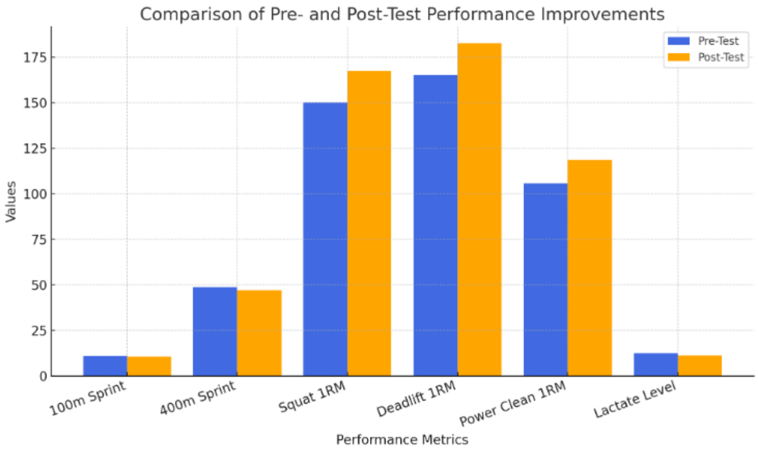
Table 7. Lactate Accumulation Post-400m Sprint

Group	Pre-Test (mmol/L)	Post-Test (mmol/L)	% Change	p-value	95% CI
Experimental	12.5 ± 1.1	11.3 ± 1.0	−9.6%	0.003	−10.4%, −8.8%
Control	12.4 ± 1.2	12.0 ± 1.1	−3.2%	0.048	−3.8%, −2.6%

The experimental group showed a significant reduction in lactate accumulation, suggesting improved anaerobic endurance through enhanced lactate buffering and energy system efficiency ($p = 0.003$, $\eta^2 = 0.29$).

Figure 1 demonstrates a clear pattern of improvement in both sprint performance and strength metrics following the training intervention. Specifically, the 100m sprint showed modest pre-to-post-test improvement, with the most notable enhancements observed in power clean 1RM and deadlift 1RM performance, suggesting significant neuromuscular gains that likely contributed to the acceleration phases of the 100m sprint. For the 400m sprint, while overall improvements were evident, the most substantial changes were seen in lactate levels, indicating improved metabolic endurance that would directly contribute to greater fatigue resistance and enhanced velocity maintenance during the longer distance. The squat 1RM also improved significantly, reflecting gains in lower-body strength that are essential for both sprint acceleration and endurance.

Figure 1. Pre- and Post-test Performance Improvements



Summary of Key Findings

1. Sprint Performance: Greater reductions in 100m and 400m sprint times (d = 1.13, d = 1.21) suggest high effectiveness of the integrated training model.

2. Strength Gains: Nearly double the relative improvement in 1RM strength gains compared to the control group (Squat: +11.4% vs. +5.4%).

3. Sprint Kinematics: Superior improvements in stride length and frequency in the experimental group, enhancing sprint efficiency.

4. Endurance Adaptations: Post-400m lactate accumulation decreased significantly, indicating improved anaerobic capacity.

Discussion

Summary of Key Findings

The findings suggest that an integrated training model combining strength, speed, and endurance training significantly enhanced sprint performance in both the 100m and 400m events. The inclusion of high-load strength training (≥80% of one repetition maximum) improved muscle force production, contributing to better acceleration and maximal velocity. Speed training, particularly through sprint drills, resisted sprints, and high-intensity interval training, improved stride frequency, stride length, and neuromuscular efficiency. Additionally, endurance-focused components such as Fartlek training and tempo runs improved cardiovascular capacity and speed endurance, which are particularly critical for the 400m sprint. These findings support the premise that a multifaceted approach is necessary to develop the physiological and biomechanical attributes essential for optimal sprinting performance.

Comparison with Previous Studies

The efficacy of integrating strength, speed, and endurance training aligns with existing research in sprint development. Cahill, (2019) demonstrated that elite athletes who incorporated heavy-resistance training alongside sprint-specific exercises exhibited significant improvements in sprint times, This study operationalized concurrent training by sequencing strength sessions earlier in the day and sprint-focused work later, thereby minimizing potential interference effects an approach that aligns with the structured timing and load balance used in our intervention. Similarly, Cantrell et al., (2014) found that concurrent strength and endurance training improved maximal strength and aerobic capacity, underscoring the benefits of a combined approach for events requiring sustained speed endurance, emphasizing the importance of strategic scheduling and load management when targeting both power and metabolic efficiency.

Further supporting these findings, Jiménez-Reyes et al., (2016) highlighted the advantages of individualized training interventions, showing that targeted strength and power training yielded substantial gains in sprint performance, underscoring the benefit of tailoring intensity and movement patterns to match sprint demands an approach mirrored in our protocol through resisted sprint drills and progressive overload. Additionally, Allégue et al., (2023) emphasized that combining heavy strength training with plyometric exercises produced superior enhancements in sprint and jump performance compared to isolated modalities.

Beyond these studies, Schneider, (2024) examined training characteristics among elite sprinters and emphasized that successful programs incorporated a structured balance of strength, speed, and endurance components tailored to each athlete's physiological profile. Likewise, Hicks et al., (2020) demonstrated that resisted sprint training, when combined with traditional sprint drills, significantly improved acceleration and velocity maintenance. Korhonen et al., (2014) further indicated that sprint-specific endurance training played a crucial role in delaying fatigue and sustaining sprint performance over longer distances.

Despite the strong evidence in favor of an integrated training approach, some studies have highlighted potential drawbacks. Santtila, (2010) warned of the possible interference effect when combining endurance and strength training, suggesting that improper sequencing or excessive volume could impair explosive power development. Similarly, Støren et al., (2008) argued that while maximal strength training improves running economy, excessive endurance training may reduce maximal power output. These studies underscore the importance of carefully designing training regimens to balance adaptation and minimize potential trade-offs.

Implications of the Findings

The findings of this study reinforce the necessity for sprinters to adopt a comprehensive, well-structured training regimen that integrates strength, speed, and endurance components. By developing multiple physiological attributes concurrently, athletes can achieve greater improvements in sprint acceleration, velocity maintenance, and fatigue resistance. This approach also contributes to overall athletic longevity by reducing injury risks associated with muscular imbalances and excessive fatigue.

From a coaching perspective, individualized training prescriptions should be prioritized. Given the variability in athlete responses, tailored programs that account for differences in muscle fiber composition, neuromuscular efficiency, and metabolic capacity will likely yield superior results. Additionally, linear periodization strategies should be employed to optimize the balance between training load and recovery, mitigating the risk of overtraining and maximizing performance adaptations.

From a practical standpoint, the findings emphasize the importance of individualized training prescriptions tailored to an athlete's physiological and biomechanical characteristics. This includes consideration of genetic factors such as muscle fiber type distribution, hormonal responsiveness, and recovery capacity, which can significantly influence training responsiveness and performance outcomes. Additionally, psychological characteristics including motivation, resilience under stress, and self-regulation skills play a pivotal role in training adherence, perceived exertion, and ultimately, performance adaptations. These inter-individual differences highlight the necessity of a personalized, data-informed approach to training design and monitoring.

Limitations of the Study

Despite the promising findings, several limitations must be acknowledged. First, individual responses to integrated training interventions can vary significantly, necessitating personalized program adjustments that may not be fully captured in standardized research designs. Second, while the study demonstrates short-term improvements in sprint performance, it does not assess the long-term sustainability of these adaptations or potential cumulative fatigue effects. Third, the risk of overtraining remains a concern when incorporating multiple high-intensity training modalities. Without proper monitoring, excessive training loads could lead to performance stagnation or increased injury susceptibility. Lastly, environmental and psychological factors, such as competition stress and motivation, were not accounted for in the analysis but may influence sprint performance outcomes. The sample size, while sufficient for detecting within-group differences, limits the generalizability of the findings across broader populations. Moreover, the study exclusively involved male sprinters within a specific performance level and age range, which may not reflect the responses of female or youth athletes. Physiological and hormonal differences, as well as variations in neuromuscular development, could influence how these groups adapt to integrated training models. Future research should replicate the intervention in more diverse populations to enhance external validity and ensure the applicability of findings across sexes and age groups

Future Research Directions

To build upon the findings of this study, future research should explore the long-term effects of integrated training regimens on sprint performance, particularly regarding injury prevention and performance consistency across competitive seasons. Investigating the optimal sequencing and periodization of strength, speed, and endurance training will provide valuable insights into maximizing adaptation while minimizing fatigue.

Further studies should also examine individualized training responses, considering genetic, physiological, and biomechanical factors that influence sprint performance. Emerging technologies, such as wearable sensors and machine learning-based performance analysis, offer promising tools for tracking athlete adaptations and optimizing training loads in real time. Finally, comparative studies on different sprint training methodologies, including resisted sprint training, velocity-based resistance training, and high-intensity interval programming, could help refine best-practice recommendations for coaches and athletes at varying competitive levels.

Conclusions

This study underscores the fundamental role of an integrated training model that strategically combines strength, speed, and endurance to enhance sprint performance in both the 100m and 400m events. The findings demonstrate that strength training enhances force production and acceleration, speed training optimizes stride frequency and neuromuscular coordination, and endurance training improves fatigue resistance—particularly crucial for the 400m sprint. By systematically integrating these components, this model offers a more comprehensive and effective framework than traditional, isolated training approaches.

Comparisons with previous research validate the superiority of this multifaceted methodology. While existing studies have confirmed the benefits of strength and plyometric training for sprint mechanics and power output, as well as the role of endurance training in fatigue resistance, this study extends the literature by empirically demonstrating that a structured integration of these elements produces superior performance adaptations. This highlights the necessity of an evidence-based, periodized approach that optimally balances training stimuli to maximize performance while mitigating potential interference effects.

From a practical standpoint, the findings emphasize the importance of individualized training prescriptions tailored to an athlete's physiological and biomechanical characteristics. Effective periodization, systematic recovery strategies, and continuous training load monitoring are essential for optimizing adaptation and minimizing injury risks. Moreover, tailoring training based on factors such as muscle fiber composition and neuromuscular efficiency can enhance sprint-specific adaptations. Advances in sports science, particularly in wearable technology and real-time data analytics, present opportunities to refine training interventions and enhance performance monitoring. The integration of velocity-based resistance training and sensor-driven feedback mechanisms could allow for more precise load adjustments, maximizing both short-term gains and long-term athletic development.

Despite the valuable insights gained, further research is required to explore long-term adaptations to integrated training models, the impact of genetic predisposition on training responsiveness, and the optimal balance between training intensity, volume, and recovery. Future studies should also investigate how emerging technologies can enhance individualized programming, mitigate performance plateaus, and refine periodization strategies tailored to sprint-specific energy system demands. Additionally, longitudinal assessments of injury risk and biomechanical efficiency across multiple competitive seasons will be essential to further substantiate the practical applications of this approach.

In conclusion, an integrated strength, speed, and endurance training model represents a scientifically validated and practically effective methodology for sprint development. By bridging research with applied coaching strategies, this approach enables athletes to achieve superior sprinting performance, supporting both immediate competitive success and sustained athletic progression.

Acknowledgements

The author would like to thank everyone who helped in publishing this research.

Financing

This research was fully financed by the author.

References

Allégue, H., Turki, O., Oranchuk, D. J., Khemiri, A., Schwesig, R., & Chelly, M. S. (2023). The effect of combined isometric and plyometric training versus contrast strength training on physical performance in male junior handball players. Applied Sciences, 13(16), 9069. https://doi.org/10.3390/app13169069

Almquist, N. W., Ettema, G., Hopker, J., Sandbakk, Ø., & Rønnestad, B. R. (2019). The effect of 30-second sprints during prolonged exercise on gross efficiency, electromyography, and pedaling technique in elite cyclists. International Journal of Sports Physiology and Performance, 15(4), 562-570. https://doi.org/10.1123/ijspp.2019-0367

Batista, M. B., Valente-dos-Santos, J., Duarte, J. P., Sousa-e-Silva, P., Coelho-e-Silva, M. J., Werneck, A. O., ... & Ronque, E. R. (2020). Independent and Combined Effects of Weight Status and Maturation on Aerobic Fitness in Adolescent School-Aged Males. The Journal of Strength & Conditioning Research, 34(9), 2663-2671. https://doi.org/10.1519/JSC.0000000000002363

Beattie, K., Carson, B. P., Lyons, M., Rossiter, A., & Kenny, I. C. (2017). The effect of strength training on performance indicators in distance runners. The Journal of Strength & Conditioning Research, 31(1), 9-23. https://doi.org/10.1519/JSC.0000000000001464

Cahill, M. J. (2019). The effectiveness of resisted sprinting to improve short distance sprint performance in young athletes. Auckland: Auckland University of Technology.

Cantrell, G. S., Schilling, B. K., Paquette, M. R., & Murlasits, Z. (2014). Maximal strength, power, and aerobic endurance adaptations to concurrent strength and sprint interval training. European journal of applied physiology, 114, 763-771. https://doi.org/10.1007/s00421-013-2811-8

Clark, K. P., & Weyand, P. G. (2014). Are running speeds maximized with simple-spring stance mechanics?. Journal of applied physiology. https://doi.org/10.1152/japplphysiol.00174.2014

Haugen, T., Seiler, S., Sandbakk, Ø., & Tønnessen, E. (2019). The training and development of elite sprint performance: an integration of scientific and best practice literature. Sports medicine-open, 5, 1-16. https://doi.org/10.1186/s40798-019-0221-0

Hicks, D. S., Schuster, J. G., Samozino, P., & Morin, J. B. (2020). Improving mechanical effectiveness during sprint acceleration: practical recommendations and guidelines. Strength & Conditioning Journal, 42(2), 45-62. https://doi.org/10.1519/SSC.0000000000000519

Jiménez-Reyes, P., Samozino, P., Brughelli, M., & Morin, J. B. (2016). Effectiveness of an individualized training based on force-velocity profiling during jumping. Frontiers in Physiology, 7, 677. https://doi.org/10.3389/fphys.2016.00677

Korhonen, M. T., Haverinen, M., & Degens, H. (2014). 16 Training and Nutritional Needs of the Masters Sprint Athlete. Nutrition and performance in masters athletes, 70, 291.

Loturco, I., Nakamura, F. Y., Kobal, R., Gil, S., Abad, C. C. C., Cuniyochi, R., ... & Roschel, H. (2015). Training for power and speed: Effects of increasing or decreasing jump squat velocity in elite young soccer players. The Journal of Strength & Conditioning Research, 29(10), 2771-2779. https://doi.org/10.1519/JSC.0000000000000951

Materne, O., Chamari, K., Farooq, A., Tabben, M., Weir, A., Holmich, P., ... & McNaughton, L. R. (2022). Shedding light on incidence and burden of physeal injuries in a youth elite football academy: A 4-season prospective study. Scandinavian journal of medicine & science in sports, 32(1), 165-176. https://doi.org/10.1111/sms.14059

Rodríguez-Rosell, D., Franco-Márquez, F., Mora-Custodio, R., & González-Badillo, J. J. (2017). Effect of high-speed strength training on physical performance in young soccer players of different ages. The Journal of Strength & Conditioning Research, 31(9), 2498-2508. https://doi.org/10.1519/JSC.0000000000001706

Santtila, M. (2010). Effects of added endurance or strength training on cardiovascular and neuromuscular performance of conscripts during the 8-week basic training period. University of Jyväskylä.
Schneider, I. (2024). Strength and Conditioning: Principles for Developing Peak Athletic Performance. Revista de Psicología del Deporte (Journal of Sport Psychology), 33(2), 292-300.
Stewart, G. (2014). Minimising the interference effect. High-performance Training for Sports. Joyce D., Lewindon D., eds. Leeds, United Kingdom: Human Kinetics, 269-276.
STØREN, Ø., Helgerud, J. A. N., Støa, E. M., & Hoff, J. A. N. (2008). Maximal strength training improves running economy in distance runners. Medicine & Science in Sports & Exercise, 40(6), 1087-1092. https://doi.org/10.1249/MSS.0b013e318168da2f

Authors' and translators' details:

WU YAO	1612638693@qq.com	Author/ Translator