Bulletin of the *Transilvania* University of Braşov
Series IX: Sciences of Human Kinetics • Vol. 18(67) No. 1 – 2025
https://doi.org/10.31926/but.shk.2025.18.67.1.3

COMPARISON BETWEEN ISOINERTIAL TRAINING AND CLASSICAL TRAINING IN JUNIOR ATHLETES: ANALYSIS OF HIP EXTENSION TEST RESULTS

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Abstract: *This study compared the performance effects of isoinertial and traditional resistance training in junior athletes (U16), with a focus on hip extension test outcomes. The Exxentric kBox 4 Pro device and kMeter application were used to accurately monitor exercise execution and collect performance data. Twelve athletes (8 males, 4 females, aged 14.5± 0.7 years) participated in hip extension assessments. Results indicated a significant increase in Mean Strength (N), from 171.75 (SD=65.08) to 259.75 (SD=86.07). A paired t-test showed a significant difference (d=1.44), suggesting the training intervention effectively enhanced strength in junior athletes, supporting its potential for youth athletic development.*

Key words: *isoinertial training, hip extension, junior athletes, track and field*

1. Introduction

As in many other domains, the world of sports has increasingly embraced the influence of modern technology. This has led to widespread awareness among coaches, educators, and athletes of the latest equipment and methods that enhance performance.

The quest for optimal methods to enhance physical fitness and sports performance has driven global research, resulting in the development of advanced machines and technologies for athlete assessment and training. Athletes and coaches seek the most efficient training methods to optimize performance in the shortest time, leading to the development of new techniques that enhance results. This continual integration of innovation underscores the critical role of technological advancements in modern sports.

A prominent example of this technological progression is isoinertial resistance training (IRT), which has

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demonstrated considerable potential in improving various aspects of muscle function, including strength, power, neuromuscular activation, and structural improvements [8].

Resistance training, particularly when involving both concentric and eccentric contractions, has long been recognized for its effectiveness [6],[14]. Isoinertial resistance training, using devices like the YoYo® ergometer, has emerged as an efficient method for rapidly improving muscle mass and strength, even in older populations. This is due to the flywheel principle incorporated into the device, which creates resistance during both the eccentric and concentric phases of contraction, promoting eccentric overload [36]. The ability of IRT to facilitate muscle adaptations in this way is especially beneficial for achieving faster results and improving performance [25],[26].

Recent studies further highlight the effectiveness of applying eccentric resistance across the full range of motion, which leads to significant strength gains compared to conventional training methods [7],[32],[39]. This approach proves to be particularly advantageous in clinical and rehabilitation settings due to its capacity to deliver results with lower energy expenditure [1],[17],[29]. As a result, IRT has become a valuable tool in strength training, aiding in the enhancement of eccentric strength and power, while also mitigating age-related muscle decline and improving quality of life [21],[22],[33].

Furthermore, isoinertial training provides a suitable stimulus through negative resistance during the deceleration phase of movement [18], such as during squats, bicep curls, or knee flexion. This leads to enhanced neuromuscular activation [19],[27],[28],[38]. For older adults, the use of isoinertial devices is particularly beneficial, as it helps adapt the musculoskeletal system to higher recruitment rates and increased impulses to motor units during resisted stretching [5],[21]. This adaptation plays a crucial role in combating sarcopenia [20],[23] and improving the internal muscular environment by increasing nerve impulse frequency [10],[11],[15],[31].

The mechanical properties of muscles and tendons enhance the effectiveness of isoinertial training, as they generate greater force and power, especially during muscle elongation phase. This increased force in the eccentric phase improves tendon stiffness, reduces energy expenditure, and boosts training efficiency [8],[12],[34],[37].

The origins of isoinertial training can be traced back to its creation for astronauts, aimed at mitigating the loss of muscle and bone mass in the absence of gravity [1],[13],[30],[33]. This method involves performing both concentric and eccentric movements with a consistent level of resistance, generated by the motion of a flywheel. This approach results in substantial strength gains during the eccentric phase, which are more pronounced than those seen during the concentric phase [30],[36].

While earlier versions of isoinertial devices were relatively rudimentary, the underlying principle remains the same: to induce concentric and eccentric contractions using a flywheel. Technological advancements have

broadened isoinertial training's applications, benefiting athletes, individuals in rehabilitation, and older adults with sarcopenia. The system has proven effective across various settings, including sports performance, physical rehabilitation [24], and cardiopulmonary interventions [36].

The core mechanism behind isoinertial devices is like that of the toy Yo-Yo [7],[16],[21],[22]. These devices consist of a rope connected to a flywheel system, which facilitates the flexion and extension of body segments. The force exerted unwinds the rope, and as the flywheel rotates in the opposite direction, it recoils, requiring the individual to exert resistance. The magnitude of the inertia is determined by the force applied during movement, along with the flywheel's diameter and circumference [30],[33]. This system promotes increased eccentric muscle activity after a concentric contraction due to the resistance generated by inertia. The mechanical output is measured using a rotary encoder, which records parameters such as power (Watts), power range (Watts), and velocity (m/s).

Stoica and Barbu (2014) [35] conclude that targeted preparatory training significantly enhances the physical and motor development of junior athletes, underscoring the promise of innovative methods such as isoinertial training.

Recent studies [2] employing the isoinertial training method on junior athletes (U16) have sought to identify and validate differences in lower limb performance, specifically examining variations in force, speed, range of motion and power between the left and the right leg consistently demonstrating higher concentric peak power and average force compared to the left, while both limbs maintained comparable eccentric capabilities. These outcomes undercore the method's efficacy in detecting and quantifying functional imbalances, highlighting its critical role in designing targeted training interventions to optimize performance and minimize injury risks in junior athletes.

In summary, isoinertial training represents a promising and efficient approach for enhancing muscle strength, power, and overall physical performance across a range of populations. Through its unique mechanism, this method offers numerous benefits, particularly in rehabilitation, sports performance, and aging populations, by promoting muscular adaptations and improving health outcomes.

2. Objectives

This study aims to emphasize the critical need for enhancing and modernizing speed training methodologies for sprinters. Additionally, it seeks to explore the application of the hip extension test as a valuable tool in optimizing sprint performance. By investigating the relationship between hip extension mechanics and sprinting efficiency, the study will provide insights into how targeted assessments can guide the development of training interventions, thereby contributing to improved athletic performance and injury prevention. Through this investigation, the research will underscore the importance of incorporating advanced testing protocols into training regimens to support the

development of elite sprinters.

3. Material and Methods

The tests were conducted using the Exxentric kBox 4 Pro in combination with the kMeter analysis system. The Exxentric kBox 4 Pro is a versatile platform featuring a range of interchangeable weight flywheels and accessories designed to accommodate different training modalities. This system enables precise control and measurement of resistance during dynamic movements, making it ideal for both strength and power assessments. The kMeter system, which provides real-time data on key performance metrics such as velocity, power, speed and force, allows for an in-depth analysis of an athlete's performance and progress throughout the testing sessions. This integration of equipment is particularly effective for isoinertial training, offering a comprehensive evaluation of muscle strength, endurance, and overall athletic capacity.

In this study, 12 athletes (8 males and 4 females, aged 14.5 ± 0.7 years) participated in hip extension assessments. Over a span of approximately 5 months, the athletes followed a training program based on isoinertial resistance using the kBox 4 Pro device. Following this training period, the athletes underwent a second round of hip extension tests to assess and analyze any differences in performance before and after the isoinertial training regimen.

The data collected from these tests were analyzed using the DataTAB software program (tools for managing and interpreting complex datasets.

4. Results

The analysis demonstrates that the training program had a substantial effect on strength performance among junior athletes. Initially, Mean Strength was 171.75 N (SD= 65.08) and increased to 259.75 N (SD=86.07) at the final assessment. A paired-samples t-test confirmed that this increase was statistically significant ($t(11)=-4.99$, $p< .001$), indicating that the probability of these results occurring by chance is very low. The large effect size (d-1.44) further suggests that the intervention produced a meaningful improvement in strength performance.

Similarly, the Peak Overload (%) indicator also showed significant enhancement. Baseline values averaged 35.04% (SD= 17.37), rising to 69.44% (SD= 47.11) following the intervention. The paired-samples t-test yielded a significant difference ($t (11) = -2.72$, $p= .02$) with a 95% confidence interval of [-62.27, -6.53] and a moderate-to-large effect size (d=0.78).

These results were obtained under the assumption that the differences between paired observations and normally distributed, which supports the validity of the t-test findings. The statistically significant improvements in both strength and overload capacity not only demonstrate the efficacy of the training program but also suggest its potential utility in enhancing youth athletic development.

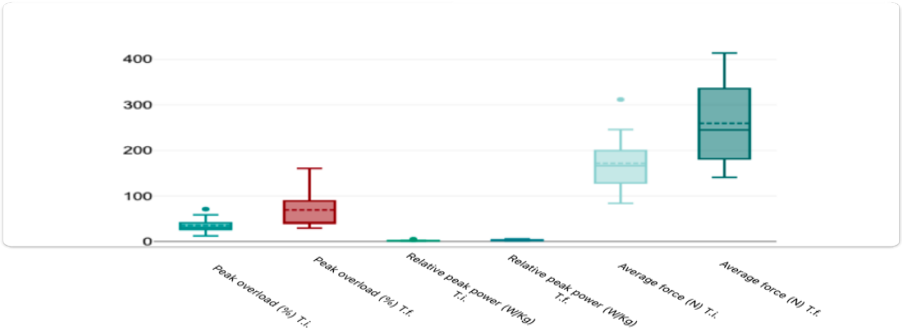

Fig. 1. *Initial and final results of the kbox4 pro hip extension test (overload, relative peak strength and average strength)*

			t	df	p	Cohen's d
Peak overload (%) T.f.	(%) T.i. -	Peak overload	-2,72	12	,02	0,78

	t	df	p	Cohen's d
Average force (N) T.i. - Average force (N) T.f.	-4,99	11	<.001	1,44

Fig. 2. I*nferential Statistics for the" Hip Extension Test" with Exxentric Kbox4pro*

5. Discussions

The current study demonstrates that the implemented training intervention significantly enhanced strength performance in junior athletes, as evidenced by statistically robust improvements based on normal data distribution. The observed outcomes corroborate previous research [3], which suggest that flywheel training represents a viable alternative to traditional resistance training techniques, although the body of supporting evidence is relatively sparse. Moreover, the comparison between flywheel and conventional resistance exercises consistently emerges as a primary focus in investigations of isoinertial training modalities [4], [9], [36].

These findings advocate for the integration of modern technological advancements and innovative training methodologies into athletic programs, particularly at the junior level, to optimize youth athletic development.

6. Conclusions

The study hypothesized that isoinertial training with the Exxentric kBox 4 Pro would improve strength and peak overload in junior athletes. Our results confirmed this, with mean strength increasing from 171.75 N to 259.75 N and peak overload from 35.04% to 69.44%, indicating robust neuromuscular adaptations. These

improvements underscore the potential of advanced training technologies to optimize performance and reduce injury risk. Nonetheless, limitations such as the small sample size and short intervention period suggest caution, while unexpected asymmetries in limb performance point to avenues for future research.

In conclusion, these findings highlight the importance of incorporating modern technological advancements and innovative training methodologies into athletic programs. Isoinertial training mehods have demonstrated greater effectiveness in enhancing strength performance compared to the traditional approaches.

Acknowledgements

We would like to express our sincere gratitude to the junior track and field athletes (U16) from Sport Club Ploiești for their enthusiastic participation in our research. We are especially thankful for their commitment and openness in allowing us to implement our training programs and conduct performance assessments throughout the study. Their contribution was essential to the success of the project, and we deeply appreciate their support and collaboration.

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