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A New Method for Evaluating the Reactive Strength Index in Track and Field Sprinting: Relationships with Muscle Architecture

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Abstract: The aim of the present study was to assess a new reactive strength index (RSI RUN) based on contact time and stride length measured in sprint running and then to correlate this index with sprint performance, muscle architecture and echo intensity of the vastus lateralis. Participants included ten elite and sub-elite sprinters (age 24.4 ± 3.1 years, height 177.5 ± 7.7 cm, mass 69.8 ± 11.7 kg) who were tested with a vertical drop jump (VDJ) and a horizontal drop jump (HDJ) from a 30 cm high box, a 20 m straight-leg running drill (SLR) and a 60 m sprint. A nearly perfect correlation (r = from −0.90 to −0.96, $p < 0.01$) was detected between RSI RUN and sprint performance (30 m, 60 m and 100 m sprint time), and a very large correlation (r = from −0.72 to −0.77, $p < 0.05$) was found between the traditional RSI from vertical drop jump (RSIDJV) and sprint performance. In addition, the RSI RUN was more correlated to sprint performance than other RSI indices studied in previous research. The echo intensity of the vastus lateralis (VLEI) was largely correlated with maximum running speed (r = from 0.76 to 0.87, $p < 0.05$) and the RSI RUN (r = −0.80, $p < 0.05$). No significant correlations were noted between echo intensity and other RSIs. In conclusion, the RSI RUN and VLEI seem to be good predictors for track and field sprinting performance.

Keywords: reactive strength index; sprint; eco intensity; performance

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1. Introduction

Reactive strength is the ability to perform fast muscle contractions by taking advantage of the stretch-shortening cycle (SSC), which consists of quick eccentric–concentric muscular contractions [1]. This muscular coupling produces a more powerful contraction than the simple concentric action due to the storage and re-utilization of elastic energy [2,3]. The transition between eccentric and concentric contraction should be as short as possible to optimally use the stored energy (i.e., <250 ms) [4]. In track and field sprinting, the ground contact time is typically below 0.250 ms during each phase of the race, i.e., the acceleration phase, the maximum velocity phase and the deceleration phase [5]. Track and field sprinting requires a fast SSC, and consequently, the efficiency of the mechanisms of reactive strength represents a crucial component of the performance, especially during the maximum velocity phase [6,7]. The reactive strength index (RSI) is the most common method for assessing the reactive strength of lower limbs [8]. The RSI is usually assessed as the ratio between jump height and contact time in specific jumps [9], such as drop jumps [10,11], rebound jumps [12] and hopping jumps (i.e., ankle jumps) [13,14]; thus, the RSI represents a commonly accepted measurement of the efficiency of the SSC [8]. Despite several studies investigating the relationship between RSIs and sprint performance in athletes of different disciplines [15], the association between RSIs and sprinting remains questionable [16]. Non-univocal results may be due to the different strategies adopted to assess the RSI (bilateral or unilateral jump, box height of the drop jump, etc.) in regard to the performance level of athletes involved in the studies and to the different sprint distances (from 20 to 60 m). Some authors reported moderate negative correlations between the RSI and sprint acceleration time (r= −0.426) and between the RSI and top speed (r = −0.326) [15]. Other studies [17,18] reported large negative correlations between the RSI and 100 m time (r = −0.566 and r = −0.75, respectively); however, some authors suggest that an RSI calculated by a horizontal jump test (bi- and unilateral) may be a better predictor of sprint performance (5–50 m) compared to an RSI calculated in vertical jumps [19–22]. Experimental studies investigating RSIs in horizontal jumps, however, present some methodological limitations in the calculation of the RSI, such as the use of non-standardized jumps. Stride length is considered a fundamental parameter for sprint performance [5] that does not require specific coordination skills (such as jumps or a bounding run); thus, an RSI based on this parameter may be more specific for sprinting compared to previously used indices [10–13].

Recently, muscle ultrasounds have been used to investigate the relationships between the muscle architecture of the lower body muscles and sprint performance in different athletic populations, such as track and field sprinters [23] and field hockey players [24]. Significant correlations were detected between the pennation angle, fascicle length and echo intensity of the vastus lateralis and sprint performance. The latter was recently indicated as the best predictor of running speed in physically active young individuals sprinting on a motorless treadmill [25]. Echo intensity is influenced by the characteristics of the contractile components of the muscle in addition to other elements, such as fat tissue and connective and fibrotic tissue within the muscle. A low level of echo intensity has been associated with low levels of intramuscular fat and connective tissue, indicating a good muscle "quality" [26]. A relationship between muscle architecture and the RSI RUN may open new perspectives in the comprehension of the main components of sprint performance in track and field athletes; therefore, the aim of this study was to assess a new RSI using a horizontal measure and to correlate this index to maximal speed and performance in 30–100 m sprints. Another aim of the present investigation was to analyze the architecture of lower limb muscles and study the relationships with the horizontal-based RSI. The authors hypothesized that the new RSI would be more related to sprint performance than the more traditional vertical-based RSI. In addition, the authors hypothesized that the new RSI may be correlated with the muscle architecture and echo intensity of the vastus lateralis.

2. Materials and Methods

2.1. Participants

Ten elite and sub-elite sprinters (age 24.4 ± 3.1 years, height 177.5 ± 7.7 cm, mass 69.8 ± 11.7 kg, seasonal best in 100 m sprint between 10.36 s and 12.77 s) participated in the present study. The group included 4 females (age 22.8 ± 3.2 years, height 169.8 ± 1.3 cm, mass 57.2 ± 3.3 kg, seasonal best in 100 m between 11.80 s and 12.77 s) and 6 males (age 25.5 ± 2.7 years, height 182.7 ± 4.7 cm, mass 78.2 ± 5.3 kg, seasonal best in 100 m between 10.36 s and 11.96 s). All the participants had at least 5 years of sprint-training experience and were not injured in the last year. All subjects provided written informed consent prior to participating in this study. This study, conducted in accordance with the Declaration of Helsinki, was approved by the local ethics committee (Prot. n. 0146122, 1 July 2022).

2.2. Procedure

Before performing the tests, athletes performed typical pre-competition 45 min warm-ups, including low-pace running, specific running exercises, active stretching and some sprints. After the warm-up, athletes performed the following assessments: a vertical drop jump (VDJ) and a horizontal drop jump (HDJ) from a 30 cm high box [16,27], a 20 m straight-leg running drill (SLR) and a 60 m sprint [14]. Before data collection, the investigators gave verbal instructions about the tests' execution; all the athletes, however, were familiar with the tests. Athletes were instructed to minimize the foot contact time and maximize the vertical or horizontal displacement in the VDJ and HDJ, respectively [22]. For SLR, the instructions were to minimize the foot contact time and maximize the speed on the 20 m. For the sprint, the athletes were asked to run at their maximum speed. Athletes performed three attempts in each jump (VDJ and HDJ) with a 2 min recovery time. Attempts not meeting a good level of technical execution were discarded. The RSI for the VDJ (RSI VDJ) was calculated as the jump height divided by the contact time. The RSI for the HDJ (RSI HDJ) was calculated as the jump distance divided by the contact time. Following the jump tests, athletes performed three trials of the SLR test, with 1 min of rest between the trials. The RSI (RSI SLR) was then calculated as the average length of eight steps divided by the average contact time of the same steps. Finally, athletes ran two full-speed 60 m sprints (a stop line was set 5 m after the 60 m mark in order to induce athletes to run at top speed until the end of the trial), with a 5 min recovery time. Intermediate times were measured at 30 m (start to 30 m and 30 m to 60 m times were then calculated). All the times were registered using photocells (Smart Speed Micrograte, Bolzano, Italy) positioned at 0, 30 m and 60 m. The photocells positioned at the starting point were positioned at a height corresponding to the athlete's knee. The height of the other photocells (30 and 60 m) corresponded to the athlete's chest level. For jumps and sprint tests, an Optojump Next system (13 m in length, Microgate, Bolzano, Italy) was used. The Optojump was placed on a portion of the track at 47 m and 60 m from the starting point to measure contact times, flight times, step lengths and speed in the maximum speed phase. The RSI for the sprint (RSI RUN) was calculated as the average length of five steps divided by the average contact time of the five steps analyzed. To avoid the influence of the athlete's anthropometric characteristics on stride lengths, RSI HDJ, RSI SLR and RSI RUN were normalized to the athlete's height [22] using the equation (step length/athletes height)/contact time, and the NRSI HDJ, NRSI SLR and NRSI RUN indices were obtained. The fastest 60 m sprint was selected for subsequent analyses.

Skeletal muscle ultrasound images were collected from the participant's right side after the anatomical locations of interest were identified using specific landmarks for the vastus lateralis muscle (VL). The VLMT (vastus lateralis muscle thickness) was measured along its longitudinal distance midway between the superior margin of the patella and the most prominent point of the great trochanter of the femur, with the knee bent 10° [28]. The probe was positioned on the skin surface without depressing the dermal layer (gain = 50 dB; image depth = 5 cm). Athletes were asked to lie on a physical therapy table for a minimum of 10 min before images were collected. The same qualified investigator performed all landmark measurements for each participant. A 12 MHz linear probe scanning head (Mindray MD20, Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China) was coated with water-soluble transmission gel to optimize spatial resolution and used to collect all ultrasound images.

All ultrasound images were taken and analyzed by the same investigator. MT (muscle thickness) measures were obtained using a longitudinal B-mode image, and three consecutive images were captured and analyzed. For each image, MT was measured with a single perpendicular line from the superficial aponeurosis to the deep aponeurosis. Echo intensity (EI) was assessed by computer-aided grey-scale analysis using ImageJ (National Institute of Health, Bethesda, MD, USA, Version 1.45). EI was determined for the VL as the corresponding index of muscle quality ranging between 0 and 255 a.u. (black = 0; white = 255).

2.3. Statistical Analysis

All data were statistically analyzed using SPSS version 26 (SPSS Inc., Chicago, IL, USA). A post hoc power analysis showed that the sample size used (n = 10) allowed the detection of significant ($\alpha = 0.05$) very large ($r > 0.7$) Pearson's r correlations with a power (1-β) ranging from 0.63 to 0.99. The Shapiro–Wilk test was used to check the normal distribution of the data. Relationships between sprint and reactive strength measures were determined using Pearson's correlation. The magnitude of the correlations was evaluated as trivial (0–0.09), small (0.1–0.29), moderate (0.3–0.49), large (0.5– 0.69), very large (0.7–0.89), near perfect (0.9–0.99) and perfect (1) [29]. The level of significance was assessed for $p < 0.05$.

3. Results

The mean and standard deviation of the analyzed variables are reported in Table 1.

Table 1. Mean and SD of the performance variables and ultrasound measurements.

Variables	Mean ± SD	Variables	Mean ± SD
Sprint performance variables		Horizontal jump test	
30 m (s)	4.16 ± 0.48	Contact time (s)	0.30 ± 0.07
60 m (s)	7.54 ± 1.04	Jump length (m)	1.39 ± 0.33
30–60 m split time (s)	3.35 ± 0.51	Jump length norm (m/BH)	0.77 ± 0.17
SB 100 m (s)	11.59 ± 0.91	RSI HDJ (a.u.)	4.84 ± 1.64
Max speed (ms^{-1})	9.10 ± 1.29	NRSI HDJ (a.u.)	2.69 ± 0.84
Contact time sprint (s)	0.12 ± 0.01	Straight-leg running drill test (SLR)	
Step length sprint (m)	2.18 ± 0.20	Contact time (s)	0.148 ± 0.02
Step length norm (m/BH)	1.23 ± 0.10	Step length (m)	1.73 ± 0.19
RSI RUN (a.u.)	19.27 ± 3.50	Step length norm (m/BH)	0.98 ± 0.12
NRSI RUN (a.u.)	10.79 ± 1.76	RSI SLR (a.u.)	11.83 ± 2.26
Vertical jump test		NRSI SLR (a.u.)	6.68 ± 1.33
Contact time (s)	0.22 ± 0.03	Ultrasound measurements	
Rebound height (cm)	47.29 ± 10.30	VLMT (mm)	15.25 ± 2.63
RSI VDJ (a.u.)	2.15 ± 0.57	VLEI	42.23 ± 5.88

BH = body height; N = normalized by body height; NRSI HDJ = normalized reactive strength index (HDJ); NRSI RUN = normalized reactive strength index (RUN); NRSI SLR = normalized reactive strength index (SLR); RSI HDJ = reactive strength index of horizontal drop jump; RSI RUN = reactive strength index of sprint; RSI SLR = reactive strength index of straight-leg running drill test; RSI VDJ = reactive strength index of vertical drop jump; SB = seasonal best; VLEI = echo intensity of vastus lateralis; VLMT = vastus lateralis muscle thickness.

Pearson's correlation and R square values between the sprint performances and RSIs are reported in Table 2.

Table 2. Pearson's correlation and R square between sprint performance and different RSIs. The orange color highlights near-perfect correlations based on r, while the yellow color highlights very large correlations.

	RSI RUN		NRSI RUN		RSI VDJ		RSI HDJ		NRSI HDJ		RSI SLR		NRSI SLR		VLMT		VLEI	
	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2
30 m (s)	−0.95 **	0.90 **	−0.91 **	0.83 **	−0.77 **	0.60 **	−0.48	0.21	−0.41	0.17	−0.52	0.27	−0.38	0.14	−0.50	0.34	0.76 *	0.58 *
60 m (s)	−0.95 **	0.91 **	−0.92 **	0.84 **	−0.77 **	0.60 **	−0.47	0.21	−0.40	0.16	−0.50	0.25	−0.37	0.13	−0.52	0.27	0.77 *	0.59 *
30–60 m (s)	−0.96 **	0.91 **	−0.92 **	0.85 **	−0.77 **	0.59 **	−0.45	0.20	−0.40	0.16	−0.49	0.24	−0.35	0.13	−0.53	0.28	0.77 *	0.59 *
Max speed ($m \cdot s^{-1}$)	0.97 **	0.94 **	0.90 **	0.82 **	0.76 *	0.59 **	0.52	0.24	0.44	0.19	0.44	0.20	0.28	0.08	0.51	0.26	−0.82 *	0.68 *
SB 100 m (s)	−0.96 **	0.92 **	−0.90 **	0.79 **	−0.72 *	0.52 **	−0.45	0.22	−0.41	0.17	−0.41	0.17	−0.26	0.07	−0.57	0.32	0.87 **	0.75 **

** $p \leq 0.01$; * $p \leq 0.05$; NRSI HDJ = normalized reactive strength index (HDJ); NRSI RUN = normalized reactive strength index (RUN); NRSI SLR = normalized reactive strength index (SLR); RSI HDJ = reactive strength index of horizontal drop jump; RSI RUN = reactive strength index of sprint; RSI SLR = reactive strength index of straight-leg running drill test; RSI VDJ = reactive strength index of vertical drop jump; SB = seasonal best; VLEI = echo intensity of vastus lateralis; VLMT = vastus lateralis muscle thickness.

As reported in Table 2, RSI RUN, NRSI RUN, RSI VDJ and VLEI only showed significant correlations (r from −0.97 to 0.87) with sprint performance. RSI RUN and NRSI RUN showed a nearly perfect correlation with all sprint variables (r from −0.96 to 0.96), while RSI VDJ showed very large correlations with sprint performance (r from −0.77 to −0.76; $p < 0.05$). In addition, VLEI showed a very large correlation with sprint performance (r from −0.82 to 0.87; $p < 0.05$).

Pearson's correlation and R square values between the different RSIs are reported in Table 3.

Among the data reported in Table 3, some correlations were also noted among the different indices. Specifically, RSI RUN showed a very large correlation with RSI VDJ (r = 0.850, $p = 0.002$) and a large correlation with RSI SLR (r = 0.632, $p = 0.05$). RSI VDJ showed a very large correlation with RSI HDJ (r = 0.742, $p = 0.014$) and RSI SLR (r = 0.761, *p*= 0.011). Therefore, it is interesting to note that RSIDVJ is the only index correlated with all other indices analyzed in this study.

Table 3. Pearson's correlation and R square between the different RSIs. The orange color highlights near-perfect correlations based on r, while the yellow color highlights very large correlations; the large correlations are highlighted with the light yellow.

	RSI RUN		NRSI RUN		RSI VDJ		RSI HDJ		NRSI HDJ		RSI SLR		NRSI SLR	
	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2
RSI RUN														
NRSI RUN	0.96 **	0.92 **												
RSIDJV	0.85 *	0.72 *	0.81 **	0.65 *										
RSIDJH	0.53	0.29	0.43	0.19	0.74 *	0.55 *								
NRSIDJH	0.56	0.31	0.56	0.31	0.72 *	0.52 *	0.74 *	0.55 *						
RSI SLR	0.63 *	0.40 *	0.70 *	0.49 *	0.76 *	0.58 *	0.43	0.18	0.68 *	0.47 *				
NRSI SLR	0.48	0.23	0.60	0.36	0.64 *	0.41 *	0.31	0.09	0.61	0.37	0.98 **	0.95 **		

** $p \leq 0.01$; * $p \leq 0.05$; NRSI HDJ = normalized reactive strength index (HDJ); NRSI RUN = normalized reactive strength index (RUN); NRSI SLR = normalized reactive strength index (SLR); RSI HDJ = reactive strength index of horizontal drop jump; RSI RUN = reactive strength index of sprint; RSI SLR = reactive strength index of straight-leg running drill test; RSI VDJ = reactive strength index of vertical drop jump.

Pearson's correlations and R square values between RSIs and ultrasound measurements are reported in Table 4.

Table 4. Pearson's correlation and R square between RSIs and ultrasound measurements.

	RSI RUN		NRSI RUN		RSI HDJ		NRSI HDJ		RSI VDJ		RSI SLR		NRSI SLR	
	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2	r	R^2
VLMT	0.62	0.38	0.67	0.44	0.46	0.21	0.50	0.25	0.53	0.28	0.46	0.21	0.42	0.18
VLEI	−0.80 *	0.63	−0.70 *	0.49	−0.34	0.11	−0.36	0.13	−0.59	0.35	−0.50	0.25	−0.34	0.11

* $p \leq 0.05$; NRSI HDJ = normalized reactive strength index (HDJ); NRSI RUN = normalized reactive strength index (RUN); NRSI SLR = normalized reactive strength index (SLR); RSI HDJ = reactive strength index of horizontal drop jump; RSI RUN = reactive strength index of sprint; RSI SLR = reactive strength index of straight-leg running drill test; RSI VDJ = reactive strength index of vertical drop jump; VLEI = echo intensity of vastus lateralis; VLMT = vastus lateralis muscle thickness.

The results reported in Table 4 show only a significant very large correlation between VLEI and RSI RUN and NRSI RUN (r = −0.80 and −0.70, respectively).

4. Discussion

The first purpose of this study was to develop a new RSI (RSI RUN) calculated for a sprint by horizontal measures (step length) and foot contact times and to correlate this index with the maximum speed and the 100 m sprint performance of competitive track and field sprinters and compare this index with the traditional vertical-based RSI.

The results of the present study show that the RSI RUN and the NRSI RUN were highly negatively correlated with the 100 m sprint time (r between −0.90 and −0.96), and positively correlated with the maximum speed (r = 0.97 and 0.90 for RSI RUN and NRSI RUN, respectively). RSI RUN is determined by contact times and stride lengths in a sprint; these are parameters that have been indicated as crucial for sprint performance [5,29,30], and in particular for the maximum running speed [6]. Nagahara and colleagues [14] showed that the RSI obtained by an ankle rebound test was more correlated with the 60 m sprint performance than the traditional RSI (r= −0.49 and r = −0.07, respectively), especially when this index was calculated in the advanced phases of athlete acceleration (from 23.4 ± 1.0 to 33.7 ± 1.4 m). This parameter supports the key role of the reactive strength of the calf muscles in achieving high running speeds. The investigations conducted to date on the relationship between sprint performances and the RSI, however, mainly included short sprints (5 to 50 m) [16,22,31], and only a few authors considered the 100 m performance [32]. In addition, these authors calculated the RSI in multiple horizontal jumps [33], a task that requires good technique and motor coordination. In addition, NRSI RUN also showed near-perfect correlations with all sprint performance measures, showing that the RSI RUN is independent of the athlete's height. Thus, the RSI RUN may be used to predict the 100 m sprint time in athletes with different anthropometric characteristics. In the present study, indeed, athletes with similar RSI RUN values were characterized by similar best seasonal performances in 100 m sprint. Therefore, since previous studies reported that acceleration up to 60 m explains only 64% of the time in the 100 m (32), a more predictive index of performance such as the RSI RUN may be useful. On the other hand, it is well known that many athletes show great performances in the 60 m sprint but are not competitive in the 100 m.

Compared with the RSI RUN and the NRSI RUN, the RSI VDJ calculated for the athletes participating in this study shows very large negative correlations with all sprint times (r = −0.77 with all sprint times) and SB 100 m (r = −0.72) and a positive large correlation with max speed (r = 0.76). Although these data are consistent with other studies [27,31,34], the correlations are slightly superior to those in other studies involving track and field sprinters (r = −0.49) [14]. A recent review [15] also reported moderate correlations between the RSI calculated in the drop jump and both sprint acceleration and maximum running speed (r = 0.42 and 0.39, respectively). This study confirmed previous research [14,35] and suggests that data obtained by vertical jumps are mainly correlated with the first acceleration phase, while leg stiffness is more important for the achievement of the maximum velocity. In this study, however, the RSI RUN and the NRSI RUN are highly correlated with sprint performances over different distances. This is likely determined by the fact that the athletes participating in this study run the 60 m sprint starting from a standing position and not from the blocks. This starting position may favor the use of reactive strength rather than explosive strength. The other indices analyzed in this study (RSI HDJ, NRSI HDJ, RSI SLR and NRSI SLR) did not show significant correlations with sprint performance. Thus, the present investigation confirms that the horizontal-based RSI represents a more specific parameter for running speed compared to the vertical-based RSI. This is consistent with the findings of Washif and Kok [31] and Nagahara et al. [14], who supported the need for large horizontal, rather than vertical, forces to achieve high running speeds [28,36]. However, observing the correlations between the different indices, the very large correlation between RSI RUN and RSI VDJ (r = 0.85) indicates that these two parameters may represent the strongest predictors of performance for the athletes involved in the present investigation.

The second aim of this study was to correlate the RSI with the muscle architecture of lower body muscles. According to Bartolomei et al. [24], no significant correlations were detected between muscle thickness of the VL and sprint performances. The present study also shows that no relationships exist between muscle thickness and any kind of RSI. Muscle thickness, indeed, represents a key factor for maximal strength [37] but is not a good predictor of dynamic performances such as sprinting or jumping. Conversely, the echo intensity of the VL shows a very large correlation with sprint performance (from 30 to 100 m), the RSI RUN and the NRSI RUN. Curiously, no relationships between echo intensity and vertical-based RSI indices were detected. Echo intensity is considered a strong predictor of muscle quality that is affected by the individual body fat, the presence of fibrous tissue, age and training status [38]. The study by Pillen et al. [38] suggests that sprint performance is particularly sensitive to this parameter of muscle quality. The correlation between this parameter and the RSI RUN indicates that contact time and stride length may be both influenced by echo intensity.

Limitations and Strengths

The RSI RUN appears to be a simple and suitable method for predicting sprint performances and identifying talents in track and field. A possible limitation of the present study is represented by the relatively small number of participants involved. The need for skilled athletes as participants in the present study, however, reduced the number of eligible individuals. Further investigations are needed to study this RSI in a larger sample of athletes, possibly including athletes of different levels and sexes, and to confirm the suggestions of this research.

5. Conclusions

In conclusion, the new horizontal-based RSI shows a greater correlation with both sprint performance and muscle echo intensity compared to the commonly used vertical-based RSI. The growing interest in echo intensity and the recent reduction in the cost of ultrasound devices made the evaluation of muscle architecture and muscle quality more popular. In addition, since contact time and stride length may be measured in a sprint by video analysis [39], the RSI RUN may be obtained without using expensive devices. The present study showed that both echo intensity and the RSI RUN represent relevant factors for sprint performance. Further investigations are warranted to examine these parameters on a large sample of sprinters and to develop a prediction equation for sprint performance based on echo intensity and RSIs. Since sprint performance is highly influenced by talent, this prediction equation may help coaches and sport scientists in identifying the individuals who are more inclined to these disciplines. In addition, the RSI RUN can be used to check a sprinter's performance during the preparation phases and to monitor the trend of both contact time and stride length. These measurements may also give relevant information to athletes and coaches about the adaptations that occurred following the different training periods. These tests may also provide relevant information to coaches and researchers about the determinant factors of sprint performance.

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