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Effectiveness of Training in Different Natural Environments on Some Biomechanical Variables of Sprint Runners in (100m, 200m, 400m) Events

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Abstract

Study purpose. Sprint events (100m, 200m, 400m) are high-performance athletic activities that rely on coordinated movement transfer governed by specific mechanical principles. Researchers have continually sought to identify the most effective training methods to enhance the performance of sprinters. The study's research problem is centered on determining the effectiveness of training in different natural environments (dense grass, soft sand, and hard soil) and identifying which training surface is most beneficial for improving selected biomechanical variables in sprinters.

Materials and method. The study aimed to examine the impact of training in different natural environments (excluding tartan tracks) and to determine which surface yields the most significant improvements for sprint runners. To achieve this, the researchers implemented an eight-week training program with two training sessions per week, using consistent sprint distances across all surfaces (10m, 20m, 30m, 40m, and 50m). The research sample consisted of 18 sprinters specializing in sprint events, divided into three equal groups: six for the 100m, six for the 200m, and six for the 400m. These athletes were in the specialized preparation phase and had participated in the first round of the Iraqi Clubs Championship in Sulaymaniyah on March 15, 2024, in preparation for the third round scheduled for October 20, 2024, in the same location.

Results. The researchers analyzed four biomechanical variables: time, velocity, stride length, and stride frequency. These variables were measured over a 50-meter flying start using five perpendicular motion-analysis cameras positioned every 10 meters. The statistical method used was analysis of variance (ANOVA) to determine which training surface had the greatest impact on performance.

Cunclotions. The study concluded that training on soft sand had a statistically significant effect, while the other surfaces did not show significant improvements. The researchers recommended conducting similar studies on different athlete categories and other athletic events.

Keywords: Training Environments, Sprinting, Analysis Of Variance.

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Introduction

Sports training is a theoretical science that can be directly applied and practiced, which is why researchers and specialists constantly strive to experiment with their philosophies to enhance and develop athletic performance and achievement. This pursuit remains a fundamental concern for sports science experts, particularly given the interconnected and cohesive nature of these disciplines. Among the sciences that play a decisive role in athletic performance, particularly in track and field events, is sports biomechanics, also known as bio-mechanics. This field focuses on refining performance alongside achieving high results, in collaboration with sports training science, allowing for the experimentation of various theories to achieve the desired objectives.

Training in natural or open environments encompasses a variety of terrains, including mountains, forests, beaches, grassy fields, and sandy areas (e.g., soft sand dunes). Such training environments enhance an athlete's ability to adapt to environmental changes, heighten sensory perception, and stimulate bodily responses, in addition to creating resistance and physical impact on the body (Parr, 2018).

Sand training, in particular, is an effective method for expanding the range of training options available to athletes. It enables daily, continuous training sessions and allows for high-intensity exercises, while also increasing the duration of training sessions. Sand provides an optimal natural resistance-training environment, contributing to the improvement of both physical and functional performance. The unique characteristics of sand training include strengthening and building the muscular system, engaging all muscle groups, and increasing body weight resistance due to the sinking effect of the feet in the sand. As movement on sand is more physically demanding than on solid ground, it presents a greater challenge, making it an ideal medium for resistance training and overall performance enhancement (Giartama, 2018).

Sandy surfaces are characterized by their low firmness, making them one of the environmental factors that increase the difficulty of an athlete’s technical, physical, and physiological tasks. Additionally, sandy surfaces impact balance, which in turn affects the precision of performance in certain skills. Similarly, dense grassy surfaces exhibit a degree of resistance to the human body, creating effects on athletes that are somewhat comparable to those experienced on sandy terrain, particularly concerning muscle groups. In contrast, training on hard soil surfaces has a lesser impact, resembling tartan tracks, which are commonly used in competitive settings (Hrysomallis, 2012).

For this reason, the researchers sought to experiment with these environments to assess their effectiveness for sprinters and to determine any positive outcomes during training and competition. According to the researchers’ review of previous studies, while there have been investigations into different training environments, prior studies primarily focused on different surfaces such as clay, asphalt, or water-based environments. However, no research was found that specifically compared these three types of ground surfaces in a structured manner.

Materials and methods

Study participants

The researchers employed the experimental method using equally matched experimental groups, as it is suitable for addressing the research problem.

The research population consisted of 18 sprinters, divided into three groups: a) 6 sprinters specializing in the 100m event, b) 6 sprinters specializing in the 200m event, c) 6 sprinters specializing in the 400m event

All participants were in the specialized preparation phase and had competed in the first round of the Iraqi Clubs Championship in Sulaymaniyah on March 15, 2024, in preparation for the third round scheduled for October 20, 2024, in the same location.

To ensure homogeneity among the groups, the researchers conducted anthropometric measurements, the details of which are presented in Table 1.

Table 1. Specifications of the athletes and their homogeneity

Variables	Unit of Measuremnt	Mean (M)	Median	Standard Deviation (SD)	Skewness Coefficient
Height	cm	177	175.5	2.65	0.710
Mass	kg	77.33	77.5	2.59	-0.481
Chronologic l Age	years	25.31	25.0	2.14	0.310
Training Age	years	7.21	7.1	3.70	-0.115

Table 1 indicates that the skewness coefficient values fall within the range of (±1), which confirms the homogeneity of the research sample in these variables, signifying a normal distribution.

Study organization

Pilot Experiment

The pilot experiment was conducted on Tuesday, April 16, 2024, at 3:00 PM using the five analysis cameras. A single sprinter, who was not part of the research sample, was filmed at Najaf International Athletics Stadium to determine the optimal placement and positioning of the cameras, assess their distances, and evaluate the different training surfaces. Additionally, the intensity of each exercise was standardized at 100%, and potential obstacles that might arise during the main experiment were identified and documented.

Main Experiment – Pre-Tests

The main experiment (pre-tests) was conducted on Friday, April 19, 2024, at 3:00 PM. The five analysis cameras (CASIO FH13.5) were calibrated to capture at 120 frames per second and positioned at a height of 1.2 meters. They were arranged perpendicularly every 10 meters along the test distance to ensure full and precise coverage of each segment, as illustrated in Figure 1 and Figure 2. The Kenova motion analysis software was used to analyze the collected data and calculate the biomechanical variables.

50-Meter Flying Sprint Test (Al-Hakim, 2004)

Objective:

Measure maximum sprint speed.

Equipment Used:

A 65-meter running track meeting legal requirements.

Three timing stopwatches (operated by official timekeepers).

A clear transverse line indicating the end of the 15-meter acceleration phase and the start of the 50-meter timed segment.

Test Procedure:

The sprinter starts from a standing position at the beginning of the acceleration zone.

Upon the starting signal, the sprinter gradually increases speed until reaching the 15-meter mark (start of the 50-meter timed segment).

At the 15-meter mark, the first assistant signals by making a quick wrist movement while holding a red flag to indicate the start of timing.

The official timekeepers start their stopwatches simultaneously.

Timing continues until the sprinter crosses the 50-meter finish line, at which point the stopwatches are stopped.

Measurement Method:

The recorded time is measured to the nearest 0.01 seconds using three stopwatches.

The median time of the three measurements is taken as the final result.

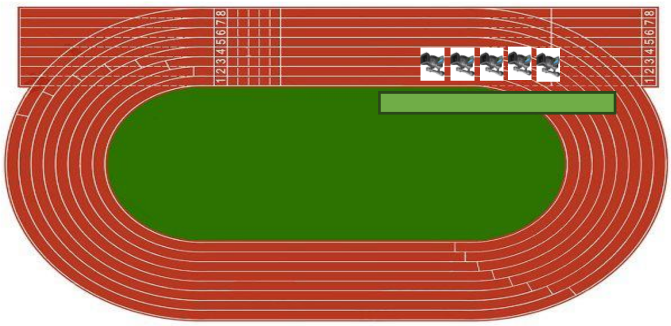

Figure 1. Illustrates the placement of cameras in the 50-meter flying start test.

Figure 2. Demonstrates the recording and calculation of variables in the 50-meter flying start test

Equivalence of Research Groups

After performing logical calculations for all study variables across the 18 sprinters, it was essential to establish group equivalence before implementing the training programs in different environments. The researchers verified the homogeneity of the three training groups, following the principle that "the researcher must establish equivalent groups, at least concerning variables relevant to the study" (Dalen, 1985).

To ensure control over variables affecting the study's accuracy and to attribute any observed differences solely to the independent variable, the researchers applied Analysis of Variance (ANOVA) for the three independent groups. This statistical test was performed on the raw data from the pre-test for all studied variables.

Table 2. Displays the means and standard deviations for the 50-meter sprint test.

Indicators	**Unit of Measurement**	**Experimental Group 1 (Pre-Test)**	**Experimental Group 2 (Pre-Test)**	**Experimental Group 3 (Pre-Test)**
		Mean (M)	SD	Mean (M)
Time	Seconds	5.52	0.289	5.43
Speed Rate	m/s	9.07	0.203	9.03

Stride Length	meters	2.30	0.010	2.28
Stride Frequency	steps/sec	4.45	0.069	4.42

Statistical significance at a degree of freedom (2, 15) and significance level ≥ (0.05).

Table 3. Equivalence Analysis of the Three Groups

Source of Variance	**Sum of Squares**	**Mean Squares**	**F Value**	**Actual Significance**	**Indication**
		Time (Seconds)			
Between Groups	0.335	0.169	2.024	0.276	Random
Within Groups	103.6	6.918			
		Speed Rate (m/s)			
Between Groups	0.111	0.057	3.043	0.098	Random
Within Groups	19.55	1.306			
		Stride Length (m)			
Between Groups	10.19	5.055	3.033	0.078	Random
Within Groups	25.22	1.664			
		Stride Frequency (steps/sec)			
Between Groups	0.112	0.053	2.510	0.199	Random
Within Groups	86.15	5.742			

The results indicate that all tested variables (time, speed rate, stride length, and stride frequency) showed no statistically significant differences among the three groups, statistically significant at a degree of freedom (2, 15) and a significance level ≥ (0.05).

The results presented in Table 3 indicate that all three groups are equivalent across all study variables. The statistical analysis confirms the presence of random differences with no significant statistical effect among the groups, ensuring their homogeneity for the research study.

Training in Different Environments

The training programs were designed based on the pre-test results, with each group conducting their exercises on a specific training surface:

Group 1 trained on grass surfaces

Group 2 trained on soft sand surfaces

Group 3 trained on hard soil surfaces

All groups followed the same intensity level, duration, and sequence of exercises, training on Sundays, Tuesdays, and Thursdays for a period of 8 weeks during the specialized preparation phase. The training period began on Sunday, April 21, 2024, and concluded on Thursday, June 13, 2024.

Training Program Details:

ABC drills – Rapid frequency exercises for fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

Stride control drills – Using small hurdles (30 cm height) for fixed distances on all surfaces (10m, 20m, 30m, 40m, 50m).

Bounding drills – Performed for fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

Frog jump drills – Conducted over fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

Hopping drills – Executed for fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

Backward running drills – Performed over fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

Natural running drills – Conducted for fixed distances across all surfaces (10m, 20m, 30m, 40m, 50m).

2.4.5 Post-Tests

The post-tests were conducted on Friday, June 14, 2024, at the Track and Field Stadium of the College of Physical Education and Sport Sciences, University of Baghdad, at 3:00 PM. The same testing procedures used in the pre-tests were carefully followed to ensure consistency in performance evaluation.

Statistical analysis

Data Collection Methods

Observation

Tests and measurements

Arabic and foreign references, as well as online sources (Internet)

Personal interviews

Data recording form

Equipment Used

Korean-made analysis camera (CASIO Exilic EX-FH12.5) – 5 units with a speed of 120 frames per second

1-meter measuring scale

Electronic medical scale for measuring body mass

Running track at Najaf International Athletics Stadium

Grass training surface

Soft sand training surface

Hard soil training surface

Nordic Swedish sprint starting blocks

Chinese-made Clack sound race-starting pistol

Three (3) timing stopwatches

Kenova motion analysis software

DELL laptop computer

Cones for marking training distances

Metric measuring tape for measuring athletes' heights

Results

Table 4 below shows the means and standard deviations for the three groups.

Table 4. Displays the means and standard deviations for the three groups.

Group	Variable	Unit of Measurement	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	t-Value	Sig. Value	Significance
Group 1 (Grass Surface)	Time	Seconds	5.52	0.289	5.45	0.235	3.795	0.013	Significant
	Speed Rate	m/s	9.07	0.203	9.17	0.201	3.002	0.027	Significant
	Stride Length	Meters	2.30	0.010	2.33	0.015	2.671	0.044	Significant

	Stride Frequency	Steps/sec	4.45	0.069	4.44	0.079	2.062	0.112	Not Significant
Group 2 (Sand Surface)	Time	Seconds	5.49	0.259	5.40	0.134	4.333	0.000	Significant
	Speed Rate	m/s	9.03	0.214	9.25	0.223	3.503	0.009	Significant
	Stride Length	Meters	2.28	0.032	2.37	0.075	2.779	0.021	Significant
	Stride Frequency	Steps/sec	4.42	0.118	4.40	0.138	2.250	0.086	Not Significant
Group 3 (Hard Soil Surface)	Time	Seconds	5.48	0.212	5.44	0.201	3.253	0.028	Significant
	Speed Rate	m/s	9.05	0.209	9.19	0.250	2.963	0.046	Significant
	Stride Length	Meters	2.34	0.043	2.35	0.141	3.053	0.041	Significant
	Stride Frequency	Steps/sec	4.40	0.055	4.42	0.059	2.045	0.272	Not Significant

Interpretation

Statistically significant improvements ($p \leq 0.05$) were observed in time, speed rate, and stride length across all groups.

Stride frequency did not show significant changes in any of the groups.

The sand surface group showed the highest significance levels, indicating a greater impact on sprint performance variables.

Table 5. Shows the results of the one-way ANOVA analysis for the three groups.

Source of Variance	Sum of Squares	Mean Squares	F Value	Actual Significance (p-value)	Significance
Time (Seconds)					
Between Groups	60.10	30.05	4.88	0.024	Significant
Within Groups	40.40	2.70			
Speed Rate (m/s)					
Between Groups	6.34	3.18	4.92	0.021	Significant
Within Groups	9.65	0.66			
Stride Length (m)					
Between Groups	14.77	7.38	4.34	0.032	Significant

Within Groups	25.50	1.72			
Stride Frequency (steps/sec)					
Between Groups	40.32	20.14	10.04	0.000	Significant
Within Groups	30.17	2.02			

Interpretation:

The F-values indicate significant differences ($p \leq 0.05$) across the three groups for all measured variables.

Stride frequency had the most significant difference ($p = 0.000$), indicating substantial variation among the training environments.

These findings suggest that different training surfaces had varying degrees of impact on sprinting performance.

Table 6. Shows the results of the Least Significant Difference (LSD) test for comparison among the three groups

Dependent Variables	Groups	Mean	Groups	Mean	Mean Difference	Sig. Value	Significance
Time (Seconds)	Group 1	5.45	Group 2	5.40	0.05	0.019	Significant
	Group 1	5.45	Group 3	5.44	0.01	0.191	Not Significant
	Group 2	5.40	Group 3	5.44	0.04	0.047	Significant
Speed Rate (m/s)	Group 1	9.17	Group 2	9.25	0.08	0.004	Significant
	Group 1	9.17	Group 3	9.19	0.02	0.124	Not Significant
	Group 2	9.25	Group 3	9.19	0.06	0.012	Significant
Stride Length (m)	Group 1	2.33	Group 2	2.37	0.04	0.041	Significant
	Group 1	2.33	Group 3	2.35	0.02	0.180	Not Significant
	Group 2	2.37	Group 3	2.35	0.02	0.180	Not Significant
Stride Frequency (steps/sec)	Group 1	4.44	Group 2	4.40	0.04	0.041	Significant
	Group 1	4.44	Group 3	4.42	0.02	0.111	Not Significant
	Group 2	4.40	Group 3	4.42	0.02	0.089	Not Significant

Interpretation

Time (seconds): The sand training group (Group 2) showed a statistically significant improvement over both the grass (Group 1) and hard soil (Group 3) groups.

Speed rate (m/s): Group 2 (sand surface) had the highest significant increase compared to Group 1 (grass) and Group 3 (hard soil).

Stride length (m): Group 2 (sand) showed a significant improvement compared to Group 1 (grass), while there was no significant difference between Groups 2 and 3 or Groups 1 and 3.

Stride frequency (steps/sec): A significant improvement was observed in Group 1 (grass) compared to Group 2 (sand), but no significant differences were found between Groups 1 and 3 or Groups 2 and 3.

These results suggest that training on sand had the most positive impact on sprint performance variables compared to grass and hard soil surfaces.

Discussions

Regarding Table 4, which presents the means, standard deviations, and t-values for the pre-test and post-test comparisons across the three groups, the results indicate statistically significant differences in all variables in favor of the post-tests for each group.

The researchers attribute this improvement to the structured training programs designed for all three groups, incorporating different training surfaces (dense grass, soft sand, and hard soil). This finding aligns with the statement by Saad Mohsen, who emphasized that, regardless of varying scientific and practical perspectives, a well-structured training program inevitably leads to performance improvement when built on a scientific foundation. This includes proper organization of training, gradual intensity progression, consideration of individual differences, optimal repetitions, effective rest periods, and guidance from specialized coaches under favorable training conditions (Ismail, 1996).

This result is further supported by the study of Morad & Shbeeb (Morad, 2023), which highlighted that variability in exercises and repetitions, when well-structured and systematically programmed, enhances performance outcomes. The researchers ensured balanced and well-distributed training loads, prioritizing adequate selection of exercises based on the target abilities being measured. Furthermore, the researchers deliberately replaced the conventional tartan track with training environments that provided resistance, such as grass, sand, and soil surfaces. This approach aligns with Abu Alaa (Abu Alaa, 2003), who stated that "any form of resistance contributes to improving an athlete's physical, technical, and functional performance, positively impacting the development of the targeted abilities set by the coach. Regarding Table 5, which presents the analysis of variance (ANOVA) for the post-tests across the three groups, all F-values were statistically significant for the measured variables across all groups.

The researchers attribute these significant differences to the designed training programs, which included a variety of targeted exercises across the different training environments. One of the most impactful components was the ABC drills, which proved highly effective in improving stride length and frequency. These drills hold a crucial role in spring training programs as they serve multiple purposes, particularly in developing agility, coordination, strength, and speed. Numerous studies indicate that these physical attributes are strongly interrelated and directly influence running speed and overall performance. This validates the application of ABC drills in sprint training to enhance athletic performance. From a biomechanical perspective, sprinting performance relies on speed, which, in essence, refers to running at the maximum possible velocity. Achieving this requires specialized exercises that enhance acceleration, balance, and coordination, all of which can be effectively developed through ABC drills. Previous studies have also demonstrated the significant impact of these exercises on sprint performance in 100m, 200m, and 400m events. Research by (Priyono, 2019) and (Mukhtar, 1998) found that short-distance sprint speeds improved considerably with structured ABC training, highlighting a strong correlation between these fundamental movement drills and sprinting efficiency.

The researchers believe that implementing the designed training exercises alongside changing training environments follows two key directions: Correct movement coordination, ensuring that athletes develop proper running mechanics. Enhancing the strength of the muscles involved in movement execution, where adding resistance to training surfaces increases friction—similar to resisted sprint drills using weighted vests or sleds. This method mimics sprint training at various distances while considering the level of exercise intensity. Scientific sources suggest that training without resistance is best applied over distances longer than 30 meters, while resistance training is more effective for distances of 30 meters or less. This is particularly important when considering anthropometric, morphological, and neuromuscular characteristics of athletes, along with their specific physical capabilities. Sprinting requires high acceleration capacity, where strength plays a crucial role, emphasizing the strong relationship between power and sprint performance. Studies indicate that this relationship can be measured through jumping tests and sprint assessments, showing statistically significant correlations between jumping performance and sprint speed under a relative load of 7%-8% across 10m, 20m, 30m, 40m, and 50m distances (Hrysomallis, 2012).

According to the study results, the varied training exercises—which included sprinting, jumping, and hopping drills—contributed to developing coordinative abilities, which in turn enhanced movement quality and the ability to adapt motor programs to changing execution conditions. This resulted in movements that were more effective, aesthetically fluid, and biomechanically efficient (Abdelkhaleq, 2005). The researchers observed that Group 2, which trained on the soft sand surface, outperformed the other two experimental groups (grass and hard soil) in all measured variables, except for stride frequency. This variable is known to be one of the most complex biomechanical aspects when studied in relation to stride length, given the inverse relationship between them. Following Group 2, the grass training group (Group 1) ranked second, while the hard soil group (Group 3) came in third, though the difference was relatively small. Meanwhile, Table 6 presents the Least Significant Difference (LSD) test results, comparing the three groups to determine which training environment had the most significant impact on sprint performance.

The researchers observed that Group 2 (trained on the sand surface) outperformed both Group 1 (grass surface) and Group 3 (hard soil surface) in most variables, particularly in time, speed rate, and sometimes stride length. However, some variables, especially stride frequency and occasionally stride length, did not show statistically significant differences. Regarding the insignificance of differences in certain variables, the researchers note that Table 6 of the LSD statistical analysis reveals minor differences that are not detected by statistical measures across the three groups. Despite this, Group 2 still demonstrated superiority over the other groups, as indicated by the mean values. The researchers attribute this similarity in performance levels across groups to the scientific and precise structuring of the training programs. According to (Hammad, 2002):

> "Any training program based on scientific principles leads to improvements in an athlete’s performance and training state; however, the extent of improvement is the decisive factor distinguishing one program from another."

The use of repetitive and high-intensity interval training methods across all groups contributed to the development of speed-related abilities. This aligns with (Mukhtar, 1998), who stated:

> "Repetitive and high-intensity interval training methods are used to enhance anaerobic processes, which are directly linked to speed development."

The researchers also agree with (Parr, 2018), who emphasized that:

> "If a runner receives training under conditions similar to competition settings, the desired adaptations will occur."

Similarly, (Saleh, 2015) highlighted that:

> "Dynamic sports require training that harmonizes strength, speed, and sensory perception. Achieving elite performance levels demands multiple specialized

> abilities, most notably a high degree of neuromuscular coordination, rapid motor execution, and quick reaction time, in addition to a strong nervous system capable of handling technical skills."

The researchers aimed to test a new training method that would help break traditional routines while also introducing natural resistance. This was implemented through various drills such as:

ABC drills with high frequency over fixed distances,
Stride control drills using 30 cm hurdles,
Bounding drills,
Frog jumps,
Hopping drills,
Backward running drills,
Natural running drills.

All these exercises were performed over fixed distances (10m, 20m, 30m, 40m, and 50m) across the three different training environments (grass, sand, and hard soil). However, the sand surface proved to be the most effective training medium, ranking first in performance improvement. Training on sand is recognized as one of the most effective resistance training methods, as it increases the difficulty of movement, enhancing both functional and physical efficiency. It also improves endurance, allowing athletes to sustain performance for extended periods, making it a powerful method for fatigue resistance.

One of the key characteristics of sand training is that it increases body weight resistance due to the feet sinking into the sand, thereby providing greater resistance to the body. According to (Al-Shukri, 2001):

> "Movement on sand is distinct from movement on other surfaces (grass, soil). When the legs move through sand, they encounter resistance that can be utilized for strengthening muscles and increasing joint range of motion. As movement speed increases, so does the resistance."

Based on these findings, the research hypotheses were confirmed, demonstrating statistically significant differences between the pre-test and post-test results for sprinters, as well as statistically significant differences in favor of one of the three training groups in the post-test results.

Conclusions

Training in varied training environments creates an engaging atmosphere, breaking the routine and serving as a necessary strategy to diversify training settings and enhance player motivation. Sand training proved to be the most effective training surface for sprinters, as the sinking resistance of the feet in the sand provides greater resistance during running, leading to improved strength and endurance. It is essential to design and implement sport-specific exercises tailored to the chosen athletic discipline and apply them in the appropriate training environment for experimental validation.

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Conflict of interest

There is none.

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