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Effect of Explosive Strength Training on Middle-Distance Performance of Junior Male Runners.

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Abstract: The present study was conducted to illustrate - through a training program (based on simultaneous Strength / Endurance training) - the importance of strength in improving performance in middle distance.
We used the experimental method that contains two groups, experimental group and control group; the athletes of both groups will perform the following tests: ¼ squat test at 110°, 20m launched sprint and 3000m running.
The two groups will follow a training for 6 weeks (2 hours / session, 5 sessions / week), 25% and less than 5% of the training time were devoted to the explosive force training respectively for the experimental and the control group. We will do a re-test afterwards to see the evolution of performance in both groups.

Keywords: Explosive Force, Sports performance, Middle distance races.

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NB: Before presenting our experimentation to readers, we affirm that this study was carried out according to IMRaD method for writing scientific research papers (Introduction - Methods - Results and Discussion).

I- Introduction :

All coaches have once asked themselves the following question: 'what more can I do to make my athlete exceed his performance?' Especially since we can now distinguish that high-level sport presents specific conditions: particular environment, nature of specific problems, exceptional conditions… the primary objective is to get athletes to the podiums during major events (Olympic Games, World Championships, Continental Championships ...); these objectives are essentially qualitative and not quantitative, the references of an international and not a national nature.

The performance progress is continuous, but above all, it becomes **denser**; the coach has competition performance or more or less sophisticated tests to assess the worth of athlete.

The evolution analysis of the various world records in middle distance during the period from 1912 to 2021 went from 1' 51" 9 to 1' 40' '91, a gain of 11 seconds, or else 9.83 %; while the 1500m record improved from 3' 55" 8 to 3' 26" 00, a gain of about 29 seconds with a percentage of 12.64 %. For longer events such as the 5000m and 10000m which have progressed by 13.89% and 16.54 % respectively, it can be deduced that it is the long events that are progressing the most, in particular during the last decades.

Nowadays, it is clear to those involved in sport that the improvement of sports performances and records in all disciplines has become possible thanks to the improvement of training methods, training planning and means of recovery…

In order to improve the performance of an athlete, the coach must determine the **specific qualities** to be improved. The specificity of training is becoming more and more important. As the increase in the frequency and intensity of training has its limits, qualitative preparation is required to continue to improve the performance of the athlete. Each training program devotes a significant volume to the development of the qualities required by the sporting discipline practiced, "Sports performance are both indicators of the quality of work provided by the athlete and the measure of his success" (Matveev, 1983).

Although success in aerobic endurance sports requires a high VO_2max value, this variable does not fully explain the observed performance differences. Another hypothesis attempts to explain fatigue and performance in aerobic endurance sports such as middle distance running; this alternative theory postulates that the ultimate limitation in aerobic performance is the **nervous system**, not the athlete's ability to transport and use oxygen during exercise. This notion is based on the idea that the central nervous system integrates information from various sources, such as muscles, heart, and respiratory system during physical activity, and prevents the recruitment of skeletal muscles beyond levels of intensity and duration for which potential damage could occur to the heart and other vital organs.

According to this hypothesis, changes in the number of motor units recruited to the skeletal striated muscle during exercise provide a more complete explanation for the decrease in efficiency that develops during exercise and during the establishment of different athletic performances.

Paavolainen and *coll.* (Paavolainen , Häkkinen , Hämäläinen , Nummela, & Rusko , 1999) presented another theoretical model whose variables are related to the level of performance over a given distance. In this new model, the traditional model of aerobic performance is complemented by the addition of **neuromuscular factors** explaining the muscle's capacity to produce force.

As an extension of the theme of our search focused on the impact of the quality of explosive force on the performance of middle distance runners, and in this perspective, we have oriented our problematic as follows:

- Is there a correlation between explosive strength and middle distance performance?
- If so, what is the nature of this correlation?

Hypothesizes of our search were as follows:

• We assume that there is a correlation between explosive strength and middle distance performance.

• We also suppose that the more the explosive force of the middle distance runners (juniors) is worked, the better their performances are (**positive correlation**).
Thus, this study was conducted to illustrate - through a training program (based on simultaneous Strength / Endurance training) - the importance of strength quality in improving performance in middle distance running.

We will show the main concepts mentioned in the research:

- **Explosive force**:
  Both Hadj Aissa and Benaki, quoting from Thépaut-Mathieu and others (Thépaut-Mathieu, Miller, & Quièvre, 1997), indicate that the explosive force or explosiveness is the ability of the neuromuscular system to rapidly increase its level of strength (Hadj Aissa & Benaki, 2021). For Hammad, the explosive force means the instantaneous ability of a muscle or a specific muscle group to produce the maximum muscle contraction for one time and as quickly as possible (حماد، 2000). As for Sulaymane, he defined it as the use of force in the least time to produce a movement (حمودي، شنوف، و لوح، 2021).

- **Sport performance:**
  Attaleb, quoting from Issam Abdel-Khaliq (الطالب، 1983) defined sport performance or athletic performance as the delivery of something to the addressee. It is a reflection of the capabilities and motives of each individual for the best possible behavior because of mutual influences of internal forces; and it is often performed individually. In addition, it is an activity or behavior that leads to a result, as well as it is the measure by which learning outcomes are measured, and it is the means by which the learning process is behaviorally expressed.

Sports performance has levels including:

- Maximum athletic performance: It means that the individual performs the best possible sporting performance as possible.
- Distinguished athletic performance: It refers what the individual actually performs, the manner of his athletic performance, and not the maximum he can perform.

- **Middle-distance races:**

Middle-distance running events are track races longer than sprints, up to 3000 meters. The standard middle distances are the 800 meters, 1500 meters and Mile run, although the 3000 meters may also be classified as a middle-distance event (Britannica, 2020)". In addition, middle distance races are so named because they are contested over intermediate distances between the sprint and the long-distance (from 800m to 3000m). The middle distance races are as follows: 800m, 1000m, 1500m, Mile (1609m), 2000m and 3000m. Only the 800m and the 1500m are on the program for the Olympic Games and World Athletics Championships, the 3000m having disappeared from the women's events at the time of the 1996 Atlanta Games and it was replaced by the 5000m race. It should be noted that it is possible to distinguish between the **Short Middle distance races** (Demi-fond court), which includes the distances between 800 and 1500 meters, and the **Long Middle distance races** (Demi-fond long), which includes other races of up to 3000 meters or up to 5000 meters, as some think." (BILLOUIN , 1980).

II– Methods and Materials:

2.1 Population: The population of our study is composed of Algerian athletes in the junior category (boys), specialists in middle distance.

2.2 Sample: Our sample is composed of 20 athletes of under 20 year’s category (U20), specialists in middle distance from OSAM sporting club.

Table (01): Characteristics of the sample.

	Age (year)	Weight (kg)	Height (cm)
Experimental group (N = 10)	19.1 ± 0.6	61.8 ± 2,9	174.1 ± 4.0
Control group (N = 10)	19.3 ± 0.4	63.6 ± 3,3	173.5 ± 3.7
Total sample (N = 20)	19.2 ± 0.4	62.7 ± 3,0	173.8 ± 3.9

Nb: N: Number / kg: Kilogram / cm: Centimeter

2.3 Research methods:

In order to achieve our objective and carry out our experiment, we have used the experimental method and the following research methods and tools:

2.3.1 Method of tests: The protocol set up for the research proposed two types of data collection: anthropometric measurements and athletic performance measurements in physical tests.

A. Anthropometric measurements:

- **The stature**: Distance going from the ground to the vertex. It is also called standing waist as opposed to sitting waist.
- **Weight**: A medical scale is used for weighing the weight with an accuracy of + or - 50grs.

B. Physical tests:

The athletes had to perform a series of tests spread over two days.

- A test measuring the maximum strength and the rate of development of the strength of the lower limbs: maximum strength test of ¼ squat at 110 ° (Slawinski, Quièvre, Lévêque, Heubert, & Gajer, 2006).
- A race of 20m maximum speed / 20m launched sprint test (anaerobic power).
- A race of 3000 m at maximum speed (an intermediate race at middle distance).
- **Test protocol**:

First day: after the anthropometric measurements and the warm-up, the strength test will take place in a weight room. Each athlete performs a **maximum strength test of ¼ squat at 110 °** (the subject lifts heavier and heavier weights each time up to the maximum load with maximum speed, a recovery period of 2 to 3 minutes is allowed between the tests, the last weight he will have been able to mobilize represents his Maximal strength performance.

The 20m launched sprint test: the athletes perform 20 meters 3 times with a swing of 30 meters; the best performance of each athlete is taken into consideration.

Second day: after the warm-up, **the 3000 m test** will take place on an athletics track.

2.3.2 Training protocol:

Once the anthropometric measurements and physical tests (1st tests) were performed, the athletes were randomly divided into 2 groups, one of which is experimental and consists of 10 athletes; the other is control group (10 athletes). Both groups trained in endurance for 6 weeks (2 hours / session, 5 sessions / week, Period: from May 15 to June 25 / 2021), for the same composition and volume of training. On the other hand, 25% and less than 5% of the training time were added to sessions to develop explosive-force respectively for the explosive force group (Experimental Group / EG) and the control group (CG). The content of the training of explosive force: {various sprints (5-10m), (20-60m), jumping exercises (alternative jumps, bilateral countermovement jumps, jumps over hurdles, and jumps downwards) as well as exercises of bending extensions of legs and leg-press at maximum speed with a light load, etc…}.

As for the other components of the program (technical work, endurance and specific training...), the two groups followed the same training rates.

2.3.3 Research tools: The following material will be used during our experiment:
- An IHM brand stopwatch.
- A medical scale with an accuracy of + or - 50 grams.
- Anthropometric rule.
- Weight room (equipped with specific equipment).
- A PC from the ASUS / i5 brand.
- Statistical processing software.

2.3.4 Statistical analysis method: In order to give meaning to the results obtained during the performance of the physical tests as well as their interpretations, we calculated:

- The Arithmetic Mean: Represents the average value of the results of a test.

- The Standard Deviation: It is given by the following formula (σ) (Champely, 2003):

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{N}}$$

x_i : Measured variable / $\bar{x}$: Arithmetic mean / N: number of individuals who performed the test.

-The Correlation Coefficient: Represents the degree of correlation between the results of two tests (2 variables) carried out by the same group of individuals. The correlation coefficient (r) is given by the following equation (Champely, 2003):

$$r = \frac{\sum_{i=0}^{n}(xy) - \frac{(\sum_{i=0}^{n} x)\,(\sum_{i=0}^{n} y)}{N}}{\sqrt{\left(\sum_{i=0}^{n} x^2 - \frac{(\sum_{i=0}^{n} x)^2}{N}\right)\left(\sum_{i=0}^{n} y^2 - \frac{(\sum_{i=0}^{n} y)^2}{N}\right)}}$$

x: First variable / y: Second variable / N: Numbe

III- Results and discussion :

3.1 Results:

➢ **Force test results (1/4 Squat at 110 °)**.

Table (2): Evolution of strength in athletes before and after carrying out the simultaneous Strength / Endurance training program (E G).

Experimental Group		
Athletes	Before	After
1	150	168
2	155	174
3	149	165
4	160	178
5	160	179
6	156	180
7	150	165
8	165	177
9	146	162
10	162	180
$\bar{X}$	**155.3 kg**	**172.8 kg**

NB: $\bar{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **kg** = kilogram.

Analysis of the maximum strength test results shown in the table above, illustrate that the group average before program application is around 155.3kg. On the other hand, after the training program this average improved and reached 172.8 kg with a maximum of 180 kg recorded in the group.

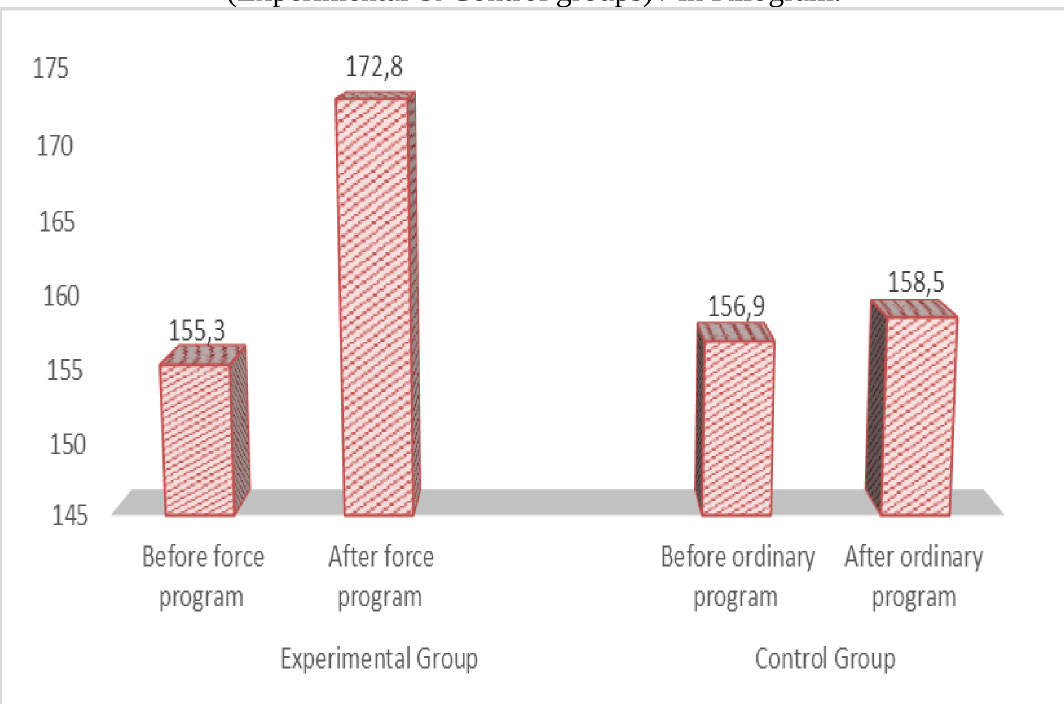
Table (3): Evolution of strength (1/4 of Squat in kg) in athletes before and after the realization of Endurance training program (C G).

Control Group		
Athletes	Before	After
1	148	152
2	152	155
3	152	153
4	155	156
5	163	161
6	161	162
7	160	164
8	158	158
9	166	167
10	154	157
$\bar{X}$	**156.9 kg**	**158.5 kg**

NB: $\bar{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **kg** = kilogram.

The reading of the table above representing the means of the results of the test of maximum strength of the control group, shows a stability of the means, which were recorded before and after the application of the ordinary program (156.9 kg against 158.5 kg).

Figure n ° (1): Evolution of the strength averages of the two groups (Experimental & Control groups) / in Kilogram.



- **Speed test results (20m sprint)**.

Table (4): Performance evolution of 20m sprint (Speed in km /h) before and after the simultaneous Strength / Endurance training (E G).

Experimental Group		
Athletes	Before	After
1	30	32.73
2	31.30	32.73
3	30	31.30
4	32.73	36
5	32	34.29
6	31.30	34.29
7	32.73	36.92
8	32	34.29
9	30.64	32.73
10	35.12	37.89
$\bar{X}$	**31.78 km/h**	**34.32 km/h**

NB: $\bar{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **km/h** = kilometer per hour.

The averages of the results of the 20m test recorded by the experimental group indicate that the group obtains the highest average after the application of the simultaneous Strength / Endurance training program, and the Experimental group average speed has moved from 31.78 km/h to 34.32 km / h after the force-training program.

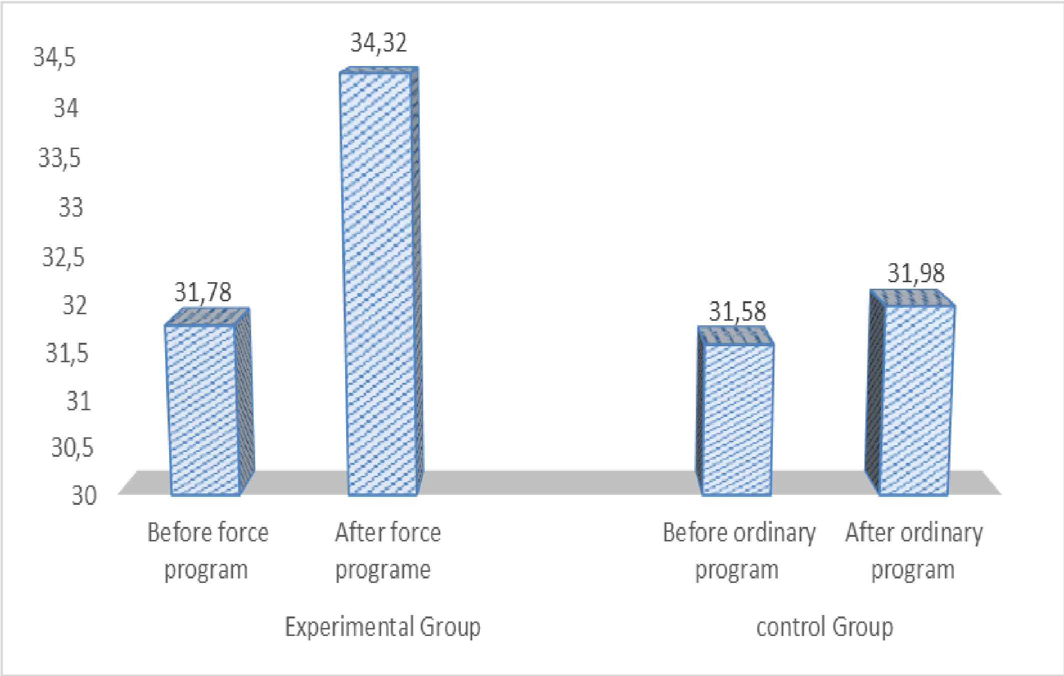
Table (5): Performance evolution of 20m sprint (Speed in km /h) before and after Endurance training program (C G).

Control Group		
Athletes	Before	After
1	30.64	31.30
2	30	30.64
3	31.30	32
4	32	32
5	32.75	33.49
6	31.30	32.73
7	35.12	34.29
8	30	30
9	32.73	32
10	30	31.30
$\bar{X}$	**31.58 km/h**	**31.98 km/h**

NB: $\bar{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **km/h** = kilometer per hour.

The results of 20m launched sprint in the control group show a stability of the averages after the completion of the ordinary (Endurance) training program (31.58 km against 31.98 km).

Figure n ° (2): Evolution of the average speed (km /h) in the 20m test (launched sprint) before and after the application of the training programs of each group.



- **Endurance test results (3000m)**.

Table (6): Performance evolution of 3000m (Speed in km /h) before and after the application of the simultaneous Strength / Endurance training program (E G).

Experimental Group		
Athletes	Before	After
1	20.88	21.57
2	21.20	20.94
3	20.86	21.49
4	20.94	21.82
5	20.43	21.75
6	20.94	21.90
7	21.10	21.70
8	20.64	21.75
9	20.20	21.30
10	21.00	21.88
$\bar{X}$	**20.82 km/h**	**21.61 km/h**

NB: $\bar{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **km/h** = kilometer per hour.

The averages of the results of the 3000 m test of the experimental group indicate that the group obtains the highest average after the application of the simultaneous Strength / Endurance training program, and the Experimental group average speed has moved from 20.82 km/h to 21.61 km/h km / h

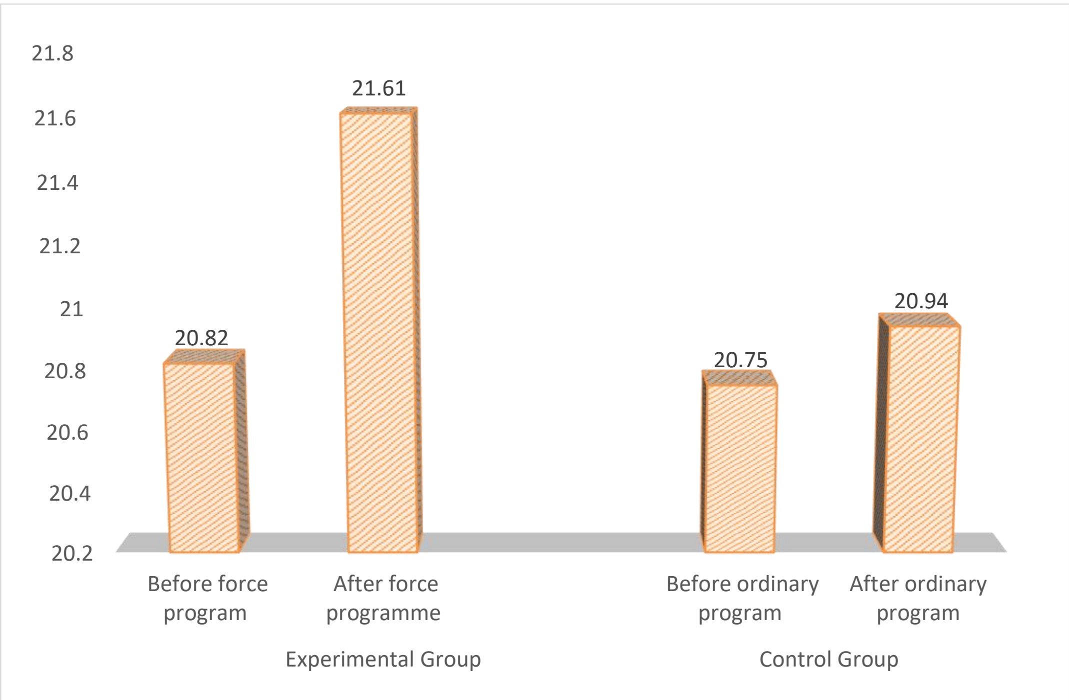
Table (7): Performance evolution of 3000m (Speed in km/h) before and after the application of the Ordinary Endurance training program.

Control Group		
Athletes	Before	After
1	20.09	20.26
2	20.26	20.39
3	20.22	20.64
4	21.51	21.56
5	21.47	20.80
6	21.34	21.47
7	20.22	21.15
8	21.30	21.43
9	20.60	21.49
10	20.46	20.20
$\overline{X}$	**20.75 km/h**	**20.94 km/h**

NB: $\overline{X}$ = Arrhythmic average / **Before**: Before carrying out the training program / **After**: After carrying out the training program / **km/h** = kilometer per hour.

The performances of the 3000m test in the control group show a stability of the averages after the completion of the ordinary training program (20.75 km against 20.94 km).

Figure n ° (3): Evolution of the average speed (km /h) in 3000m test before and after the application of the training programs of each group.



3.2 Discussion:

3.2.1 Discussion of test results.

*** Strength test (¼ Squat test at 110 °):**

We can say that the simultaneous Strength / Endurance training (mainly the Strength work) that was carried out by the Experimental group athletes affected their results in the second Strength test (re-test), where there was an improvement of 17.5kg (i.e. a gain of 11.27% / with the presence of significant differences). Unlike the Experimental group, the Control group who underwent ordinary training program (Absence of Strength training) shown only a slight improvement of 1.6 kg in Strength (i.e. a gain of 1.01%). In addition, the comparative analysis of the performances of the two groups in Maximum Strength recorded after the application of the programs of each group shows the presence of significance between the two means, this means that the Experimental group observed a greater improvement compared to the group Witness (control). This improvement is due to the work of explosive force which was carried out by the experimental group (work of explosive force = 25%). Our search results affirm the conclusions of many researches like Aagaard's labor (Aagaard, et al., 2011) who conclude that concurrent strength/endurance training in young elite competitive cyclists led to an improved 45-min time-trial endurance capacity that was accompanied by an increased proportion of muscle fibers..

The strength training increases the hypertrophy of the muscle fibers and the muscles resistance and effectiveness.

*** 20m launched sprint test:**

An improvement of 2.54 km / h (i.e. a gain of 7.99% / presence of significance) was noted in the Experimental group. On the other hand, the Control group that underwent ordinary training program (absence of force exercises) observed only a slight improvement of 0.4 km / h in their Average Speed (i.e. a gain of 1.27%). In addition, the comparative analysis of the performances of the two groups in the 20m test recorded after the application of the programs of each group shows the presence of significance between the two averages, in other words, the Experimental group observed a greater improvement in power-anaerobic compared to the Control group. This improvement can be explained by the adaptations of the nervous activation and by an increase in the power of the lower limbs. Additionally, as the power is the result of qualities of force and speed; therefore this increase is due to an improvement in the level of strength, which results in an improvement in performance in the 20m (Maximum Speed) test.

This exploration affirms the conclusions of several researches like Styles's and others (Styles, Matthews, & Comfort, 2016) who conclude in their research (titled: Effects of Strength Training on Squat and Sprint Performance in Soccer Players) that Strength training resulted in significant improvements in absolute and relative strength. Similarly, there were significant improvements in sprint performance over 5 m, 10 m, and 20 m. Changes in maximal squat strength seem to be reflected in improvements in short sprint performance highlighting the importance of developing maximal strength to improve short sprint performance.

*** 3000m test (Endurance):**

The evolution of Speed (means of the two groups) in the 3000m test shows a visible increase in the average Speed of the Experimental group (difference between the two means before and after the simultaneous Strength / Endurance training = 0.79 km / h, i.e. a gain of around 19 seconds). Therefore, the difference between the two means is statistically significant (Test t = 17.185, dof = 9, p =, 000). This improvement is explained as follows, the more powerful the motor units of the muscles of the lower limbs, the less their number must be important to maintain a given speed, which would reduce the oxygen demand and the energy cost at the level of the muscles actives in favor of improving the racing economy.

Regarding the Control group, and according to the Speed evolution in the 3000m test, we observed a slight increase of 0.19 km /h (i.e. a gain of 4.3 seconds) in the average speed after the achievement of

the 6 weeks ordinary program. It is clear that the progression observed in the Experimental group was greater than that of the Control group, and this is confirmed by the results of T-Test between the means of the Experimental group and the Control group, where the difference was statistically significant (over than 14 seconds was noted between the two averages).
In the same field, we find that our results affirm the conclusions of Barnes and other who conclude: ‘Running economy (RE) represents a complex interplay of physiological and biomechanical factors which is generally defined as the energy demand for a given running speed. This review examined a wide range of acute and chronic interventions that have been investigated with regards to improving economy by increasing one or more components of the metabolic, cardiorespiratory, biomechanical or neuromuscular systems.
Endurance training in runners leads to a wide range of physiological responses, and it is very likely that these characteristics of running training will influence the RE. Training history and training volume have been suggested to be important factors in improving RE, while high-intensity interval training uphill and at ground level represents forms frequently prescribed training that can lead to further improvements in the economy.
More recently, research has shown short-term resistance and plyometric training has resulted in improved RE. This improvement in RE was thought to be the result of improved neuromuscular characteristics.’ (Barnes & Kilding, 2015).
According to the previous studies and our present results, we conclude that the combination of Endurance training with Strength training can improve the middle distance performance.

3.2.2 Correlative analysis between the test results (Strength and Speed) and the 3000m results (Endurance):

In this part, we calculated the correlations between the different test results and the 3000m results.
We will present the results as follows:

• Correlation between the results of the strength test and the 3000m test:

According to the correlation test, a strong correlation is observed between the results of the Maximum Strength test (1/4 squat at 110 °) and the results of 3000m, with a correlation coefficient of 0.76. So Analysis of the data from the present research shows that there is a relationship between 3000m results and peak strength performance (r =, 762, p =, 000). In other words, the more the maximum force performance increases the more the performance in 3000m improves (time decreases); this can be explained by adaptations of the nerve activation and an increase in the frequency of discharge of the motor units.

• Correlation between the results of the 20m test and the 3000m test:

According to the correlation test, a strong correlation was observed between the results of the 20m test and the results of 3000m, with a correlation coefficient of 0.57. From this, data analysis shows the presence of a relationship between 3000m results and speed performance (r =, 566, p =, 000). In other words, the more you work the speed the more the performance of 3000m increases (time on 3000m decreases and average speed increases).
This is explained as follows; the more the motor units of the leg muscles are powerful, the less their number must be important to maintain a speed given, which would reduce oxygen demand and energy cost in active muscles for the benefit of improving running economy. Thus, strength may itself represent an independent and important limitation of aerobic performance.

IV- Conclusion:

Here we are at the end of our research or we will have to conclude; where the response to all coaches who have once asked themselves ‘what more can they do to make their athletes exceed their performances?’ it is to clearly seek other keys of success that they have not used before, where the place to quality of training became very important in the moden sport…

In addition, the results of the present study will be summarized as follows:

• A visible increase in Strength (17.5 kg) for the Experimental group after completing the simultaneous Strength / Endurance training program.

• A slight increase in Strength (1.6 kg) for the Control group who underwent an ordinary training program (no Explosive Force training).

• A visible increase in Maximum Speed (20m launched sprint test) in the Experimental group, against a slight increase in the Control group.

• A visible increase in performance on the 3000m test (improvement of 19 seconds) for the Experimental group.

Therefore, the progression observed in the Experimental group was greater than that in the Control group. Then, we can say that the simultaneous Strength / Endurance training program that was carried out by the Experimental group athletes influenced their results in the second 3000m test and had a positive impact on their performance. Consequently, we can confirm our study Hypothesizes' that there is a correlation between explosive strength and middle distance performance; and its nature is a **positive correlation**, therefore, the more the explosive force of the middle distance runners (juniors) is worked, the better their performances are.

In conclusion, we can see that our research confirms the results of Slawinski and collaborators (Slawinski, Quièvre, Lévêque, Heubert, & Gajer, 2006) who show that the middle distance runner's ability to accelerate, to vary his running speed according to the requirements of tactics, remains dependent on the two essential factors which are, on the one hand, reserves and rapid production of metabolic energies and on the other hand, increased neuromuscular capacities which optimize the implementation of the impulses of force governing its course. In the same field, our results go with Paavolainen and collaborators's conclusions (Paavolainen , Häkkinen , Hämäläinen , Nummela, & Rusko , 1999) who concluded that simultaneous explosive-strength and endurance training improved the 5 Kilometers time in well-trained endurance athletes without changes in their VO_2 max. This improvement was due to improved neuromuscular characteristics that were transferred into improved VMART and running economy.

Thus, the improving in Endurance test (3000m running) of our present search can be explained by improving in neuromuscular characteristics (because of the Explosive Strength training) that were transferred into improved running economy.

Therefore, the work of explosive force improves the performances of Force, Speed and those of middle distance (Endurance). This observation should push specialists to reorient their training based on the volume and quantity of work towards a **more specific training** based on **quality**.

Although we have been able to demonstrate the impact of the Explosive Force on the performance in middle distance races, it remains to reveal the rate that must be reserved for the quality of force in general and for the Explosive Force in particular in training planning, in order to increase performance in this specialty through future studies.

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