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# MUSCLE STRENGTH ACCUMULATION AND ITS TRANSFER TO TENNIS GAME IN CHILDREN AND JUNIORS USING AN AQUATIC TRAINING PROGRAM

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**Abstract:** The primary objective of this study is to highlight the effect of physical exercises specific to the game of tennis, carried out in the aquatic environment for the optimization of motor qualities, strength and speed of execution and the optimization of performance capacity. In the experimental study, 20 tennis players aged 10-12 years were involved, who took an initial and a final assessment, with the aim of identifying the advantages of the means used in the aquatic environment, on the strength of the main muscle groups involved in this sport.

Medicine ball training has a long history in strength training programs for athletes, and tennis requires high explosive muscle strength in the upper limbs of its athletes. However, during medicine ball training, attention should be paid to the gradual way. First, we should take medicine ball training with primary difficulty, and then gradually move to medicine ball training with intermediate and advanced difficulty. At the same time, attention must be paid to the safety of athletes in the dangerous practice of throwing medicine balls. Medicine ball training should be done under the guidance of professional trainers throughout the training. Although the main purpose of medicine ball training is to increase explosive arm strength of tennis players, it can have a great impact on developing the strength and power of the whole body.

The medicine ball training should be carried out during the training process, especially the coordination training of the upper and lower limbs, which can effectively improve the coordination of the whole body. Tennis requires high speed and strength. It is an explosive sport of strength. At the same time, upper limb explosive force is also the foundation of tennis players' professional quality. If there is no good upper limb explosive force, it will restrict the improvement of tennis players'skill level. In tennis, like many sports, strength training is essential for a great performance. The strength and power development, can lead to a high capacity of movement speed, great ball pace during tennis shots and not at last it will prevent the tennis players from injuries.

**Key words:** tennis, medicine ball, muscle strength, aquatic environment

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## INTRODUCTION

Considering the advancements in Strength and Conditioning (S&C) training principles and technology over the past few decades (i.e. racquet design), the nature of the game has been shown to gradually gravitate towards a power and speed-dominant play style, with athletes consistently serving upwards of 200+ km/h.

The ability to hit the ball with power in order to optimize the speed efficiency factor in the game of tennis is conditioned by the muscular strength of the upper body, the muscles of the back of the abdomen and the arms.

Consequently, a training program in the aquatic environment, using exercises for the development of these muscle groups, represents an important means that could be implemented in the training plan of tennis players.

Antony & Ameerali, 2017 stated that training using medicine balls is an effective and safe way to increase the training load and the occurrence of adaptation to the functional systems of the player's body.

Physical exercise in the aquatic environment develops most muscle groups, trains and tones almost all muscle groups, which leads to an increase in muscle strength and endurance (Żukowska & Szark-Eckardt, 2017).

Water sports and swimming strengthen the ligaments and help prevent injuries caused by excessive stress placed on them during training on hard surfaces. (Muniz-Pardos et al., 2022).

A significant benefit of physical exercises carried out in water is given by the fact that, in the aquatic environment, the body "loses" weight according to Archimedes' principle, corresponding to the volume of water displaced. This aspect facilitates the execution of movements and allows more efficient recovery of deficient muscle groups, due to more favorable conditions in terms of mechanical stress (Cumming, 2017).

The short-term cold water program increases the output of striated muscles, so fatigue sets in later (Knechtle et al., 2020). If the duration of the program in cold water increases, they can lead to an increase in muscle tone, externalized clonic contractions appear in the form of involuntary tremors (Knechtle et al., 2020).

Practicing swimming brings numerous benefits in terms of correcting posture, due to the particularities specific to the aquatic environment, such as the positioning of the body and the bodily demands required for movement in the water. These elements can support the balanced development of the locomotor system, cardiorespiratory functions and metabolism (Zuzana et al., 2022).

In the aquatic environment, the joints are freed from the weight (Archimedes' principle), so that the muscular effort can be diminished or amplified depending on the exercises performed (Tate et al., 2020; Taşkıran, 2020).

## MATERIAL AND METHODS PURPOSE OF RESEARCH

The selection of some means and the development of an unconventional methodical line (carried out in the aquatic environment) dedicated to optimizing the profile of tennis players in order to develop the quality of mortic force, respectively to increase the speed of execution of specific technical procedures in the current game of tennis.

Monitoring training programs in the aquatic environment, in order to identify the most important and relevant aspects that can contribute to the development and optimization of biomotor qualities and their subsequent implementation in long-term planning in the tennis game.

**HYPOTHESES OF THE RESEARCH**

The means of training in the aquatic environment, using physical exercises from gymnastics, fitness, with the medicine ball and last but not least exercises specific to the game of tennis (with racket) could have positive effects on the development of strength and power, at the level of the entire muscular system (with emphasis on the upper body) and optimization of efficiency factors, especially ball speed in basic strokes (serve, forehand and two-handed backhand).

**PROCEDURES AND METHODS OF RESEARCH**

Bibliographic study, organizing-conducting the experimental study, graphical analysis, statistical relevance (arithmetic mean, median, standard deviation, coefficient of variation, amplitude);

*Procedure*

In the experimental research, 3 kg medicine balls were used for the evaluation of muscle strength in the trunk, back and abdomen, and equipment specific to the game of tennis.

Tests for efficiency factor, ball speed for basic techniques, serve, forehand and two-handed backhand were conducted in the environment specific to the game of tennis, Supido radar speedometer that registers speed between 5-200 km/h rackets, balls and spin shot ball machine.

*Applied test*

Assessment of motor quality, strength for the upper limbs was evaluated by means of the following tests:

• throwing the medicine ball from above the head (service)
• throwing the medicine ball from the side (forehand )
• throwing the medicine ball from the side (backhand)

Evaluation of the ball speed efficiency factor in the game of tennis for the basic technical procedures of the serve, the forehand and the two-handed backhand.

*Participants and experiment development*

The tennis players involved in the experimental research were 20 in number, organized in the two conventional experimental groups (experimental and control), engaged in the performance activity by participating in field tennis competitions.

The duration of the experimental approach was 12 months. The experimental and control groups were monitored throughout this interval (taking data to allow the interpretation of the adaptation to the specific effort, respectively to allow the validation of the effectiveness of the proposed training means.

Data were taken that reveal the specific evolution of the following parameters: strength and speed of execution and the optimization of performance capacity.

While the control group performed a standard training program according to the conventional training plan, the experimental group took part in adapted courses (where the actuation systems are adapted to the aquatic environment), courses inserted into the conventional annual plan.

The means applied within the adapted, non-conventional program refer synthetically to: moving in water, water games (volleyball, polo, torso twists with and without a medicine ball, imitative exercises for the right shot and the lapel shot using rackets with and without connection). All these means are carried out in swimming pools, where the athletes evolved in water with progressively increased depth (the level of the coxofemoral joint, the elbow, the scapulo-humeral joint).

The introduction into the training program of swimming exercises (free style) over a distance of 100-125m in each training lesson can have a contribution to the development of strength in the upper limbs and last but not least to the capacity for effort.

**RESULTS AND DISCUSSIONS**

The results of the current study confirm the hypothesis that physical exercises specific to the game of tennis, carried out in the aquatic environment, develop the motor qualities, strength and power in the muscles of the upper body and speed of execution of the basic technical procedures of the serv, forehand shot and two handed backhand.

The results of many studies dealing with medicine ball training have shown a significant and notable improvement in physical capabilities related to explosive muscular strength, strength characterized by speed, strength endurance and flexibility, in addition to the fact that speed, agility and technical skills for various sports such as studies (Kobak et al., 2019).

*Discussions*

Several studies recommend medicine ball throws (MB) and resistance training (RT) methods to increase ball velocity in tennis (Fernandez-Fernandez, et al. 2013) or overhead throw sports (Escamilla RF, 2012).

The explosive strength of the tennis players' upper limbs can be effectively improved through the Medicine Ball training. The tennis players' overall speed also benefited, reflecting the improvement of the tennis players' specific performance.

Following a study after using aquatic training programs, (Mateescu. 2010) which aimed to develop and experiment some training programs through schemes of aquatic and dry land combined contractions, concluded that, due to unstable water environment and its resistance, aquatic exercises involve all muscle groups in an attempt to maintain the vertical position of the body, and the execution speed is fast and explosive, all of which are a effective way to develop strength.

Research findings by Terraza-Rebollo M, Baiget E in 2021 on the acute and delayed effects of strength training on ball speed and accuracy in young competitive tennis players indicate that MB and RT, avoiding repetition to failure and at maximum intended execution, have no acute and delayed deleterious effects on stroke tennis performance. Therefore, it could be suggested that these two strength training methods using these protocols could be useful to train maximal and explosive strength without decreasing ball speed and accuracy and could be used before a technique session. tactics on the field or off-season, and in-season.

The results of the current study came in line with the studies of each of (Kobak et al, 2019; Beckham et al, 2019; Pramod & Divya 2019);which showed that there is a positive effect of physical training programs on the muscle strength (explosive force, and the force characterized by speed),speed, and endurance of strength, and from here the researchers stated that programming the training by using traditional methods without working with modern methods cannot reach the player to the highest level of achievement.

**Table 1**. Test values "two-handed medicine ball throw at serve"

| Statistical indicators | T.I | T.F. | Statistical indicators | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 3.91 | 4.38 | **Average of differences** | | 0.47 |
| **Median** | 3.92 | 4.41 | **Progress** | | 12.1% |
| **Abaterea std.** | 0.09 | 0.14 | **95% C.I.** | | (0.41 ; 0.53) |
| **Minimum** | 3.8 | 4.1 | **Standard deviation** | | 0.09 |
| **Maximum** | 4.1 | 4.6 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 0 | 0 | | -2.807 | 0.005 |
| **Coef. variability** | 2.3% | 3.1% | **Statistical indicators** | | 0.63 |

Following a study, Pramod & Divya, 2019, states that training using medicine balls is a good way to develop muscle strength, which is an essential component of all movements and technical skills.

In the test of throwing the medicine ball with two hands at the service, the length of the throw increased at the final testing of the experimental group, on average, by 0.47 m. The progress achieved, regarding the force and speed of the ball at the service, is 12.1%. With a confidence of 95% the difference of the means is in the range (0.41 ; 0.53). The dispersion of the results shows a homogeneous structure for each test. The size of the effect is large to very large and statistically significant, p=0.005<0.05, for Z = -2.81.

Synthesis

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 0.47 | 12.1% | high to very high | statistically significant | is rejected |

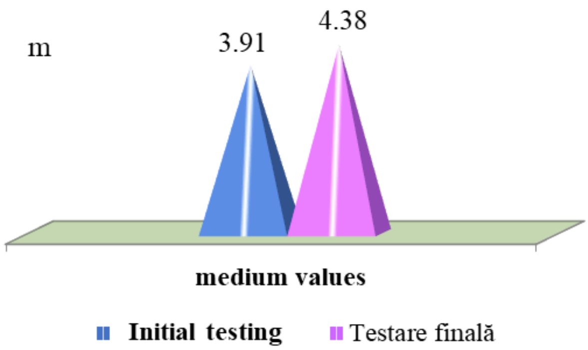


**Figure 1**. . Synthesis of the evaluation results "throwing the medicine ball with two hands at serve"

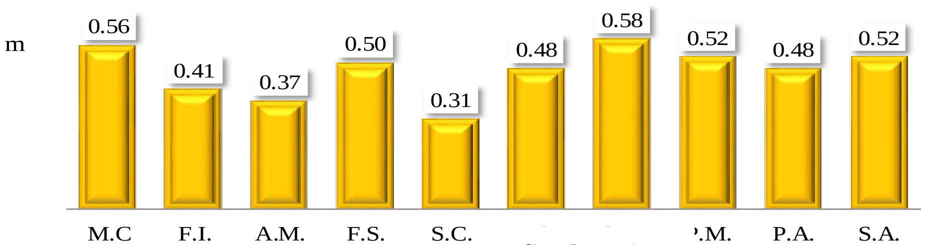


**Figure 2**. . Graphical representation of individual progress i ... ine ball throwing at Serve

**Table 2.** Values of the "two-handed backhand medicine ball throw" test values

| Statistical indicators | 4.92 | 5.52 | Statistical indicators | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 4.91 | 5.48 | **Average of differences** | | 0.61 |
| **Median** | 0.12 | 0.17 | **Progress** | | 12.4% |
| **Abaterea std.** | 4.7 | 5.3 | **95% C.I.** | | (0.54 ; 0.68) |
| **Minimum** | 5.1 | 5.9 | **Standard deviation** | | 0.10 |
| **Maximum** | 0 | 1 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 2.5% | 3.1% | | -2.805 | 0.005 |
| **Coef. variability** | 4.92 | 5.52 | **Statistical indicators** | | 0.63 |

Throw length increased at the final testing of the experimental group by an average of 0.61 m when throwing the medicine ball with two hands on the backhand. The progress achieved, regarding the force and speed of the ball on the backhand shot, is 12.4%. The 95% confidence interval for the difference in means is (0.54 ; 0.68). The dispersion of the results shows a homogeneous structure for each test. The difference between the means is large to very large and statistically significant, p=0.005<0.05, for Z = -2.81.

.Synthesis

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 0.61 | 12.4% | high to very high | statistically significant | is rejected |

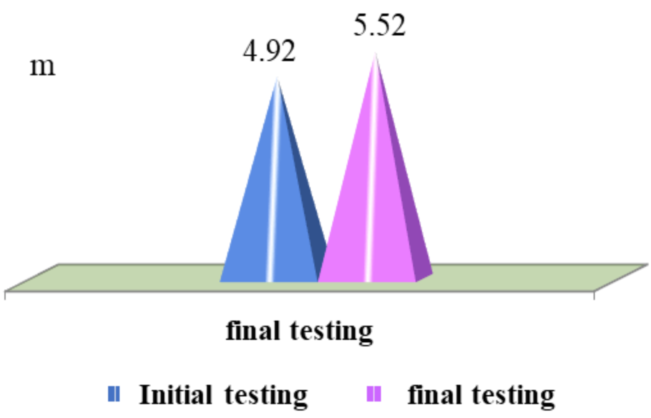


**Figure 2.** Synthesis of the results of the "two-handed backhand medicine ball throw" evaluation results

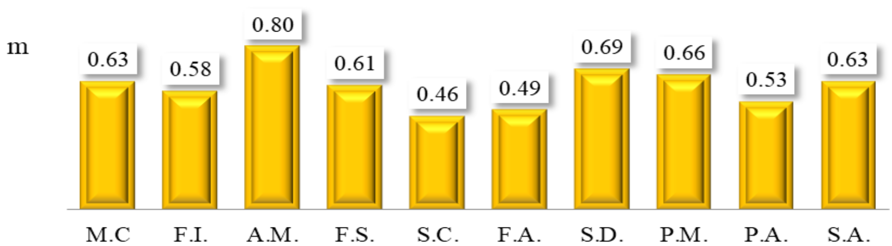

**Figure 4** Graphic representation of individual progress "two-handed backhand medicine ball throw"

**RUNNING 6 x 20 m**

**Table 3.** Values of the "two-handed medicine ball throw on the forehand" test

| Statistical indicators | T.I | T.F. | Statistical indicators | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 3.91 | 4.38 | **Average of differences** | | 0.47 |
| **Median** | 3.92 | 4.41 | **Progress** | | 12.1% |
| **Abaterea std.** | 0.09 | 0.14 | **95% C.I.** | | (0.41 ; 0.53) |
| **Minimum** | 3.8 | 4.1 | **Standard deviation** | | 0.09 |
| **Maximum** | 4.1 | 4.6 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 0 | 0 | | -2.807 | 0.005 |
| **Coef. variability** | 2.3% | 3.1% | **Statistical indicators** | | 0.63 |

The average time in the 6x20 m run decreased at the final testing of the experimental group by 0.13 sec. The progress achieved in the development of movement speed and agility in order to optimize the tennis game is 2.8%. The difference of means is in the range (-0.17; -0.08), in 95% of cases. The results are homogeneously dispersed in the case of both tests. The size of the effect is large to very large and statistically significant, p=0.005<0.05, for Z = -2.80.

Sintesys

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 0.65 | 13.1% | high to very high | statistically significant | is rejected |

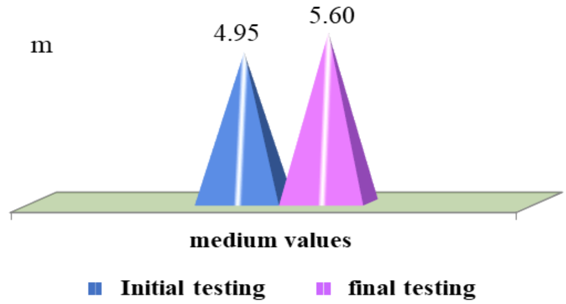


**Fig.5** Synthesis of the results of the evaluation "throwing the medicine ball with two hands on the right"

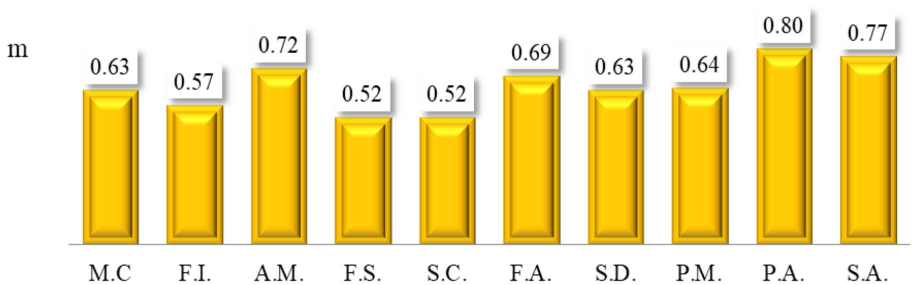


**Fig.6** Graphical representation of individual progress "two-handed medicine ball throw on the right"

**Table 4**. Efficiency factor test values "speed of serv. 1"

| Statistical indicators | T.I | T.F. | Statistical indicators | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 70.80 | 82.35 | **Average of differences** | | 11.55 |
| **Median** | 70.25 | 81.75 | **Progress** | | 16.3% |
| **Abaterea std.** | 3.30 | 2.68 | **95% C.I.** | | (10.23 ; 12.87) |
| **Minimum** | 67.50 | 79.50 | **Standard deviation** | | 1.85 |
| **Maximum** | 79.00 | 89.00 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 11.50 | 9.50 | | -2.809 | 0.005 |
| **Coef. variability** | 4.7% | 3.3% | **Statistical indicators** | | 0.63 |

Service 1 speed increased at the final testing of the experimental group, on average, by 11.55 m/s. The progress made regarding the development of the ability to hit with precision in the desired areas is 16.3%. With a confidence of 95% the difference of means is in the range (10.23 ;12.87). The dispersion of the results recorded in both tests is homogeneous. The size of the effect is large to very large and statistically significant, p=0.005<0.05, for Z = -2.81.

Synthesis

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 11.55 | 16.3% | high to very high | statistically significant | is rejected |

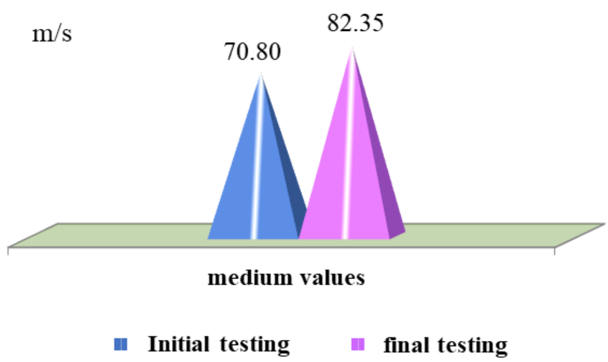


**Fig. 7.** Summary of the results of the evaluation of the efficiency factor "speed of shoot 1”

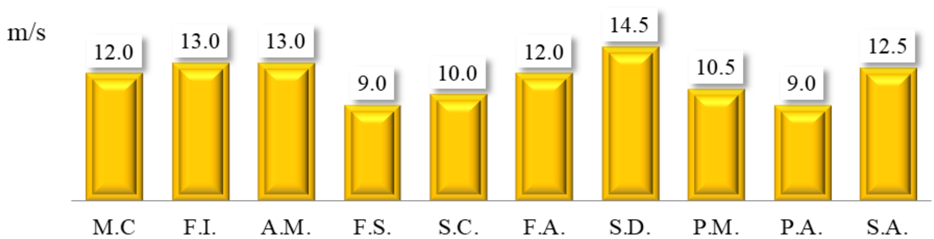


**Fig. 8**. Graphic representation of the individual progress of the speed efficiency factor

**Table 5**. Values of the efficiency factor test "speed of the forehand"

| Statistical indicators | T.I | T.F. | Statistical indicators | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 61.80 | 77.95 | **Average of differences** | | 16.15 |
| **Median** | 61.00 | 78.00 | **Progress** | | 26.1% |
| **Abaterea std.** | 3.45 | 3.32 | **95% C.I.** | | (15.24 ; 17.06) |
| **Minimum** | 58 | 74 | **Standard deviation** | | 1.27 |
| **Maximum** | 70 | 86 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 12 | 12 | | -2.814 | 0.005 |
| **Coef. variability** | 5.6% | 4.3% | **Statistical indicators** | | 0.63 |

On the forehand, the speed increased in the final testing of the experimental group, on average, by 16.15 m/s. The progress achieved in developing the ability to hit with precision in the desired areas is 26.1%. With a confidence of 95% the difference of the means is in the interval (15.24 ; 17.06). The dispersion of the results is homogeneous in the case of both tests. The size of the effect is large to very large and statistically significant, $p=0.005<0.05$, for $Z = -2.81$

Synthesis

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 16.15 | 26.1% | high to very high | statistically significant | is rejected |

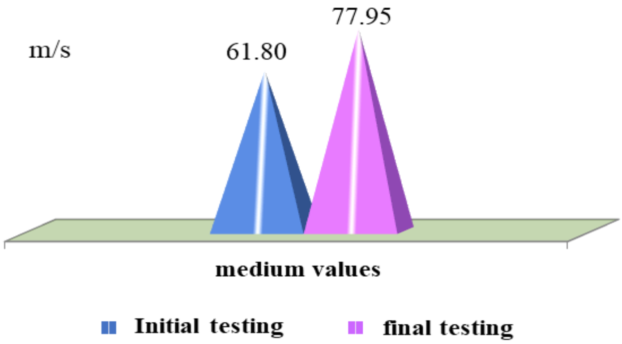


**Fig. 9.** Synthesis of the results of the evaluation of the efficiency factor of the speed of the right shoot

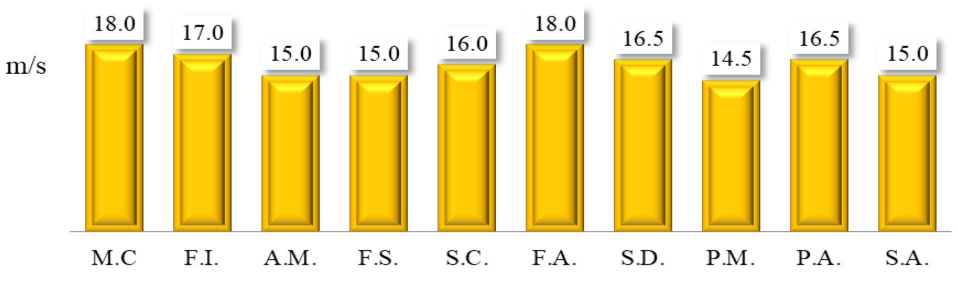


**Fig. 10.** Graphic representation of the individual progress of the speed efficiency factor

**Table 6.** Values of the efficiency factor test "speed of the backhand"

| **Statistical indicators** | T.I | T.F. | **Statistical indicators** | T.F.- | T.I. |
|---|---|---|---|---|---|
| **Average** | 58.10 | 76.55 | **Average of differences** | | 18.45 |
| **Median** | 57.50 | 76.50 | **Progress** | | 31.8% |
| **Abaterea std.** | 2.34 | 4.13 | **95% C.I.** | | (15.39 ; 21.51) |
| **Minimum** | 55 | 71 | **Standard deviation** | | 4.28 |
| **Maximum** | 63 | 84 | **The non-parametric Wilcoxon test** | Z | p |
| **Amplitude** | 8 | 14 | | -2.807 | 0.005 |
| **Coef. variability** | 4.0% | 5.4% | **Statistical indicators** | | 0.63 |

The speed of the backhand stroke increased in the final testing of the experimental group, on average, by 18.45 m/s. The progress made is 31.8%. With a confidence of 95% the difference of means is in the range (15.39 ; 21.51). The dispersion of the results recorded in both tests is homogeneous. The difference between the means is large to very large and statistically significant, $p=0.005<0.05$, for $Z = -2.81$.

Synthesis

| Diff. Average | Progress | Effect size | The difference is: | The null hypothesis |
|---|---|---|---|---|
| 18.45 | 31.8% | high to very high | statistically significant | is rejected |

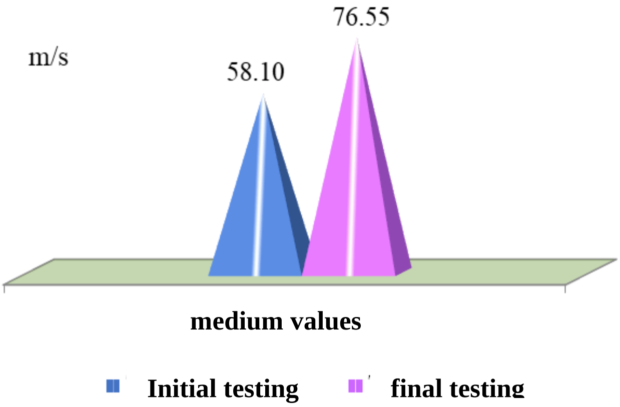


**Fig. 11.** Synthesis of the results of the evaluation of the backhand speed efficiency factor

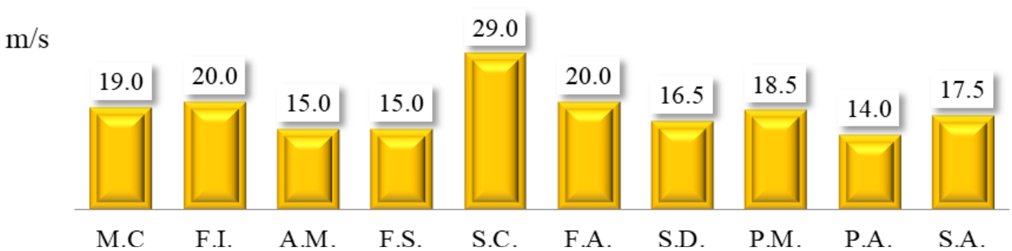


**Fig. 12.** Graphic representation of the individual progress of the speed efficiency factor

**DISCUSSIONS**

Several studies recommend medicine ball throwing (MB) and resistance training (RT) methods to increase ball speed in tennis (Fernandez-Fernandez, Ellenbecker , Sanz-Rivas , Ulbricht , Ferrauti). or overhead throwing sports (Escamilla RF, Ionno M, Scott de Mahy M, Fleisig GS, Wilk KE, Yamashiro K. 2012 & Van Den Tillaar. 2004).

The explosive strength of the upper limbs of tennis players can be effectively improved by training with the shown edicine ball. The overall speed of the tennis players also benefited, reflecting the improvement in the specific performance of the tennis players.

Following a study, following the use of aquatic training programs, (Mateescu. 2010) which aimed to develop and experiment with training programs through combined contraction schemes in water and on land, concluded that, due to the aquatic environment unstable and its resistance, water exercises involve all muscles. groups in an attempt to maintain the vertical position of the body, and the speed of execution is fast and explosive, all of which are an effective way to develop strength.

Research findings by Terraza-Rebollo M, Baiget E in 20121 on the acute and delayed effects of strength training on ball speed and accuracy in young competitive tennis players indicate that MB and RT, avoiding repetition to failure and at maximum intended execution, have no acute and delayed deleterious effects on stroke tennis performance. Therefore, it could be suggested that these two strength training methods using these protocols could be useful to train maximal and explosive strength without decreasing ball speed and accuracy and could be used before a technical session- tactics on the field or off-season, and in-season.

The results of the current study were consistent with studies by (Kobak et al., 2019; Beckham et al., 2019; Pramod et al., 2019; Falgenbaum et al., 2018; Soloman, 2018; Trajkovic et al., 2017 ; Marques; et al, 2013; Szymanski et al, 2007 Ignjatovic et al, 2012 et al, 2011) who showed that there is a positive effect of physical training programs on muscle strength (explosive strength and strength characterized by speed) , speed and strength endurance, and hence the researchers stated that programming training using traditional methods without working with modern methods cannot reach the player at the highest level of achievement.

Following a study, Pramod & Divya, 2019 states that training using medicine balls is a good way to develop muscle strength, which is an essential component of all movements and technical skills.

**CONCLUSIONS**

The body's ability to adapt to the effort is improved thanks to the versatility of the exercises applied in difficult conditions, in the aquatic environment.

Regarding the hypothesis according to which the integration in the sports training of some motor structures specific to tennis carried out in the aquatic environment can have a positive effect on the development of strength and power and the optimization of efficiency factors, especially the speed of the ball in the basic shots (serv, forehand and two-handed backhand the results of the experiments are still uncertain.

In our study we can observe that the progress of the experimental group was noticeably higher than that of the control group, the results obtained validate the research hypothesis.

Consecuetly we recommend the implementation of such a program that has beneficial effects that can be found in the performance of 10-12-year-old children.

The limitation of our study derives from the small sample of participants.

This aspect is related to the difficulties of identifying children who will accept membership in such experiments involving physical exercise for a long period of time, in a non-specific environment, as well as their willingness to engage in intervention programs, despite the fact that they can produce positive changes in sports training.

Consequently, we recommend the implementation of means of training in the aquatic environment using physical exercises with the body's own weight and with medicine balls to optimize the performance capacity of children and juniors in the game of tennis.

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