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Article

Effects of Specific Training Using a Rowing Ergometer on Sport Performance in Adolescents

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Abstract: The main purpose of the study was to study the effects of a specific rowing ergometer training program on the athletic performance of young adolescents ($n=56$; 11.73 ± 1.4 years old) compared to a workout based on general strength training. Eight-week training program was implemented, with four sessions per week and two-hours per session. Sample was divided in two groups: a control group (CG) that performed circuit training with exercises aimed at building general strength and an experimental group (EG) who focused on specifically training on a rowing ergometer (rowing machine). The data obtained in a rowing meter test over the competition distance were analyzed to obtain the average power attained (W) at the beginning of the training, at the middle (4 weeks), at the end of the training (8 weeks) and one year after the experimentation. The results show that, although both forms of training improve the average W obtained in both categories, the EG subjects (+29.94W) obtained better averages in all phases of the study compared to the CG (+5.88W). Furthermore, this increase was greater in male rowers (+34.06W) than in female rowers (+24.54W). These results reveal that a specific rowing ergometer training program has a significant effect than a general strength program and these effects can even be observed a year after the intervention.

Keywords: rowing; sport performance; adolescents

1. Introduction

Rowing is a strength and endurance sport in which competition performance depends on a combination of parameters involving cardiovascular endurance, muscular strength and motor skills, making it a perfect activity for adolescents who want to develop a range of physical and mental skills while enjoying a rewarding physical sport experience [1,2]. Consequently, muscular strength is a vital component of rowing, and the major role it plays in this discipline cannot be underestimated.

Muscular strength is the capacity of a muscle to exert a force through contraction, allowing it to overpower, resist or exert pressure against a resistance [3–5]. Muscular strength plays a critical role in rowing because athletic performance is built over physical strength [2]. Young athletes who engage in this sport work on building strength in many muscle groups, such as those of the arms, legs, back and trunk; it is also a challenge for the cardiorespiratory system, since rowing requires a large intake of oxygen [6]. Strength in these muscle groups gives rowers the power they need to efficiently and quickly move the boat through the water [2,7,8].

One of the advantages of focusing on building muscle strength in adolescence is that it is a critical period of growth and development [3]. Research into strength training in young people has generated significant controversy in the physical fitness world over the years [9,10]. Although the earliest studies published on how strength training influences adolescents did not report positive effects for young people [11,12], there is now sufficient scientific evidence to assert that strength training in adolescents, provided it is controlled and supervised by professionals who focus on developing proper technique and ensuring individual safety, is beneficial to the health and performance of young athletes [3].

World Health Organization's global recommendations suggest that children and adolescents spend at least 60 minutes per day in moderate to vigorous intensity physical activity, mainly aerobic, and engage in muscle and bone strengthening activities at least three times per week [13]. Additionally, American College of Sports Medicine prioritizes strength training at an early age to improve musculoskeletal system function and the overall fitness level of young people through the practice of a variety of safe, effective and fun strength training activities [3].

Among the benefits of strength training in 11-13 year olds, there are studies showing how mechanical stress, induced through strength training, was beneficial for body and bone growth [8,14]. This not only corroborates the theory that suggests that, because of the low surrounding hormone levels in bone structures, adolescents cannot handle overloading during training and, therefore, may suffer alterations in the bone formation process or deformities, as some studies suggest without sufficient significant evidence [15], but it also shows us that strength training based on moderate and high intensity exercises can be a powerful positive stimulus on bone structures [8,16]. Furthermore, regarding another controversial topic of strength training research—the high risk of injury during training— recent studies have shown that strength training at an early age helps to reduce injuries by up to 50% [3]. This suggests that the increase in physical conditioning levels enables adolescents to successfully cope with the challenges posed by the demands on the musculoskeletal system during physical and sports activities, thus reducing the injury rate [17].

Adolescents who engage in rowing-specific strength training programs not only improve their ability to perform on the water, but also help develop healthy cardiorespiratory, muscular and skeletal systems [5,6]. Moreover, as we have seen above, muscular strength in rowing has a direct impact on preventing injuries [17]. Strong muscles provide additional joint support and help stabilize the body during the repetitive motion involved in rowing. This decreases the risk of injury to joints and muscles, critical to keeping teens active and healthy throughout their rowing careers.

Another advantage of developing muscular strength through rowing is its impact on mental performance. The confidence and self-esteem of adolescents increase as they see improvements in their strength and performance. Likewise, the discipline required to stick to a consistent strength training program translates into greater determination and perseverance, valuable skills that will apply to all areas of a young person's life [18].

However, when it comes to lower-level performance, is general strength training enough to improve athletic performance? In the following experimental study, we aim to observe the influence of a controlled specific muscle strength training program on athletic performance in young people aged between 11-13 years. The aim of this study is to determine which training (specific rowing ergometer training program vs a workout based on general strength training) is more beneficial on athletic performance in adolescent rowers, ages 11-13 years old.

2. Materials and Methods

2.1. Subjects

A sample of students/rowers ($N=56$; boys: $n=32$; girls: $n=24$), with a mean age of 11.73 ± 1.4 years, belonging to two categories (10-11 years old: $n=25$); and (12-13 years old: $n=31$) completed an eight-week training programme, with four weekly sessions of two hours each one, consisting of one hour of specific training followed by an hour of rowing on the water.

The sample was divided into two groups:

1) A control group (CG: $n=26$) received a specific training based in general strength circuit training with exercises using their own body weight at six stations (squat jump, push-up, plank, back-squat, pull-ups with elastic bands, side-plank). They performed three 30-second sets of each exercise in a rotating circuit with 30-second rests between each set.

2) An experimental group (EG: $n=30$) whose training consisted in a specific training protocol using a rowing ergometer (rowing machine model CONCEPT 2 D PM5) [18] consisted of two blocks of five sets of 90 seconds, at 18 strokes at maximum power, resting 60 seconds between sets and four minutes between each of the blocks. A drag factor (DF) of 140 was established (higher than what is usually set during training in the juvenile and youth categories, which is around 90-100 DF or the resistance of the water when paddling). The DF measures how quickly the fan blades slow down between each pull.

2.2. Procedure

To determine participants' level, several tests were first performed using the rowing ergometer to find the baseline of each athlete. A pre-test measurement was taken during the first week, using the competition distance as a reference (500 meters for the 10-11 years old category; 1000 meters for the 12-13 years old category) where data related to the watts (W) generated in relation to the time/distance covered were obtained (all these figures are available using the rowing machine's PM5 software).

During the training protocol, a test (intermediate test) was established at 4 weeks; and a measurement (post-test) at the end of 8 weeks of training. Finally, a test was carried out one year after the experimentation in order to know the effects of both training programmes (All measurements were taken over the same competition distance based on category and under controlled conditions).

Participants were informed about the importance of performing the tests to the best of their abilities. To avoid positively or negatively influencing the data collection, each athlete performed the test without being given any data, technical details, or external motivation. At the end of the test, information was collected from the sample.

Classification into the different groups of the study (CG vs EG) was made considering the result obtained in the initial test, sex, category, and weight/height of the participants, understanding that, with the same categories, sex, weight, height and result in the rowing ergometer test, one subject was included in the CG, and the most similar subject according to the same criteria was included in the EG. The breakdown of the comparative groups in the study was as follows (Table 1):

Table 1. Breakdown of the groups in the study.

| Category | 10-11 years old (N=25) | | | | 12-13 years old (N=31) | | | |
|-----------------|------------------------|----------------|----------------|----------------|------------------------|----------------|----------------|----------------|
| | Male | | Female | | Male | | Female | |
| <i>n</i> | 14 | | 11 | | 17 | | 14 | |
| Study group | CG | EG | CG | EG | CG | EG | CG | EG |
| | 7 | 7 | 6 | 5 | 8 | 9 | 5 | 9 |
| Age (Mean± SEM) | 10,71 ±0.28 | 11,14 ±0.26 | 10,50 ±0.22 | 10,60 ±0.25 | 12,37 ±0.18 | 12,50 ±0.16 | 12,40 ±0.25 | 12,75 ±0.16 |

CG: control group; EG= experimental group; SEM (Standard Error of the Mean).

2.3. Equipment

The tests were performed on a CONCEPT 2 D PM5 rowing ergometer¹⁸. This model is equipped with software and various applications that can track all the rower's data (meters, strokes, watts, etc.), as well as the transformation of watts (W) to time and vice versa; it can also provide other measurements such as the average watts achieved in the test, an important factor considering that we have two groups with different competition distances (10-11 years old: 500 m, and 12-13 years old: 1000 m). This implies that, if a subject completes a distance of 500 meters in 2:00 minutes, the average watts (average of $W = \text{distance}/\text{time}$) will be 2:00; on the other hand, if another subject

completes 1000 meters in 4:00 minutes (double the distance and time) the average watts would also be the same.

2.4. Ethical Aspects

Once the initial selection was made, informed consents were collected from both the participating rowers and the parents/legal guardians after a discussion where the nature of the study was explained to them, clarifying that their anonymity would be maintained at all times, following the ethical considerations of *Sport and Exercise Science Research* [20], and with the principles included in the Declaration of Helsinki [21], which define the ethical guidelines for research on human subjects, and the University of Malaga gave the identification number registered for the Ethics Committee: 65-2020-H. During study and afterwards, we acted under the provisions of Organic Law 3/2018, of December 5, on the Protection of Personal Data and Guarantee of Digital Rights, regarding the protection of personal data under Spanish law.

2.5. Statistical Analysis

A frequency analysis was conducted for the variables of age, sex, group, and study category. An analysis of descriptive statistics was also performed according to the experimental group to quantify the changes produced in the means obtained from the different measurements of the study. Unless otherwise indicated, data are presented as mean \pm SEM (Standard Error of the Mean). To determine the influence of the category variable considering the sample group and the measurements obtained in the test performed with the rowing machine in the different phases of the study, a comparative analysis of the averages (ANOVA) was performed. Likewise, we used the same statistical procedure to determine the influence of the sex variable on the results obtained in each group. On the other hand, we also took into account the estimated intra-subject marginal measures (Group*Measure) to quantify the interaction between the variables and their evolution over time through a repeated measures ANOVA, applying the Holm-Sidak post hoc test. Analysis of all study variables was conducted using the SPSS version 25 statistical package (SPSS, inc, IBM).

3. Results

Table 2 shows the frequency analysis of the sample. Participants were divided according to sex, group, age, and age category (Table 2).

Table 2. Frequency analysis.

| | | Frequency | Percentage (%) |
|-------------|-----------------|-----------|----------------|
| Age (years) | 10 | 9 | 16.07 |
| | 11 | 13 | 23.21 |
| | 12 | 18 | 32.14 |
| | 13 | 16 | 28.57 |
| Sex | Male | 32 | 57.14 |
| | Female | 24 | 42.85 |
| Group | Control | 26 | 46.42 |
| | Experimental | 30 | 53.57 |
| Category | 10-11 years old | 25 | 44.64 |
| | 12-13 years old | 31 | 55.35 |

The analysis of the descriptive statistics by sample group shows that control group subjects obtained lower averages in all phases of the study, compared to the experimental group (Table 3).

Table 3. Descriptive statistics by group.

| | Control (Mean± SEM) | Experimental (Mean±SEM) |
|-----------------------|---------------------|-------------------------|
| Pre-test (W) | 134.21±8.99 | 156.89±8.01 |
| Intermediate-Test (W) | 137.13±8.98 | 179.44±10.56 |
| Post-test (W) | 140.10 ±9.21 | 186.83±10.69 |

[F_(3,216)=0.81; two-way ANOVA and Holm-Sidak test]. W= watts; SEM (Standard Error of the Mean).

Figure 1 shows the evolution of the averages obtained by the different groups according to the phase of the study. This graph shows a positive evolution for both study groups, but it is higher in the experimental group (dif_{pre-test/post-test}=+29.94W) respect to the control group (dif_{pre-test/post-test}=+5.88W). Statistically significant differences were found between groups (F_(3,216) =0.81; two-way ANOVA and Holm-Sidak test).

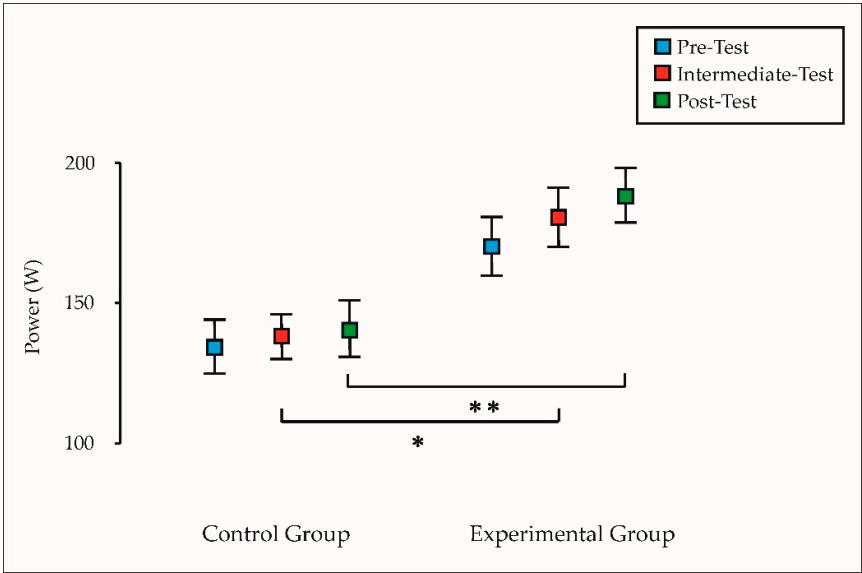


Figure 1. Evolution of the averages obtained (W) on the rowing ergometer. Statistically significant interaction between tests and groups were found [F_(3,216)=0.81; two-way ANOVA and Holm-Sidak test; *, p<0.05; **, p<0.001)].

Table 4 analyzes the influence of the category to which subjects belong in the study groups. There is an improvement in the mean values obtained in the parameters of muscular strength (W), which is statistically higher in those subjects in the experimental group (EG10-11 years old: dif_{pre/post-test}=+15.82W; EG12-13 years old: dif_{pre/post-test}=+39.35W) than that obtained by the control groups (CG10-11 years old: dif_{pre/post-test}=+4.56W; CG12-13 years old: dif_{pre/post-test}=+7.21W). In addition, the measurements obtained by the 12-13 years old subjects are statistically higher than those of the 10-11 years (Figure 4). [F_(9,208) =0.54; two-way ANOVA and Holm-Sidak test; p<0.05]).

Table 4. Intrasubject analysis of muscle strength by group and category.

| | Control Group | | Experimental Group | |
|-----------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | 10-11 years (Mean± SEM) | 12-13 years (Mean± SEM) | 10-11 years (Mean± SEM) | 12-13 years (Mean± SEM) |
| Pre-test (W) | 112.05±12.13 | 156.38±10.37 | 134.28±11.22 | 171.97±9.74 |
| Intermediate-Test (W) | 114.45±12.30 | 159.82±9.94 | 144.23±11.66 | 202.91±13.31 |
| Post-test (W) | 116.61±12.74 | 163.58±9.97 | 150.10±11.67 | 211.32±13.35 |

[$F_{(9,208)}=0.54$; two-way ANOVA and Holm-Sidak test].

Figure 2 offers the evolution of the different values obtained by sex and the study group. Although the improvement is noticeable in both groups, there is a more prominent positive trend in the experimental groups, specially in male group.

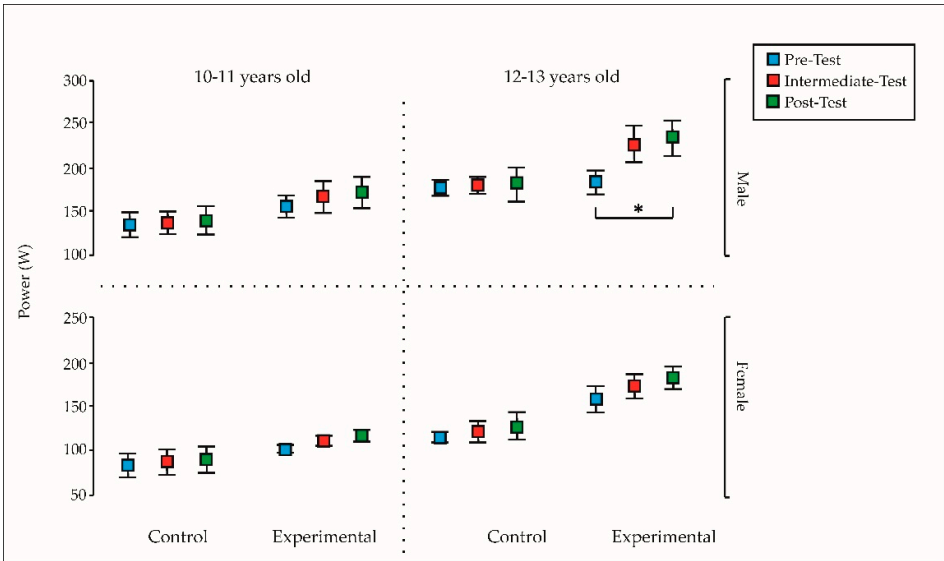


Figure 2. Evolution of the averages obtained by group and sex. CG= control group; EG= experimental group; W= watts. [$F_{(21,192)}=0.45$; two-way ANOVA and Holm-Sidak test; *, $p<0.05$].

Table 5 examines how sex influences the study groups, and how the averages obtained in the experimental group are statistically higher than those obtained in the control group in both, male and female cases [$F_{(9,208)}=0.39$; two-way ANOVA and Holm-Sidak test]. Comparing changes produced throughout the different phases of the study by sex, an improvement is seen for both the control group (Male CG: difpre/post-test=+3.86W; Female CG:difpre/post-test=+8.65W), and the experimental group (Male EG: difpre/post-test=+34.06W; Female EG: difpre/post-test=+24.54W), although the change is statistically more pronounced in the latter (Figure 4).

Table 5. Intra-subject analysis of muscle strength by group and sex.

| | Control Group | | Experimental Group | |
|-----------------------|---------------|--------------|--------------------|--------------|
| | Male | Female | Male | Female |
| | (Mean± SEM) | (Mean± SEM) | (Mean± SEM) | (Mean± SEM) |
| Pre-test (W) | 159.18±9.85 | 100.16±9.55 | 173.97±9.38 | 134.5±11.46 |
| Intermediate-Test (W) | 160.49±10.08 | 105.27±10.31 | 201.68±13.72 | 150.35±13.00 |
| Post-test (W) | 163.04±10.51 | 108.81±10.99 | 208.04±13.99 | 159.10±13.55 |

[$F_{(9,208)}=0.39$; two-way ANOVA and Holm-Sidak test]. W= watts; SEM (Standard Error of the Mean).

Finally, once eight weeks of the intervention program were completed, both groups of rowers returned to identical training sessions: 4 sessions/week (2 hours duration: 1 hour of general muscular strength exercises, and 1 hour of rowing. One year after the beginning of the program, a test on the rowing machine was again performed to collect data on subjects' performance (Figure 3).



Figure 3. Evolution of the averages obtained (W) according to group (control vs experimental) and category (10-11 years vs 12-13 years); and results obtained one year after the training program. [$F_{(9,208)}=0.54$; two-way ANOVA and Holm-Sidak test; (**, $p<0.001$; *, $p<0.05$)]. W= watts.

Table 6 shows the effects of specific strength training in adolescents continued to provide statistically significant differences one year later and had a positive correlation with respect to the performance of the rowing test on the rowing machine (Table 6, Figure 4).

Table 6. Intrasubject analysis of muscle strength by group and category one year after the training program.

| | Control Group | | Experimental Group | |
|---|-------------------------|-------------------------|-------------------------|-------------------------|
| | 10-11 years (Mean± SEM) | 12-13 years (Mean± SEM) | 10-11 years (Mean± SEM) | 12-13 years (Mean± SEM) |
| Post-test (W) | 116.61±12.74 | 163.58±9.97 | 150.10±11.67 | 211.32±13.35 |
| One year later (W) | 152.92±11.25 | 191.85±8.286 | 177.83±11.71 | 254.83 ±16.79 |
| Δ Dif _{post-test/one year later} (W) | +36.32 | +28.26 | +27.73 | +43.52 |

[$F_{(9,208)}=0.54$; two-way ANOVA and Holm-Sidak test]. W= watts.

Table 7and Figure 4 show the evolution of the different groups according to sex one year after the training programme. Statistically significant differences were found after one year of training in the experimental groups (male and female) with respect to their control groups ([$F_{(9,208)}=0.39$; two-way ANOVA and Holm-Sidak test]).

Table 7. Intra-subject analysis of muscle strength by group and sex one year after the training program.

| | Control Group | | Experimental Group | |
|---|---------------|--------------|--------------------|--------------|
| | Male | Female | Male | Female |
| | (Mean± SEM) | (Mean± SEM) | (Mean± SEM) | (Mean± SEM) |
| Post-test (W) | 163.04±10.51 | 108.81±10.99 | 208.04±13.99 | 159.10±13.55 |
| One year later (W) | 191.47±8.41 | 146.36±10.67 | 246.65±18.67 | 194.46±14.37 |
| Δ Dif _{post-test/one year later} (W) | +28.43 | +37.55 | +38.61 | +35.36 |

[F_(9,208) =0.39; two-way ANOVA and Holm-Sidak test]. W=watts.

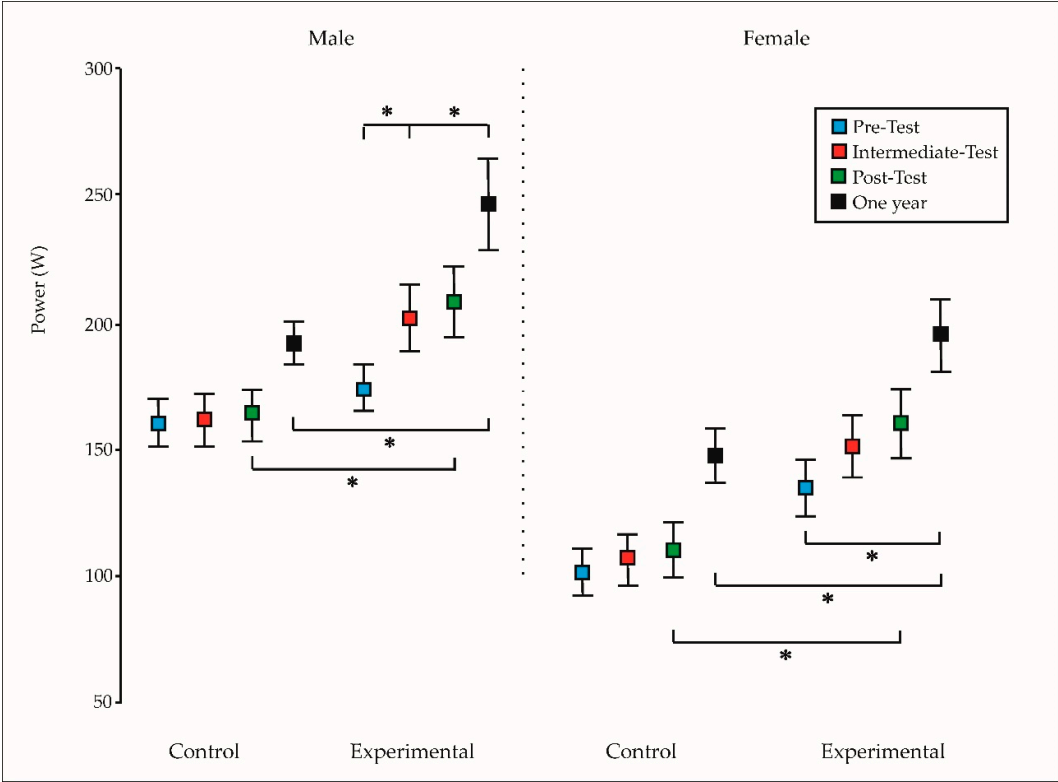


Figure 4. Evolution of the averages obtained (W) according to group and sex; and results obtained one year after the training program. [F_(9,208) =0.39; two-way ANOVA and Holm-Sidak test; (*, p<0.05)]. W= watts.

4. Discussion

The purpose of this study was to test the effects of a specific rowing ergometer training program compared to general strength training on sport performance in adolescent rowers. After analyzing the results obtained, we were able to verify that, although results improved in both the CG and the EG following the training program, there was a greater positive and statistically significant correlation between the power achieved in the rowing ergometer test (W) and the rowing-specific strength training.

To assess the performance of rowers in both categories, we adjusted the competition course distance to match their accustomed level of challenge. This procedure allows us to know the athletic performance of each participant and compare the results of both categories, and thus we set out to estimate the athletic performance of each participant to compare the results after completing the defined training program. In this sense, there are studies that show significant relationships between

strength values and performance, using the rowing ergometer tests as a predictor of athletic performance in rowers [7].

If we focus on the sport of rowing in relation to muscular strength, the studies that analyze the influence of aerobic capacity on athlete performance are largely prevalent with respect to disciplines, such as Olympic rowing, with research addressing the issue of the relative contribution and demands of muscular strength and power only being very limited [2]. In this sense, recent studies have shown how important muscle strength is during the initial phase of rowing, when the athlete is subjected to high levels of acceleration while extending the upper body [2,5,6]. Therefore, it is important to investigate the relationship between the way we train our young athletes and their performance, to encourage their athletic performance while promoting proper body development.

Accordingly, a literature review reveals the importance of strength training as a beneficial tool for the health of the target population. Some examples indicate that an eight-week training program based on strength training significantly improves the sit-ups, push-ups, sit and reach, standing broad jump, as well as the height reached during the Counter Movement Jump (CMJ) test [22]. In a recently published review on the influence of variables associated with muscle strength training in prepubescent youth, demonstrated its efficacy, not only in increasing muscle strength values in 100% of cases, but also in significantly increasing jumping and sprinting skills. At a morphological level, strength training helps to decrease the percentage of body fat and increase lean body mass [3], so it is not only beneficial for maintaining an adequate body mass index, but also helps in the correct motor development of young athletes [13].

Lee et al. [23] conducted a study comparing various training protocols in female rowers and found greater benefits, compared to the time spent in covering 2000 meters on the rowing meter, in those groups that performed a higher intensity strength training based on weight lifting exercises (with equipment for five sets of 30 seconds and a maximum of 18 repetitions for each exercise), compared to another group that performed low repetitions (four sets with two to six repetitions per exercise). On the other hand, Thiele et al. [24] performed a comparison with adolescent competitive female rowers who trained following a high-intensity strength-endurance training program (four sets of 12 repetitions at 75-95% of 1-MR -maximum repetition-) versus a low-intensity strength-endurance training program (four sets of 30 repetitions at 50-60% of 1-MR). In this study they concluded that rowers improved their fitness level with high-intensity training (maximum strength, muscular power, anaerobic endurance, and speed of execution), whereas low-intensity exercises were shown to be more effective in improving specific performance in the sport of rowing. Consequently, we suggest further research is to identify the relationship between the type of specific strength training and sport-specific performance in rowing sports.

Regarding the results obtained in this study, taking into account the gender of the rowers and the competition category, improvements were obtained in both groups after completing the training program, although more notably in the experimental group that underwent the specific training program on rowing machines.

Other studies which refer to the difference between sex in adolescent rowers, concluded that the boys obtained greater muscular power (measured in W), but also a higher score in perceived effort at all ages except between 12 and 14 years old [25], which could be associated with a greater metabolic demand at the age of puberty, although other factors should also be taken into account. In terms of differences in performance, other study found improvements in the rowing ergometer tests at the end of the program, but particularly in women [26]. This study shows that there is a significant progression in both groups although our results show better results in 12-13 years old people than in 10-11 years old and in boys more than in girls.

Rowing training in adolescents is associated with the adaptation not only of the cardiorespiratory system, including an increase in the internal diameter and size of the myocardium, but also of the skeletal muscles, triggering the processes of hypertrophy in the muscle fibers, especially in the slow twitch ones. Additionally, a correct development program with qualified coaches can favor correct biological growth and body development, as well as the improvement of physical fitness (muscular strength, muscular endurance) [27]. According to this study, our results

show that specific training programs conducted on rowing machines can help and be a useful tool for developing rowing talent, since they are highly correlated with athletic performance.

5. Conclusions

The present study has been able to verify the positive effect of specific training in rowing on the meter rowing in the improvement of performance in male and female rowers. This information contributes to clarify the relationship between strength training and performance in young athletes, which can be very beneficial as long as the prescription and supervision are provided by qualified personnel, giving importance to technique, load progression and safety standards.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of University of Málaga (protocol code 65-2020H and date of approval: 09/10/2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: For privacy reasons, the data presented in this study are available upon request to the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

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