applied sciences

MDPI

Article

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

Juan Gavala-González [1,2], Mª Elena Porras-García [2,3,*], José Carlos Fernández-García [2,4,*] and Mateo Real-Pérez [2]

1 Department of Physical Education and Sports, School of Education Sciences, University of Seville, 41013 Seville, Spain; jgavala@us.es
2 Researching in Sport Sciences: Research Group (CTS-563) of the Andalusian Research Plan, University of Málaga, 29010 Málaga, Spain; mateo.realperez@gmail.com
3 Department of Physiology, Anatomy and Cellular Biology, University of Pablo de Olavide, 41013 Seville, Spain
4 Department of Didactics of Languages, Arts and Sport, Andalucía-Tech, Instituto de Investigación Biomédica de Málaga (IBIMA), University of Málaga, 29016 Málaga, Spain
* Correspondence: meporgar@upo.es (M.E.P.-G.); jcfg@uma.es (J.C.F.-G.)

Abstract: The main purpose of this 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. An eight-week training program was implemented, with four sessions per week and two hours per session. The sample was divided into 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 (+29.94 W) obtained better averages in all phases of the study compared to the CG (+5.88 W). Furthermore, this increase was greater in male rowers (+34.06 W) than in female rowers (+24.54 W). These results reveal that a specific rower rowing ergometer training program has a more significant effect than a general strength program and these effects can even be observed a year after the intervention.

Keywords: rowing; sport performance; adolescents

check for updates

Citation: Gavala-González, J.; Porras-García, M.E.; Fernández-García, J.C.; Real-Pérez, M. Effects of Specific Training Using a Rowing Ergometer on Sport Performance in Adolescents. *Appl. Sci.* **2024**, *14*, 3180. https://doi.org/10.3390/app14083180

Academic Editors: Andrea Fusco and Barbara Gilic

Received: 14 March 2024
Revised: 5 April 2024
Accepted: 8 April 2024
Published: 10 April 2024

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 resistance [3,4]. 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 [5]. Strength in these muscle groups gives rowers the power they need to efficiently and quickly move the boat through the water [2,6,7].

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 [8,9]. Although the earliest studies published on how strength training influences adolescents did not report positive effects for young people [10,11], 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].

The World Health Organization's global recommendations suggest that children and adolescents should spend at least 60 min per day engaging in moderate to vigorous intensity physical activity, mainly aerobic, and engage in muscle and bone strengthening activities at least three times per week [12]. Additionally, the 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 [8,13]. 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 [14], but it also shows us that strength training based on moderate and high-intensity exercises can be a powerful positive stimulus on bone structures [8,15]. 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 [16].

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]. Moreover, as we have seen above, muscular strength in rowing has a direct impact on preventing injuries [6,16]. 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 [17].

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 and 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 for athletic performance in adolescent rowers aged 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 program, 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 the following two groups:

(1) A control group (CG: $n = 26$) received specific training based on 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-s sets of each exercise in a rotating circuit with 30-s rests between each set.

(2) An experimental group (EG: $n = 30$) whose training consisted of a specific training protocol using a rowing ergometer (rowing machine model CONCEPT 2 D PM5, Concept-2, Morrisville, VT, USA) [18] consisted of two blocks of five sets of 90 s, at 18 strokes at maximum power, resting 60 s between sets and 4 min 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 the 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 m for the 10–11 years old category; 1000 m 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 (https://www.vermontc2.com/tienda/monitor-pm5-rowerg/ (accessed on 1 March 2024)).

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 analyze the effects of both training programs (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)**			
Sex	**Male**		**Female**		**Male**		**Female**	
n	**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 ergometer [18]. 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 m in 2:00 min, the average watts (average of W = distance/time) will be 2:00; on the other hand, if another subject completes 1000 m in 4:00 min (double the distance and time), the average watts would also be the same.

2.4. Ethical Aspects

Once the initial selection was made, informed consent was 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 [19], and with the principles included in the Declaration of Helsinki [20], 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 the 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 was performed (ANOVA test [groups (control vs. experimental) $\times$ test (pre-test vs. intermediate-test vs. post-test and vs. one year-test)]). Likewise, we used the same statistical procedure to determine the influence of the sex variable on the results obtained in each group ANOVA test [groups (control vs. experimental) $\times$ test (pre-test vs. intermediate-test vs. post-test and vs. one year-test) $\times$ sex (female vs. male)] and the age (ANOVA test [groups (control vs. experimental) $\times$ test (pre-test vs. intermediate-test vs. post-test and vs. one year-test) $\times$ age group (10–11 vs. 12–13 years old)]). The Holm–Sidak post hoc test was applied in all cases. Analysis of all study variables was conducted using the SPSS version 25 statistical package (SPSS, Inc., IBM, Armonk, NY, USA).

3. Results

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

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).

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 ($dif_{pre\text{-}test/post\text{-}test}$ = +29.94 W) with respect to the control group ($dif_{pre\text{-}test/post\text{-}test}$ = +5.88 W). Statistically significant differences were found between groups ($F_{(3,216)} = 0.81$; two-way ANOVA and Holm–Sidak test).

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

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).

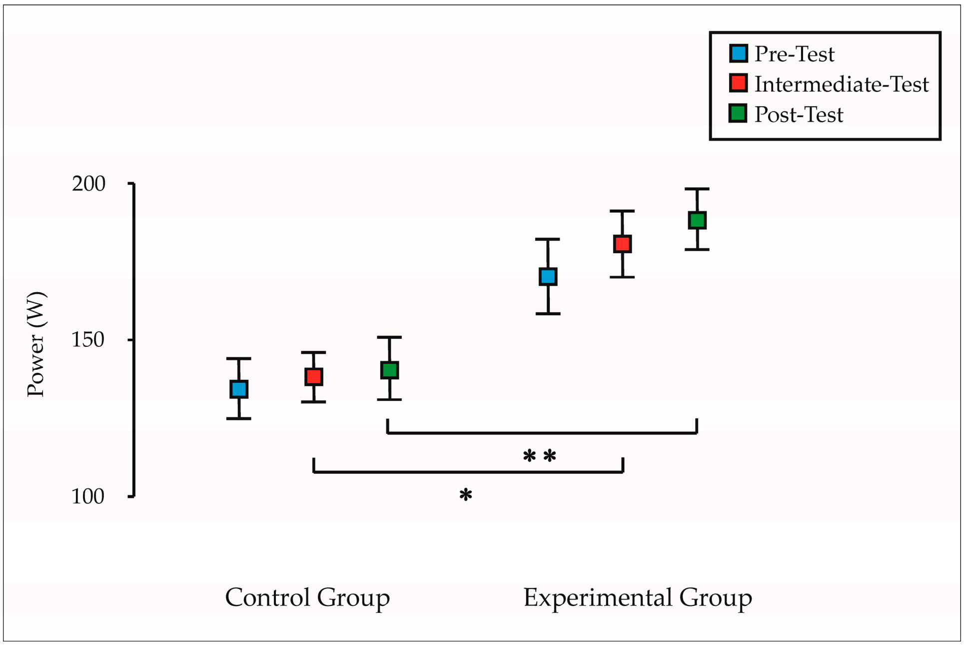

Figure 1. Evolution of the averages obtained (W) on the rowing ergometer. Statistically significant interaction between tests and groups were found [$F_{(3,216)}$ = 0.81; two-way ANOVA and Holm-Sidak test; *, $p < 0.05$; **, $p < 0.001$)].

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: $dif_{pre/post\text{-}test}$ = +15.82 W; EG12–13 years old: $dif_{pre/post\text{-}test}$ = +39.35 W) than that obtained by the control groups (CG10–11 years old: $dif_{pre/post\text{-}test}$ = +4.56 W; CG12–13 years old: $dif_{pre/post\text{-}test}$ = +7.21 W). In addition, the measurements obtained by the 12–13-year-old subjects are statistically higher than those of the subjects aged 10–11 years old (Table 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, especially in the male group.

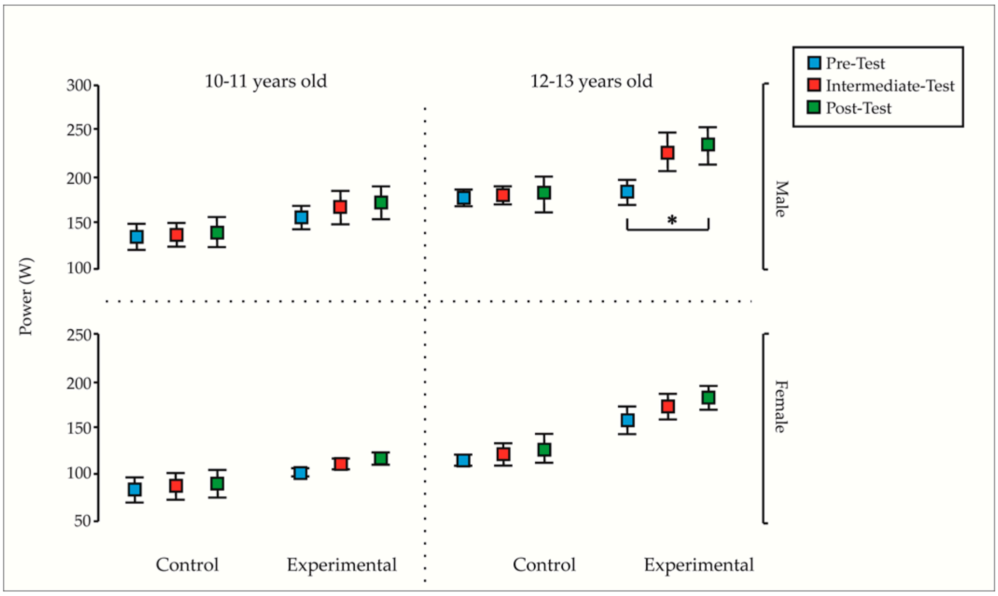

Figure 2. Evolution of the averages obtained by group and sex. CG = control group; EG = experimental group; W = watts. [$F_{(21,192)}$ = 0.45; two-way ANOVA and Holm–Sidak test; *, $p < 0.05$].

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 can be seen for both the control group (male CG: $dif_{pre/post\text{-}test}$ = +3.86 W; female CG: $dif_{pre/post\text{-}test}$ = +8.65 W), and the experimental group (male EG: $dif_{pre/post\text{-}test}$ = +34.06 W; female EG: $dif_{pre/post\text{-}test}$ = +24.54 W), although the change is statistically more pronounced in the latter (Table 5).

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

	Control Group		Experimental Group	
	Male (Mean ± SEM)	**Female (Mean ± SEM)**	**Male (Mean ± SEM)**	**Female (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: four sessions/week (2 h duration: 1 h of general muscular strength exercises, and 1 h of rowing). One year after the beginning of the program, a test on the rowing machine was again performed to collect data on the subjects' performance (Figure 3).

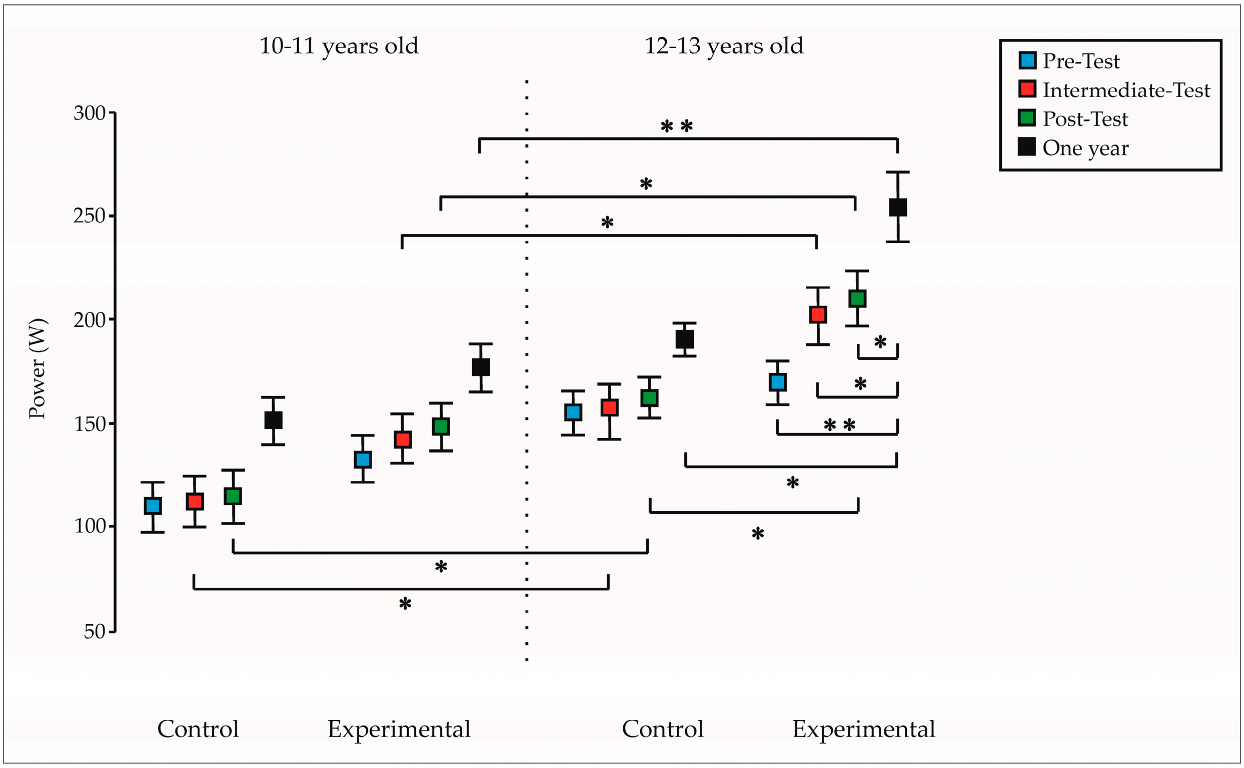

Figure 3. Evolution of the averages obtained (W) according to the group (control vs. experimental) and category (10–11 years vs. 12–13 years); and results obtained one year after the training program. [$F_{(9,208)}$ =0.54; two-way ANOVA and Holm–Sidak test; (**, $p < 0.001$; *, $p < 0.05$)]. W = watts.

Table 6 shows that 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
$\Delta Dif_{post\text{-}test/one\ year\ later}$ (W)	+36.32	+28.26	+27.73	+43.52

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

Table 7 and Figure 4 show the evolution of the different groups according to sex one year after the training program. 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]).

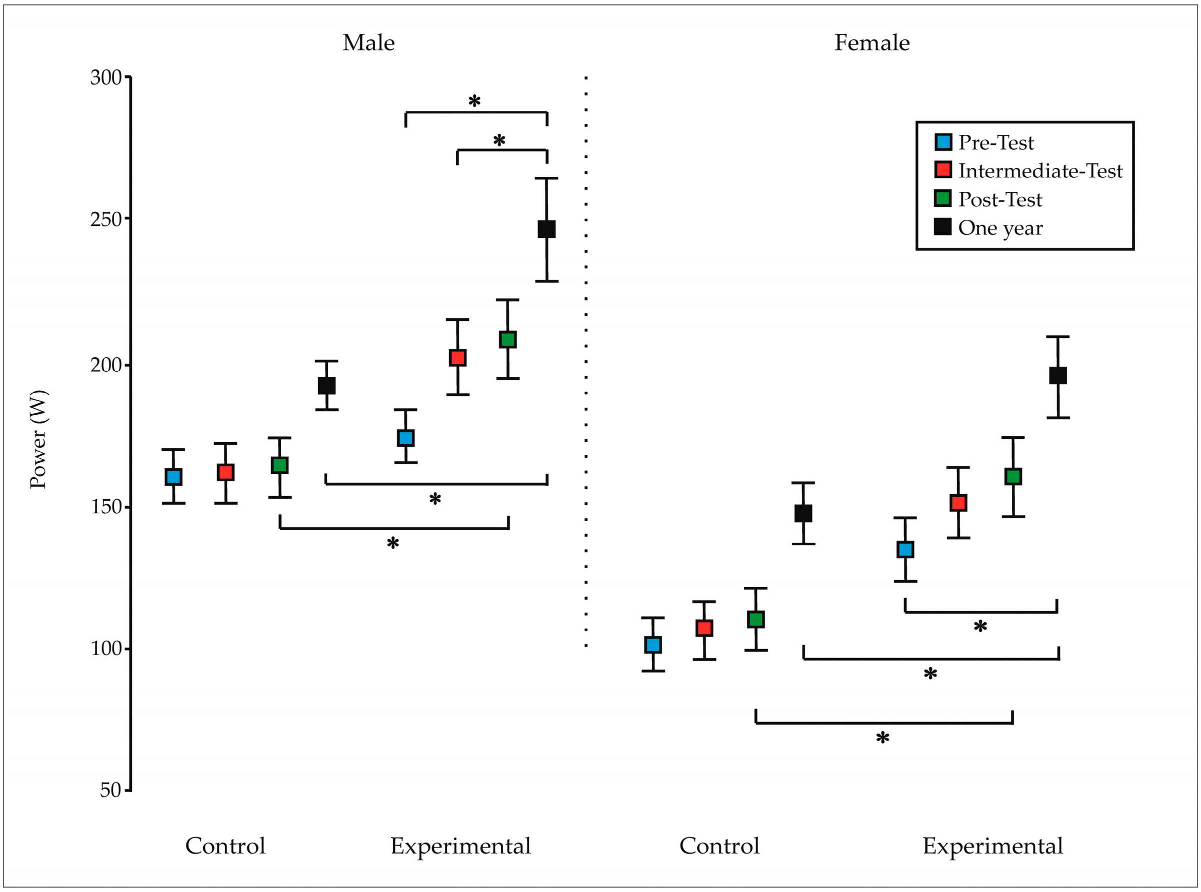

Figure 4. Evolution of the averages obtained (W) according to group and sex; and results obtained one year after the training program. [$F_{(9,208)}$ = 0.39; two-way ANOVA and Holm–Sidak test; (*, $p < 0.05$)]. W = watts.

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

	Control Group		Experimental Group	
	Male (Mean ± SEM)	**Female (Mean ± SEM)**	**Male (Mean ± SEM)**	**Female (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
$\Delta Dif_{post\text{-}test/one\ year\ later}$ (W)	+28.43	+37.55	+38.61	+35.36

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

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 the 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 allowed us to analyze 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 [6].

If we focus on the sport of rowing in relation to muscular strength, studies analyzing the influence of aerobic capacity on athlete performance are predominantly prevalent across various disciplines, including Olympic rowing [21] 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]. 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 [22,23].

Accordingly, a literature review reveals the importance of strength training as a beneficial tool for the health of the target population [24]. Some examples indicate that an eight-week training program based on strength training significantly improves sit-ups, push-ups, sit and reach, standing broad jumps, as well as the height reached during the Counter Movement Jump (CMJ) test [25]. 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 [3,26], so it is not only beneficial for maintaining an adequate body mass index, but also helps in the correct motor development of young athletes [12,27].

Lee et al. [28] conducted a study comparing various training protocols in female rowers and found greater benefits, compared to the time spent in covering 2000 m on the rowing meter, in those groups that performed higher intensity strength training based on weight lifting exercises (with equipment for five sets of 30 s 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. [29] carried out a comparison with adolescent competitive female rowers who trained following a high-intensity strength–endurance training program (4 sets of 12 repetitions at 75–95% of 1-MR maximum repetition) versus a low-intensity strength–endurance training program (4 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 required 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 that refer to the difference between sex in adolescent rowers concluded that boys demonstrated greater muscular power (measured in W), but also a higher score in perceived effort at all ages except between 12 and 14 years old [30], 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, another study found improvements in the rowing ergometer tests at the end of the program, but mostly in women [31]. This study shows that there is significant progression in both groups, although our results show better results in 12–13-year-old adolescents than in 10–11-year-old adolescents and in boys more than in girls.

Rowing training in adolescents is associated with 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 fibers. 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 confirm the positive effect of specific rowing training using a rowing ergometer on performance improvement in male and female rowers. This information contributes to clarifying the relationship between strength training and performance in young athletes, which can be highly beneficial as long as the training is supervised by qualified personnel. It's crucial to consider the importance of technique, gradual load progression, and adherence to safety standards.

As a result of this study, coaches involved in rowing with adolescents should complement water training with rowing ergometer sessions to improve muscular strength and endurance since during these ages, we have found that the effects of this type of training are noticeable even one year after experimentation.

In the future, it would be interesting to increase the sample of rowers and corroborate these results with a larger sample and with different ages to see if the same differences exist and, at the same time, to continue observing how long significant differences exist between the performance of EG and CG subjects.

Author Contributions: Conceptualization, M.R.-P. and J.G.-G.; methodology, J.G.-G. and J.C.F.-G.; software, M.E.P.-G. and M.R.-P.; validation, J.G.-G. and J.C.F.-G.; formal analysis, M.R.-P., M.E.P.-G. and J.G.-G.; investigation, M.R.-P. and J.G.-G.; resources, J.G.-G. and J.C.F.-G.; data curation, M.R.-P. and M.E.P.-G.; writing—original draft preparation, M.R.-P. and M.E.P.-G.; writing—review and editing, J.G.-G. and J.C.F.-G.; visualization, J.G.-G.; supervision, J.G.-G. and J.C.F.-G.; project administration, J.G.-G. and J.C.F.-G.; funding acquisition, J.C.F.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

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 patients to publish this paper.

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

Acknowledgments: We would like to thank the students/rowers (and their parents/guardians) who participated in this study. We would also like to acknowledge Patricio Rojas Aznar, an exceptional rower, student and teacher/coach.

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

References

1. Maetsu, J.; Jurimae, J.; Jurimae, T. Monitoring of Performance and Training in Rowing. *Sport Med.* **2005**, *35*, 597–617.
2. Ledergerber, R.J.; Jacobs, M.W.; Roth, R.; Schumann, M. Differential Effects of Strength Determinants on Different Phases of Olympic Rowing Performance in Adolescent Athletes. *Curr. Issues Sport Sci.* **2023**, *8*, 022. [CrossRef]

3. Sánchez Pastor, A.; García-Sánchez, C.; Marquina Nieto, M.; de la Rubia, A. Influence of Strength Training Variables on Neuromuscular and Morphological Adaptations in Prepubertal Children: A Systematic Review. *Int. J. Environ. Res. Public Health* **2023**, *20*, 4833. [CrossRef] [PubMed]
4. González-Badillo, J.J.; Ribas Serna, J. *Bases de La Programación Del Entrenamiento de La Fuerza*; INDE: Barcelona, Spain, 2003.
5. Volianitis, S.; Yoshiga, C.C.; Secher, N.H. The Physiology of Rowing with Perspective on Training and Health. *Eur. J. Appl. Physiol.* **2020**, *120*, 1943–1963. [CrossRef]
6. Akça, F. Prediction of Rowing Ergometer Performance from Functional Anaerobic Power, Strength and Anthropometric Components. *J. Hum. Kinet.* **2014**, *41*, 133–142. [CrossRef] [PubMed]
7. Penichet-Tomás, A.; Pueo, B. Performance Conditional Factors in Rowing. *Retos Nuevas Tend. En Educ. Física Deport. Y Recreación* **2017**, *32*, 238–240.
8. Chen, L.; Zhang, Z.; Huang, Z.; Yang, Q.; Gao, C.; Ji, H.; Sun, J.; Li, D. Meta-Analysis of the Effects of Plyometric Training on Lower Limb Explosive Strength in Adolescent Athletes. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1849. [CrossRef] [PubMed]
9. Nuzzo, J.L. Narrative Review of Sex Differences in Muscle Strength, Endurance, Activation, Size, Fiber Type, and Strength Training Participation Rates, Preferences, Motivations, Injuries, and Neuromuscular Adaptations. *J. Strength Cond. Res.* **2023**, *37*, 494–536. [CrossRef]
10. Vrijens, J. Muscle Strength Development in the Pre- and Post-Pubescent Age. *Med. Sci. Sport* **1978**, *11*, 152–158.
11. Docherty, D.; Wenger, H.A.; Collis, M.L.; Quinney, H.A. The Effects of Variable Speed Resistance Training on Strength Development in Prepubertal Boys. *J. Hum. Mov. Stud.* **1987**, *13*, 377–382.
12. Comité Nacional de Medicina del Deporte Infantojuvenil. Entrenamiento de La Fuerza En Niños y Adolescentes: Beneficios, Riesgos y Recomendaciones. *Arch. Argent. Pediatr.* **2018**, *116*, 82–91. [CrossRef]
13. Behm, D.G.; Faigenbaum, A.D.; Falk, B.; Klentrou, P. Canadian Society for Exercise Physiology Position Paper: Resistance Training in Children and Adolescents. *Appl. Physiol. Nutr. Metab.* **2008**, *33*, 547–561. [CrossRef] [PubMed]
14. Pitton, P.M. Prepubescent Strength Training: The Effects of Resistance Training on Strength Gains in Prepubescent Children. *Natl. Strength Cond. Assoc. J.* **1992**, *14*, 55. [CrossRef]
15. Paillard, T.; El Hage, R.; Al Rassy, N.; Zouhal, H.; Kaabi, S.; Passelergue, P. Effects of Different Levels of Weightlifting Training on Bone Mineral Density in a Group of Adolescents. *J. Clin. Densitom.* **2022**, *25*, 497–505. [CrossRef] [PubMed]
16. Lloyd, R.S.; Cronin, J.B.; Faigenbaum, A.D.; Haff, G.G.; Howard, R.; Kraemer, W.J.; Micheli, L.J.; Myer, G.D.; Oliver, J. National Strength and Conditioning Association Position Statement on Long-Term Athletic Development. *J. Strength Cond. Res.* **2016**, *30*, 1491–1509. [CrossRef] [PubMed]
17. Camuñas Vega, D.; Alcaide Risoto, M. La Influencia de La Práctica Deportiva En El Autoconcepto y Rendimiento Académico En Alumnos de Secundaria. *Rev. Española Educ. Física Y Deport.* **2021**, 55–67. [CrossRef]
18. Soper, C.; Hume, P.A. Rowing: Reliability of Power Output during Rowing Changes with Ergometer Type and Race Distance. *Sports Biomech.* **2004**, *3*, 237–248. [CrossRef] [PubMed]
19. Harriss, D.J.; Macsween, A.; Atkinson, G. Standards for Ethics in Sport and Exercise Science Research: 2018 Update. *Int. J. Sports Med.* **2017**, *38*, 1126–1131. [CrossRef]
20. Ebihara, A. World Medical Association Declaration of Helsinki. *Jpn. Pharmacol. Ther.* **2000**, *14*, 983–986. [CrossRef]
21. Ledergerber, R.; Jacobs, M.W.; Roth, R.; Schumann, M. Contribution of Different Strength Determinants on Distinct Phases of Olympic Rowing Performance in Adolescent Athletes. *Eur. J. Sport Sci.* **2023**, *23*, 2311–2320. [CrossRef]
22. Almeida-Neto, P.F.D.; Silva, L.F.D.; Miarka, B.; De Medeiros, J.A.; de Medeiros, R.C.D.S.C.; Teixeira, R.P.A.; Aidar, F.J.; Cabral, B.G.D.A.T.; Dantas, P.M.S. Influence of Advancing Biological Maturation on Aerobic and Anaerobic Power and on Sport Performance of Junior Rowers: A Longitudinal Study. *Front. Physiol.* **2022**, *13*, 892966. [CrossRef]
23. Almeida-Neto, P.F.D.; de Morais Ferreira, A.B.; Baxter-Jones, A.; de Medeiros, J.A.; Felipe da Silva, L.; Silva Dantas, P.M.; Cabral, B.G.D.A.T. Physiological Mechanisms of Muscle Strength and Power Are Dependent on the Years Post Obtaining Peak Height Velocity in Elite Juniors Rowers: A Cross-Sectional Study. *PLoS ONE* **2023**, *18*, e0286687. [CrossRef] [PubMed]
24. Gabbett, T. Training the Adolescent Athlete. *Sports Health Multidiscip. Approach* **2022**, *14*, 11–12. [CrossRef] [PubMed]
25. Kretschmann, R. Effects of an 8-Week after-School Resistance Program in Secondary School Students. *J. Phys. Educ. Sport* **2023**, *23*, 1376–1384. [CrossRef]
26. Manzano-Carrasco, S.; Garcia-Unanue, J.; Lopez-Fernandez, J.; Hernandez-Martin, A.; Sanchez-Sanchez, J.; Gallardo, L.; Felipe, J.L. Differences in Body Composition and Physical Fitness Parameters among Prepubertal and Pubertal Children Engaged in Extracurricular Sports: The Active Health Study. *Eur. J. Public Health* **2022**, *32* (Suppl. S1), i67–i72. [CrossRef]
27. Thiele, D.; Prieske, O.; Gäbler, M.; Granacher, U. Association between Biological Maturity, Body Constitution and Physical Fitness with Performance on a Rowing Ergometer in Elite Youth Female Rowers. *Sport. Sport.* **2023**, *37*, 116–125. [CrossRef]
28. Lee, M.; Waddell, M.; Belfry, G. A Four-Week 30 s Weight Training Intervention Improves 2000 m Rowing Ergometer Performance of Provincial to National Collegiate Female Rowers during Their Competitive Season. *Gazz. Medica Ital. Arch. Sci. Mediche* **2022**, *181*, 731–743. [CrossRef]
29. Thiele, D.; Prieske, O.; Lesinski, M.; Granacher, U. Effects of Equal Volume Heavy-Resistance Strength Training Versus Strength Endurance Training on Physical Fitness and Sport-Specific Performance in Young Elite Female Rowers. *Front. Physiol.* **2020**, *11*, 888. [CrossRef]

30. Bardin, J.; Maciejewski, H.; Diry, A.; Droit-Volet, S.; Thomas, C.; Ratel, S. Sex- and Age-related Differences in the Rating of Perceived Exertion after High-intensity Rowing Exercise during Childhood and Adolescence. *Psychophysiology* **2023**, *60*, e14296. [CrossRef]
31. Riganas, C.; Papadopoulou, Z.; Margaritelis, N.V.; Christoulas, K.; Vrabas, I.S. Inspiratory Muscle Training Effects on Oxygen Saturation and Performance in Hypoxemic Rowers: Effect of Sex. *J. Sports Sci.* **2019**, *37*, 2513–2521. [CrossRef]