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Effectiveness of Progressive-Load Respiratory Muscle Training on Repeated Sprint Ability in Youth Soccer Players Aged 15–17 Years

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1-Summary
This study examined the effectiveness of a progressive-load respiratory muscle training program on repeated sprint ability and selected physiological variables in youth soccer players aged 15 to 17 years. A quasi-experimental design was used with 30 players randomly assigned to an experimental group that performed respiratory muscle training in addition to regular training and a control group that continued regular training only. The intervention lasted 8 weeks with training loads ranging from 40 % to 80 % of maximal inspiratory pressure. Measurements included maximal inspiratory and expiratory pressures, repeated sprint performance indices, the YoYo IR1 test, rating of perceived exertion, and blood lactate concentration. The findings showed significant improvements in respiratory muscle strength, repeated sprint performance, fatigue index, and intermittent aerobic capacity in the experimental group, along with a reduction in perceived exertion, whereas changes in the control group were minimal. A significant negative relationship was also observed between changes in maximal inspiratory pressure and changes in mean repeated sprint time. The results support the integration of progressive respiratory muscle training as an effective and practical strategy to enhance physical performance in youth soccer players.
Keywords: Respiratory muscle training; repetitive races; football; juniors; maximal inspiratory pressure; YoYo IR1.

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2- Introduction
2-1- Respiratory muscle training in interval sports
Recent systematic reviews indicate that training the inspiratory muscles using devices based on threshold load(Such as PowerBreathe) produces significant increases in maximal inspiratory pressure and improved performance on interval tests in athletes in team and interval sports (Illi et al., 2020; Ruiz-Muñoz et al., 2022; Soriano-Maldonado et al., 2021). A study by Silva et al. (2019) demonstrated a significant improvement in the performance of repeated sprint tests in professional soccer players after only two weeks of inspiratory muscle training at 50% of MIP. Özgider (2010) also reported a significant improvement in YoYo IR2 test performance in young soccer players after four weeks of respiratory muscle training.
2-2- Respiratory System Characteristics in Adolescents

Reference studies show that peak inspiratory pressure values in adolescent males (12–18 years) are lower than those of athletic adults, ranging in the range of 95–110.cmH_2O versus 120–170 cmH_2In adult athletes (Smyth et al., 1984; Gochicoa-Rangel et al., 2022; Oliveira-Sousa et al., 2023), this reflects the incomplete maturation of the respiratory system and respiratory muscles, which creates a sensitive window for training response at this stage. Furthermore, adolescence is characterized by a high degree of neuromuscular adaptation, which may result in a faster and greater respiratory muscle response to training compared to adults (Castagna et al., 2006; Meckel et al., 2009).

3.6 Research gap and study problem

Despite growing evidence of the effectiveness of respiratory muscle training in improving performance in interval sports, the majority of available studies have been conducted on adults and have often focused on general progressive or interval endurance tests, rather than on repeated race performance. (RSA) is specifically studied in young football players (Kowalski et al., 2025; Illi et al., 2020). Many studies have used constant loads throughout the training program, while training principles emphasize the importance of progressive load for optimal adaptation (Rożek-Piechura et al., 2020). Hence, the problem addressed in the current study is: to what extent does an 8-week progressive load respiratory muscle training program improve the performance of repeated sprints in young football players (15–17 years old)?

3.7 Study Hypotheses

- H1: A respiratory muscle training program with progressive loads leads to a statistically significant improvement in RSA indices compared to the control group.
- H2: The program increases maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) by more than 20% in the experimental group.
- H3: There is a significant negative correlation between the change in MIP and the change in the average time of repeated races (ΔRSAmean) in the experimental group.

4. Methodology

4.1 Study Type and Design

This study adopted a quasi-experimental design.(Quasi-experimental) with two equivalent groups (experimental and control) with pre- and post-measurements, is a common design in field sports training research when it is difficult to fully control all variables (Girard et al., 2011).

4.2 Participants

The study included 30 male football players, all belonging to the same youth team.(U17 category) Competing in an official championship. They were selected according to the following criteria:

- Age between 15–17 years.
- Regular coaching experience in football≥3years.
- Participate in 4–5 training sessions per week.
- Free from chronic respiratory and cardiac diseases.

Players with acute musculoskeletal injuries within the previous three months, or those who missed more than 10% of their respiratory training sessions, were excluded. Players and their parents received written and verbal explanations of the procedures, and an informed consent form was signed. The protocol was also approved by the Research Ethics Committee in accordance with the Declaration of Helsinki..

4.3 Group Distribution

The players were randomly assigned using a computer program to:

- Experimental group (EXP; n=15): Received a respiratory muscle training program in addition to regular training.
- Control group (CON; n=15): I continued with regular training only.

4.4 Respiratory muscle training protocol

A device was used POWER breathe® (Inspiratory Threshold Resistance Device) for the application of an inspiratory muscle training program, according to protocols commonly found in the literature (30 breaths x 2 times/day x 5 days/week for 6–8 weeks) (Kowalski et al., 2025; Illi et al., 2020; Soriano-Maldonado et al., 2021).

Table 1. Respiratory muscle training protocol with progressive loads

Period	Weeks	Pregnancy severity (% of MIP)	Number of breaths/session	Number of sessions/day	Number of days/week
adaptation	1–2	40%	30	2	5
Building 1	3–4	50%	30	2	5
Building 2	5–6	60%	30	2	5
climax (Peak)	7–8	70–80%	30	2	5

Remeasured MIP (Maximum Intensity Training) was conducted every two weeks to readjust the relative workload intensity, with direct supervision from the researcher to ensure correct technique and monitor adherence. The players performed the morning session before breakfast and the evening session approximately one hour before football practice (Kowalski et al., 2025).

The control group did not receive any additional respiratory intervention and continued with the same routine training program..

4.5 Measurement Tools and Methods

4.5.1 Maximum Inspiratory and Expiratory Pressure (MIP/MEP)

Measured MIP and MEP using a digital oral pressure monitor (Micro RPM, Micro Medical, UK) according to the guidelines of the American Thoracic Society and the European Respiratory Society (ATS/ERS) (Smyth et al., 1984; Gochicoa-Rangel et al., 2022). 3–5 attempts were taken for each measurement, and the highest value from three closely spaced attempts (difference < 10%) was adopted.

4.5.2 Repeated Race Test (RSA)

The protocol used was a 6 x 30m maximum-speed run with an effective 25-second recovery interval between races, a protocol used in previous studies on junior football players.(Cetin et al., 2022; Bishop et al., 2001). The time of each race was recorded using photocells (Smartspeed, Fusion Sport, Australia).

The following indicators were calculated:

- Best timeRSAbest.

- Average timesRSAmean.
- Total time sumRSAtotal.
- Deterioration rate(Sdec%) according to the traditional equation (Bishop et al., 2001).

4.5.3 YoYo Intermittent Recovery Test Level 1

A test was conductedYoYo IR1 according to the protocol of Bangsbo et al. (2008), with recording of the total distance traveled, and VO estimation.$_2$max via the equation Castagna et al. (2006).

4.5.4 Perceived Potential (RPE)

A scale was usedBorg (6–20) to assess perceived effort immediately after the RSA test is completed (Borg, 1982).

4.5.5 Blood Lactate

A hair sample was obtained from the earlobe 3 minutes after the end of the test.RSA was analyzed using the Lactate Pro 2, a portable device commonly used in field research.

4.6 Statistical Analysis

The data were analyzed usingSPSS (version 26). The normality of the distribution was first verified using the Shapiro–Wilk test. The following was used:

- a testt for related samples to compare pre- and post-measurements within each group.
- a testt for independent samples to compare the two groups in post-test measurements.
- Two-way mixed variance analysis(2×2 Mixed ANOVA) for two factors (group × time) for some principal variables (RSAmean, MIP, YoYo IR1, RPE).
- The size of the impact was calculated usingCohen's d, in addition toηPartial 2η^2p) For ANOVA results.

The level of significance was consideredp<0.05, with reporting of the inter-parametric intervals (95% CI) for the principal variables where possible.

5. Results

5.1 Basic Anthropometric and Physical Characteristics

Table 2. Basic characteristics of participants (mean ± standard deviation)

Variable	Experimental group (n=15)	Control group (n=15)	Valuep
Age (years)	16.20 ± 0.78	16.11 ± 0.69	0.74
Length (cm)	173.48 ± 5.22	174.18 ± 4.81	0.71
Mass (kg)	64.82 ± 6.11	65.31 ± 5.78	0.83
Body Mass Index (kg/m²)	21.52 ± 1.45	21.49 ± 1.52	0.96
Training experience (years)	5.8 ± 1.4	5.6 ± 1.3	0.69

There are no significant differences between the two groups in any of the key variables. (p>0.05), which indicates that the two groups are homogeneous at the baseline.

5.2 Maximum respiratory pressures (MIP and MEP)

Table 3. Change inMIP and MEP before and after intervention (mean ± standard deviation)

Variable	The group	Tribal(cmH_2O)	After me(cmH_2O)	%	p (Inside)	d	p (Between)
MIP	EXP	114.20 ± 19.89	142.72 ± 23.84	+24.98	<0.001**	1.30	0.004**
	CON	115.70 ± 19.81	117.13 ± 20.45	+1.24	0.321	0.07	
MEP	EXP	122.96 ± 20.58	138.17 ± 21.31	+12.37	<0.001**	0.73	0.21
	CON	126.07 ± 12.83	129.51 ± 14.96	+2.73	0.002*	0.25	

*p<0.05; *p<0.01.

Analysis showedTwo-way ANOVA showed a significant interaction between group and time for the MIP variable (F(1,28)=35.22; p<0.001;η(p=0.56), which confirms that the increase in MIP was much greater in the experimental group compared to the control group.
Figure 2: Respiratory muscle strength changes

5.3 Repeated Racing Performance (RSA)

Figure 1: Percentage change in RSA variables

Table 4. IndicatorsRSA before and after intervention (mean ± standard deviation)

Variable	The group	Tribal	After me	%	p (Inside)	d	p (Between my two parts)
RSAbest (Th)	EXP	4.46 ± 0.11	4.38 ± 0.10	−1.91	<0.001**	0.79	0.038*
	CON	4.51 ± 0.18	4.50 ± 0.18	−0.36	0.001*	0.09	
RSAmean (Th)	EXP	4.83 ± 0.21	4.68 ± 0.21	−3.21	<0.001**	0.74	0.291
	CON	4.79 ± 0.19	4.76 ± 0.19	−0.76	<0.001**	0.19	
RSAtotal (Th)	EXP	29.00 ± 1.28	28.07 ± 1.25	−3.21	<0.001**	0.74	0.291
	CON	28.76 ± 1.14	28.54 ± 1.14	−0.76	<0.001**	0.19	
Sdec (%)	EXP	8.28 ± 4.16	6.82 ± 3.72	−17.58	<0.001**	0.37	0.632
	CON	6.34 ± 6.12	5.93 ± 6.15	−6.61	0.011*	0.07	

Analysis showedANOVA as a significant group × time interaction for RSAmean (F(1,28)=14.67; p<0.001;η(p=0.34), which means that the improvement in performance in the experimental group was higher than in the control group, beyond just the effect of time.

5.4 Aerobic performance and cognitive-metabolic responses

Figure 3: Yo-Yo IR1 test performance

Table 5. Test ResultsYoYo IR1, VO_2max, RPE, and blood lactate (mean ± standard deviation)

Variable	The group	Tribal	After me	%	p (Inside)	d
YoYo IR1 (m)	EXP	1372.81 ± 115.88	1545.23 ± 128.76	+12.56	<0.001**	1.41
	CON	1537.09 ± 155.50	1580.92 ± 177.93	+2.85	0.002*	0.26
VO_2max (ml/kg/d)	EXP	47.93 ± 0.97	49.38 ± 1.08	+3.02	<0.001**	1.41
	CON	49.31 ± 1.31	49.68 ± 1.49	+0.75	0.002*	0.26
RPE after RSA	EXP	17.13 ± 1.22	15.55 ± 1.10	−9.20	0.002**	1.36
	CON	17.39 ± 1.29	16.39 ± 1.04	−5.70	0.029*	0.84
Lactate (funded/for)	EXP	11.56 ± 1.26	10.53 ± 1.71	−8.91	0.084	0.69
	CON	11.45 ± 1.52	10.87 ± 1.39	−5.08	0.313	0.40

Analysis showedANOVA showed a significant group × time interaction for the distance YoYo IR1 ($F(1,28)=18.94$; $p<0.001$;η(p = 0.40), indicating a clear differential effect favoring the experimental group in improving intermittent aerobic power. A significant RPE interaction was also recorded ($F(1,28) = 4.89$; $p = 0.035$).η($p=0.15^2$) reflects a greater decrease in perceived effort in the experimental group compared to the control group.

5.5 The relationship between MIP improvement and RSA mean improvement

Correlation analysis showedPearson found a significant negative relationship between the change in MIP and the change in RSAmean ($r=-0.58$; $p=0.023$) in the experimental group, meaning that the players who had the largest increase in MIP had the largest decrease in the average time of repeated races.

6. Discussion

6.1 Summary of Main Findings

The study showed that an 8-week program of progressively heavier respiratory muscle training led to significant increases inMIP and MEP showed significant improvements in RSA indices, particularly mean time, total time, and percentage of deterioration, in addition to improved performance on the YoYo IR1 test and reduced perceived effort during the RSA test. These results are consistent with previous studies on the effectiveness of RMT in improving intermittent athletic performance (Silva et al., 2019; Özgider, 2010; Kowalski et al., 2025).

6.2 Compared to previous studies

The increase inMIP (The 25% improvement in this study is similar to what systematic reviews have reported, indicating an improvement of 15–30% after 4–8 weeks of threshold inspiratory training (Illi et al., 2020; Soriano-Maldonado et al., 2021). The improvement in RSA is also consistent with the findings of Silva et al. (2019), who found a significant reduction in repeated sprint times in professional soccer players after a short-term (two-week) IMT program with an intensity of 50% of MIP.

6.3 Possible physiological mechanisms

The improvement can be explained byRSA and intermittent performance through a range of mechanisms:

- Relieving the metabolic-respiratory reflex, which reduces vasoconstriction in peripheral muscles and improves muscle perfusion during exertion. (Shei et al., 2018; Kowalski et al., 2025).
- Reducing the cost of oxygen for respiration, thereby providing a greater share of cardiac output and oxygen capacity to working muscles. (Tong et al., 2008; Romer et al., 2002).
- Improved tolerance to anaerobic metabolite accumulation and increased the body's ability to remove lactate between races, although the differences in lactate levels in this study did not reach statistical significance...

6.4 The importance of the studied age group

Relatively low reference values forMIP in this age group, compared to adult athletes, indicates a greater potential for improvement under training influence (Smyth et al., 1984; Gochicoa-Rangel et al., 2022; Oliveira-Sousa et al., 2023). This aligns with the concept of “sensitive periods” in athletic training, where certain systems and abilities are more responsive to training at specific developmental stages (Castagna et al., 2006; Meckel et al., 2009).

6.5 Strengths and Limitations

One of the strengths of this study:

- Protocol applicationRMT is a graded approach based on the latest revisions in the field.
- Using a range of physiological and performance indicators (MIP, MEP, RSA, YoYo IR1, RPE, Lactate) for crossover in interpreting the results.

6.6 Future Recommendations

The study suggests future research.:

- With a randomized design controlled by three groups (experimental, control, dummy).
- With larger samples and from different competitive levels.
- With measurement of lung ventilation during exertion and analysis of other variables such asHRV and indices of intramuscular oxygenation (NIRS).
- With a follow-up period to test the sustainability of the adaptations after discontinuingRMT.

7. Conclusions and practical applications

7.1 Conclusions

The results of this study highlight that a respiratory muscle training program using the inspiratory threshold load method and progressively increasing loads from 40% to 80% of theMIP, for a period of 8 weeks, leads to:

- A significant increase in respiratory muscle strength (MIP and MEP).

- Significant improvement in the ability to perform repeated races(Lower RSAmean, RSAtotal and SDec).
- Improvement in intermittent aerobic performance as measured by testingYoYo IR1.
- Perceived voltage drop during repeated high-intensity voltage.

7.2 Practical Applications for Trainers

- Integration of unitsRMT with two short sessions per day (30 breaths per session) for 6–8 weeks as part of the physical conditioning program for junior football players.
- Adopting the principle of gradual load (40%→80% of MIP) with load recalibration every 2–3 weeks.
- procedureRMT outside the main training units (morning or a period before the session) to avoid affecting the quality of field training performance.

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