Journal of Exercise Science & Physiotherapy Volume 21 No.2 (July - December) 2025
I2OR Impact Factor = 7.754 ISSN: 0973-2020 (Print) ISSN: 2454-6089 (Online)

JOURNAL OF EXERCISE SCIENCE AND PHYSIOTHERAPY
Indexed, Peer Reviewed, Referred

# Exploring the Effect of Respiratory Muscle Training on a Paralympic Para-powerlifter: An Observational Case Analysis

**Snehangshu Biswas, Ashok Kumar, Manika Ghosh and Sumita Porel**

## Abstract

**Aim:** To examine whether a 14-week IMT programme improves respiratory muscle strength and pulmonary function in an elite female para powerlifter, and to discuss practical implications for training. **Materials & Method**: One 34-year-old international PP athlete completed twice-daily IMT (10 sessions·$week^{-1}$) with a threshold device at 25–30% maximal inspiratory pressure (MIP). Spirometry [forced vital capacity (FVC), forced expiratory volume in one second ($FEV_1$), $FEV_1$/FVC] and maximum voluntary ventilation (MVV) were assessed, alongside MIP, at baseline and after 4, 8 and 14 weeks. Percentage changes were analysed descriptively. **Results:** All ventilatory variables except FVC showed small increases after four weeks of IMT, with FVC rising slightly by week eight then returning close to baseline by week fourteen. MVV showed minor fluctuations only. In contrast, MIP increased from 90 to 135 $cmH_2O$ after four weeks and remained clearly above baseline thereafter (≈122–128 $cmH_2O$), indicating substantial gains in inspiratory muscle strength. No parallel improvement in bench-press performance was observed. **Conclusion:** In this para powerlifter, 14 weeks of low-intensity IMT produced meaningful increases in inspiratory muscle strength without clear changes in spirometric indices or lifting performance. IMT may help attenuate respiratory muscle fatigue during heavy bench-press training, but higher loads, volumes, or longer interventions may be required to elicit performance benefits.

**Snehangshu Biswas**
Ph..D Scholar
Department of Sports Science, Punjabi University, Patiala (Punjab )India
E-mail: snehangshubiswas.sai@gmail.com
**Ashok Kumar**
Professor, Department of Sports Science
Punjabi University, Patiala (Punjab )India
**Manika Ghosh**
Sports Scientist
Jharkhand High Performance Sports Science Center, Abhinav Bindra Targeting Performance (ABTP), Ranchi (Jharkhand) India
**Sumita Porel**
Performance Analyst
Department of Exercise Physiology
SAI NSSC, Bangalore (Karnataka) India

**Key words: Paralympic Powerlifting , Inspiratory Muscle Training, Maximal Inspiratory Pressure, Spirometry, Case study**

**DOI: 10.18376/jesp/2025/v21/i2/47757**

## Introduction

The rise in popularity of paralympic powerlifting is evident from the growing number of participants in international competitions and the remarkable surge in performance witnessed over the past few years (Anon n.d.). Powerlifting is a sport that heavily relies on muscular strength. It consists of three primary exercises: the squat, bench press, and deadlift. These three movements define powerlifting and testify to the athletes' remarkable physical prowess and capabilities (Puce et al. 2022) Paralympic Powerlifting (PP), previously referred to as "International Paralympic Committee" (IPC) powerlifting, is specifically designed for athletes with disabilities. This format caters to these athletes' unique abilities and challenges, providing them with a platform to excel in powerlifting. Distinguishing itself from the version designed for able-bodied athletes, paralympic powerlifting (PP) solely focuses on the bench press (BP) exercise. (Anon n.d.; Ferland and Comtois 2019). Both men and women with physical disabilities in their lower limbs participate in these sports. The sport has garnered significant interest among numerous participants, making it increasingly crucial to closely monitor athletes' preparation to optimize their performance in competitions. Consequently, monitoring the athletes' physiological adaptation becomes essential to maximize their performance. (da Silva et al. 2022; De Sousa et al. 2017).

When performing the bench press with the feet off the floor, there is heightened activation of both the prime mover (e.g., pectoralis major) and the stabilizer muscles (e.g., obliques) while lifting a submaximal load (Muyor et al. 2019). With increased training, the cardiovascular and musculoskeletal systems undergo greater structural and functional adaptations in athletes. The chest wall, airways, and gas exchange system are constantly strained when engaging in intense activity. When these strains continue, they push the envelope, necessitating adequate minute ventilation and gas exchange in a setting where demands outweigh supply. (McKenzie 2012) (Hackett 2020).

The diaphragm, rib cage, and abdominal muscles are the three functional groups into which the respiratory muscles can be divided. When the diaphragm contracts, the lowest part of the abdomen and rib cage expands. During inspiration and expiration, the rib cage muscles—which comprise the intercostals, parasternal, scalene, and neck muscles—act mostly on the upper part of the rib cage. The abdominal muscles mainly support the expiratory phase of breathing and contract the abdomen and lower rib cage. (Kowalski, Granda, and Klusiewicz 2024)

During exercise, elite athletes experience heightened ventilatory demands, leading to an increased neural drive to the respiratory muscles. This phenomenon has the potential to influence exercise performance significantly. As a result, this points to an escalation in the mechanical power generated by the muscles. Muscle power is calculated as the product of velocity of shortening and pressure. In contrast to the other muscles, the main role of the diaphragm is as a "flow generator." This implies that the mechanical power generated by the diaphragm is primarily manifested through the velocity of shortening rather than pressure. Conversely, the ribcage & abdominal muscle serve primarily as "pressure generators," producing the pressures required to move the ribs and abdomen, respectively (Aliverti et al. 1997). Nevertheless, the expiratory muscles actively contribute to the breathing process during exercise. Each breath requires careful coordination between the expiratory and inspiratory rib cage muscles. During inspiration, rib cage muscles contract, and abdominal muscles relax. In contrast, the abdominal muscles contract during expiration while the rib cage muscles relax. (Aliverti 2016).

Strengthening the lower extremities and posterior trunk is the main focus of the squat and deadlift exercises, whereas the upper extremities and anterior trunk are the main focus of the bench press. Each of these procedures results in an increase in intra-abdominal pressure (IAP), or the pressure inside the abdominal cavity. This pressure is generated by the contraction of the respiratory muscles, especially the transverse abdominis and the diaphragm (Brown et al. 2013). The intra-abdominal pressure (IAP) generated during these lifting movements notably enhances the activation of the diaphragm. Therefore, the strength of the diaphragmatic muscles is directly linked to para-powerlifting performance.

Numerous studies have demonstrated that respiratory muscle fatigue significantly impacts athletes' performance through a mechanism known as the metaboreflex. This process involves the accumulation of metabolites, such as lactic acid, within the respiratory muscles. The activation of group III and particularly group IV afferent nerve fibers by the metaboreflex leads to an elevation in sympathetic outflow from the brain, resulting in vasoconstriction within the exercising muscle (Dempsey et al. 2006). This physiological response occurs as a consequence of the increased nerve activity during exercise. During exercise, the progressive fatigue of limb muscles occurs linearly, prompting athletes to cease their physical activity earlier than when respiratory muscle fatigue is prevented. By avoiding or minimizing the impact of respiratory muscle fatigue, athletes can prolong their exercise duration and potentially enhance overall performance (Illi et al. 2012)

In this context, respiratory muscle training (RMT) during exercise can effectively diminish the occurrence of respiratory muscle fatigue, lower blood lactate concentration, and reduce sympathetic activation. RMT has proven to enhance athletes' performance by delaying the aforementioned metaboreflex response (Witt et al. 2007). The diaphragm and other inspiratory muscles are subjected to an additional load during inspiratory muscle training (IMT), a common form of RMT. By doing so, IMT strengthens and enhances the endurance of these respiratory muscles, leading to improved breathing efficiency and overall athletic performance. Additionally, during continuous training loads, RMT may increase ventilation, heart rate (HR), oxygen intake, and perceptual responsiveness by changing the mechanics of breathing (Mackała et al. 2019; Ozmen et al. 2017). IMT contributes to increased strength in the upper chest and neck muscles. Over time, this training can lead to improved chest geometry, as the vital capacity (VC) parameter increases. Additionally, the diaphragm's thickness is observed to increase following the training regimen (Okrzymowska et al. 2019).

Previous research revealed that world-class powerlifters who regularly perform non-respiratory maneuvers like squats, deadlifts, and bench presses, experience enhanced respiratory muscle strength and diaphragm thickness. (Brown et al. 2013). However, there were no significant improvements in pulmonary function observed.The author is unaware of any scientific studies on paralympic powerlifters and respiratory muscle training. Therefore, this case study will examine how respiratory muscle training affects a paralympic powerlifter. Through this research, we aim to gain insights into how respiratory muscle training can increase strength and influence a paralympic powerlifter's performance and overall capabilities.

## Materials and Methods

*Study Design* **-** Changes in pulmonary function parameters, which measure numerous aspects of respiratory system performance, were assessed using an observational, probable design. For this case study, an international paralympic powerlifter was chosen. In order to freely engage in this study, the athlete and her coach provided written informed consent. Before the study started, the athlete received a thorough explanation of all the procedures. The local institutional research ethics committee accepted the study, which complied with the 1964 Declaration of Helsinki's guidelines.

*Participant* - The participant of this study was a 34-year Paralympic powerlifter (Table 1). The athlete was chosen based on age, training experience, and sports level. Testing took place in the powerlifting training hall. The athlete was free from asthma, respiratory illness, lung-affecting medications, and major injury previous to this study. The participant upheld a routine of powerlifting-specific training three times per week and engaged in specific strength training twice a week throughout the entire study duration.

**Table 1 Demographic detail of the athlete**

| Gender | Age (Year) | Height (cm) | Weight (kg) |
|---|---|---|---|
| Female | 34 | 140 | 49 |

*Pulmonary function test* **-** Pulmonary function tests were conducted using the Spirolab apparatus. Before the tests, the athlete received comprehensive instructions regarding the protocols for each assessment. Practice trials were also conducted on the athlete. The measurements of lung function were performed while the subjects were seated. The athlete wore a nose clip during the testing and was told to keep their lips tightly sealed around the mouthpiece to keep air from escaping. The forced vital capacity (FVC) test was initially completed by the athlete. This process involved the athlete following instructions to exhale fully, then inhale deeply, and finally exhale again. Every trial included a minimum of three repetitions of the FVC test. The FEV1/FVC ratio and forced expiration volume in one second (FEV1) were computed using this lung function test. (Durmic et al. 2017; Graham et al. 2019). Subsequently, the maximum voluntary ventilation (MVV) test was conducted. The athlete was instructed to breathe deeply and rapidly for 12 seconds upon command. There was around a 30-second interval for recovery between each trial of lung function testing. In general, a more extended break was taken between efforts for maximum voluntary ventilation (MVV). A minimum of three MVV trials were executed. Data analysis was conducted using the best trial for all measures. (Hackett 2020; Karaduman, Bostancı, and Bayram 2022).

*Respiratory muscle strength assessment* - Muscle strength for inhaling and exhaling was assessed by measuring "MIP (Maximal Inspiratory Pressure)" and "MEP (Maximal Expiratory Pressure)". The maximum sub-atmospheric pressure that can be produced during inspiration against a closed airway is known as PImax. (Muller manoeuvre). PEmax is the maximum pressure attainable with a strong expiratory effort against an obstructed airway (Valsalva manoeuvre). The strength of the respiratory muscles was assessed using maximal inspiratory pressure (PImax) and maximal expiratory pressure (PEmax), with results expressed in cmH2O (Mackała et al. 2019). An apparatus was used to measure MIP, comprising a well-fitted mouthpiece attached to a small chamber connected to a pressure gauge. The concept was adopted from a research article (Evans and Whitelaw 2009). Measurement was taken in a seated position while the athlete was looking straight ahead and wearing a nose clip. While measuring MIP, the athlete gripped the mouthpiece with both hands, maintaining firm lip closure around it without bending the body. To prevent nasal air leakage, a nose clip was used. The athlete then exhaled to residual volume and subsequently inhaled maximally against the gauge's resistance for over 1 second. The athlete performed three inspiratory efforts, maintaining each effort for a minimum of 1 second. Encouragement was consistently provided to the athlete during the test. The optimal outcome from the three attempts was selected for analysis, with approximately 1 minute of rest between each effort. (Jalan et al. 2015)

*Procedure* **-** Prior to initiating respiratory muscle training, a pulmonary function test and an assessment of respiratory muscle strength were performed. Following four, eight, and twelve weeks of training, the same tests were conducted to measure the respiratory function parameter.

*Respiratory muscle training routine* **-** Due to the nature of the training device, inspiratory muscle strength was converted into cmh2o from mmHg (1 mmHg =1.359 cmh2o). Inspiratory muscle training occurred in a 12-week pattern, with a frequency of 10 sessions per week, equating to twice daily sessions. One session took place in the morning before training, and another in the evening after training. The training was conducted utilizing a manual Threshold IMT device (manufactured by Philips Respironics). Following the assessment of athlete PImax, the training load has been decided accordingly. The load increased according to the diagram given in Table 2. The inhalation was full, fast & strong whereas the exhalation was long & slow (Mackała et al. 2019; Okrzymowska et al. 2019; Vašíčková, Neumannová, and Svozil 2017). The initial training session took place at the powerlifting hall. The athlete trained each morning between 7:00 to 8:00 A.M under the supervision of an exercise physiologist at the powerlifting hall. The second session occurred in the evening, about 7:30 p.m., immediately following the powerlifting training session. The designated exercises were executed while seated. The initial load selected prioritized the safety of the training schedule. (Esposito et al. 2010). Athletes trained at 30% of the "Maximum Inspiratory Presessure (MIP)", with weekly load changes based on the latest MIP evaluation.

*Data analysis* **-** In this case study, data were evaluated through visual inspection, and alterations across time points were computed. The extent of the change was assessed by percentage change.

**Table 2. Changes in training load throughout the 12 weeks**

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load (% of PImax) | 25 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Morning Time (min) | 5 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Evening Time (min) | 5 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| One Session (Breath) | 30 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |

**Results and Discussion**

After 12 weeks after the targeted training, we observed differences between the pre-training & post-training on FVC, FEV1, FEV1/FVC. MVV & MIP. All ventilatory measures, with the exception of FVC, exhibited an increase following four weeks of respiratory muscle training; however, the improvement was not statistically significant. Forced vital capacity increased following 8 weeks of respiratory muscle training. An appreciable improvement in the strength parameter (MIP) of respiratory muscles was noted following training.

**Discussion**

The principal outcome of this prospective observational case study was to examine the effects of IMT on a para powerlifter. The aim was to investigate the efficacy of a 12-week IMT program in improving respiratory muscle strength. The findings indicate a notable enhancement in maximal inspiratory pressure as a result of the training regimen. Enhanced respiratory muscle strength demonstrates an adaptation to targeted inspiratory muscle training. This adaptation could potentially decrease the demand on inspiratory muscles during exercises with the same load before undergoing training. This could potentially result in decreased respiratory exertion at equivalent exercise intensities. As activity intensity increases, the reduction in respiratory effort offers athletes the advantage of preserving and upholding their overall physical performance more effectively. When exercise-induced fatigue initiates, there's an elevated demand for blood flow directed towards respiratory muscles. Simultaneously, there's a reduction in the blood flow demand to peripheral musculature. This dynamic shift in blood flow allocation affects overall physical performance. The heightened blood flow to respiratory muscles is essential to sustain adequate oxygen supply during exertion. The decreased blood flow to peripheral muscles might lead to reduced strength and endurance, impacting an individual's ability to maintain optimal performance levels as fatigue accumulates during exercise. Strengthening the respiratory muscles decreases the demand on respiratory muscles compared to peripheral muscles, thereby supporting the maintenance of powerlifting performance (Romer and Polkey 2008).

In the process of resistance training, the typical changes involve the development of muscle strength and an increase in muscle mass. Research indicates that the diaphragm is engaged while performing bench presses and its activation increases with heavier loads. Compared to bench presses, squats, and deadlifts demand increased spinal stability. Research reveals a correlation between the effective execution of resistance exercises like bench presses and the strength of respiratory muscle (Al-Bilbeisi and McCool 2000; Hackett and Sabag 2021). Therefore, the strength of the diaphragmatic muscles is directly linked to powerlifting performance. Intense exercises involved in powerlifting competitions can lead to fatigue in the respiratory muscles. Consequently, Inspiratory Muscle Training (IMT) presents a dependable approach for enhancing respiratory muscle strength (Brown et al. 2013; Dempsey et al. 2006; Hajghanbari et al. 2013). The bench press in powerlifting enhances the development of the upper extremities and anterior trunk musculature. During bench press activities, athletes produce intra-abdominal pressure in the abdominal cavity by contracting respiratory muscles (Brown et al. 2013). It increases as a result of heavier load. IAP generated during these lifting increases diaphragm activation. This, in turn, enhances core stability. Consequently, the muscles engaged in respiration—namely the diaphragm, thoracic cage muscles, as well as abdominal muscles—are activated during lifting to augment intra-abdominal pressure. When athletes engage in daily bench presses with heavy loads, this pressure continuously increases. So, strengthening the diaphragm becomes crucial for athletes to achieve optimal performance. If a para-athlete regularly engages in bench press sessions lasting over an hour, incorporating varying training load volumes three times a week, there's a risk of respiratory muscle fatigue during these sessions, subsequently impacting performance. Therefore, Inspiratory Muscle Training (IMT) holds significant potential to enhance respiratory muscle strength and reduce respiratory muscle fatigue, offering considerable benefits for Para powerlifters.

This research shows a rise in maximum inspiratory pressure (MIP) following inspiratory muscle training (IMT). However, this increase did not lead to enhanced athletic lifting performance. Similar outcomes were reported by Hart et al., where an increase in inspiratory muscle strength was observed without corresponding physical performance improvements. This implies that performance improvement via inspiratory muscle training may correlate with greater improvements in respiratory muscle strength (Hart et al. 2001). This study attributes the increase in MIP after 4 weeks of training to the enhanced recruitment of respiratory muscles resulting from training conducted at 30% of MIP. This may be the reason for increasing the maximum inspiratory pressure. Research shows that regular non-respiratory maneuvers, such as squats, deadlifts, and bench presses, performed by World Class Powerlifters, result in enhanced respiratory muscle strength and thicker diaphragms. These powerlifters demonstrate significantly stronger global inspiratory (22%) and expiratory (16%) muscle strength, as well as increased diaphragm thickness (27%) when compared to matched untrained controls (Brown et al. 2013). This research involved a 14-week implementation of IMT, which may lead to diaphragm hypertrophy, since studies indicate that IMT is one of the most frequently referenced interventions, noted for generating the greatest activation of the inspiratory muscles. (Illi et al. 2012).This investigation revealed no substantial enhancement in lung function indices, with only a minor rise observed in the majority of parameters following 14 weeks of Inspiratory Muscle Training (IMT). Likewise, another study noted that there were no differences in FVC and FEV1 following six weeks of RMT and biweekly pre-season soccer training in twelve recreational players (Ozmen et al. 2017) The athlete's training of the pulmonary muscles led to better ventilation. No notable alterations in pulmonary metrics suggested that IMT enhanced respiratory muscles' strength. The augmented power of the respiratory muscles enabled the subjects to execute greater effort (i.e., displace more air) while breathing less frequently. As part of the normative aging process, there is a natural decline in both skeletal muscle mass and strength, including the muscles responsible for breathing.

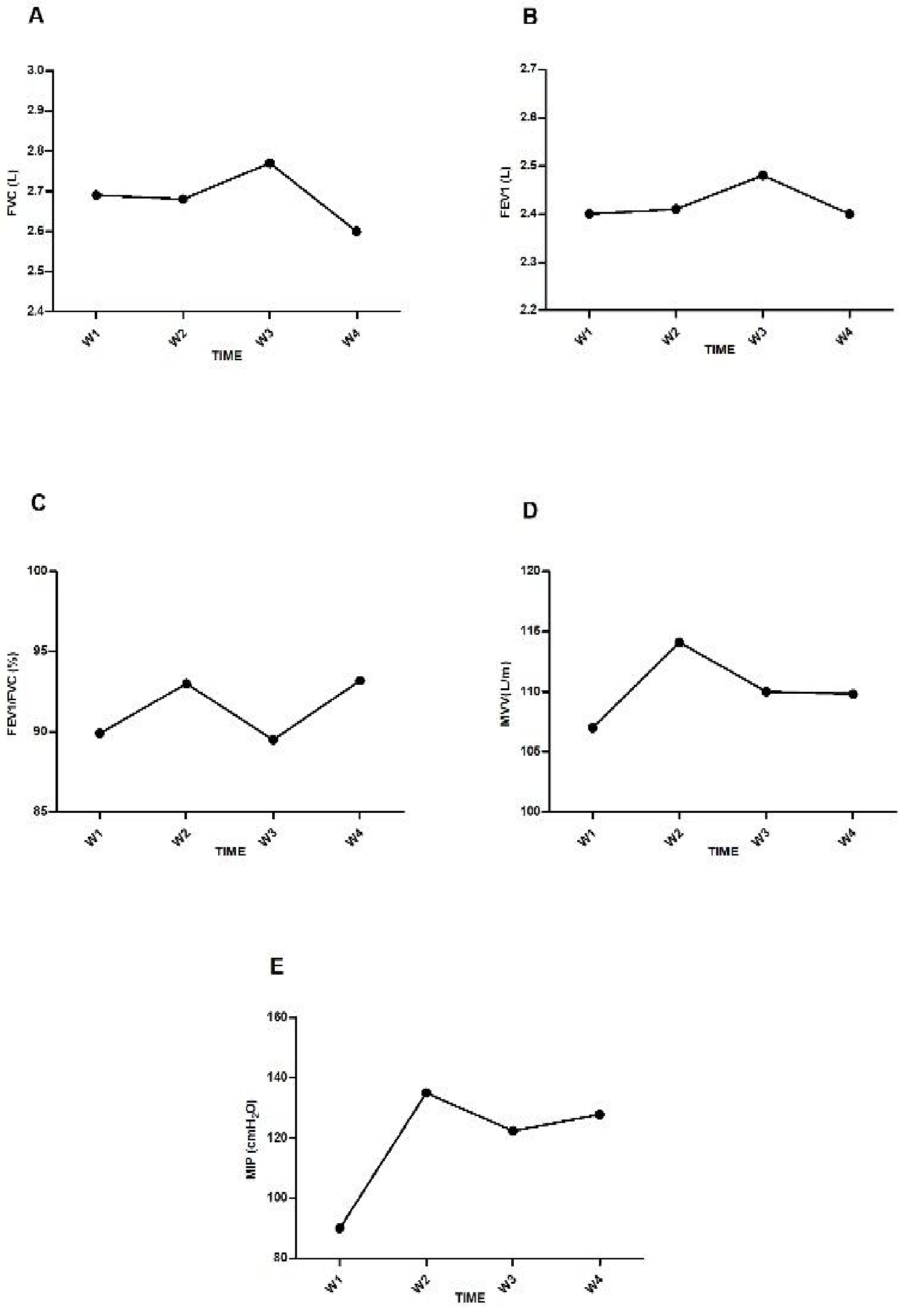


**Figure. 1 Changes in pulmonary function parameters from Week 1 to Week 12**

**Table 3. Changes in Pulmonary Function and Respiratory Muscle Strength Parameters throughout the Training session**

| Variable | Measured Value | | | |
|---|---|---|---|---|
| | Before RMT | After 4 weeks | After 8 weeks | After 14 weeks |
| FVC (L) | 2.69 | 2.68 | 2.77 | 2.60 |
| FEV1 (L) | 2.40 | 2.41 | 2.48 | 2.40 |
| FEV1/FVC (%) | 89.9 | 93 | 89.5 | 93.2 |
| MVV (L/m) | 107 | 114.1 | 110.0 | 109.8 |
| MIP (cmH2O) | 90 | 135 | 122.36 | 127.8 |

Research has demonstrated that aging leads to significant structural alterations in the respiratory system, resulting in reduced pulmonary function and changes in breathing mechanics during physical activity. Specifically, the respiratory muscles undergo structural modifications that lead to a gradual loss in strength, as evidenced by decreases in maximal respiratory pressures (Summerhill et al. 2007). Studies have indicated that lung function remains relatively stable between the ages of 20 and 35, but it starts to decline thereafter. The reduction in diaphragm strength with aging is mostly associated with muscle atrophy and the age-related fall in fast-twitch muscle fibers, essential for generating high peak stresses. The age-related reduction in diaphragmatic strength can render older persons more vulnerable to diaphragmatic fatigue and respiratory failure under heightened respiratory demands. (Sharma and Goodwin 2006). This may explain the lack of significant improvement in performance and the plateau found in respiratory muscle strength within this study. Following the above-mentioned research, our understanding is that para powerlifters have a demand on their respiratory muscles. As a result, enhancing the conditioning of their inspiratory muscles could potentially lead to increased respiratory muscle strength that is directly linked with para powerlifting performance & decreased fatigue in the inspiratory muscles during powerlifting. This, in turn, might contribute as a factor leading to improved performance.

## Conclusion

The outcomes of this study indicated that a 14-week regimen of IMT enhanced maximal inspiratory pressure (MIP). Nevertheless, no enhancements were noted in forced vital capacity (FVC), FEV1, or lifting capability among para powerlifters. These outcomes highlight only the positive enhancements in inspiratory muscle strength. Future research should explore alternative training protocols to achieve further improvements. In all forms of resistance training, changes are implemented not just to intensity but also to total volume and time. It's possible that engaging in training with a higher volume could potentially yield more adaptations in the respiratory muscles. Enhancements in respiratory muscle strength resulting from Inspiratory Muscle Training have the potential to enhance powerlifting performance and assist athletes in reducing muscle fatigue. As a result, Inspiratory Muscle Training can hold a pivotal role in para powerlifting.

## Reference(s)

Al-Bilbeisi, Fadi, and F. Dennis McCool. 2000. "Diaphragm Recruitment during Nonrespiratory Activities." *American Journal of Respiratory and Critical Care Medicine* 162(2 Pt 1):456–59. doi: 10.1164/AJRCCM.162.2.9908059.

Aliverti, A., S. J. Cala, R. Duranti, G. Ferrigno, C. M. Kenyon, A. Pedotti, G. Scano, P. Sliwinski, Peter T. Macklem, and S. Yan. 1997. "Human Respiratory Muscle Actions and Control during Exercise."

*Journal of Applied Physiology (Bethesda, Md.: 1985)* 83(4):1256–69. doi: 10.1152/JAPPL.1997.83.4.1256.

Aliverti, Andrea. 2016. "The Respiratory Muscles during Exercise." *Breathe* 12(2):165. doi: 10.1183/20734735.008116.

Anon. n.d. "Powerlifting - About the Sport." Retrieved December 14, 2024 (https://www.paralympic.org/powerlifting/about).

Brown, Peter I., Heather K. Venables, Hymsuen Liu, Julie T. De-Witt, Michelle R. Brown, and Mark A. Faghy. 2013. "Ventilatory Muscle Strength, Diaphragm Thickness and Pulmonary Function in World-Class Powerlifters." *European Journal of Applied Physiology* 113(11):2849–55. doi: 10.1007/s00421-013-2726-4.

Dempsey, Jerome A., Lee Romer, Joshua Rodman, Jordan Miller, and Curtis Smith. 2006. "Consequences of Exercise-Induced Respiratory Muscle Work." *Respiratory Physiology & Neurobiology* 151(2–3):242–50. doi: 10.1016/J.RESP.2005.12.015.

Durmic, Tijana, Biljana Lazovic Popovic, Mirjana Zlatkovic Svenda, Marina Djelic, Vladimir Zugic, Tamara Gavrilovic, Zoran Mihailovic, Marija Zdravkovic, and Roman Leischik. 2017. "The Training Type Influence on Male Elite Athletes' Ventilatory Function." *BMJ Open Sport & Exercise Medicine* 3(1). doi: 10.1136/BMJSEM-2017-000240.

Esposito, Fabio, Eloisa Limonta, Giampiero Alberti, Arsenio Veicsteinas, and Guido Ferretti. 2010. "Effect of Respiratory Muscle Training on Maximum Aerobic Power in Normoxia and Hypoxia." *Respiratory Physiology & Neurobiology* 170(3):268–72. doi: 10.1016/J.RESP.2010.02.004.

Evans, John A., and William A. Whitelaw. 2009. "The Assessment of Maximal Respiratory Mouth Pressures In Adults." *Respiratory Care* 54(10).

Ferland, Pierre Marc, and Alain S. Comtois. 2019. "Classic Powerlifting Performance: A Systematic Review." *Journal of Strength and Conditioning Research* 33 Suppl 1:S194–201. doi: 10.1519/JSC.0000000000003099.

Graham, Brian L., Irene Steenbruggen, Igor Z. Barjaktarevic, Brendan G. Cooper, Graham L. Hall, Teal S. Hallstrand, David A. Kaminsky, Kevin McCarthy, Meredith C. McCormack, Martin R. Miller, Cristine E. Oropez, Margaret Rosenfeld, Sanja Stanojevic, Maureen P. Swanney, and Bruce R. Thompson. 2019. "Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement." *American Journal of Respiratory and Critical Care Medicine* 200(8):E70–88. doi: 10.1164/RCCM.201908-1590ST.

Hackett, Daniel A. 2020. "Lung Function and Respiratory Muscle Adaptations of Endurance- and Strength-Trained Males." *Sports (Basel, Switzerland)* 8(12). doi: 10.3390/SPORTS8120160.

Hackett, Daniel A., and Angelo Sabag. 2021. "Lung Function and Respiratory Muscle Strength and Their Relationship with Weightlifting Strength and Body Composition in Non-Athletic Males." *Respiratory Physiology & Neurobiology* 286. doi: 10.1016/J.RESP.2021.103616.

Hajghanbari, Bahareh, Cristiane Yamabayashi, Teryn R. Buna, Jonathan D. Coelho, Kyle D. Freedman, Trevor A. Morton, Sheree A. Palmer, Melissa A. Toy, Cody Walsh, A. William Sheel, and W. Darlene Reid. 2013. "Effects of Respiratory Muscle Training on Performance in Athletes: A Systematic Review with Meta-Analyses." *Journal of Strength and Conditioning Research* 27(6):1643–63. doi: 10.1519/JSC.0B013E318269F73F.

Hart, N., K. Sylvester, S. Ward, D. Cramer, J. Moxham, and M. I. Polkey. 2001. "Evaluation of an Inspiratory Muscle Trainer in Healthy Humans." *Respiratory Medicine* 95(6):526–31. doi: 10.1053/RMED.2001.1069.

Illi, Sabine K., Ulrike Held, Irène Frank, and Christina M. Spengler. 2012. "Effect of Respiratory Muscle Training on Exercise Performance in Healthy Individuals: A Systematic Review and Meta-Analysis." *Sports Medicine (Auckland, N.Z.)* 42(8):707–24. doi: 10.1007/BF03262290.

Jalan, Nikita S., Sonam S. Daftari, Seemi S. Retharekar, Savita A. Rairikar, Ashok M. Shyam, and Parag K. Sancheti. 2015. "Intra- and Inter-Rater Reliability of Maximum Inspiratory Pressure Measured Using a Portable Capsule-Sensing Pressure Gauge Device in Healthy Adults." *Canadian Journal of Respiratory Therapy: CJRT = Revue Canadienne de La Thérapie Respiratoire : RCTR* 51(2):39.

Karaduman, Emre, Özgür Bostancı, and Levent Bayram. 2022. "Respiratory Muscle Strength and Pulmonary Functions in Athletes: Differences by BMI Classifications." *Journal of Men's Health* 18(3). doi: 10.31083/JOMH.2021.076/HTM.

Kowalski, Tomasz, Dominika Granda, and Andrzej Klusiewicz. 2024. "Practical Application of Respiratory Muscle Training in Endurance Sports." *Strength & Conditioning Journal*. doi: 10.1519/SSC.0000000000000842.

Mackała, Krzysztof, Monika Kurzaj, Paulina Okrzymowska, Jacek Stodółka, Milan Coh, and Krystyna Rożek-Piechura. 2019. "The Effect of Respiratory Muscle Training on the Pulmonary Function, Lung Ventilation, and Endurance Performance of Young Soccer Players." *International Journal of Environmental Research and Public Health* 17(1). doi: 10.3390/IJERPH17010234.

McKenzie, Donald C. 2012. "Respiratory Physiology: Adaptations to High-Level Exercise." *British Journal of Sports Medicine* 46(6):381–84. doi: 10.1136/BJSPORTS-2011-090824.

Muyor, José M., David Rodríguez-Ridao, Isabel Martín-Fuentes, and José A. Antequera-Vique. 2019. "Evaluation and Comparison of Electromyographic Activity in Bench Press with Feet on the Ground and Active Hip Flexion." *PLoS ONE* 14(6):e0218209. doi: 10.1371/JOURNAL.PONE.0218209.

Okrzymowska, Paulina, Monika Kurzaj, Wojciech Seidel, and Krystyna Rożek-Piechura. 2019. "Eight Weeks of Inspiratory Muscle Training Improves Pulmonary Function in Disabled Swimmers-A Randomized Trial." *International Journal of Environmental Research and Public Health* 16(10). doi: 10.3390/IJERPH16101747.

Ozmen, Tarik, Gokce Y. Gunes, Ilyas Ucar, Hanife Dogan, and Tuba U. Gafuroglu. 2017. "Effect of Respiratory Muscle Training on Pulmonary Function and Aerobic Endurance in Soccer Players." *The Journal of Sports Medicine and Physical Fitness* 57(5):507–13. doi: 10.23736/S0022-4707.16.06283-6.

Puce, Luca, Khaled Trabelsi, Carlo Trompetto, Laura Mori, Lucio Marinelli, Antonio Currà, Emanuela Faelli, Vittoria Ferrando, Patrick Okwen, Jude Dzevela Kong, Achraf Ammar, and Nicola Luigi Bragazzi. 2022. "A Bibliometrics-Enhanced, PAGER-Compliant Scoping Review of the Literature on Paralympic Powerlifting: Insights for Practices and Future Research." *Healthcare 2022, Vol. 10, Page 2319* 10(11):2319. doi: 10.3390/HEALTHCARE10112319.

Romer, Lee M., and Michael I. Polkey. 2008. "Exercise-Induced Respiratory Muscle Fatigue: Implications for Performance." *Journal of Applied Physiology (Bethesda, Md.: 1985)* 104(3):879–88. doi: 10.1152/JAPPLPHYSIOL.01157.2007.

Sharma, Gulshan, and James Goodwin. 2006. "Effect of Aging on Respiratory System Physiology and Immunology." *Clinical Interventions in Aging* 1(3):253–60. doi: 10.2147/CIIA.2006.1.3.253.

da Silva, Donizete Chaves, Marcelo Danillo Matos Dos Santos, Felipe J. Aidar, Breno Guilherme de Araújo Tinoco Cabral, Eduardo Stieler, Renan Alves Resende, André Gustavo Pereira de Andrade, Paulo Francisco de Almeida-Neto, Alexandre Bulhões-Correia, Renato Carvalho Guerreiro, Marco Túlio de Mello, and Andressa da Silva. 2022. "Effect of Strength Training on Psychophysiological aspects in Paralympic Powerlifting Athletes: A Pilot Study." *Human Movement* 23(3):150–59. doi: 10.5114/hm.2022.111391.

De Sousa, Evitom Corrêa, Odilon Abrahin, Ana Lorena Lima Ferreira, Rejane Pequeno Rodrigues, Erik Artur Cortinhas Alves, and Rodolfo Paula Vieira. 2017. "Resistance Training Alone Reduces Systolic and Diastolic Blood Pressure in Prehypertensive and Hypertensive Individuals: Meta-Analysis." *Hypertension Research* 40(11):927–31. doi: 10.1038/HR.2017.69.

Summerhill, Eleanor M., Nadia Angov, Carol Garber, and F. Dennis McCool. 2007. "Respiratory Muscle Strength in the Physically Active Elderly." *Lung* 185(6):315–20. doi: 10.1007/S00408-007-9027-9.

Vašíčková, Jana, Kateřina Neumannová, and Zbyněk Svozil. 2017. "The Effect of Respiratory Muscle Training on Fin-Swimmers' Performance." *Journal of Sports Science & Medicine* 16(4):521.

Witt, Jonathan D., Jordan A. Guenette, Jim L. Rupert, Donald C. Mckenzie, and A. William Sheel. 2007. "Inspiratory Muscle Training Attenuates the Human Respiratory Muscle Metaboreflex." *The Journal of Physiology* 584(Pt 3):1019–28. doi: 10.1113/JPHYSIOL.2007.140855.

Conflict of Interest: None declared