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Diaphragmatic-Based Complementary Training in Basketball: The Science Behind Pre-Activation of Inspiratory Muscles – A Randomized Trial

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Conflict of Interest Disclosure: None.

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Running Title: Inspiratory muscle warm-up on basketball

Abstract

Background: Inspiratory muscle pre-activation (IMpa) has been suggested as a potential strategy to enhance athletic performance by improving respiratory muscle function and reducing fatigue. However, its immediate effects on basketball skills remain unclear. This study aimed to investigate the impact of IMpa on passing, dribbling, and shooting performance in basketball players.

Methods: Ten healthy male basketball players (aged 18–25) participated in a randomized, placebo-controlled, crossover study. Each player completed four different trials on separate days: (1) Control (CON), (2) Inspiratory muscle pre-activation (IMpa, 40% maximal inspiratory pressure), (3) Placebo inspiratory muscle pre-activation (IMPpa, 5% maximal inspiratory pressure), and (4) General warm-up (GW). Basketball skills were assessed using the Johnson basketball skill test and the AAHPERD speed shooting test. Statistical analyses were performed using repeated measures ANOVA ($p < 0.05$).

Results: Significant improvements were observed in the IMpa and GW conditions compared to the CON and IMPpa trials. The IMpa trial increased passing accuracy by 21.97% ($p < 0.05$) and speed shooting performance by 13.09% ($p < 0.05$) compared to the CON trial. No significant differences were observed in dribbling and shooting scores among the trials ($p > 0.05$).

Conclusions: Inspiratory muscle pre-activation at 40% maximal inspiratory pressure improves passing accuracy and speed shooting performance in basketball players. This diaphragmatic-based approach can serve as a complementary warm-up strategy to enhance precision-based basketball skills

Trial registration

Clinical trial number: not applicable.

Keywords: respiratory, exercise, accuracy, innovative training

Introduction

The capacity of athletes to demonstrate their abilities to the fullest extent is contingent upon their physical fitness. Oxygen delivery and utilization become crucial during athletic pursuits, as muscle oxygen demand increases with exercise [1]. The mechanical functioning of the respiratory system is largely dependent on the capacity of the respiratory muscles [2]. For these reasons, inspiratory muscle pre-activation, which positively affects the efficiency of pulmonary circulation, increases the functional capacity of the respiratory muscles [3], reduces fatigue in the respiratory muscles [4], and plays a critical role in exercise physiology and athlete performance.

It has been demonstrated that inspiratory muscle exercises elicit a range of effects on performance. Studies show reductions in blood lactate levels among short-distance runners, thereby facilitating a positive enhancement in the post-performance recovery process [5], improve respiratory functions and both aerobic and anaerobic capacity in basketball players [6], positively affect performance in Olympic swimmers [7], increase performance in professional rowers [8] and cyclists [9], enhance aerobic exercise performance in wheelchair basketball players [10], affect exercise performance in tennis players [11], increase performance in professional football players [12] and handball players [13], affect shooting performance in archers [14], positively affect shot-hit performance in ice hockey players [15], and increase shot and drag-flick hit performance in hockey players [16]. Nevertheless, there is a paucity of data concerning the impact of inspiratory muscle pre-activation on basketball performance. Many of these studies focus on longer-term training adaptations rather than a single short session of pre-activation.

The fundamental techniques of basketball can be classified into four main categories: passing, shooting, dribbling, and rebounding. Of these, shooting and passing are skills that require a high degree of accuracy in order to be performed effectively within the context of the game [17]. A review of the literature reveals that training the inspiratory muscles is an effective method for improving athletic skills that require accuracy [14,15,16], as it enhances the stabilization of core muscles [18,19,20]. However, the exact mechanism by which a brief inspiratory muscle pre-activation session might benefit precision-based movements remains under discussion. Therefore, the aim of this study was to examine whether a diaphragmatic-based method to prepare inspiratory muscles could improve passing, dribbling, and shooting among basketball players. By evaluating its immediate impact on key basketball tasks, we aim to clarify the value of such exercises in routine training.

Methods

Participants

The sample size was determined based on a power analysis using previous studies that investigated the effects of inspiratory muscle training on athletic performance. A minimum sample size of 10 participants was estimated to achieve a statistical power of 80% ($\beta = 0.20$) with an alpha level of 0.05, assuming a moderate effect size (Cohen's d = 0.5–0.6). The study involved 10 healthy male participants, aged between 18 and 25 years (mean age: 21.1 ± 2.42 years), who were engaged in competitive basketball. In order to be included in the study, the basketball players had to be free of both chronic and acute upper respiratory tract infections, as well as any chest diseases. The recruitment period took place between [01, 2023] and [02, 2023], during which participants were screened and enrolled in the study. The follow-up period, consisting of four separate experimental sessions per participant with a 48-hour washout period between conditions, was completed by [02, 2023]. All data collection and assessments were finalized within this timeframe, ensuring consistency across all participants. No interim analyses were performed in this study. Given the crossover design and the relatively small sample size (n=10), all participants completed all four intervention conditions, and no predefined stopping criteria were established. The study was conducted in a controlled environment with strict adherence to standardized procedures, ensuring that all participants completed the experimental trials without modifications to the original protocol. Therefore, no early termination or adaptive adjustments were necessary.The study was conducted in accordance with the ethical standards of the Declaration of Helsinki (52nd World Medical Association General Assembly, Edinburgh, Scotland, October 2000) and was approved by the Gaziantep University Social and Human Sciences Ethics Committee (approval number: 2023-2). Prior to the commencement of the study, informed consent was obtained from all participants.

Experimental design

The study was designed according to a randomized, placebo-controlled, crossover structure. Following the initial familiarization session, participants underwent a series of skill tests on four occasions throughout the course of the study, in accordance with established pre-activity steps. During this initial session, participants were provided with general information about the research project and study procedures. Additionally, baseline measurements, including age, height, and weight, were recorded, and an orientation session was conducted to ensure participants were familiar with the testing protocols. In the subsequent four visits (1st, 2nd, 3rd, and 4th visits), randomised trials were carried out, including a control trial (no inspiratory pre-activation), an inspiratory muscle pre-activation (IMpa) at 40% MIP, a placebo inspiratory muscle pre-activation (IMPpa) at 5% MIP, and a general warm-up (GW) specific to basketball. The intensity values (40% for IMpa and 5% for IMPpa) were selected based on prior research [21, 22] indicating that moderate loading can meaningfully engage inspiratory muscles, whereas near-minimal loading provides an effective placebo condition. The study was conducted at the Faculty of Sport Sciences, Gaziantep University, Turkey. All data collection procedures, including basketball skill tests and inspiratory muscle pre-activation sessions, were carried out in the university's sports performance laboratory and indoor basketball court under standardized conditions. The random allocation sequence was generated by an independent researcher who was not involved in data collection or intervention administration. The sequence was created using a card-drawing method to ensure allocation concealment. Participants were enrolled by the principal investigator, who provided detailed information about the study and obtained informed consent. The assignment of participants to interventions was conducted by a second researcher who was blinded to the study hypothesis. This ensured that participants followed the assigned intervention order without bias. Data collection and outcome assessments were performed by a separate research team to maintain objectivity. Following the random selection of participants by means of a card-drawing method, the Johnson basketball skill test and the AAHPERD speed shooting test were administered. A single-blind design was implemented, where participants were blinded to the intervention condition (IMpa vs. IMPpa). They were unaware of the true inspiratory muscle pre-activation (IMpa) and the placebo condition (IMPpa), as both interventions followed an identical protocol except for the resistance level. The researchers conducting the intervention were not blinded, as they had to administer the inspiratory muscle training protocol and ensure proper execution. However, outcome assessors who recorded basketball skill test results were blinded to the intervention conditions to prevent potential bias in performance evaluation. Blinding was maintained by using identical devices for IMpa and IMPpa conditions, ensuring that participants could not distinguish between active and placebo interventions. This study was conducted in accordance with the CONSORT guidelines for reporting randomized trials, ensuring methodological transparency and reproducibility. The study design, participant allocation, interventions, and outcome assessments were reported following CONSORT recommendations.

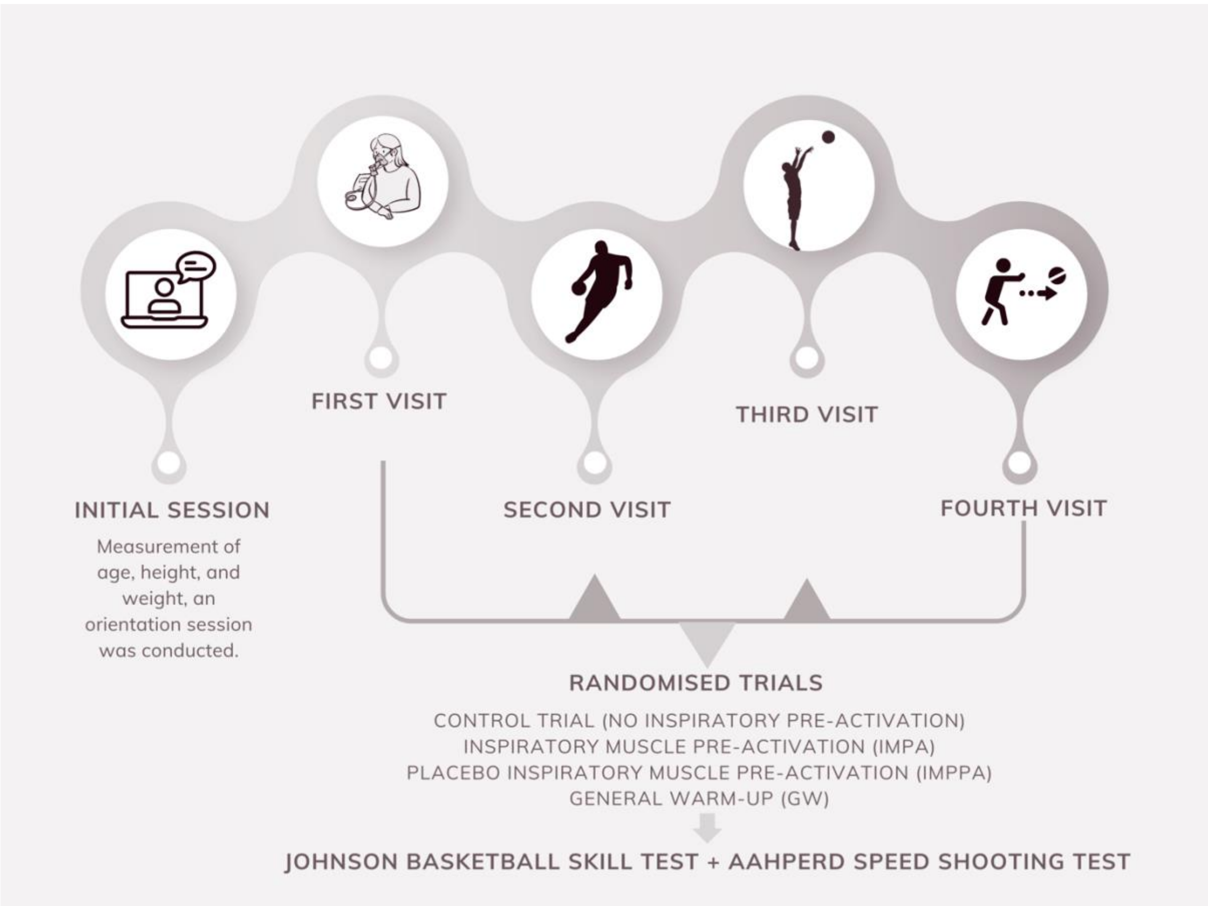


Figure 1. Schematic Overview of the Study Design and Procedures

Procedures

Inspiratory muscle pre-activation trial (IMpa)
The Powerbreathe brand device was used to perform inspiratory muscle pre-activation. Two sets of 30 breaths were carried out at 40% of each participant's maximal inspiratory mouth pressure (MIP), with a one-minute rest in between [21,22]. MIP was measured once at the first session, and that value determined 40% and 5% for IMpa and IMPpa, respectively, in later visits. Participants were seated, wearing a nose clip, instructed to exhale forcefully, then inhale forcefully against a closed airway for one to three seconds. Measurements were repeated until values within 5 cmH_2O of each other were obtained, recording the best result in cmH_2O [21,22].

Placebo inspiratory muscle pre-activation trial (IMPpa)
The Powerbreathe brand inspiratory muscle warm-up device was employed to facilitate an exercise regimen comprising two sets of 30 breaths, performed at an intensity of 5% of the participants' maximal inspiratory mouth pressure (MIP), with a one-minute interval between sets [18]. This minimal load was intended as a placebo-like condition for inspiratory muscle usage.

General warm-up protocol (GW)
The participants engaged in a 10-minute jogging activity, which was followed by a 10-minute stretching exercise. Subsequently, the general warm-up protocol was completed with shooting drills tailored to the specific requirements of basketball, without inducing fatigue.

Data collection

Johnson basketball skill test

In order to assess shooting ability, each participant was required to attempt to make as many successful shots as possible within a 30-second period from a distance of their own choosing, in close proximity to the basket. Each successful shot was awarded a value of one point. To assess the participants' passing abilities, they were instructed to execute a one-handed baseball pass from a distance of 12 metres to rectangles delineated on a wall. The rectangles were arranged in an overlapping configuration, with the smallest width of 50 cm, length of 25 cm, the central rectangle measuring 1 m by 60 cm, and the largest rectangle measuring 1.5 m by 1 m. A successful pass that struck the centre rectangle was awarded three points, two points for a pass that hit the middle rectangle, and one point for a pass that struck the outer rectangle. In order to assess the participants' ability to dribble, four obstacles were positioned at 180-cm intervals along a line. The distance between the initial obstacle and the starting line was 360 centimetres. Participants commenced the dribbling task from the starting line, navigating the obstacles and returning to the starting line within a specified time limit of 30 seconds. The total number of obstacles successfully negotiated was recorded as the score [23]. The Johnson basketball skill test yielded four parameters: passing, shooting, dribbling, and the total score of the test.

AAHPERD basketball speed shooting test

The participants commenced shooting at the starting line within the designated shot-testing area. The participants propelled their shots towards the hoop from the initial zone, allowing them to rebound the ball and subsequently dribble to the alternative shooting zone, where they proceeded to shoot. Each participant was required to shoot at least once from each of the five designated shooting zones, with at least one foot within the shooting zone at the time of shooting. Following unsuccessful attempts at shooting, participants were permitted to attempt a layup after the rebound. However, it was not permitted to attempt two consecutive layups. A maximum of four layups was permitted throughout the course of the test. The participant was required to execute a legal shot or layup from the five-shot zone until the “stop” signal was given. Upon the expiration of the 60-second interval, the speed shooting test was concluded. Successful shots and layups were recorded by the practitioner as two points. In the event of a failed shot that subsequently returned from the hoop, the participant was awarded one point. If a layup shot was successfully made after the ball had been controlled and subsequently rebounded, two points were awarded. In the event of two consecutive successful layup shots, no points were awarded for the second shot. A maximum of four layups could be attempted within the 60-second period. No points were awarded for layup shots attempted after the fourth shot. No points were awarded for shots that constituted rule violations, such as steps, ball carrying, and shooting line violations [24].

Statistical analyses

At the end of the research, the SPSS software package [25] was used for the statistical analysis of the obtained data. The data were presented as mean and standard deviation. The Shapiro–Wilk test was applied for normality, and the Levene test was used for homogeneity. Skewness and kurtosis values were checked for data sets that did not show a normal distribution, and data sets within ±2 were considered to have a normal distribution [26]. The Mauchly sphericity test was used to test the sphericity assumption. The Greenhouse–Geisser correction was applied in measurements where the sphericity assumption was not met. A one-way analysis of variance (ANOVA) for repeated measures with a 95% confidence interval was applied to analyze the differences among the protocols. The least significant difference correction was used to determine in which specific protocols the differences occurred. Effect sizes were calculated using partial eta squared (ηp^2) to determine the magnitude of observed differences. Statistical results were evaluated at a significance level of $p < 0.05$.

Results

Table 1. Differences in basketball skill test points between trials.

	CON		IMpa	IMPpa	GW
Pass (point)	13.2 ± 1.48		16.1 ± 2.56[a,b]	13.2 ± 1.75	16.3 ± 3.27[a,b]
		Difference from CON	2.9	0	3.1
		Percent change from CON(%)	21.97	0	23.48
Shoot (point)	13.5 ± 2.8		15 ± 1.94	14.2 ± 2.15	15.5 ± 2.8
		Difference from CON	1.5	0.7	2
		Percent change from CON	11.11	5.19	14.81
Dribbling (point)	26.9 ± 2.56		27.8 ± 1.48	27.7 ± 1.42	28.3 ± 1.34
		Difference from CON	1.9	0.8	1.4
		Percent change from CON	7.06	2.97	5.2
AAHPERD Speed Shooting (point)	19.1 ± 3.25		21.6 ± 2.5[a,b,c]	19.3 ± 2.16	18.4 ± 2.91
		Difference from CON	2.5	0.2	-0.7
		Percent change from CON	13.09	1.04	-3.66

Total Johnson (point)	53.6 ± 5.1		58.9 ± 4.7[a]	55.1 ± 4.12	60.1 ± 4.28[a,b]
		Difference from CON	5.3	1.5	6.5
		Percent change from CON	9.89	2.8	12.13

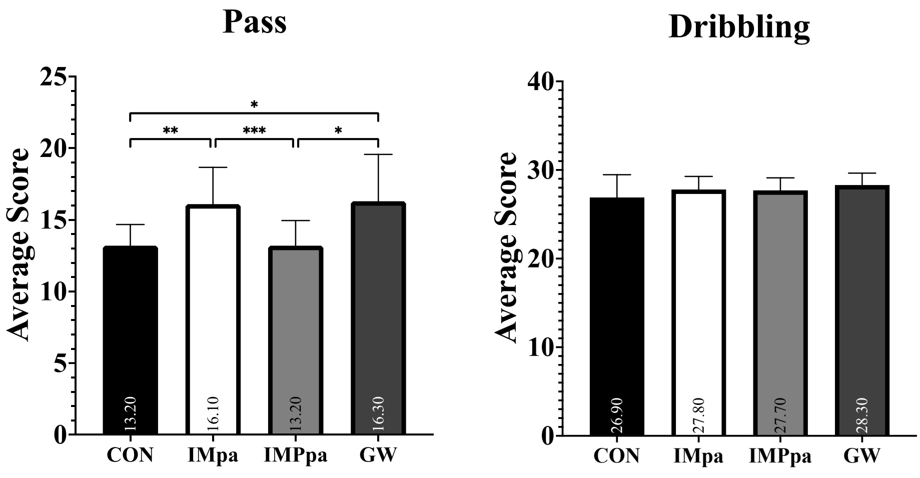
CON—control trial, IMW—inspiratory muscle pre-activation trial, IMPpa—placebo inspiratory muscle pre activation trial, GW— general warm-up trial. Pass—Johnson basketball pass accuracy skills test, Shoot— Johnson basketball shooting skills test, Dribbling— Johnson basketball dribbling skills test, Total Johnson— The average scores obtained from the Johnson basketball skill test.

[a] Significant difference between CON

[b] Significant difference between IMPpa

[c] Significant difference between GW

Table 1 presents the statistical analysis of the mean scores obtained from the subtests of the Johnson basketball skill test (the pass accuracy test, the dribbling test, the shooting test, and the total score) as well as from the AAHPERD basketball speed shooting test. Significant differences (df = 3, F = 8.99, p = 0.000, ηp² = 0.500) were identified in the Pass subtest (CON = 13.2 ± 1.48 points, IMPpa = 13.2 ± 1.75 points, IMpa = 16.1 ± 2.56 points, GW = 16.3 ± 3.27 points) between IMpa vs. IMPpa, IMpa vs. CON, GW vs. CON, and GW vs. IMPpa. Similarly, the AAHPERD basketball speed shooting test (CON = 19.1 ± 3.25 points, IMPpa = 19.3 ± 2.16 points, IMpa = 21.6 ± 2.5 points, GW = 18.4 ± 2.91 points) demonstrated significant differences (df = 3, F = 3.40, p = 0.032, ηp² = 0.74) between the IMpa protocol and all other trials. Furthermore, the total Johnson score (CON = 53.6 ± 5.1 points, IMPpa = 55.1 ± 4.12 points, IMpa = 58.9 ± 4.7 points, GW = 60.1 ± 4.28 points) demonstrated notable alterations (df = 3, F = 6.69, p = 0.002, ηp² = 0.426) between IMpa and CON, GW and CON, and GW and IMPpa (Figure 1). The results of the repeated measures analysis of variance of the mean scores obtained from the dribbling and shooting tests, which are subtests of the Johnson basketball ability test, revealed no statistically significant difference between the protocols (df = 3, F = 2.05, p = 0.130, ηp² = 0.186; df = 3, F = 1.52, p = 0.231, ηp² = 0.145).



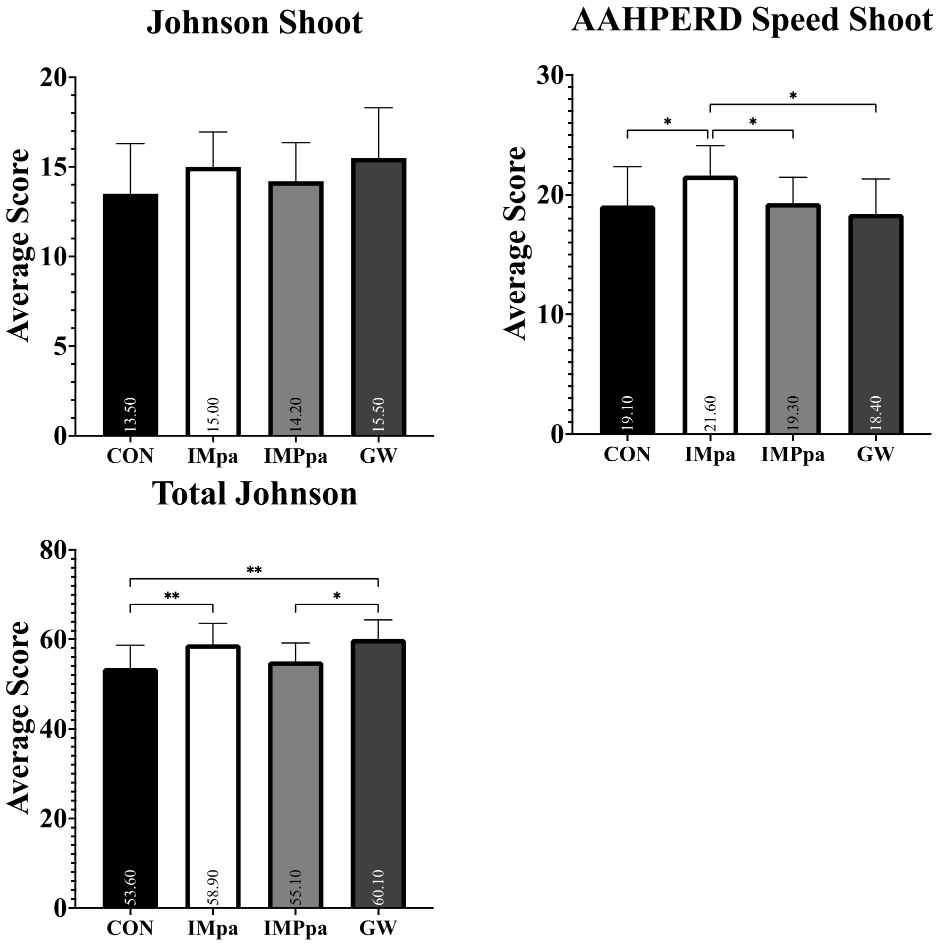


Figure 2. Summary of Key Performance Metrics Under Different Inspiratory Muscle Pre-Activation Conditions

Discussion

This study set out to determine whether incorporating an inspiratory muscle pre-activation could serve as a new, diaphragmatic-based training method to enhance passing, dribbling, and shooting in basketball. Two principal findings emerged. First, the results demonstrated that the inspiratory muscle pre activation trial significantly improved both pass accuracy and speed shooting performance compared to the control and a placebo trial. This aligns with previous studies suggesting that inspiratory muscle exercises may contribute to accuracy in sports requiring precision, such as archery and hockey [14,15]. Second, the general warm-up protocol also yielded significant improvements in pass accuracy, underscoring the well-established benefits of preparatory activities on sports performance [27,28,29]. However, the placebo inspiratory muscle pre-activation did not yield any statistically significant improvements, indicating that it did not produce a placebo effect capable of enhancing precision-based basketball skills.

Previous research has demonstrated the effects of inspiratory muscle interventions on a range of physical abilities, including repeated sprinting [30], exercise capacity [11, 13, 31], agility and speed [32], swimming performance [33], intermittent running to exhaustion [34], lung function [35] and combined pulmonary responses to exercise [36]. However, these results are often based on several weeks of training rather than a single pre-activation session.

Inspiratory muscle pre-activation in basketball performance has yet to be investigated, which is why we focus on a single visit approach to highlight any immediate effects.

One of the fundamental skills in basketball is passing, which requires a high degree of accuracy. The accuracy of a pass is influenced by several variables, including the defensive pressure applied by the opposition [37], the height of the passer and the level of cohesion within the team [38], as well as upper extremity fatigue [39]. A previous study demonstrated that the outcomes of the basketball passing skill test did not influence the accuracy of passing in competitive play [40]. However, in this study, only the Johnson basketball pass test was employed for determining pass accuracy.

The factors that affect shooting include fatigue [41], ball release height, angle, and velocity [42], defensive pressure from opponents [43], the impact of resistance exercise [44], backspin alignment [45], and isokinetic strength [46]. In particular, the direct and versatile impact of core muscle strength on shot performance has been the subject of investigation [47]. A study [48] demonstrated that an intervention designed to enhance core strength resulted in a 36.2% increase in dynamic shooting accuracy among basketball players. It is therefore imperative that players possess sufficient core strength in order to maintain equilibrium and stabilise the body during shooting. It is therefore postulated that the abdominal muscles exert a direct influence on respiratory function, thereby affecting shooting accuracy in basketball by forming functional kinetic chains with the diaphragm, multifidus, muscles surrounding the abdomen, and pelvic floor muscles [49]. The importance of inspiratory muscles in activities requiring precision, particularly in sports involving the upper extremities, is attributed to their significant influence on accuracy, which outweighs the impact of core muscle stabilisation and respiratory rate [47,48]. The training of inspiratory muscles has been demonstrated to enhance the stabilisation of these muscles and contribute to increased postural stability, depending on the level of attention required during the shooting process [14,15,18,50]. Nevertheless, the immediate effect of a 2-set, 30-breath pre-activation of inspiratory muscles on core strength or postural stability is not conclusively shown, and the mechanism may involve decreased respiratory effort that indirectly improves balance or motor control.

The Johnson basketball skill test comprises three distinct stages [51]. Upon conducting a statistical analysis of the mean scores obtained from the test, a notable disparity was observed in favor of both the experimental application and the general warm-up protocol. However, although an increase was observed for both protocols in the dribbling and shooting components of the test, no significant differences were detected. This may be attributed to the obstacles not being sufficiently challenging in the dribbling application, and to successful shots made under the basket in a limited time not being adequate to demonstrate the impact of the protocols in the shooting component. The absence of a time limit in the passing accuracy application of the test, which only measures the degree of accuracy, lends further support to the lack of a significant difference in the other two tests.

In the application of the AAHPERD speed shooting test, a statistically significant difference was observed between the experimental trial and the other trials, with the former exhibiting superior performance when conducted with moving shots from a medium distance and five zones [52]. It is our contention that this has a more pronounced effect on the measurement of shooting accuracy in basketball for the participants. It can be stated that the AAHPERD speed shooting test is an effective method for measuring shooting accuracy.

Overall, these results highlight that pre-activation of inspiratory muscles as a simple yet potent method for refining passing and shooting in basketball—two skills vital for success on the court. Coaches looking to elevate accuracy within tight training windows can seamlessly integrate this diaphragmatic-based approach into existing training routines. In doing so, they may unlock hidden performance gains without overhauling their entire program.

In practical terms, this can involve instructing players to perform two sets of 30 breaths at 40% MIP prior to skill drills, requiring only a few extra minutes. Such a straightforward routine could be readily adopted by teams at various competition levels, from amateur to professional.

Future studies could build upon these insights by combining pre-activation of inspiratory muscle exercises with targeted shooting and passing drills over multiple sessions, examining whether these initial benefits translate into lasting improvements in both skill and stamina. By embracing this new, diaphragmatic-based complementary training method, teams add a practical, cost-effective protocol to their arsenal—one capable of sharpening focus and precision in high-stakes moments of the game.

Author Declarations

Ethics approval

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki (52nd World Medical Association General Assembly, Edinburgh, Scotland, October 2000) and was approved by the Gaziantep University Social and Human Sciences Ethics Committee (approval number: 2023-2).

Consent to participate

Informed consent was obtained from all participants prior to the commencement of the study.

Clinical Trial

Clinical trial number: not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the Figshare repository, 10.6084/m9.figshare.28536197.

Competing interests

The authors declare that they have no competing interests.

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References

1. Romer LM, Polkey MI. Exercise-induced respiratory muscle fatigue: implications for performance. *J Appl Physiol*. 2008;104(3):879–888.
2. Kantarson J, Jalayondeja W, Chaunchaiyakul R, Pongurgsorn C. Effect of respiratory muscles warm-up on exercise performance in sedentary subjects. *J.Med. Technol. Phys. Ther.* 2010;22(1):71–81.
3. Volianitis S, McConnell AK, Koutedakis Y, Jones DA. The influence of prior activity upon inspiratory muscle strength in rowers and non-rowers. *Int.J. Sports Med.* 1999;20(8):542–547.
4. Volianitis S, McConnell AK, Jones DA. Assessment of maximum inspiratory pressure prior submaximal respiratory muscle activity ('warm-up') enhances maximum inspiratory activity and attenuates the learning effect ofrepeated measurement. *Respiration*. 2001a;68(1):22–27.
5. Romer LM, McConnell AK, Jones DA. Effects of inspiratory muscle training upon recovery time during high intensity, repetitive sprint activity. *Int J Sports Med*. 2002a;23(05):353–360.
6. Tranchita E, Minganti C, Musumeci L, Squeo MR, Parisi A. Inspiratory muscles training in young basketball players: Preliminary evaluation. *Medicina dello Sport*. 2014;67(67):411–422.
7. Pyne D, Tresin C, Hopkins W. Progression and variability of competitive performance of olympic swimmers. *J Sports Sci*. 2004;22(7):613–620.
8. Volianitis S, McConnell AK, Koutedakis Y, Jones DA. Specific respiratory warm-up improves rowing performance and exertional dyspnea. *Med. Sci. Sports Exerc*. 2001b;33(7):1189–1193.
9. Romer LM, McConnell AK, Jones DA. Effects of inspiratory muscle training on time-trial performance in trained cyclists. *J Sport Sci*. 2002b;20(7):547–590.
10. Antonelli CBB, Hartz CS, Silva SS, Moreno MA. Effects of inspiratory muscle training with progressive loading on respiratory muscle function and sports performance in high-performance wheelchair basketball athletes: Randomized clinical trial. *International Journal of Sports Physiology and Performance*. 2020;15(2):238–242.
11. Wu CY, Yang TY, Lo PY, Guo LY. Effects of respiratory muscle training on exercise performance in tennis players. *Medicina dello Sport*. 2017;70:318–327.
12. Archiza B, Andaku DK, Caruso FCR, Bonjorno Jr JC, Oliveira CRD, Ricci PA, Amaral AC, Mattiello SM, Libardi CA, Phillips SA, Arena R, Borghi-Silva A. Effects of inspiratory muscle training in professional women football players: a randomized sham-controlled trial. *Journal of sports sciences*. 2018;36(7):771–780.
13. Hartz CS, Sindorf MA, Lopes CR, Batista J, Moreno MA. Effect of inspiratory muscle training on performance of handball athletes. *Journal of human kinetics*. 2018;63(1):43–51.

14. Bostanci O, Kabadayi M, Mayda MH, Yilmaz AK, Yilmaz C. The relationship between shooting performance and respiratory muscle strength in archers aged 9-12. *Balt J Health Phys Act*. 2021;13(3):31–36.
15. Boland M, Delude K, Miele EM. Relationship between physiological off-ice testing, on-ice skating, and game performance in division I female ice hockey players. *Journal of Strength and Conditioning Research.* 2019;33(6):1619–1628.
16. Avcı N, Özdal M, Vural M, Influence of inspiratory muscle warm-up exercise on field hockey drag-flick and shooting performance. *European Journal of Physical Education and Sport Science*. 2021;6(11).
17. Schelling X, Ronda LT. Conditioning for basketball: quality and quantity of training. *Strength and conditioning journal*. 2013;35(6):89–94.
18. Özdal M. Acute effects of inspiratory muscle warm-up on pulmonary function in healthy subjects. *Respir. Physiol. Neurobiol*. 2016a;227:23–26.
19. Özdal M. Influence of an eight-week core strength training program on respiratory muscle fatigue following incremental exercise. *Isokinet. Exerc. Sci*. 2016b;24(3):225–230.
20. Özdal M, Bostanci Ö. Influence of inspiratory muscle warm-up on aerobic performance during incremental exercise. *Isokinet. Exercise Sci.* 2018;26(3):167–173.
21. Lomax M, McConnell AK. Influence of prior activity (warm-up) and inspiratory muscle training upon between-and within-day reliability of maximal inspiratory pressure measurement. *Respiration.* 2009;78(2):197–202.
22. Tong TK, Fu FH. Effect of specific inspiratory muscle warm-up on intense intermittent run to exhaustion. *Eur J Appl Physiol*. 2006;97:673–680.
23. Johnson LW. Objective Basketball Tests for High School Boys. Unpublished master's thesis, University of Iowa; 1934 (See also: Clarke HH. *The Application of Measurement to Health and Physical Education*. New York: Prentice-Hall; 1945).
24. American Alliance for Health, Physical Education, *Recreation and Dance. Basketball for boys and girls. Skills Test Manual*, VA: Reston; 1984.
25. IBM Corp. Released 2011. *IBM SPSS Statistics for Windows, Version 20.0.* Armonk, NY: IBM Corp.
26. George D, Mallery M. *SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 update (10a ed.)* Boston: Pearson; 2010.
27. Sander A, Keiner M, Schlumberger A, Wirth K, Schmidtbleicher D. Effects of functional exercises in the warm-up on sprint performances. *J Strength Cond Res*. 2013;27(4):995–1001.
28. Dunsky A, Ben-Sira D. Do different warm-up protocols affect isometric explosive muscular contraction?. *Isokinetics and Exercise Science*. 2016;24(1):51–58.
29. Abad CCC, Prado ML, Ugrinowitsch C, Tricoli V, Barroso R. Combination of general and specific warm-ups improves leg-press one repetition maximum compared with specific warm-up in trained individuals. *J Strength Cond Res*. 2011;25(8):2242–2245.
30. Silva RLC, Hall E, Maior AS. Inspiratory muscle training improves performance of a repeated sprints ability test in professional soccer players. *Journal of bodywork and movement therapies*. 2019;23(3):452–455.
31. Cheng CF, Hsu WC, Kuo YH, Chen TW, Kuo YC. Acute effect of inspiratory resistive loading on sprint interval exercise performance in team-sport athletes. *Respiratory Physiology & Neurobiology*. 2020;282:103531.
32. Formiga MF, Wong ML, Feigenbaum LA, Musto AA, Raya MA, Rice RP, Scrima L, Kuik MT, Cahalin LP. Inspiratory muscle performance is significantly related to agility and speed in collegiate tennis players. *Medicine & Science in Sports & Exercise*. 2017;49(5S):959.

33. Kilding AE, Brown S, McConnell AK. Inspiratory muscle training improves 100 and 200 m swimming performance. *Eur J Appl Physiol*. 2010;108:505–511.
34. Lomax M, Grant I, Corbett J. Inspiratory muscle warm-up and inspiratory muscle training: separate and combined effects on intermittent running to exhaustion. *Journal of Sports Sciences*. 2011;29(6):563–569.
35. Alvarenga GMD, Charkovski SA, Santos LKD, Silva MABD, Tomaz GO, Gamba HR. The influence of inspiratory muscle training combined with the Pilates method on lung function in elderly women: A randomized controlled trial. *Clinics*, 2018;73.
36. Yilmaz ÖF, Özdal M. Acute, chronic, and combined pulmonary responses to swimming in competitive swimmers. *Respiratory physiology & neurobiology.* 2019;259:129–135.
37. Vencúrik T, Nykodým J, Bokůvka D, Vacenovský P. Factors influencing passing skills during competitive basketball games. *Proceedings Of The 11th International Conference On Kinanthropology: Sport And Quality Of Life.* 2017;396–402.
38. Maimón AQ, Courel-Ibáñez J, Ruíz FJR. The basketball pass: a systematic review. *J Hum Kinet*. 2020;71:275–284.
39. Ahmed T. The effect of upper extremity fatigue on grip strength and passing accuracy in junior basketball players. *J Hum Kinet*. 2013;37:71–9.
40. Sachanidi M, Apostolidis N, Chatzicharistos D, Bolatoglou T. Passing efficacy of young basketball players: test or observation?. *International Journal of Performance Analysis in Sport*. 2013;13(2):403–412.
41. Li F, Li Z, Borović I, Rupčić T, Knjaz D. Does fatigue affect the kinematics of shooting in female basketball?. *International Journal of Performance Analysis in Sport*. 2021;21(5):754–766.
42. Okazaki VHA, Rodacki ALF. Increased distance of shooting on basketball jump shot. *Journal of Sports Science & Medicine*. 2012;11(2):231.
43. Csataljay G, James N, Hughes M, Dancs H. Effects of defensive pressure on basketball shooting performance. *International Journal of Performance Analysis in Sport*. 2013;13(3):594–601.
44. Cabarkapa D, Cabarkapa DV, Ciccone AB, Whiting SM, Philipp NM, Eserhaut DA, Fry AC. Acute influence of resistance exercise on basketball shooting mechanics and accuracy. *Frontiers in Sports and Active Living*. 2023;5.
45. Slegers N, Love D. The role of ball backspin alignment and variability in basketball shooting accuracy. *Journal of Sports Sciences*. 2022;40(12):1360–1368.
46. Tang WT, Shung HM. Relationship between isokinetic strength and shooting accuracy at different shooting ranges in Taiwanese elite high school basketball players. *Isokinetics and Exercise Science*. 2005;13(3):169–174.
47. Zhang M, Miao X, Rupčić T, Sansone P, Vencúrik T, Li F. Determining the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting accuracy in professional female basketball players. *Applied Sciences*. 2023;13:8624.
48. Chen WH, Wu HJ, Lo SL, Chen H, Yang WW, Huang CF, Liu C. Eight-week battle rope training improves multiple physical fitness dimensions and shooting accuracy in collegiate basketball players. *J. Strength Cond. Res*. 2018;32(10):2715–2724.
49. Akuthota V, Nadler SF. Core strengthening. *Archives of physical medicine and rehabilitation*. 2004;85;86–92.
50. Hassan AK, Bursais AK, Alibrahim MS, Selim HS, Abdelwahab AM, Hammad BE. The impact of core complex training on some basketball-related aspects of physical strength and shooting performance. *European Journal of Investigation in Health, Psychology and Education*. 2023;13(9):1624–1644.

51. Ford HT, Puckett JR. Effects of prescribed weight-training and basketball programs on selected basketball skill test scores. *Perceptual and Motor Skills.* 1980;50(3_suppl):1151–1155.
52. Ahmed TAE. Improving musculoskeletal fitness and the performance enhancement of basketball skills through neuromuscular training program. *Journal of Human Sport and Exercise*. 2015;10(3):795–804.