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Sports Bras, Respiratory Mechanics, and Running Economy in Women: A Narrative Review

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Abstract

Background: A sports bra reduces breast movement and discomfort during exercise. Assessing its impact on running requires distinguishing between breast support, pressure from the underband, and perceived tightness.

Aim: The aim of this review was to compare the effects of support and compression on biomechanics, running economy, and respiration in women, with particular attention to discrepancies between subjective sensations and physiological measurements.

Materials and Methods: Twenty-five publications identified in PubMed were purposefully selected. A detailed analysis was based on 25 articles. Populations, interventions, protocols, and outcomes were compared. Studies on bras were supplemented with physiological and methodological literature. No meta-analysis was performed.

Results: Greater support reduced breast movement and pain and altered selected biomechanical parameters. Findings regarding oxygen consumption during running were inconsistent. Increased band tightness was associated with increased respiratory effort and submaximal oxygen consumption or changes in breathing pattern and inspiratory pressure after exercise. Perceived tightness did not always correspond to differences in the assessed cardiorespiratory parameters. Comparisons were limited by small participant groups, differences in protocols, and measurement methods.

Conclusions: Breast support, band pressure, and subjective sensations require separate evaluation. The available data support an individualized assessment of fit during activity but do not establish a universal pressure threshold or confirm improvements in race times. Further studies are needed that combine measurements of breast motion, dynamic pressure, energy expenditure, and comfort.

Key words: sports bra, breast support, running economy, respiratory mechanics, dyspnea.

Introduction

Breast Support and Running Economy

During running, the breasts move relative to the torso, and the degree of support affects the magnitude of this movement and the perceived discomfort. In a study of women with larger breasts, the use of a high level of support limited breast movement and reduced pain during running [1]. Proper bra fit is also important for women's participation in physical activity. Concerns about breast movement, difficulties in selecting a bra, and insufficient knowledge about breast support can act as barriers to engaging in physical activity [2].

One of the key parameters for endurance running is running economy, defined as energy demand while running at a specific speed. It is often assessed based on steady-state oxygen consumption during submaximal exercise. Lower oxygen consumption at the same speed corresponds to better running economy, provided that comparable measurement conditions are maintained. This parameter reflects the interaction of metabolic processes, the functions of the cardiorespiratory system, and biomechanical and neuromuscular properties [3].

Breast support may be important for analyzing the biomechanics of female runners. Wearing a sports bra alters the coordination of breast and trunk movement during running [4]. A systematic review and meta-analysis of observational studies identified associations between selected biomechanical characteristics and running economy [5]. A synthesis of these observations justifies investigating the potential energetic consequences of breast support, although the change in movement coordination alone does not allow for determining the magnitude of the change in oxygen consumption.

The results of studies directly assessing the physiological consequences of breast support are inconsistent. A study involving 15 recreational female runners found lower oxygen consumption and better running economy with greater breast support [6]. In contrast, a study

of 10 women showed no significant changes in the assessed physiological parameters depending on the level of support, despite differences in some kinematic and subjective indicators [7]. This discrepancy highlights the need to consider the characteristics of the participants, the bras used, and the exercise protocols when interpreting the results.

Bra Compression and Respiratory Mechanics

When evaluating a sports bra, the load on the respiratory system must also be taken into account. Respiratory muscles consume oxygen, and the energy cost of their work increases as ventilation increases. A study comparing women and men showed that, at comparable ventilation levels, the oxygen cost of respiration was higher in women [8]. This observation provides a physiological rationale for the interest in factors that may increase the work of respiration during exercise in women.

An important distinction is the separation between the level of breast support and the pressure exerted by the bra band located beneath the breasts. In highly trained female runners, it was shown that greater pressure from this band increased the mechanical work of breathing during maximal exercise and oxygen consumption during submaximal running [9]. In another study, a tighter band affected the breathing pattern and the coordination of chest and abdominal movements, and after running, it was associated with a greater decrease in maximum inspiratory pressure [10]. The latter parameter is an indirect indicator of inspiratory muscle function and requires careful interpretation.

Perceived tightness constitutes a separate dimension of bra evaluation. In a study involving 23 women during a cycling test, a bra with greater support was perceived as tighter than a model with less support, despite the absence of significant differences between these conditions in the assessed cardiorespiratory parameters and the time to complete the test [11]. The abstract of a subsequent treadmill study points to a similar discrepancy between perceived tightness and the assessed physiological parameters [12].

Rationale and Purpose of the Review

A scoping review by Haworth et al. discussed bra fit, user experiences, and barriers to participation in sports [2]. The present review focuses on comparing the effects of breast support and underband tightness, as well as on discrepancies between subjective perceptions

and physiological measurements. Differences in definitions, bra designs, and exercise protocols hinder a common interpretation of the results [6,9,10].

The aim of this narrative review is to critically compare data on breast support and sports bra compression in terms of running economy and respiratory mechanics in women. The analysis covers definitions and measurement methods, biomechanical effects and the oxygen cost of running, respiratory sensations, as well as study limitations and their practical implications. Particular attention was paid to why perceived pressure does not necessarily correspond to an objective deterioration in the assessed respiratory parameters.

Research Materials and Methods

Nature of the Review and Source Material

This study was designed as a narrative review examining the impact of breast support and sports bra compression on respiratory mechanics and running economy in women. The selection of publications was purposeful. The bibliography comprises 25 publications. The detailed synthesis is based on 25 articles available in the PubMed database. Studies involving women that compared support or underband tightness formed the core of the analysis. The literature on respiratory physiology and the measurement of running economy was used as an interpretive framework.

Search and Selection of Publications

The literature was searched in PubMed, with no restriction on publication date. The English-language terms "sports bra," "sports bras," "breast support," and "underband" were combined using the AND and OR operators with the terms "running," "exercise," "cycling," "running economy," "oxygen consumption," "respiratory," "breathing," "breathlessness," "pressure," and "tightness." The search was supplemented with queries regarding the cost of breathing, restrictions on chest mobility, and methods for measuring running economy.

An illustrative search string restricted to the title and abstract fields is:

("sports bra"[Title/Abstract] OR "sports bras"[Title/Abstract] OR "breast support"[Title/Abstract] OR underband[Title/Abstract]) AND (running[Title/Abstract] OR exercise[Title/Abstract] OR cycling[Title/Abstract] OR respiratory[Title/Abstract] OR breathing[Title/Abstract])

During the selection process, the relevance of the publications to the review's objective, the intervention under study, the type of exercise, and the range of measured parameters was assessed. Titles and abstracts were evaluated, followed by the available full-text English-language articles. These were obtained from PubMed Central, Europe PMC, publishers' websites, institutional repositories, and copies provided by the authors. Bibliographic data were verified in PubMed records and with publishers. A correction to Figure 8 in the paper by Van Hooren et al. [5] and a correction to the captions of Figures 1–3 in the paper by Harbour et al. [10] were also taken into account. Full-text availability influenced the scope of the analysis.

Analysis and Synthesis of Publications

From the full-text articles, we extracted data on the number and characteristics of participants, fitness level, method of determining breast size or volume, bra type, method of assessing support, and method of adjusting and measuring underband pressure. We also considered the location and conditions of pressure measurement, the type of exercise, its intensity, and duration. Results regarding oxygen consumption, running economy, biomechanics, ventilation, mechanical work of breathing, perceived breathing effort, and inspiratory muscle function were compiled, along with assessments of comfort, tightness, and shortness of breath. The most important findings are presented in two comparative tables.

A qualitative synthesis of the results was conducted, with a separate assessment of breast support, measured underband pressure, and individual perceptions of pressure. Definitions of the studied characteristics, measurement methods, and exercise protocols were compared. Limitations were assessed descriptively, taking into account sample sizes, participant characteristics, bra fit, and the possibility of simultaneous changes in support and compression. The results of the cycling studies were treated as supplementary data to the running studies. No meta-analysis or independent statistical tests were conducted; the assessment of limitations did not include a formal risk-of-bias assessment tool.

Research Results

Breast Support and Chest Compression

The level of support was determined based on the bra model or by measuring breast movement relative to the torso. Displacements, velocities, accelerations, and coordination during the running cycle were recorded [1,4]. Fong and Powell compared two models with different designs, without quantitatively measuring breast movement or band pressure [6]. Risius and colleagues compared everyday bras, sports bras, and running without a bra, combining kinematic measurements and subjective assessments [7]. The term "high support" therefore did not refer to a uniform research procedure.

Breast size was described using cup size, the difference in circumferences, or estimated volume [6,7,11]. McGhee and Steele found that 16 women had a larger underbust circumference during inhalation than during exhalation ($p = 0.001$), which altered the calculated bra band size [13]. Standardizing the respiratory phase is therefore important for the comparability of measurements, although this study did not assess exercise capacity.

Underband pressure was measured using various methods. Kipp and colleagues used a balloon catheter and continuous recording during running. The maximum underband pressure during submaximal running was 22.4 ± 5.0 cmH2O with the loose underband and 25.0 ± 5.2 cmH2O with the tight underband [9]. Harbour and colleagues determined the settings using a surface sensor at rest, at functional residual capacity and total lung capacity, after which they removed the sensor [10]. Illidi and Jensen measured pressure before a cycling test at two locations beneath the underband [11]. Differences in location, sensor, respiratory phase, and timing of measurement limit direct comparison of values, even when using the same unit.

In Kipp's study, the minimum pressure during running was 12.6 ± 5.4 cmH2O with the loose underband and 16.9 ± 4.8 cmH2O with the tight underband [9]. In Harbour's study, the loose, preferred, and tight settings corresponded at rest to values of 16.4 ± 2.7, 19.3 ± 5.8, and 23.1 ± 7.1 cmH2O at functional residual capacity and 24.2 ± 4.4, 29.6 ± 5.1, and 39.1 ± 8.0 cmH2O at total lung capacity [10]. These values illustrate the importance of the respiratory phase; the calibration values do not describe dynamic pressure during running.

Perceived tightness, pain, and shortness of breath were assessed separately, including using the Borg CR10 scale [10,11]. Tests of the shoulder straps and underband adjustments provided additional data on local pressure and comfort, without measuring the mechanical work of

breathing [14,15]. Skin pressure, chest wall movement, and subjective sensations are therefore distinct outcomes, not interchangeable measures.

The Effect of Support on Body Movement and the Oxygen Cost of Running

Biomechanical results

White and colleagues evaluated 11 recreationally active women with larger breasts at a speed of 2.58 m/s. Greater support reduced breast displacement, selected velocities and accelerations, and pain, without significant differences in the assessed kinematics of the trunk and upper limbs [1]. Williams and colleagues studied 12 women with a UK size of 34D at 10 km/h. The phase alignment between breast and trunk movement accounted for approximately 67% of the cycle without a bra, 93% in the compression model, and 96% in the model with separate cups. The lag in breast movement relative to the trunk also decreased [4]. None of these studies measured oxygen consumption.

Milligan, Mills, and Scurr analyzed electromyographic (EMG) data from 10 women during 5-km trials. Greater support reduced peak activity in the pectoralis major and the anterior and medial portions of the deltoid muscle during selected segments, particularly at the start of the run. No effect on the activity of the upper trapezius was observed; however, the results for peak and integrated activity were not consistent [16]. In a study on the kinematics of 10 women, greater support reduced breast movement and pain, but the range of breast movement increased over time even when wearing a sports bra. Changes in the arms, pelvis, and trunk depended on the segment of the run [17].

Powell, Fong, and Nelson analyzed 12 of the 13 recruited female runners, comparing three-minute trials without a sports bra and with low and high levels of support. Greater support restricted vertical breast movement and was associated with greater knee stiffness; the difference between high and low support was significant ($p = 0.028$). No effect on peak knee extension torque was observed [18]. These studies indicate changes in movement mechanics but do not specify their energy cost. Lower EMG amplitude or higher joint stiffness alone do not allow for the calculation of changes in oxygen consumption [3,5].

Direct measurements of oxygen consumption

Fong and Powell compared two bra models in 15 recreational female runners during 10-minute trials at the same individual speed, averaging 2.9 ± 0.4 m/s. Oxygen consumption from minutes

3–10 was 2.07 ± 0.40 L/min with low support and 1.92 ± 0.36 L/min with high support ($p < 0.001$). The mean individual reduction was 6.9 ± 4.0%. The distance-per-liter-of-oxygen ratio increased from 88.6 ± 29.1 to 95.2 ± 31.1 m/L O_2. No significant differences were detected in cadence, stride length, or ground contact time [6].

Risius and colleagues evaluated 62 metrics in 10 women with a UK bra size of 34D. The tests in bras lasted 10 minutes at 2.8 m/s, while running without a bra was shortened to 2 minutes due to pain. Twenty-two indicators differed between the conditions, mainly kinematic and subjective ones. No significant effect was observed on measured oxygen consumption, running economy, ventilation, or heart rate [7]. Unlike the study by Fong and Powell, this result did not confirm a physiological benefit of greater support.

Kipp and colleagues adjusted the underband of a single bra model for nine highly trained female runners. At 16 km/h, two five-minute trials were performed in each of the three settings. Oxygen consumption was 2.78 ± 0.18 L/min with the loose underband, 2.82 ± 0.16 L/min with the self-selected setting, and 2.82 ± 0.17 L/min with the tight underband. The average individual increase between the tight and loose settings was 1.3 ± 1.1% ($p < 0.05$) [9]. This result pertained to adjustments in tightness rather than a comparison of the two support levels. The percentage values from these studies do not describe a combined effect and are not a direct measure of improvement in race times [6,9].

Interpretation of Running Economy

Changes in breast and trunk movement can affect several elements of running mechanics simultaneously. Moore's review points to the interaction of spatiotemporal parameters, kinematics, forces, and muscle activity, with non-uniform relationships between individual characteristics and running economy [19]. This provides an interpretive framework but does not allow for attributing a specific change in oxygen consumption to a single bra characteristic. Lee, Zhang, and Kong evaluated 69 recreationally active students at three submaximal intensities and during a 1,000-meter run. Oxygen consumption and energy expenditure increased with intensity, and allometric scaling was more effective than simple division by body mass at limiting the influence of body mass on comparisons between participants [20]. A meta-analysis by Lee et al. confirmed that the exponent of the relationship between oxygen consumption and body mass does not necessarily equal one; however, estimates varied across populations and testing methods [21]. When comparing studies, it is therefore necessary to check the units, normalization, intensity, and steady state of gas exchange. A constant

denominator for the same participant does not, in and of itself, explain the percentage difference between bra settings.

Respiratory Mechanics, Perceived Tightness, and Shortness of Breath

Effects of underband adjustment during running

Kipp and colleagues determined the mechanical work of breathing from the pressure-volume loop using an esophageal catheter. In the maximal trials analyzed in eight female runners, the work was 350 ± 78 J/min with a tight underband and 301 ± 78 J/min with a loose underband. Both the elastic and resistive components were higher. Ventilation increased from 106 ± 10 to 111 ± 9 L/min, respiratory rate from 52 ± 7 to 57 ± 6/min, and tidal volume decreased from 2.05 ± 0.23 to 1.97 ± 0.20 L ($p < 0.05$). No difference in maximum oxygen consumption was observed [9].

During submaximal running, mechanical work of breathing was also higher with the tight underband: 188 ± 44 versus 178 ± 42 J/min. At rest, no significant differences were observed in mechanical work of breathing or in the assessed ventilatory parameters [9]. The absence of a difference at rest did not, therefore, rule out a response under greater exertion.

Harbour and colleagues studied 17 young, trained female runners during trials at a speed corresponding to their recent 10-km time; on average, 13.7 ± 0.9 km/h for 19.8 ± 3.5 min. Chest wall and abdominal movements were recorded using optoelectronic plethysmography. During the final minute, ventilation was higher with a tight underband than with a loose underband, by an average of 8.4 ± 13.1% ($p = 0.03$), with no significant between-condition differences in respiratory rate or tidal volume. The temporal coordination of abdominal movement relative to the chest wall varied [10].

Maximal inspiratory mouth pressure (MIP) decreased after running by 1.1 ± 7.3%, 8.8 ± 6.1%, and 9.8 ± 8.3% for the loose, preferred, and tight underband settings, respectively. The relative changes differed between the loose and preferred ($p = 0.01$) and tight settings ($p = 0.004$). However, baseline MIP was higher with the tight underband, and lung volumes at the start of the maneuver were not controlled. This is an indirect indicator of inspiratory muscle function, not an isolated measure of diaphragmatic fatigue [10].

Forced inspiratory vital capacity (FIVC) was lower before running with a tight underband than with a loose underband by 4.2 ± 5.1% ($p = 0.034$). No differences were observed between the settings in the other assessed spirometric parameters, including forced expiratory vital capacity

(FVC). However, perceived breathing effort and respiratory restriction were greater, without affecting the assessed effort of the lower limbs. The study did not include a comparative measurement of oxygen consumption [10].

Forced vital capacity (FVC) decreased after running in all underband settings, with no significant differences among them. FIVC, FVC, and inspiratory capacity (IC) are distinct measurements and should not be interpreted interchangeably [10].

Perceived tightness and localized pressure

Illidi and Jensen studied 23 recreationally active women during three 10-km cycling trials: with high support, low support, and in their own bras. Resting pressure was higher in the low-support model than in the high-support model: 57.8 ± 10.8 versus 44.4 ± 6.7 cmH2O ($p < 0.001$), even though the high-support model was perceived as tighter ($p = 0.042$). No effect of the condition was observed on measured oxygen consumption, ventilation, tidal volume, respiratory rate, dyspnea, or time to test completion [11]. The results are based on a cycle ergometer, without direct measurement of mechanical work of breathing.

The abstract of the 2025 study by Illidi and Jensen describes 20 recreationally active women performing three five-minute treadmill tests at varying intensities, wearing high- and low-support bras. Greater support limited breast acceleration but, in participants with larger breasts, was associated with greater perceived chest compression during running. No differences were found in the assessed cardiorespiratory parameters, inspiratory muscle activity, or operating lung volumes. This review relied solely on this general description from the abstract, without a detailed evaluation of the full protocol [12].

Coltman, McGhee, and Steele compared six strap configurations in 23 women. Vertical straps caused less discomfort than those crossed at the back, despite no significant difference in pressure between the orientations. Wider straps reduced pressure; pressure measurements were obtained for 15 participants [14]. Yick and colleagues studied 21 women while they ran at 8 km/h for 15 minutes. Shortening the underband increased pressure at several sites, but no specific correlation was found between pressure and ratings of constriction and support [15]. These studies describe comfort rather than the mechanical work of breathing.

Physiological Background of the Respiratory Response

A review by Dominelli and Molgat-Seon describes the impact of sex-related anatomical differences on respiratory muscle energetics and ventilatory limitations, which depend on intensity, age, and fitness level [22]. Kipp and colleagues evaluated 40 participants in groups

of younger and older women and men who simulated exercise ventilation without limb exertion. At ventilation levels corresponding to peak exercise, the cost of breathing accounted for a higher percentage of peak oxygen consumption in younger women than in men; no such difference was observed in the older groups. The relationship between mechanical work and oxygen cost differed across populations [23].

Grift and colleagues assessed 30 healthy adults during progressively increasing cycling exercise. Women performed greater respiratory work at higher, comparable ventilation values after adjusting for FVC. A similar result was obtained in a subgroup of seven women and seven men matched for FVC and age [24]. FVC therefore does not fully describe the workload during exercise; however, bras and airway dimensions were not directly examined in this study.

Mendonca and colleagues evaluated 20 healthy men during cycling tests with and without external thoracic restriction. A belt that reduced vital capacity by approximately 20% increased the electrical activity of the diaphragm as well as the intensity and unpleasantness of dyspnea. The coupling between the respiratory drive and the mechanical response remained relatively intact; the authors attributed the dyspnea to the increased drive required to maintain ventilation [25]. This is a model of a mechanism whose magnitude of effect cannot be extrapolated to a typical women's bra.

Comparison of Study Results

The tables below summarize the physiological (Table 1) and biomechanical (Table 2) studies analyzed based on the full-text articles. Details of the measurements and limitations are presented in the text.

Table 1. Physiological studies of support and compression

Study and Participants	Comparison and Exercise	Main Finding
Fong and Powell 2022 [6] n = 15, Recreational	Low and high support; 10-minute run at the same speed.	Lower oxygen consumption with greater breast support; underband pressure was not measured.
Risius et al. 2017 [7] n = 10; UK 34D	Everyday bra, sports bra, and no bra; running at 2.8 m/s.	Differences in biomechanical and subjective outcomes; no significant changes in the assessed physiological parameters.
Kipp et al. 2024 [9] n = 9; maximal trial: n = 8, highly trained	Three underband settings; submaximal and maximal runs.	Tight underband: higher mechanical work of breathing and submaximal oxygen consumption.
Harbour et al. 2025 [10] n = 17, trained	Three underband settings; 15–30 min of running at a pace corresponding to a 10-km time.	Tight underband: greater decrease in MIP and changes in breathing; no comparative measurement of oxygen consumption.
Illidi and Jensen 2024 [11] n = 23, recreational	Three bra conditions; 10-km cycling test.	High support perceived as tighter; no significant differences in time or assessed cardiovascular and respiratory parameters.
Source: authors' own analysis [6,7,9–11]. n—number of subjects analyzed; MIP—maximal inspiratory pressure. Limitations and		

Study and Participants	Comparison and Exercise	Main Finding
measurement details are discussed in the text.		

Table 2. Biomechanical studies of breast support

Study and Participants	Comparison and Exercise	Main Finding
White et al. 2015 [1] n = 11, larger breasts	Two levels of support; running at 2.58 m/s.	Less breast movement and pain; no significant changes in the assessed kinematics of the trunk and upper limbs.
Williams et al. 2024 [4] n = 12, UK size 34D	No bra, compression model, and separate cups; running at 10 km/h.	Greater phase alignment between breast and trunk motion when wearing bras.
Milligan et al. 2014 [16] n = 10	Low and high support; 5-km run.	Lower peak activity of selected muscles with higher support at selected stages of the run.
Milligan et al. 2015 [17] n = 10	Low and high support; 5-km run.	Less breast movement and pain; kinematic changes varied across stages of the run.
Powell et al. 2023 [18] n = 12	No bra, low and high support; 3-minute trials.	Less vertical breast movement and greater knee stiffness with higher support.
Source: authors' own compilation [1,4,16–18]. None of these studies included direct measurements of running economy.		

Discussion

Interpretation of Conflicting Results

The studies do not describe a single effect of greater sports bra support or tightness. Comparisons of different models varied support, design, and potentially pressure distribution, while underband adjustment examined the tightness of a single model [6,7,9,10]. The lack of independent, simultaneous measurements of support and pressure makes it difficult to attribute the effect to a single feature. The results of Fong and Powell, as well as Kipp et al., may therefore describe the coexisting benefits of movement restriction and the costs of increased pressure, rather than conflicting responses to the same intervention.

Changes in coordination, EMG, and knee stiffness provide possible explanations for the energy benefit, but do not confirm the entire mechanism linking reduced breast movement to a decrease in oxygen consumption [4,16-19]. In the study showing a reduction in oxygen consumption, the assessed spatiotemporal parameters did not change significantly [6]. The analysis therefore requires consideration of the interaction of movement characteristics, in line with the broader biomechanical literature [5,19].

Mechanical work of breathing, ventilation, and oxygen cost are also not equivalent. Physiological data justify the focus on respiratory load in women but do not specify the magnitude of the bra's effect [8,22-24]. The increase in mechanical work of breathing with a tight underband is consistent with an increase in oxygen cost, but does not allow us to determine what portion of the difference in oxygen consumption resulted solely from the work of the respiratory muscles [9,23].

Perceived Tightness and Practical Implications

A local sensor measures pressure at a specific site, whereas the sensation of tightness may pertain to the entire garment. Straps, fabric, and pressure distribution are possible factors, but the cycling study does not determine their individual contributions [11,14,15]. Comfort remains important for participation in the activity, even when no changes in cardiorespiratory parameters have been detected [2,11]. Normal resting spirometry, however, does not determine the mechanical work of breathing during running [9,10].

The external thoracic constraint model shows that dyspnea may worsen with increased respiratory drive without a loss of neuromuscular coupling [25]. However, it does not prove an identical mechanism in a sports bra. It justifies a separate assessment of garment tightness, shortness of breath, and physiological response, rather than treating a single indicator as a surrogate.

A practical interpretation of this synthesis is to evaluate support, pain, fit stability, and breathing comfort under conditions of planned activity. This is a proposal requiring verification, not a standardized selection criterion. Increasing tightness is not a proven method for improving running economy; loosening the underband should be evaluated while maintaining support [1,2,9,10]. The data do not establish a universal pressure threshold. Comparing effects requires consistent units and normalization of running economy. Changes in laboratory oxygen consumption do not directly determine changes in race time [3,6,9,20,21].

Limitations and Further Research

Most studies involved small groups of young women, specific breast sizes, and single bra models. Short trials and varying levels of fitness limit the generalizability of the findings. The absence of a significant difference does not prove equivalence of conditions, and cycling results cannot be directly applied to running. Resting pressure does not describe changes in pressure during exercise [6,7,9-11].

MIP is effort dependent and is influenced by lung volume at the start of the maneuver; in the study by Harbour et al., lung volume was not controlled, and baseline MIP varied across conditions [10]. A decrease in this measure therefore does not, on its own, confirm diaphragmatic fatigue. The discrepancy in one participant's breast size between the Fong and Powell tables limits a detailed interpretation of the relationship between the effect and size [6]. Harbour and colleagues disclosed funding from adidas and a co-author's employment with the company; according to their statement, the manufacturer and that co-author participated in the conception and design but not in the analysis or reporting of results [10].

Limitations of the review include selective sampling, dependence on the availability of full-text articles, and a descriptive assessment of limitations. The synthesis does not ensure completeness of the literature or a combined effect estimate. The lack of the full text of a more recent treadmill study limits the assessment of its methods and relevance for comparing results [12]. Further studies should independently vary support and pressure, measure breast

movement, dynamic underband pressure, energy expenditure, mechanical work of breathing, and perceived breathing effort, and standardize the initial volume during MIP. More diverse groups, longer trials, adequate sample sizes, and a balanced sequence of conditions are needed, as well as verification of the durability of the effects and actual athletic performance [6,9-11,20,21].

Conclusions

Breast support and underband compression require separate evaluation. Greater support reduces breast movement and pain, but the benefits regarding oxygen consumption were inconsistent. Increasing the tightness of the underband may increase mechanical work of breathing and the oxygen cost of exercise or alter the breathing pattern. The available data do not support equating stronger compression with better running economy [1,6,7,9,10].

Perceived tightness is not an independent indicator of deterioration in measured respiratory parameters. Comfort, shortness of breath, and physiological response require separate assessment, and cycling performance cannot be directly extrapolated to running [9-11,14,15].

The data support an individualized assessment of breast support, fit, and comfort during the planned activity, without establishing a universal pressure threshold. Small sample sizes and methodological differences limit generalizations; improvements in laboratory measures of running economy do not, by themselves, establish improvements in race times. Future studies should simultaneously assess breast movement, dynamic underband pressure, energy expenditure, respiratory mechanics, and participants' subjective experiences [2,3,6,9-11].

Disclosure

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References

1. White J, Mills C, Ball N, Scurr J. The effect of breast support and breast pain on upper-extremity kinematics during running: implications for females with large breasts. *J Sports Sci*. 2015;33(19):2043-2050. https://doi.org/10.1080/02640414.2015.1026378. PMID: 25793936

2. Haworth L, Aitkenhead R, Grecic D, Chohan A. Understanding experience, knowledge and perceived challenges related to bra fit for sports participation: a scoping review. *Res Sports Med*. 2024;32(2):302-315. https://doi.org/10.1080/15438627.2022.2102922. PMID: 35856556

3. Barnes KR, Kilding AE. Running economy: measurement, norms, and determining factors. *Sports Med Open*. 2015;1(1):8. https://doi.org/10.1186/s40798-015-0007-y. PMID: 27747844

4. Williams GKR, Reeves J, Vicinanza D, Mills C, Jones B, Wakefield-Scurr J. Breast-torso movement coordination during running in different breast support. *Sci Rep*. 2024;14(1):21365. https://doi.org/10.1038/s41598-024-71337-y. PMID: 39266598

5. Van Hooren B, Jukic I, Cox M, Frenken KG, Bautista I, Moore IS. The Relationship Between Running Biomechanics and Running Economy: A Systematic Review and Meta-Analysis of Observational Studies. *Sports Med*. 2024;54(5):1269-1316. https://doi.org/10.1007/s40279-024-01997-3. PMID: 38446405. Erratum in: *Sports Med*. 2025;55(3):779-780. https://doi.org/10.1007/s40279-024-02157-3. PMID: 39821518

6. Fong HB, Powell DW. Greater Breast Support Is Associated With Reduced Oxygen Consumption and Greater Running Economy During a Treadmill Running Task. *Front Sports Act Living*. 2022;4:902276. https://doi.org/10.3389/fspor.2022.902276. PMID: 35774380

7. Risius D, Milligan A, Berns J, Brown N, Scurr J. Understanding key performance indicators for breast support: An analysis of breast support effects on biomechanical, physiological and subjective measures during running. *J Sports Sci*. 2017;35(9):842-851. https://doi.org/10.1080/02640414.2016.1194523. PMID: 27291899

8. Dominelli PB, Render JN, Molgat-Seon Y, Foster GE, Romer LM, Sheel AW. Oxygen cost of exercise hyperpnoea is greater in women compared with men. *J Physiol*. 2015;593(8):1965-1979. https://doi.org/10.1113/jphysiol.2014.285965. PMID: 25652549

9. Kipp S, Leahy MG, Sheel AW. Sports Bra Restriction on Respiratory Mechanics during Exercise. *Med Sci Sports Exerc*. 2024;56(6):1168-1176. https://doi.org/10.1249/MSS.0000000000003403. PMID: 38350462

10. Harbour E, Farlock R, Marko D, Bahenský P, Schwameder H. Sports bra tightness affects respiratory muscle fatigue, breathing pattern, and perceptual responses during running. *J Sports Sci*. 2025;43(17):1871-1884. https://doi.org/10.1080/02640414.2025.2526277. PMID: 40581946. Erratum in: *J Sports Sci*. 2025;43(17):1896-1897. https://doi.org/10.1080/02640414.2025.2533614. PMID: 40673716

11. Illidi CR, Jensen D. Supported to perform: sports bras and breast volume do not impair cycling performance in females. *Front Sports Act Living*. 2024;6:1439403. https://doi.org/10.3389/fspor.2024.1439403. PMID: 39465208

12. Illidi CR, Jensen D. Does level of breast support differentially affect exertional symptoms and respiratory system responses in large- and small-breasted women during treadmill exercise? *Appl Physiol Nutr Metab*. 2025;50:1-12. https://doi.org/10.1139/apnm-2025-0043. PMID: 40503646

13. McGhee DE, Steele JR. How do respiratory state and measurement method affect bra size calculations? *Br J Sports Med*. 2006;40(12):970-974. https://doi.org/10.1136/bjsm.2005.025171. PMID: 17021004

14. Coltman CE, McGhee DE, Steele JR. Bra strap orientations and designs to minimise bra strap discomfort and pressure during sport and exercise in women with large breasts. *Sports Med Open*. 2015;1(1):21. https://doi.org/10.1186/s40798-015-0014-z. PMID: 26284162

15. Yick KL, Keung YC, Yu A, Wong KH, Hui KT, Yip J. Sports Bra Pressure: Effect on Body Skin Temperature and Wear Comfort. *Int J Environ Res Public Health*. 2022;19(23):15765. https://doi.org/10.3390/ijerph192315765. PMID: 36497840

16. Milligan A, Mills C, Scurr J. The effect of breast support on upper body muscle activity during 5 km treadmill running. *Hum Mov Sci*. 2014;38:74-83. https://doi.org/10.1016/j.humov.2014.06.001. PMID: 25255202

17. Milligan A, Mills C, Corbett J, Scurr J. The influence of breast support on torso, pelvis and arm kinematics during a five kilometer treadmill run. *Hum Mov Sci*. 2015;42:246-260. https://doi.org/10.1016/j.humov.2015.05.008. PMID: 26079773

18. Powell DW, Fong HB, Nelson AK. Increasing breast support is associated with altered knee joint stiffness and contributing knee joint biomechanics during treadmill running. *Front Sports Act Living*. 2023;5:1113952. https://doi.org/10.3389/fspor.2023.1113952. PMID: 37152112

19. Moore IS. Is There an Economical Running Technique? A Review of Modifiable Biomechanical Factors Affecting Running Economy. *Sports Med*. 2016;46(6):793-807. https://doi.org/10.1007/s40279-016-0474-4. PMID: 26816209

20. Lee J, Zhang X, Kong Z. Quantifying Running Economy in Amateur Runners: Evaluating VO2 and Energy Cost with Model-based Normalization. *J Sports Sci Med*. 2025;24(3):684-695. https://doi.org/10.52082/jssm.2025.684. PMID: 40933336

21. Lee J, Wang Z, Chen M, Liu S, Yu Q, Hu M, Kong Z, Nie J. Allometric exponents for scaling running economy in human samples: A systematic review and meta-analysis. *Heliyon*. 2024;10(10):e31211. https://doi.org/10.1016/j.heliyon.2024.e31211. PMID: 38818143

22. Dominelli PB, Molgat-Seon Y. Sex, gender and the pulmonary physiology of exercise. *Eur Respir Rev*. 2022;31(163):210074. https://doi.org/10.1183/16000617.0074-2021. PMID: 35022254

23. Kipp S, Arn SR, Leahy MG, Guenette JA, Sheel AW. The metabolic cost of breathing for exercise ventilations: effects of age and sex. *J Appl Physiol (1985)*. 2024;137(2):329-342. https://doi.org/10.1152/japplphysiol.00282.2023. PMID: 38841757

24. Grift GO, Dunsford JR, Dhaliwal JK, Dominelli PB, Molgat-Seon Y. Sex differences in the work of breathing during exercise are independent of forced vital capacity in healthy adults. *Exp Physiol*. 2025;110(12):2036-2048. https://doi.org/10.1113/EP092586. PMID: 40321092

25. Mendonca CT, Schaeffer MR, Riley P, Jensen D. Physiological mechanisms of dyspnea during exercise with external thoracic restriction: role of increased neural respiratory drive. *J Appl Physiol (1985)*. 2014;116(5):570-581. https://doi.org/10.1152/japplphysiol.00950.2013. PMID: 24356524