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Research on the Influence of Dynamic Fit of Dance Costumes based on Computer Vision and Pressure Sensing on Stage Performance

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ABSTRACT

Traditional static assessment fails to capture the critical garment–body interactions during dance. This study investigates the influence of a costume's dynamic fit on stage performance using a novel, synergistic methodology that integrates computer vision with pressure sensing to provide a holistic, quantitative assessment of garment–body dynamics. Two leotards, a "Standard Fit" (SF) and an "Optimized Fit" (OF) designed using 3D scanning and dynamic pattern engineering, were tested on ten elite ballet dancers. During a series of standardized movements, we synchronously measured interface pressure, garment–body gap, and biomechanical performance kinematics. The OF garment demonstrated a significantly superior dynamic fit, achieving a 28% reduction in peak shoulder pressure and reducing fabric gapping in the lumbar region compared with the SF garment ($p < 0.01$). These physical improvements correlated directly with enhanced performance, including a 5.7% greater hip abduction angle in the grand jeté and a 4.2% higher peak angular velocity in the pirouette ($p < 0.05$). Dancers' subjective ratings were also substantially higher in the OF leotard, with a 67% improvement in perceived freedom of movement and an 85% improvement in comfort. This research establishes a quantitative, data-driven link between specific dynamic fit characteristics and tangible performance gains, providing a new evidence-based paradigm for the design of high-performance functional apparel.

KEYWORDS
wearable sensors, e-textiles, dynamic fit, computer vision, pressure performance analysis

INTRODUCTION

In dance, the costume is not merely an aesthetic adornment but a critical component of the performance interface, acting as a second skin that can augment or inhibit a dancer's physical expression [1]. The concept of *garment fit* has long been a central focus in apparel science, traditionally evaluated through static measurements and subjective feedback. However, for high-performance garments worn during high-mobility activities, such as ballet, gymnastics and swimming, the notion of *dynamic fit*—the ability of the garment to conform and adapt to the body's changing geometry during movement—is far more critical [2].

A poor dynamic fit can manifest in several detrimental ways. Excessive pressure points, particularly over major joints and muscle groups, can cause discomfort, restrict blood flow, and even alter proprioceptive feedback, leading to modified movement patterns [3-5]. Conversely, areas where the garment gaps or bunches away from the body can create air resistance, disrupt the aesthetic line intended by the choreographer, and cause chafing [6]. These issues can compromise not only the dancer's comfort and confidence but also their objective biomechanical performance, potentially reducing joint range of motion (ROM), explosive power, and movement stability.

Conventional methods for assessing garment fit, such as 3D static body scanning, provide excellent data for initial pattern creation but fail to capture the interactions that occur during motion [7,8]. While 4D body scanning (3D + time) has emerged, its application is often limited to simple, slow movements and does not directly measure the forces exerted by the garment on the body [9]. Concurrently, biomechanical studies in dance have extensively used marker-based motion capture systems to analyze kinematics, but these studies typically treat the costume as a negligible factor [10,11].

While similar sensing approaches have been explored separately in previous studies, this work combines them within a dance-specific context, aiming to provide a more comprehensive evaluation of dynamic fit. To bridge this gap, the fields of wearable technology and electronic textiles (e-textiles) offer promising tools. For instance, flexible pressure sensors can be integrated into garments to create an instrumented textile capable of providing direct, real-time measurement of the interface pressure between the fabric and the skin [12,13]. Simultaneously, advanced computer vision techniques, specifically motion capture, can track the spatial relationship between the garment surface and the underlying body, quantifying phenomena like fabric strain, slippage, and gapping [11]. A synergistic approach combining these two technologies could provide an unprecedented, holistic view of dynamic fit.

This research posits that a quantifiable improvement in a dance costume's dynamic fit, achieved through advanced design techniques, leads to measurable enhancements in stage action performance. The primary objective of this study is to develop and validate an integrated system using computer vision and pressure sensing to quantify the dynamic fit of dance costumes. A secondary objective is to use this system to compare a standard-fit garment with an optimized-fit garment and correlate the differences in dynamic fit with key biomechanical performance indicators and subjective comfort ratings. By establishing a scientific link between fabric-body interaction and performance, this work aims to provide a new evidence-based framework for the design and engineering of high-performance apparel.

MATERIALS AND METHODS

Garment Design and Fabrication

Two long-sleeved dance leotards, which were a “Standard Fit” (SF) and an “Optimized Fit” (OF), were created for this study. Both were fabricated from the same high-performance warp-knitted fabric, a blend of 82% nylon and 18% spandex, with a weight of 190 g/m². The fabric’s mechanical properties were characterized using a universal testing machine (Instron 5967) according to ASTM D5034 standards. The fabric exhibited an ultimate tensile strength of 550 N and an elongation at break of 120% in the warp direction and 180% in the weft direction.

- SF garment: The pattern for the SF leotard served as the experimental control and was designed to represent a high-quality, non-optimized industry standard. To ensure the garment was appropriately sized for the cohort, key body measurements (chest, waist, hip circumference) were taken from all ten participants. The pattern utilized conventional design principles with minimal seam lines and was based on a generic block for a static, upright posture, deliberately excluding dynamic or anatomical considerations. This approach ensures that the primary variable being tested against the OF garment is the *design philosophy* (static vs. dynamic engineering), not simply a poor initial size match.
- OF garment: The design of the OF leotard began with a full-body 3D scan of a representative participant (Artec Eva 3D Scanner). The static 3D models were then digitized with digital joints using the Autodesk Maya software to achieve key dance postures (such as arabesque, deep plie). This process generated visual skin strain maps, highlighting the areas with the greatest deformation. These maps laid the foundation for the “dynamic pattern engineering” process carried out in the CLO 3D software. This process involved several specific adjustments: Firstly, the panels on the back, shoulders, and hips were reoriented to align the maximum stretching direction of the fabric (weft direction, with a 180% breaking elongation rate) with the main skin stretching lines identified in the strain map. For example, the yarn direction of the back panel pattern was tilted to accommodate the stretching of the scapulae during the arabesque movement. Additionally, the standard side seams were removed and replaced with

anatomical contour seams running along the direction of the latissimus dorsi, allowing each piece to slide and stretch more independently, thereby reducing pressure concentration. This data-driven approach also achieved local slack and shaping; in areas with greater deformation, additional allowances were selectively added to the pattern (for example, increasing the length of the back panel to prevent a gap at the waist), while specific areas were appropriately reduced in size to provide compression control. Crucially, while the *principles* of this dynamic pattern engineering (e.g., anatomical seam placement, strain-aligned panel orientation) were derived from the representative model, these principles were then applied to create individually scaled patterns for all ten participants. For each dancer, we utilized their key body measurements (chest, waist, hip, torso length) to grade the master OF pattern, ensuring that the resulting garment was not a single size but was individually tailored to each subject's dimensions. This ensures that the comparison between the SF and OF garments is a test of the underlying design philosophy rather than a test of individual size matching.

Integrated Sensing System

A dual-modal sensing system was integrated into both leotards to capture dynamic fit parameters (Figure 1).

- Pressure Sensing System: A flexible sensor matrix consisting of 64 piezoresistive Force-Sensing Resistors (FSRs, Tekscan FlexiForce A201) was custom-built and integrated into the garments. To mitigate perspiration effects on sensitivity, each FSR was encapsulated in a thin, moisture-resistant silicone coating prior to integration. Each A201 element has an active sensing area of 71.3 mm² (9.53 mm diameter). To ensure stable positioning and minimize the influence of off-axis shear forces, each sensor was housed within a thin, stitched fabric pocket on the garment's interior. Interface pressure (P) was calculated from the measured force (F) using $P = F/A$, where A is the sensing area. The specific locations were: (1) the right shoulder (over the deltoid and scapula), a region critical for the extensive range of motion in arm carriage (port de bras) and prone to high pressure during upper body extension movements like the arabesque; (2) the lower back (lumbar region), which undergoes extreme changes in curvature during flexion (plié) and hyperextension (arabesque), making it a primary site for either garment gapping or excessive pressure; and (3) the left hip and thigh (over the greater trochanter and tensor fasciae latae), an area central to executing leg extensions and leaps (grand jeté) and where fabric tension can directly restrict hip abduction and flexion. A rigorous multi-point dynamic calibration was performed for each sensor within a temperature-controlled environment (22°C ± 1°C) to mitigate thermal drift. This process was repeated before each participant's testing session to ensure cross-day reproducibility. The calibration involved three full loading-unloading cycles against a calibrated universal testing machine, from which the calibration curve was derived by averaging the response. The hysteresis loop was analyzed, and the hysteresis was quantified to be less than 6% of the full-scale output. The coefficient of variation (CV) for repeatability across cycles was below 5%. After the garment was donned, a two-minute stabilization period was observed to account for initial sensor drift from wearing. The sensor matrices were designed to be removable before the garments were cleaned, ensuring consistent sensor performance throughout the study. Data were acquired at a sampling rate of 100 Hz via a custom data acquisition unit (DAQ) and transmitted wirelessly to a host computer.

- Computer vision system: A 12-camera optical motion capture system (Vicon T160, Oxford, UK) operating at 240 Hz was used. A total of 58 hemispherical retro-reflective markers (9-mm diameter) were placed. Thirty-four markers were attached directly to the dancer's skin at key anatomical landmarks according to the Plug-in-Gait model to capture body kinematics. An additional 24 markers were securely attached to the exterior surface of the leotards, positioned in proximity to the anatomical markers but on the garment itself. This dual-marker setup allowed for the simultaneous tracking of both the body segment and the overlying garment segment.

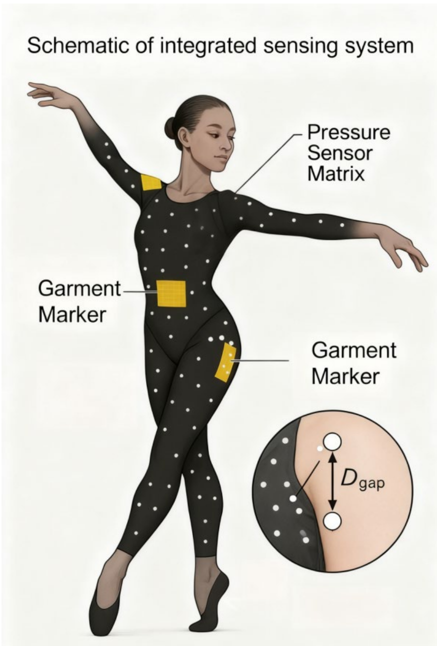

Figure 1. Schematic of the integrated sensing system on the OF leotard, showing the placement of pressure sensor matrices (yellow squares) at the shoulder, lower back, and hip, and the placement of computer vision markers (white dots) on both the body and garment surface.

Participants and Experimental Protocol

Ten elite female ballet dancers (age: 22.4 ± 2.1 years; height: 1.68 ± 0.04 m; weight: 52.6 ± 3.5 kg), each with over 10 years of professional training, were recruited. This study has been approved by the Ethics Committee of Nanhai, Haikou University of Economics. All participants provided informed consent prior to the study.

Each dancer attended two testing sessions, one for each garment type (SF and OF), with the order counterbalanced to prevent learning effects. After a standardized 15-minute warm-up, participants performed a choreographed sequence of four fundamental ballet movements:

- Grand plié: a deep knee bend, testing fit in the hips, thighs, and lower back during flexion.
- Arabesque: standing on one leg while the other is extended behind, testing fit across the back, shoulders, and hips during extension and hyperextension.
- Grand jeté: a large leap from one foot to the other, testing the garment's response to explosive, large-range movements.
- Pirouette: a full rotation on one foot, testing for garment slippage and torsional stability.

Each movement was repeated five times, with a one-minute rest period between repetitions. Pressure data and motion capture data were synchronized using a common trigger signal. After completing the movements in each garment, participants completed a subjective evaluation questionnaire. The questionnaire assessed three items using a 10-point Likert scale, with specific questions and anchors as follows:

(1) Overall comfort: rated on a 10-point scale where 1 = "Extremely uncomfortable" and 10 = "Extremely comfortable".

(2) Freedom of movement: rated on a 10-point scale where 1 = "Very restrictive" and 10 = "Completely unrestricted".

(3) Overall confidence: rated on a 10-point scale where 1 = "Not at all confident" and 10 = "Extremely confident".

Data Analysis

Dynamic pressure analysis: Pressure data from each sensor matrix were used to generate dynamic pressure maps. Key metrics extracted were peak pressure (P_{peak}) and a pressure-uniformity index (PUI), calculated as:

$$PUI = 1 - \frac{\sum_{i=1}^{n} \left| P_i - P_{avg} \right|}{n \cdot P_{avg}}$$

where n is the number of sensors in the matrix, P_i is the pressure at sensor *i*, and P_{avg} is the average pressure across the matrix. A PUI value closer to 1 indicates more uniform pressure distribution.

Motion Capture Data Processing

The 3D coordinates of all markers were processed using Vicon Nexus software. The raw marker trajectory data were filtered using a fourth-order, zero-lag, low-pass Butterworth filter with a cut-off frequency of 10 Hz to reduce noise.

Dynamic Fit Metrics Calculation

From the processed motion capture data, the following dynamic fit metrics were calculated:

- Garment–body gap (*D*gap): The Euclidean distance between each garment marker and its corresponding body marker was calculated for every frame. No re-pairing was performed during the movement cycle; the analysis focused on measuring the displacement from this initial fixed pairing to quantify phenomena like fabric slippage and gapping. The maximum gap distance during a movement cycle was identified.
- Fabric strain (ε): The relative change in distance between adjacent garment markers was calculated and used as a proxy for fabric strain in specific regions.

Biomechanical Performance Analysis

Key kinematic parameters were extracted from the filtered body marker data. To facilitate averaging across repetitions, each of the five movement trials was first segmented into a discrete movement cycle based on key kinematic events (e.g., from peak knee flexion to the next peak knee flexion for the *Grand Plié*). Each cycle was then time-normalized to 100%, allowing for the calculation of mean kinematic profiles. The following key parameters were extracted:

- *Arabesque:* maximum trunk hyperextension and rear leg abduction angle (range of motion, ROM).
- *Grand jeté:* maximum vertical displacement of the center of mass (jump height) and

maximum hip abduction angle.

- *Pirouette:* peak angular velocity of the trunk during rotation.

- Statistical analysis: A paired-samples t-test was used to compare the dynamic fit metrics (pressure, gap) and performance metrics (kinematics, subjective scores) between the SF and OF garments. Pearson's correlation coefficient (r) was computed to assess relationships between specific fit parameters and performance outcomes. The significance level was set at $\alpha = 0.05$.

RESULTS

Dynamic Pressure Distribution

Pressure data revealed significant differences in the *garment–body interface dynamics* between the SF and OF leotards. Figure 2a-b illustrates the representative pressure maps for the lower back and shoulder regions at the peak of the arabesque movement.

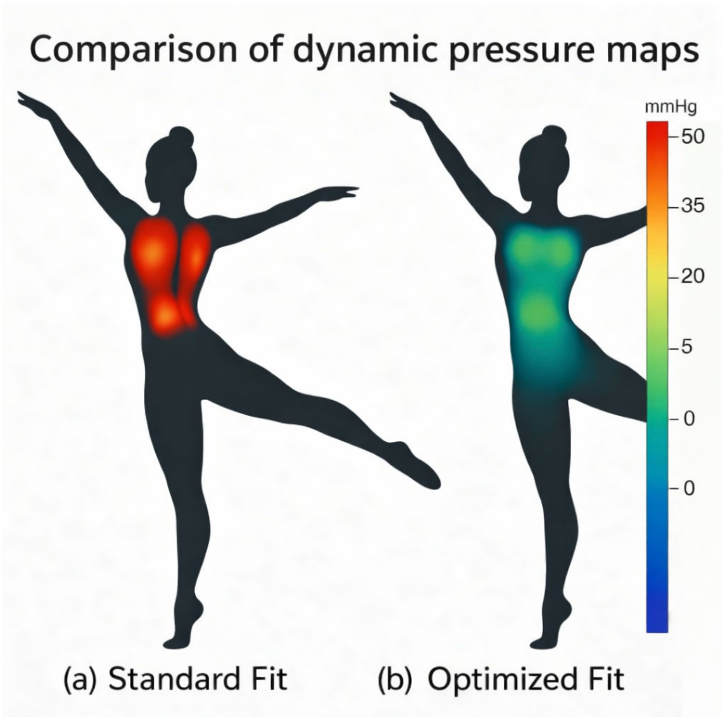

Figure 2. Dynamic pressure maps from a representative participant at the moment of maximum trunk hyperextension during the arabesque. The figure illustrates the typical pattern of high-pressure concentrations in the SF garment (a) versus the more uniform distribution in the OF garment (b). For full quantitative analysis and group diversity statistics (Mean ± SD), see Section "Dynamic Pressure Distribution". Note: The color bar is saturated at 50 mmHg for visualization; actual peak pressures in the red zones exceeded this value, as reported in the text.

For the SF garment, intense pressure hot spots (mean P_{peak} = 38.3 ± 7.2 mmHg) were consistently observed over the acromion process of the shoulder and along the erector spinae muscles in the lumbar region. In contrast, the OF garment distributed the pressure more evenly, resulting in a significantly lower average peak pressure (mean P_{peak} = 27.5 ± 5.1 mmHg, $p < 0.01$). The pressure uniformity index (PUI) for the OF garment's lower back region was 0.82, compared to 0.55 for the SF garment, quantitatively confirming the visual data.

Garment–Body Spatial Dynamics

The computer vision analysis quantified the physical behavior of the fabric during movement. A key finding was the significant gapping of the SF garment away from the body, especially in the lumbar region during the *arabesque*. Figure 3 plots the garment–body gap distance over time for one cycle of the movement.

The SF garment exhibited a maximum gap distance (D_{gap}) of 3.2 ± 0.6 cm, indicating that the fabric was not conforming to the curvature of the dancer's lower back. The OF garment, with its anatomically designed panels, maintained a much closer fit, with a maximum gap of only 0.7 ± 0.2 cm ($p < 0.001$). This adherence to the body contour not only improves the aesthetic line but also suggests a more stable and predictable garment behavior. In regions of high stretch, such as across the hips during the grand jeté, a quantitative analysis of fabric strain (ε) from the garment markers revealed significant differences. The SF garment exhibited a high strain concentration at the side seam termination point, reaching a mean peak strain of 46.8% (± 2.5%) in this localized area. In contrast, the OF garment's anatomically engineered seams distributed forces more effectively, resulting in a significantly lower mean peak strain of 31.5% (± 1.8%) across the entire region. To provide a quantitative measure of distribution uniformity, the CV for strain was calculated across the hip markers. The OF garment demonstrated a much more uniform strain distribution (CV = 0.18) compared to the SF garment (CV = 0.52), providing numerical evidence for the qualitative observation.

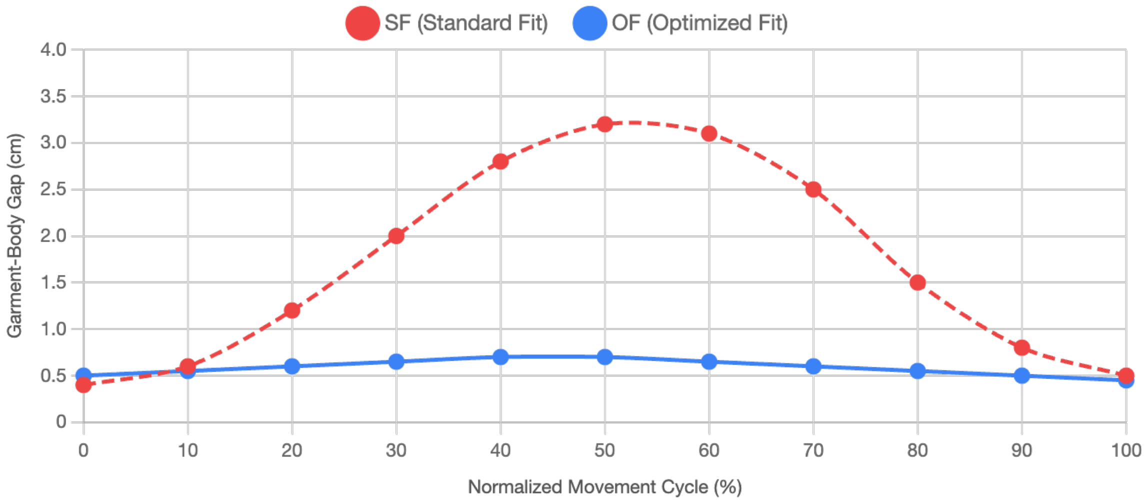

Figure 3: Garment–body gap distance (Dgap) in the lumbar region during the arabesque movement cycle for a representative participant. The SF garment shows a significantly larger gap compared to the OF garment.

Biomechanical Performance and Subjective Evaluation

The improvements in dynamic fit offered by the OF garment translated directly into measurable enhancements in dance performance. Table 1 summarizes the key kinematic parameters for the four analyzed movements.

Table 1. Comparison of biomechanical performance metrics between SF and OF garments (Mean ± SD, n = 10)

Performance Metric	Movement	Standard Fit (SF)	Optimized Fit (OF)	Improvement (%)	p value	Effect Size (Cohen's d)
Max. Trunk Hyperextension (deg)	Arabesque	25.4 ± 3.1	27.8 ± 3.3	9.4%	0.012*	0.95
Max. Rear Leg Abduction (deg)	Arabesque	105.2 ± 6.8	110.1 ± 7.1	4.7%	0.021*	0.88
Max. Jump Height (cm)	Grand Jeté	41.3 ± 4.5	43.1 ± 4.6	4.4%	0.035*	0.75
Max. Hip Abduction	Grand Jeté	155.6 ± 8.2	164.5 ± 8.5	5.7%	0.009**	1.21

Angle (deg)						
Peak Angular Velocity (deg/s)	Pirouette	480.5 ± 25.1	500.7 ± 26.3	4.2%	0.028*	0.92

Notes: *Significant at $p < 0.05$, **Significant at $p < 0.01$

Dancers wearing the OF leotard consistently achieved a greater range of motion, higher jump heights, and faster rotational speeds. For instance, the 5.7% increase in hip abduction during the *grand jeté* is a substantial improvement in ballet, allowing for a more visually impressive and technically proficient execution of the movement.

Subjective feedback strongly corroborated the objective data. On a 10-point scale, freedom of movement averaged 9.2 ± 0.7 for the OF garment versus 5.5 ± 1.1 for the SF garment ($p < 0.001$). Overall comfort was rated 8.9 for OF versus 4.8 for SF. Similarly, “Overall Confidence” scores were significantly higher for the OF garment (9.1 ± 0.8) compared to the SF garment (5.2 ± 1.2, $p < 0.001$). Several dancers commented that the SF garment felt “restrictive” in the shoulders and “unsupportive” in the lower back, whereas the OF garment felt as though it moved with them.

Correlation between Fit and Performance

A strong negative correlation was found between peak pressure on the shoulder (P_{peak}) and the maximum rear leg abduction angle in the *arabesque* (r = -0.78, $R^2 = 0.61$, $p < 0.01$). Similarly, a negative correlation was observed between the lumbar garment–body gap (D_{gap}) and the subjective rating for “overall confidence” (r = -0.65, $R^2 = 0.42$, $p < 0.05$). These correlations suggest that high pressure points directly restrict movement, while a lack of garment adherence to the body negatively impacts a dancer’s psychological comfort and sense of security.

DISCUSSION

This study successfully developed and implemented a dual-modal sensing system to provide a comprehensive, quantitative assessment of dance costume dynamic fit. The results clearly demonstrate that an OF, achieved through 3D scanning and dynamic pattern engineering, significantly outperforms a SF in terms of both garment–body interaction and its subsequent effect on dance performance.

The key innovation of this work lies in the synergy between pressure sensing and computer vision. Pressure sensors provide crucial information about the forces normal to the skin surface. The high-pressure zones observed with the SF garment are indicative of poor load distribution, where the fabric tension required for the garment to stay on the body is concentrated in small areas. This is a direct consequence of a pattern that does not account for the body's complex 3D curvature during movement. Such pressure points can inhibit the contraction of underlying muscles and create discomfort that forces the dancer to subconsciously alter their technique, thereby limiting their ROM, as seen in the reduced trunk and leg extension. By using anatomical seam lines and 3D-informed patterns, the OF garment effectively transforms localized pressure "peaks" into broader, more uniform plateaus, allowing dancers to realize greater physical potential.

Computer vision, on the other hand, reveals the spatial dynamics of fit—how the garment moves in relation to the body. The significant gapping observed in the SF garment's lumbar region during the *arabesque* is a classic example of poor dynamic fit. This occurs because the 2D pattern cannot accommodate the dramatic change in length and curvature of the back during hyperextension. This gapping is not only aesthetically undesirable but also indicates a loss of functional contact and support. The OF garment's ability to maintain close contact demonstrates the success of the dynamic design approach. The simultaneous measurement of body and garment markers is a powerful method for quantifying this adherence, providing designers with a clear target metric to optimize for.

The link between these improved fit metrics and enhanced biomechanical performance is the most significant finding of this study. The increases in ROM, jump height, and rotational velocity observed with the OF garment are not trivial; in the highly competitive world of professional dance, such gains can be the difference between good and exceptional performance. This confirms the hypothesis that the costume is an active component in the performance ecosystem. By reducing physical restrictions (high pressure) and improving biomechanical alignment (better support and less gapping), the OF garment effectively lowers the "energy cost" of the movement, allowing the dancer to channel more power into the execution of the skill itself. The strong correlation between fit parameters and performance outcomes provides empirical evidence for this mechanism.

The subjective evaluations align perfectly with the quantitative data, highlighting the importance of the psychological dimension of fit. When a dancer feels secure and unconstrained by their attire, their confidence increases, which can lead to a more expressive and daring performance. The OF garment provided this psychological comfort, which is an invaluable, though often overlooked, aspect of performance wear.

This study has some limitations. The experiments were conducted in a controlled laboratory setting, which, while necessary for precise data capture, does not fully replicate the multifaceted demands of a live stage performance. For instance, the psychological state of a dancer—influenced by adrenaline, musical interpretation, and an audience—can alter movement quality and explosiveness in ways that might magnify the restrictive effects of a poorly fitting garment. Furthermore, environmental factors such as intense stage lighting, heat, and humidity could introduce variables like perspiration, potentially altering the fabric-skin interface and comfort in ways not assessed in this study. The sample size, while sufficient for statistical significance in this controlled study, could be expanded in future work. Furthermore, this study focused on a single fabric type; future research should explore how different material properties (e.g., bi-axial modulus, moisture management) interact with dynamic fit. Future iterations of this work could also involve integrating electromyography (EMG) sensors to directly measure the effect of pressure on muscle activation patterns, further elucidating the physiological mechanisms at play.

Furthermore, while the focus on "elite ballet dancers" was intentional to test the limits of performance wear under extreme conditions, the fundamental principles derived from this study have broader implications. The core findings—that reducing concentrated pressure points and minimizing garment–body gapping enhance both biomechanical efficiency and subjective comfort—are likely applicable to a wide range of athletic and recreational activities. For instance, athletes in gymnastics, figure skating, and swimming, who also require extensive range of motion, could benefit from apparel designed with similar dynamic fit principles. For recreational dancers and fitness enthusiasts, while the absolute performance gains may be of a different scale, the significant improvements in comfort, confidence, and freedom of movement could be even more critical for encouraging sustained participation and preventing discomfort or chafing. Future research should therefore aim to validate these findings across different user groups, including athletes of varying skill levels and body types, and in other sports where the garment–body interface is crucial to performance.

Furthermore, this study's findings have significant implications for industrial applications, addressing key questions of scalability and integration into modern design workflows. While our research utilized a detailed optimization process based on an individual scan, the methodology can be translated into a scalable mass-customization model. The core principles—such as the identified anatomical seam lines and strain-aligned panel orientations—can be codified into a library of "smart pattern blocks." These optimized modules can then be algorithmically applied to standard sizing systems or integrated into online platforms where consumers provide a few key measurements. This approach would generate semi-customized, high-performance garments without the need for a full 3D scan of every individual.

Moreover, the entire research process provides a blueprint for a formalized computer-aided design (CAD) and computer-aided engineering (CAE) workflow. A designer could begin with a 3D avatar in a CAD environment (like CLO 3D, as used in our study). Subsequently, integrated CAE tools, such as finite element analysis (FEA), could simulate skin deformation and fabric tension during virtual movements, generating the quantitative pressure and strain maps we collected physically. This "digital twin" approach would allow designers to rapidly iterate and validate the dynamic fit of a garment in a virtual environment before a physical prototype is ever made, creating a truly evidence-based design cycle that significantly accelerates the development of next-generation performance apparel.

CONCLUSIONS

This research has demonstrated the significant impact of a dance costume's dynamic fit on stage performance. By pioneering an integrated measurement approach that combines computer vision and pressure sensing, this study moves beyond traditional, static notions of fit to provide a nuanced, quantitative understanding of garment–body interaction during complex, high-intensity movements. The proposed dual-sensing methodology is a highly effective tool for objectively evaluating and comparing the dynamic fit of functional garments, capturing critical parameters like interface pressure, fabric strain, and garment–body gapping. Moreover, an optimized dynamic fit, achieved through a design process informed by 3D body scanning and dynamic posture analysis, leads to statistically significant and practically meaningful improvements in dancers' biomechanical performance, including enhanced range of motion, greater jump height, and faster rotation. These objective gains are strongly supported by subjective improvements in comfort and confidence. The implications of this work are significant for the textile and apparel industry, particularly in the domain of sportswear and performance wear. It provides a clear, scientific rationale and a methodological blueprint for an evidence-based design process. Instead of relying solely on tradition and subjective feedback, designers can use these quantitative tools to engineer garments that work in harmony with the human body, reducing restrictions and augmenting athletic potential. This study paves the way for a new generation of high-performance apparel where the costume is not just worn, but is an integrated and optimized component of the athlete's success.

Author Contributions

All work in this study was independently completed by Wangfeifei DONG.

Conflicts of Interest

The author declares no conflict of interest.

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Ethics Approval and Consent to Participate

This study has been approved by the Ethics Committee of Nanhai, Haikou University of Economics. All participants provided informed consent prior to the study.

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