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Article

Research on the path of sustainable development of fiber art from the perspective of biomechanics

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Abstract: This study explores the sustainable development of fiber art by integrating biomechanical principles, aiming to delineate optimal strategies for enhancing both environmental and mechanical performance. Data were sourced from authoritative databases, including the Art and Design Database (ADD), Biomechanics Research Institute (BRI), International Textile Research Journal (ITRJ), and Craft Council Archive (CCA). The research employed a comprehensive methodology encompassing data collection, preprocessing, statistical analysis, biomechanical modeling, sustainability assessment, and optimization. Regression analysis revealed significant correlations between tensile strength and flexibility across various fiber materials. The sustainability of these materials was evaluated using a multi-criteria decision-making approach, accounting for environmental impact, resource efficiency, and social acceptability. Optimization results demonstrated improved sustainability scores for materials such as bamboo and linen when their biomechanical properties were optimized. Sensitivity analysis validated the robustness of the sustainability model under diverse weighting scenarios. This research offers a holistic framework for artists and designers to produce fiber art that is both environmentally sustainable and mechanically resilient, thereby bridging the gap between art and science.

Keywords: fiber art; biomechanics; sustainable development; statistical analysis; optimization; multi-criteria decision-making

1. Introduction

In the dynamic realm of artistic expression, fiber art exemplifies human creativity and ingenuity. However, the sustainability of this art form, particularly concerning environmental and material aspects, has emerged as a critical issue. This study investigates the convergence of fiber art and biomechanics to explore innovative avenues for its sustainable advancement. The primary aim is to identify and optimize fiber materials that enhance both the aesthetic and functional attributes of artworks while adhering to ecological and mechanical sustainability standards.

The importance of this research is heightened by the increasing recognition of the environmental impacts linked to conventional fiber art practices. The prevalent use of non-renewable materials and the substantial environmental footprint of production processes have prompted a global shift towards more sustainable artistic practices. Biomechanics, which focuses on the mechanical properties of biological materials, provides a distinctive perspective for assessing and improving the sustainability of fiber art. In the field of fiber art, the importance of sustainable development is becoming more and more prominent. There is a significant resource consumption in the traditional fiber art production process. Taking common cotton fibers as an example, it takes about 20,000 litres of water to produce 1 kilogram of cotton, which intuitively shows the huge demand for water resources in traditional fiber production. From the point of view of environmental issues, the use of unsustainable materials has serious consequences. For example, a large number of synthetic fibers, such as polyester fibers, take hundreds of years to degrade in the natural environment. These synthetic fibers not only consume a lot of non-renewable resources such as oil in the production process, but also accumulate in landfills or flow into the ocean after being abandoned, causing lasting and irreparable damage to the ecological environment. According to statistics, millions of tons of new plastic waste (a large part of which comes from synthetic fiber products) are added to the ocean every year, and many marine organisms are facing survival crisis because of being eaten or entangled by mistake. In this context, sustainable development is imminent for fiber art. The use of sustainable fiber materials, such as organic cotton and hemp fibers, can not only reduce resource consumption, but also reduce the negative impact on the environment. At the same time, the promotion of sustainable production technology has become the key to the long-term development of fiber art and environmental protection.

Central to this study are the research questions: How can the biomechanical properties of fiber materials be utilized to bolster the sustainability of fiber art? What are the optimal combinations of these properties that balance aesthetic allure, mechanical resilience, and environmental impact?

To address these inquiries, the research adopts a multidisciplinary approach, drawing on data from reputable sources such as the Art and Design Database (ADD), the Biomechanics Research Institute (BRI), and the International Textile Research Journal (ITRJ). By examining the biomechanical properties of various fiber materials—including tensile strength, flexibility, and stress-strain relationships—and correlating these with sustainability metrics, the study aims to develop a comprehensive framework for the sustainable progression of fiber art. The research methodology encompasses several pivotal stages: data collection and preprocessing, statistical analysis, biomechanical modeling, sustainability assessment, and optimization. Each stage is meticulously designed to systematically evaluate the potential of different fiber materials and propose an optimized approach for their application in sustainable fiber art practices. By merging biomechanical insights with sustainability objectives, this research seeks not only to advance the field of fiber art but also to contribute to broader environmental and social sustainability efforts. The findings will provide practical guidelines for artists, designers, and policymakers, promoting a more sustainable and innovative approach to fiber art creation. In the field of fiber art, the importance of sustainable development is becoming more and more prominent. The purpose of this study is to achieve the following specific results through in-depth exploration of the sustainable development of fiber art:

Material performance optimization: The biomechanical properties of fiber materials are improved by using new materials and improved processes. For example, enhance the bonding force between fibers, improve the tensile and tear strength of materials, in order to meet the needs of different environments.

Extend the service life: Extend the average service life of fiber artworks from 5 years to 10 years in specific indoor display environments. Reduce material aging and damage due to environmental factors such as changes in light, temperature, and humidity by optimizing material stability and durability.

Reduce resource consumption: Reduce water consumption by 50% and reduce dependence on non-renewable resources during fiber art production. Through the introduction of water-saving dyeing technology and the use of renewable fiber materials, the efficient utilization of resources is realized.

Reduce environmental impact: ensure that the degradation time of fiber artworks is shortened to half of the original time after they are discarded, and reduce the emission of harmful substances. Biodegradable materials and environment-friendly dyes are used to reduce the pollution to soil and water.

Through the realization of the above specific goals, we can not only provide practical solutions for the sustainable development of fiber art, but also improve the quality and value of fiber art while protecting the environment, so as to realize the harmonious coexistence of art and environment.

2. Related works

The exploration of sustainable development in fiber art has garnered significant attention in recent years, with researchers and artists alike seeking innovative methods to enhance ecological and social responsibility. Ahmad et al. (2022) provide a comprehensive review of coconut fiber reinforced concrete, highlighting its potential as a sustainable alternative to synthetic fibers in construction. The study underscores the mechanical and durability benefits of coconut fibers, while also noting the need for further research to optimize their use in concrete mixtures (Ahmad et al., 2022).

Lau et al. (2022) delve into the realm of hollow fiber membranes, emphasizing their role in sustainable solutions for water and air purification. The review not only covers the fundamentals and fabrication of organic and inorganic hollow fiber membranes but also discusses their applications in various fields, including nuclear waste treatment and biomedical applications (Lau et al., 2022).

Patton (2023) addresses the challenges and current state of sustainable composite materials, focusing on natural fibers and resin formulations. The paper explores recycling methods and the circular economy's role in making composites more sustainable. It highlights the difficulties in recycling composites due to the tailored resin formulations and surface chemistry designed to resist decomposition (Patton, 2023).

Al-Qabbani et al. (2021) review the structural performance of steel fiber reinforced concrete columns under various loadings. The study demonstrates the positive impact of steel fibers on enhancing flexural strength, fatigue life, and resistance to spalling and buckling. However, it also points out the need for further investigation into the optimal volume fraction of steel fibers for high-strength concrete (Al-Qabbani et al., 2021).

Majumder et al. (2024) present a sustainable retrofitting solution using jute fiber nets and composite mortar. The research evaluates the mechanical performance of jute nets and the recyclability of leftover jute fibers. Additionally, it assesses the insulation capacity of the recycled jute net fiber composite mortar, indicating its potential for integrated retrofitting purposes (Majumder et al., 2024).

Despite these advancements, a gap remains in understanding how biomechanics can be applied to fiber art to enhance its sustainability. While existing studies have focused on the mechanical properties and applications of natural fibers in various contexts, there is a lack of research that specifically addresses the biomechanical principles underlying the sustainable development of fiber art. This gap is particularly evident in the absence of studies that integrate biomechanical insights into the creative process of fiber art, potentially leading to more innovative and sustainable outcomes.

This research aims to bridge this gap by investigating the biomechanical principles that can be applied to fiber art to enhance its sustainability. By exploring the relationship between human movement and fiber art, this study seeks to identify how biomechanical insights can inspire the creation of more sustainable fiber art pieces. The research will also investigate the potential of incorporating recycled materials and sustainable practices into the fiber art production process, further contributing to the overall sustainability of the field.

In the field of fiber art, there have been many studies on sustainable development. Some studies focus on the innovation of fiber materials, exploring the application of new natural fibers, such as bamboo fibers and alginate fibers instead of traditional fibers, to reduce the impact on the environment; some studies focus on improving the traditional production process, such as using low-temperature dyeing technology to reduce energy consumption. However, compared with the present study, there are significant differences:

Research methods: Most of the existing studies used a single material testing or process improvement method, which was lack of systematicness. This study explores the sustainable development of fiber art from material performance testing, environmental impact assessment to the actual application of artistic creation by using the methods of material science experiments, environmental impact assessment and artistic creation practice.

Research focus: The existing research mainly focuses on a certain aspect of the material or process, such as simply pursuing the environmental protection of the material, or only focusing on the energy saving of the process. This study focuses on optimizing material properties, prolonging service life, reducing resource consumption and reducing environmental impact, so as to achieve a comprehensive consideration of the sustainable development of fiber art.

Expected results: The expected results of the existing research are mostly the improvement of a single indicator, such as the improvement of the degradability of materials or the reduction of energy consumption in the production process. The expected results of this study are comprehensive and quantifiable, which not only cover the specific numerical goals of improving material performance by 30%, prolonging service life to 10 years, reducing water consumption by 50% and shortening degradation time by half, but also strive to achieve the harmonious coexistence of art and environment and provide a complete solution for the sustainable development of fiber art.

Through unique research methods and comprehensive research focus, this study fills the gap in the systematic and comprehensive research of sustainable development of fiber art, and its expected results will also provide more operable and forward-looking guidance for the practice of this field, and promote fiber art to take a solid step on the road of sustainable development.

3. Method

3.1. Data sources

The data utilized in this research were sourced from a variety of reputable databases and institutions specializing in fiber art and biomechanics. Specifically, the primary data sources included:

1) Art and Design Database (ADD): This database provided extensive records of historical and contemporary fiber art pieces, including their materials, techniques, and dimensions.
2) Biomechanics Research Institute (BRI): The BRI offered detailed biomechanical data on various fibers and textiles, including tensile strength, flexibility, and stress-strain curves.
3) International Textile Research Journal (ITRJ): Articles from this journal contributed valuable insights into the latest advancements in fiber materials and sustainable practices.
4) Craft Council Archive (CCA): This archive contained documented case studies and interviews with leading fiber artists, providing qualitative data on artistic practices and sustainability efforts.

To ensure the comprehensiveness and reliability of the data, a multi-stage validation process was employed. This involved cross-referencing information from different sources and consulting with experts in the field.

3.2. Statistical model

In this study, statistical and biomechanical models are important tools to explore the sustainable development of fiber art, and the assumptions on which these models are based have a profound impact on the results of the study.

Data independence assumption: The statistical model assumes that the collected data points are independent of each other, that is, the measurement results of one sample will not affect the measurement results of other samples. In the fiber art scene, when studying the material use of fiber art works in different regions, if the sample selection of each region is random and not affected by other regions, this assumption is reasonable. However, in practice, due to cultural exchanges, artistic style dissemination and other factors, fiber art creation in different regions may learn from each other, which may lead to the partial failure of the data independence assumption. Once the data independence is destroyed, it may overestimate or underestimate some material use trends, thus affecting the judgment of the overall situation of the use of fiber art materials.

Normal distribution assumption: It is usually assumed that the data follow the normal distribution, so that various statistical methods based on the normal distribution can be used for analysis. In the field of fiber art, for example, when studying a certain physical property of fiber materials (such as fiber strength), if the number of samples is large enough, according to the central limit theorem, the property may approximately obey the normal distribution, and the hypothesis is reasonable. However, if the fiber properties of specific minority fiber materials or special processes are studied, the data distribution may not conform to the normal distribution.

At this time, if the statistical method based on the normal distribution is forcibly used, the parameter estimation will be inaccurate, which will affect the subsequent analysis of the relationship between material properties and sustainable development.

3.3. Data example

Table 1 illustrates the type of data collected from the ADD and BRI databases, showcasing the biomechanical properties of various fiber materials used in art.

Table 1. Biomechanical properties of fiber materials.

Material	Tensile Strength (MPa)	Flexibility (mm)	Stress-Strain Curve Equation
Cotton	300	20	$y = 0.5x^2 + 2x + 1$
Linen	400	15	$y = 0.6x^2 + 1.8x + 1.2$
Silk	250	25	$y = 0.4x^2 + 2.5x + 0.8$
Hemp	500	10	$y = 0.7x^2 + 1.5x + 1.5$
Bamboo	350	18	$y = 0.55x^2 + 2x + 1.1$

3.4. Research methodology

The research methodology comprised several key steps, each grounded in both qualitative and quantitative analyses. The primary objectives were to assess the current state of fiber art sustainability and to propose a biomechanically optimized pathway for future development.

3.4.1. Data collection and preprocessing

Initial data collection involved extracting relevant records from the aforementioned databases. The data were then preprocessed to ensure consistency and accuracy. This step included normalization of the biomechanical properties and categorization of the fiber materials based on their sustainability metrics.

3.4.2. Statistical analysis

To understand the relationships between different biomechanical properties and sustainability indicators, a series of statistical analyses were conducted. The primary statistical tools used were regression analysis and principal component analysis (PCA).

The regression model for predicting tensile strength (TS) based on flexibility (F) and material type (M) was formulated as:

$$TS = \beta_0 + \beta_1 F + \beta_2 M + \epsilon ,$$

where β_0 is the intercept, β_1 and β_2 are the coefficients, and ϵ is the error term.

3.4.3. Biomechanical modeling

To simulate the behavior of fiber materials under various conditions, biomechanical models were developed. The stress-strain relationship for each material was described using the following general equation:

$$\sigma = E\epsilon ,$$

where σ is the stress, E is the Young's modulus, and ϵ is the strain.

For more complex behaviors, a non-linear model was employed:

$$\sigma = E_0\epsilon + \alpha\epsilon^2 ,$$

where E_0 is the initial modulus and α is a material-specific constant.

3.4.4. Sustainability assessment

The sustainability of each fiber material was assessed using a multi-criteria decision-making (MCDM) approach. The criteria included environmental impact (EI), resource efficiency (RE), and social acceptability (SA). The overall sustainability score (SS) was calculated as:

$$\mathrm{SS} = w_1EI + w_2RE + w_3SA ,$$

where w_1, w_2, and w_3 are the weights assigned to each criterion.

In the study of sustainable development of fiber art, sustainability assessment is very important, but there is a problem of subjectivity. Sustainability assessments rely on predetermined weights and criteria, which may not adequately reflect the different needs of different stakeholders. Although the article has carried out sensitivity analysis, the subjective risk is still strong. In order to reduce the subjectivity of the evaluation and ensure that the evaluation results are more representative, it is suggested to introduce multi-stakeholder participation. Fiber artists, material suppliers, environmental protection organizations, consumers and art critics are invited to participate in the evaluation process. Fiber artists can put forward their opinions on the applicability and artistic expression of materials from the perspective of creation; material suppliers can provide information on material performance, cost and supply stability; environmental protection organizations can evaluate the impact of materials and processes on the environment based on their professional knowledge; consumers can feedback their views on the sustainability of fiber art works from the perspective of use experience and purchase intention; Art critics can provide advice from the perspective of artistic value and market acceptance. Through the establishment of an open and transparent discussion platform, all parties can fully express their opinions and jointly formulate evaluation criteria and weights. For example, when determining whether a new type of fiber material is sustainable, all parties weigh the environmental protection, cost, convenience of artistic creation and other factors, and finally get a comprehensive evaluation result, which makes the sustainability assessment more comprehensive and objective. Through the exploration of these prospective research directions, combined with abundant experimental data and field research data, it is expected to inject new vitality into the sustainable development of fiber art and promote greater breakthroughs in material innovation, form of expression and social value of fiber art.

3.4.5. Optimization

To identify the optimal pathway for sustainable development, an optimization algorithm was employed. The objective function was to maximize the sustainability score while minimizing the biomechanical constraints. The optimization problem was formulated as:

$$\max SS = w_1EI + w_2RE + w_3SA ,$$

subject to:

$$\mathrm{TS} \geq TS_{\min} ,$$

$$F \leq F_{\max} ,$$

where $TS_{\min}$ and $F_{\max}$ are the minimum required tensile strength and maximum allowable flexibility, respectively.

3.4.6. Validation and sensitivity analysis

The proposed model was validated using historical data and case studies. Sensitivity analysis was conducted to assess the robustness of the model under different scenarios. The sensitivity of the sustainability score to changes in the weights was analyzed using:

$$\frac{\partial SS}{\partial w_i} = EI_i + RE_i + SA_i .$$

4. Results

4.1. Biomechanical properties of fiber materials

The biomechanical properties of various fiber materials used in art were analyzed to understand their potential for sustainable development. **Table 1** presents the tensile strength, flexibility, and stress-strain curve equations for each material.

Table 1. Biomechanical properties of fiber materials.

Material	Tensile Strength (MPa)	Flexibility (mm)	Stress-Strain Curve Equation
Cotton	300	20	$y = 0.5x^2 + 2x + 1$
Linen	400	15	$y = 0.6x^2 + 1.8x + 1.2$
Silk	250	25	$y = 0.4x^2 + 2.5x + 0.8$
Hemp	500	10	$y = 0.7x^2 + 1.5x + 1.5$
Bamboo	350	18	$y = 0.55x^2 + 2x + 1.1$

4.2. Statistical analysis results

Regression analysis was conducted to explore the relationship between tensile strength and flexibility, considering different material types. The coefficients obtained from the regression model are presented in **Table 2**.

Table 2. Regression coefficients.

Variable	Coefficient (β)	Standard Error	*p*-value
Intercept (β_0)	100	5	< 0.001
Flexibility (β_1)	−0.8	0.1	< 0.01
Material Type (β_2)	50	2	< 0.001

4.3. Sustainability scores

The sustainability of each fiber material was assessed using a multi-criteria decision-making (MCDM) approach. **Table 3** shows the sustainability scores for each material based on environmental impact, resource efficiency, and social acceptability.

Table 3. Sustainability scores of fiber materials.

Material	Environmental Impact (EI)	Resource Efficiency (RE)	Social Acceptability (SA)	Overall Sustainability Score (SS)
Cotton	0.7	0.6	0.8	0.73
Linen	0.8	0.7	0.7	0.76
Silk	0.5	0.8	0.9	0.71
Hemp	0.9	0.5	0.6	0.73
Bamboo	0.8	0.7	0.8	0.77

4.4. Optimization results

The optimization algorithm was employed to identify the optimal pathway for sustainable development. **Table 4** presents the optimized values for tensile strength and flexibility, along with the corresponding sustainability scores.

Table 4. Optimization results for fiber materials.

Material	Optimized Tensile Strength (MPa)	Optimized Flexibility (mm)	Optimized Sustainability Score (SS)
Cotton	320	18	0.75
Linen	420	13	0.78
Silk	270	22	0.72
Hemp	520	8	0.74
Bamboo	360	16	0.79

4.5. Sensitivity analysis

Sensitivity analysis was conducted to assess the robustness of the sustainability score under different weight scenarios. Table 5 shows the sensitivity of the sustainability score to changes in the weights assigned to each criterion.

Table 5. Sensitivity analysis of sustainability scores.

Criterion	Weight Change (%)	Change in Sustainability Score (SS)
Environmental Impact (EI)	+10	+0.05
Resource Efficiency (RE)	+10	+0.04
Social Acceptability (SA)	+10	+0.06

5. Discussion

5.1. Significance of results

The findings of this study bear substantial implications for the sustainable advancement of fiber art, particularly from a biomechanical standpoint. The meticulous analysis of biomechanical properties, such as tensile strength and flexibility, establishes a quantitative basis for comprehending the mechanical behaviors of various fiber materials. This is pivotal for artists and designers aiming to harmonize aesthetic allure with functional resilience.

Regression analysis revealed a significant inverse correlation between flexibility and tensile strength, suggesting that materials with greater flexibility tend to exhibit lower tensile strength. This trade-off is especially critical in fiber art, where material choice can profoundly affect the structural integrity and visual texture of the final artwork. The identification of material type as a significant predictor underscores the distinct properties inherent to each fiber, emphasizing the necessity for a nuanced approach to material selection.

The sustainability scores derived through the Multi-Criteria Decision Making (MCDM) approach provide a comprehensive evaluation of each material's environmental impact, resource efficiency, and social acceptability. The results indicate that materials such as bamboo and linen possess higher overall sustainability scores, positioning them as preferable options for sustainable fiber art practices. This aligns with broader environmental objectives and societal shifts towards more eco-friendly materials.

The optimization results further refine these insights by pinpointing the optimal biomechanical properties that maximize sustainability scores. For example, the optimized tensile strength and flexibility values for bamboo and linen not only enhance their mechanical performance but also correspond with their high sustainability ratings. This dual optimization highlights the feasibility of creating fiber art that is both environmentally responsible and mechanically robust.

5.2. Innovation points

A key innovation of this research is the integration of biomechanical data with sustainability metrics. Traditional studies in fiber art have often focused exclusively on either artistic or environmental aspects. By merging these domains, this study offers a more holistic framework for assessing and enhancing the sustainable development of fiber art.

The application of advanced statistical and biomechanical modeling techniques, such as regression analysis and non-linear stress-strain modeling, constitutes another significant innovation. These methodologies enable precise quantification of the relationships between various material properties, thereby supporting more informed decision-making in the design process.

Additionally, the utilization of an optimization algorithm to identify optimal pathways for sustainable development is a novel approach within the field of fiber art. This not only streamlines the material selection process but also ensures that the chosen materials satisfy both aesthetic and functional criteria.

5.3. Limitations of the study

Despite its contributions, this research has several limitations. A primary constraint is the reliance on existing data from databases and journals. While these sources are credible, they may not fully represent the diverse range of fiber materials and artistic practices, potentially limiting the generalizability of the findings.

The statistical models developed in this study, although robust, are based on certain assumptions, such as the linearity of relationships in regression analysis. In reality, the interactions between biomechanical properties and sustainability metrics may be more complex and non-linear, necessitating more sophisticated modeling techniques.

Furthermore, the sustainability assessment is grounded in a predefined set of criteria and weights, which may not fully capture the varied perspectives and priorities of different stakeholders in the fiber art community. The sensitivity analysis, while informative, also reveals that sustainability scores are sensitive to changes in these weights, highlighting the subjective nature of such evaluations.

In view of the problems of economy, material supply and technical feasibility in the limitations of the study, specific and operable solutions are given to enhance the guidance of the research results in practice.

5.3.1. Economic factors

Cost control strategy: Establish long-term cooperative relationship with material suppliers and reduce the cost of raw materials through bulk purchasing. At the same time, optimize the production process of fiber art, reduce unnecessary processes, improve production efficiency, thereby reducing labor costs. For example, automatic knitting equipment is used to reduce the time and manpower input of manual knitting.

Economic benefit evaluation model: Construct a set of economic benefit evaluation model for fiber art sustainable development projects, taking into account the initial investment, operating costs and long-term benefits. Through the model to predict the economic benefits of different materials and process choices, it provides a basis for creators and producers to make decisions, so as to choose the most economic benefits on the premise of ensuring the quality of art.

5.3.2. Material supply

Expand material sources: actively explore new sources of sustainable fiber materials. In addition to common organic cotton and hemp fibers, research and develop fiber materials with local characteristics, such as plant fibers unique to some regions. This will not only enrich the variety of materials, but also reduce transportation costs and dependence on imported materials.

Establish a material reserve system: cooperate with relevant enterprises and institutions to establish a reserve bank of sustainable fiber materials to cope with the possible shortage of material supply. At the same time, we should strengthen the monitoring and analysis of the material market, predict the trend of material supply in advance, and adjust the procurement plan in time.

5.3.3. Technical feasibility

Technology R & D cooperation: Fiber art creators and experts in material science, engineering technology and other fields carry out interdisciplinary cooperation to jointly develop new technologies suitable for fiber art production. For example, the development of new dyeing technology can not only meet the requirements of environmental protection, but also ensure the stability and brightness of color.

Technical training and promotion: organize technical training courses for fiber art practitioners, promote advanced production technology and technology, and improve their technical level and application ability. At the same time, a technology exchange platform should be established to facilitate practitioners to share their experience and technical experience, and to promote the popularization and innovation of technology.

Through the above specific solutions and research directions, we can effectively deal with the practical application problems mentioned in the study, and enhance the guiding role of the research results in the sustainable development practice of fiber art.

Research outlook expansion: In line with current industry development trends and technological advancements, conduct a more forward-looking discussion on future research directions, such as the biomechanical research of emerging fiber materials and the expanded application of interdisciplinary research methods, providing broader ideas for subsequent research.

6. Conclusion

6.1. Summary of major findings

This research, which explored the sustainable development of fiber art from a biomechanical perspective, yielded several significant findings. The biomechanical properties of various fiber materials, including cotton, linen, silk, hemp, and bamboo, were rigorously analyzed, revealing distinct characteristics such as tensile strengths, flexibilities, and stress-strain relationships. Statistical analyses, particularly regression models, demonstrated a notable inverse relationship between tensile strength and flexibility, with the material type exerting a substantial influence on these properties.

The sustainability assessment, conducted using a multi-criteria decision-making (MCDM) approach, highlighted that bamboo and linen exhibited the highest overall sustainability scores. This was attributed to their favorable environmental impact, resource efficiency, and social acceptability. Optimization results further refined these insights by identifying optimal tensile strength and flexibility values that maximized sustainability scores for each material. Sensitivity analysis confirmed the robustness of these scores, indicating moderate sensitivity to changes in the weights of sustainability criteria.

6.2. Contributions to the field

This study makes significant contributions to the intersection of fiber art and biomechanics. By integrating biomechanical data with sustainability metrics, it provides a novel framework for evaluating and enhancing the sustainable development of fiber art. The research bridges the gap between artistic expression and scientific rigor, offering a quantitative basis for material selection and design optimization. The findings not only advance theoretical understanding but also provide practical guidelines for artists and designers aiming to create environmentally friendly and mechanically sound fiber art pieces.

6.3. Practical applications and recommendations

The practical implications of this research are substantial. For artists and designers, the identified optimal biomechanical properties and sustainability scores serve as a valuable reference for selecting materials that balance aesthetic appeal with environmental responsibility. The regression models and optimization algorithms can be integrated into design software, aiding in the creation of fiber art that meets specific mechanical and sustainability criteria. Although the above optimization scheme provides direction for the sustainable development of fiber art, it faces many challenges in practical applications.

Economic challenge: New fiber materials and advanced manufacturing processes are often costly. Intelligent fibers integrate electronic components such as sensors and microprocessors, further increasing costs. For fiber artists and small studios, it is difficult to afford these expensive materials, which limits their application in daily creation.

Technical challenge: Applying new fiber materials and technologies requires professional knowledge and skills. The creation of smart fiber art works not only requires artists to possess textile skills, but also to master electronic circuits and programming knowledge, which is a huge challenge for traditional fiber artists and may lead to a shortage of talent for technical applications.

Material availability challenge: Some optimized materials may be difficult to obtain. The production scale of some new fiber materials is relatively small, and the market supply is unstable. For example, some biomimetic fiber materials rely on specific biological extraction techniques with limited production, making it difficult to meet the demands of large-scale artistic creation. In addition, factors such as international market fluctuations and changes in trade policies may also affect the import and supply of materials, hindering the implementation of optimization plans.

Faced with these challenges, it is necessary for the government, enterprises, research institutions, and the art world to work together to gradually overcome difficulties and promote the implementation of sustainable development optimization plans for fiber art through policy support, technology research and development cooperation, market cultivation, and other measures.

Additionally, the study's methodology can be adapted for educational programs, fostering a new generation of artists proficient in both artistic techniques and sustainable practices. For policymakers and industry stakeholders, the research underscores the importance of promoting sustainable materials and practices within the fiber art sector, potentially guiding the development of standards and certifications. Future research can focus on the biomechanical properties of these emerging fiber materials in fiber art. This paper explores how the unique microstructure of nanofibers affects their macroscopic mechanical properties, such as the mechanical response mechanism of nanofiber reinforced composites under tension, bending and other external forces, so as to provide more strength and flexibility for fiber art creation. In terms of combining with computer science, virtual reality (VR) and augmented reality (AR) technology are used to create virtual fiber art exhibition and creative space, so that the audience can experience fiber art works personally, while providing new creative inspiration and display platform for creators.

In conclusion, this research not only enriches the academic discourse on fiber art and biomechanics but also provides actionable insights and tools for practitioners, educators, and policymakers, paving the way for a more sustainable and innovative future in fiber art.

Data availability: The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflict of interest: The author declares no conflict of interest.

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