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IMPACT OF GREEN MANUFACTURING ON ENVIRONMENTAL SUSTAINABILITY IN SPORTS GOODS MANUFACTURING FIRMS

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Article Info

Abstract

Environmental sustainability has become a critical concern for manufacturing industries due to increasing environmental degradation, resource depletion, and regulatory pressure for sustainable industrial operations. In this context, green manufacturing has emerged as an effective strategy for minimizing environmental impact while enhancing production efficiency and long-term sustainability. The present study investigates the impact of green manufacturing practices on environmental sustainability in sports goods manufacturing firms located in Sialkot, Pakistan. Specifically, the study examines the influence of energy conservation practices, waste management initiatives, environmentally responsible supply chain practices, and implementation of environmental management systems on the environmental sustainability performance of manufacturing firms. A quantitative research approach was employed using structured questionnaire-based survey data collected from 203 respondents working in sports goods manufacturing firms. Statistical analysis, including descriptive statistics, correlation, and regression analysis, was used to evaluate the relationship between green manufacturing dimensions and environmental sustainability outcomes. The findings reveal that green manufacturing practices have a significant positive impact on environmental sustainability, indicating that firms adopting sustainable manufacturing practices achieve improved environmental performance through reduced emissions, efficient resource utilization, and enhanced waste management. Among the factors examined, implementation of environmental management systems and environmentally responsible supply chain practices demonstrated the strongest influence on environmental sustainability. The study provides valuable insights for manufacturing managers, policymakers, and industrial stakeholders by highlighting the strategic importance of green manufacturing adoption in improving sustainability performance and maintaining competitiveness in export-oriented manufacturing sectors. The findings further support the promotion of environmentally responsible manufacturing strategies for achieving sustainable industrial development in the sports goods manufacturing industry.

Keywords: *Green manufacturing; Environmental sustainability; Sports goods manufacturing; Sustainable production; Environmental management systems; Supply chain sustainability.*

Introduction

Environmental sustainability has emerged as one of the most critical concerns for manufacturing industries worldwide due to increasing industrialization, excessive consumption of natural resources, growing environmental pollution, and heightened awareness regarding climate change. Industrial manufacturing activities contribute significantly to environmental degradation through greenhouse gas emissions, energy overconsumption, waste generation, and depletion of natural resources (Chen & Usman, 2025; Dai et al., 2025; El Khoury et al., 2025). As governments, policymakers, and international organizations continue to impose stricter environmental regulations, manufacturing firms are under increasing pressure to integrate sustainable and environmentally responsible practices into their operational systems (Javed et al., 2025; Opoku, 2025; Rodrigues et al., 2025). Consequently, modern manufacturing organizations are no longer expected to focus solely on profitability and production efficiency but are also required to incorporate sustainability principles into their business strategies to minimize ecological damage while maintaining competitiveness and long-term operational success (Jindal, 2025; Liu, 2025; Tazhibekova & Shametova, 2024).

In response to these growing environmental concerns, green manufacturing has gained substantial attention as an effective strategy for achieving sustainable industrial development (Chen et al., 2025; Ullah et al., 2025). Green manufacturing refers to the systematic implementation of environmentally friendly manufacturing processes designed to reduce the negative environmental impact of industrial activities throughout the product life cycle (Islam et al., 2025; Mohammadian et al., 2025). It includes strategies such as energy conservation, efficient use of raw materials, waste minimization, recycling initiatives, pollution prevention, environmentally responsible procurement, and sustainable supply chain management (Kaur & Thapliyal, 2025; Zhu et al., 2025). The core objective of green manufacturing is to improve manufacturing efficiency while simultaneously reducing environmental harm, thereby creating a balance between industrial productivity and ecological preservation. Over the past decade, the adoption of green manufacturing practices has accelerated globally as firms increasingly recognize the strategic importance of sustainability in maintaining market competitiveness and regulatory compliance.

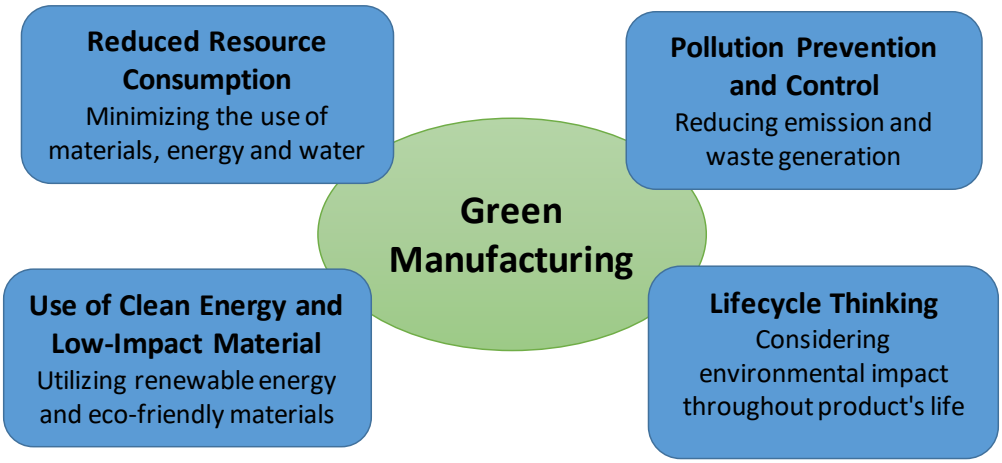

Figure 1 Green Manufacturing

Prior literature suggests that green manufacturing significantly contributes to improved environmental performance across multiple industrial sectors. Studies have demonstrated that organizations implementing green manufacturing strategies experience reductions in carbon emissions, lower waste generation, improved resource efficiency, and enhanced environmental sustainability performance (Awwad et al., 2026; Chen & Cao, 2025; Faeni et al., 2025; Yang et al., 2025). Among Pakistan's industrial sectors, the sports goods manufacturing industry holds significant economic importance and contributes substantially to national exports and industrial employment. Sialkot is internationally recognized as one of the world's leading hubs for sports goods manufacturing, producing a wide range of products including footballs, cricket equipment, gloves, protective gear, and other sporting accessories for global markets (Charter et al., 2025; Li et al., 2024). The city has developed a strong reputation for supplying sports goods to international brands and exporting products to Europe, North America, and Asia. However, despite its strong contribution to economic growth, the sports goods manufacturing sector also presents considerable environmental concerns due to its dependence on energy-intensive manufacturing processes, material waste, emissions, and unsustainable production practices.

The production of sports goods often involves multiple environmentally intensive activities such as synthetic material processing, rubber and polymer utilization, chemical adhesives,

leather treatment, textile finishing, and machinery-based manufacturing, all of which generate substantial environmental impacts (Alkandi, 2025; Bukhari et al., 2025; Rahim & Rafika, 2025). In addition, improper disposal of industrial waste, inefficient energy utilization, and lack of structured environmental management practices further contribute to environmental degradation in manufacturing clusters. As global consumers and international buyers become increasingly concerned about sustainable sourcing and ethical manufacturing, sports goods manufacturers are facing increasing pressure to adopt environmentally responsible production systems to meet international environmental standards and preserve export competitiveness. This lack of sector-specific research creates a substantial knowledge gap regarding how green manufacturing practices influence environmental sustainability in sports goods production environments (Bai et al., 2025; Kumar Saha et al., 2025; Masoudi & Shahin, 2025; Qu & Kim, 2025). Additionally, the unique production characteristics, export orientation, and operational challenges of sports goods manufacturing firms necessitate independent investigation rather than direct generalization from other manufacturing sectors.

Given this research gap, it is essential to examine the extent to which green manufacturing practices contribute to environmental sustainability in sports goods manufacturing firms, particularly in Sialkot's industrial context. Understanding this relationship can provide important insights into how sports goods manufacturers can improve environmental performance while maintaining productivity and competitiveness in international markets (Ling & Li, 2025; Nazarian et al., 2025; Wu, 2024). Furthermore, such analysis can support policymakers, industrial stakeholders, and managers in designing targeted sustainability strategies that encourage environmentally responsible industrial development.

Against this background, the present study investigates the impact of green manufacturing on environmental sustainability in sports goods manufacturing firms located in Sialkot, Pakistan (Mahar et al., 2025; Sonia et al., 2025). Specifically, the study examines the influence of four key dimensions of green manufacturing, namely energy conservation practices, waste management initiatives, environmentally responsible supply chain practices, and implementation of environmental management systems, on the environmental sustainability performance of manufacturing firms.

Methodology

Research Design & Variables

This study employed a quantitative cross-sectional research design to examine the impact of green manufacturing practices on environmental sustainability in sports goods manufacturing firms. A quantitative approach was selected because it enables objective measurement of variables and statistical testing of relationships through numerical data analysis. In addition, a descriptive-correlational design was adopted to assess the strength and direction of relationships between green manufacturing practices and environmental sustainability outcomes. The study includes four independent variables and one dependent variable. The independent variables represent major dimensions of green manufacturing practices, while the dependent variable reflects environmental sustainability outcomes.

The first independent variable is Energy Conservation Practices, which refers to strategies and techniques adopted by firms to reduce energy consumption during manufacturing processes. The second independent variable is Waste Management Initiatives, which include practices such as waste reduction, recycling, waste segregation, and proper disposal methods aimed at minimizing manufacturing waste and reducing environmental impact. The third independent variable is Environmentally Responsible Supply Chain Practices, which assess the use of sustainable procurement methods, green logistics, eco-friendly transportation, and supplier environmental compliance. The fourth independent variable is Environmental Management Systems (EMS) Implementation, referring to the adoption of structured environmental management policies such as ISO 14001 certification, environmental audits, sustainability monitoring, and regulatory compliance frameworks. The dependent variable is Environmental Sustainability, which reflects the ability of firms to minimize environmental degradation.

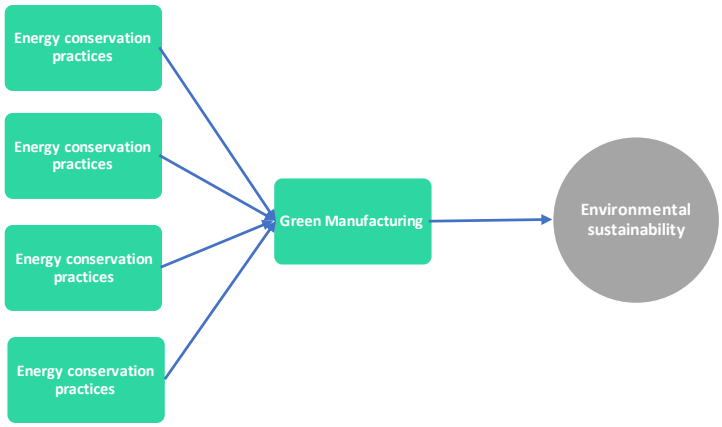

Figure 2 Research Framework

Hypothesis Development

Based on the conceptual framework and literature review, the following hypotheses were developed:

H1: Green manufacturing practices significantly influence environmental sustainability in sports goods manufacturing firms.

H1a: Energy conservation practices positively influence environmental sustainability.

H1b: Waste management initiatives positively influence environmental sustainability.

H1c: Environmentally responsible supply chain practices positively influence environmental sustainability.

H1d: Environmental Management Systems implementation positively influences environmental sustainability.

Population and Sampling & Data Collection

The target population of this study comprised management staff working in sports goods manufacturing firms located in Sialkot, Pakistan. Sialkot was selected due to its global recognition as a leading manufacturing hub for sports goods production. A purposive sampling technique was employed to collect data from respondents who possess knowledge relevant to the study variables. A total of 203 valid responses were collected from 49 sports goods manufacturing firms, including small-, medium-, and large-scale enterprises. Most participating firms are export-oriented organizations involved in international business operations.

Primary data were collected using a structured questionnaire developed based on previous literature and aligned with the study objectives. The questionnaire consisted of two main sections. The first section collected demographic and organizational information, while the second section included items related to the independent and dependent variables. A five-point Likert scale was used to measure responses, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire was created using Google Forms and distributed electronically via WhatsApp and email to respondents across sports goods manufacturing firms.

Data Analysis Techniques

The collected data was exported into Microsoft Excel and analyzed using Minitab® Version 22.1. Both descriptive and inferential statistical methods were employed. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondent demographics and response patterns. Inferential statistical techniques included Pearson correlation analysis and multiple linear regression analysis. Pearson correlation was used to determine the strength and direction of relationships among variables, while regression analysis was conducted to assess the predictive impact of green manufacturing practices on environmental sustainability. Before conducting regression analysis, assumptions of normality, linearity, homoscedasticity were examined to ensure statistical validity.

RESULTS AND DISCUSSION

Demographic Analysis

A total of 203 valid responses were collected from employees and management personnel of 49 sports goods manufacturing firms. The demographic analysis provides an overview of the characteristics of the participating firms and respondents. Regarding firm size, 60% of respondents belonged to large firms, 34% represented medium-sized firms, and 6% came from small firms. This indicates that most of the sampled respondents were associated with well-established manufacturing organizations having significant operational capacity. The inclusion of respondents from firms of varying sizes improves the generalizability of the study and reflects the diverse industrial composition of Sialkot's sports goods sector. In terms of export orientation, nearly all surveyed firms were export-oriented, with 202 respondents indicating that their firms export products internationally. This confirms the strong international focus of the sports goods manufacturing industry in Sialkot. The export region analysis further reveals that Europe represents the dominant export market, followed by the USA and Asian countries, demonstrating the dependence of these firms on environmentally sensitive global markets.

Furthermore, demographic analysis indicates that 61% of respondents belonged to firms located outside industrial zones, while 39% operated within industrial zones. This distribution suggests that sports goods manufacturing activities are spread across both formal industrial estates and independent production units. The variety of product categories represented in the sample includes bags, footballs, hockey equipment, bats, and other sports-related products.

Table 1 Demographic Analysis

Attribute	Sub attribute	Frequency (n)	Percentage (%)	Total percentage (%)
Firm Size	Small	12	6%	100
	Medium	70	34%	
	Large	121	60%	
Export Orientation	Yes	202	100%	100
	No	1	0%	
Export Region	Asia	17	8%	100
	Europe	141	69%	
	USA	44	22%	
	No	1	0%	
Industrial Zone	Yes	124	61%	100
	No	79	39%	
Goods Manufactured	Bags	48	24%	100
	Bats	2	1%	
	Football	36	18%	
	Hockey	5	2%	
	Others	112	55%	

Descriptive Analysis

Descriptive statistical analysis was conducted to examine the average responses of participants regarding the study variables. The mean values of all constructs ranged between 4.23 and 4.45, indicating a high degree of agreement among respondents concerning the adoption of green manufacturing practices and environmental sustainability measures. Environmental sustainability recorded the highest mean score, demonstrating that most respondents perceive their organizations to be actively engaged in environmentally sustainable practices. Waste management initiatives and energy

conservation practices also exhibited high mean values, suggesting that these areas receive considerable organizational attention.

Environmentally responsible supply chain practices recorded the lowest mean among the independent variables; however, the score remained above 4.0, indicating that respondents still positively perceived their firms' efforts toward sustainable supply chain management. The relatively lower mean may suggest that while firms have adopted internal sustainability practices, supply chain integration remains comparatively less developed. Overall, the descriptive findings indicate that green manufacturing practices are generally well recognized and positively implemented across sports goods manufacturing firms.

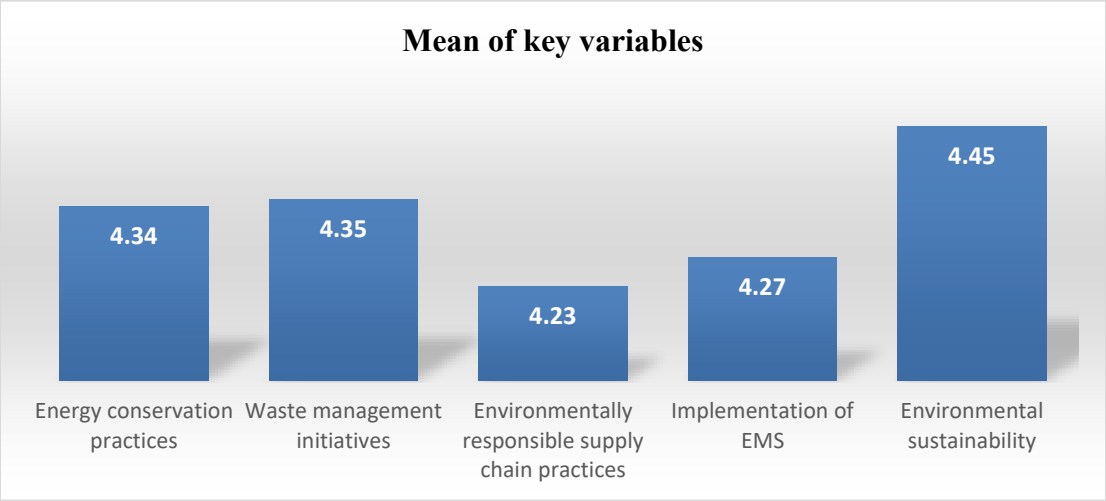

Figure 3 Graphical Summary of Key Variables

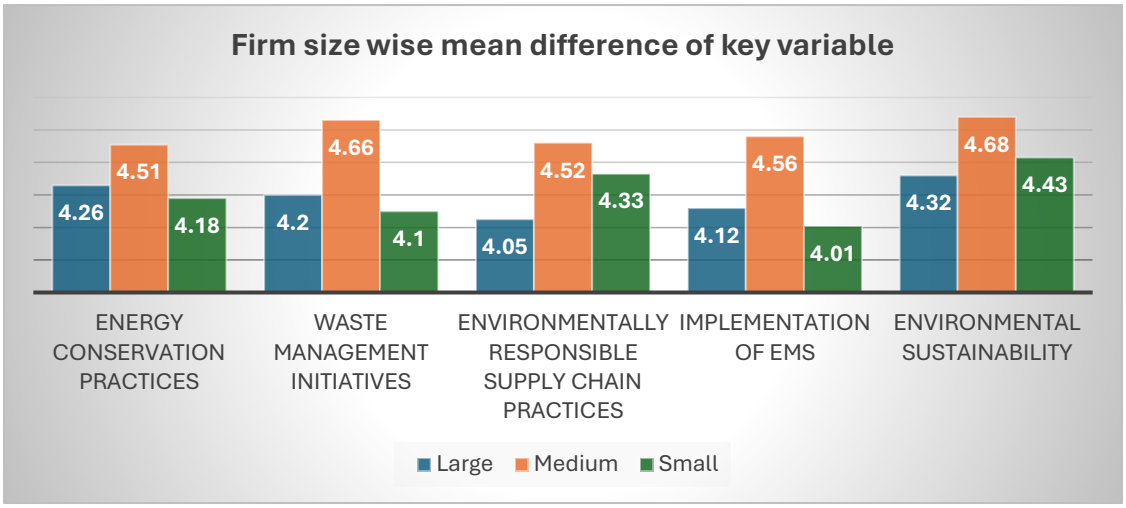

Figure 4 Firm Size Wise Key Variable Mean Value

Reliability Analysis

Reliability analysis was performed using Cronbach's Alpha to assess the internal consistency of the questionnaire items. The overall Cronbach's Alpha value of 0.9403 indicates excellent reliability and confirms that the research instrument is highly consistent in measuring the intended constructs. In addition, all individual constructs exceeded the minimum acceptable threshold of 0.70, demonstrating satisfactory internal reliability for each study variable.

Specifically, energy conservation practices showed a Cronbach's Alpha of 0.9031, waste management initiatives demonstrated 0.9262, environmentally responsible supply chain practices yielded 0.9201, and implementation of EMS showed 0.8470, and environmental sustainability recorded 0.9424. These values indicate that the questionnaire items effectively captured respondents' perceptions and that the measurement instrument is statistically dependable for further inferential analysis.

Table 2 Reliability Analysis of Responses

Key Variables	Cronbach's Alpha	Number of items
Overall	0.9403	203
Energy conservation practices	0.9031	203
Waste management initiatives	0.9262	203
Environmentally responsible supply chain practices	0.9201	203
Implementation of EMS	0.847	203
Environmental sustainability	0.9424	203

1.1. Correlation Analysis

Pearson correlation analysis was conducted to determine the strength and direction of the relationships between green manufacturing dimensions and environmental sustainability. The results revealed significant positive correlations between all independent variables and the dependent variable, confirming that stronger implementation of green manufacturing practices is associated with higher environmental sustainability. Energy conservation practices exhibited a strong positive correlation with environmental sustainability (r =

0.708), suggesting that firms implementing effective energy-saving measures tend to achieve better sustainability outcomes. Waste management initiatives demonstrated a moderate-to-strong positive correlation (r = 0.559), indicating that improved waste reduction and recycling practices contribute positively to environmental sustainability.

Environmentally responsible supply chain practices showed a strong positive correlation (r = 0.746), indicating that firms integrating sustainability into procurement, logistics, and supplier relationships tend to perform better environmentally. EMS implementation exhibited the strongest positive correlation (r = 0.813), highlighting the importance of structured environmental systems in enhancing sustainability performance. These findings support the theoretical expectation that environmental sustainability improves as organizations adopt stronger green manufacturing strategies.

Table 3 Correlation Analysis of Key Variables

	Energy conservation practices	waste management initiatives	Environment responsible supply	EMS implementation	Environmental sustainability
Energy conservation practices	1				
waste management initiatives	0.677	1			
Environmentally responsible supply	0.604	0.514	1		
EMS implementation	0.679	0.627	0.695	1	
Environmental sustainability	0.708	0.559	0.746	0.813	1

1.2. Regression Analysis

Multiple regression analysis was conducted to assess the predictive influence of green manufacturing dimensions on environmental sustainability. The regression model demonstrated strong explanatory power, with an R^2 value of 0.74, indicating that 74% of the variance in environmental sustainability is explained by the selected independent

variables. This reflects a highly robust model and suggests that the predictors included are effective determinants of sustainability performance in sports goods manufacturing firms.

Energy conservation practices showed a statistically significant positive impact on environmental sustainability ($\beta = 0.2528$, $p < 0.001$), confirming that firms that optimize energy usage and implement conservation technologies improve their environmental performance. Environmentally responsible supply chain practices also demonstrated a significant positive effect ($\beta = 0.2338$, $p < 0.001$), indicating that sustainability initiatives beyond internal operations are important contributors to overall environmental performance. Implementation of EMS was found to be the strongest predictor of environmental sustainability ($\beta = 0.4266$, $p < 0.001$), suggesting that firms adopting structured environmental policies and management systems achieve superior sustainability outcomes. However, waste management initiatives did not demonstrate a statistically significant independent effect on the overall regression model ($\beta = -0.0518$, $p = 0.267$). Although waste management showed positive correlation with sustainability, its non-significant regression coefficient suggests that its effect may overlap with other broader environmental strategies and may not independently predict sustainability when all variables are considered simultaneously.

1.3. Regression Equation

$$\begin{aligned}\text{Environmental Sustainability} &= 0.753 + 0.2528\ energy\ conservation\ practices \\ &- 0.0518\ waste\ management\ initiatives \\ &+ 0.2338\ environment\ responsible\ supply \\ &+ + 0.4266\ EMS\ implementation\end{aligned}$$

Table 4 Regression Analysis

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.753	0.176	4.28	0.000	
energy conservation practices	0.2528	0.0576	4.39	0.000	2.41
waste management initiatives	-0.0518	0.0466	-1.11	0.267	2.04
environment responsible supply	0.2338	0.0404	5.79	0.000	2.07
EMS implementation	0.4266	0.0513	8.31	0.000	2.61

S	R-sq	R-sq(adj)	R-sq (pred)
0.267491	0.74	0.74	0.73

Table 5 Regression Analysis Model Summary

1.4. Discussion of Findings

The findings of this study provide strong empirical support for the hypothesis that green manufacturing practices positively influence environmental sustainability in sports goods manufacturing firms. The positive relationship between energy conservation practices and environmental sustainability suggests that firms adopting energy-efficient machinery, optimized production schedules, and reduced energy consumption strategies are better positioned to lower emissions and conserve resources. These findings align with previous sustainability research indicating that energy efficiency is a key driver of environmental performance in manufacturing industries.

Similarly, environmentally responsible supply chain practices emerged as a significant contributor to environmental sustainability. This indicates that firms extending sustainability beyond internal manufacturing operations and integrating environmental responsibility into procurement, supplier management, and logistics systems are more likely to achieve superior sustainability outcomes. Given the export-oriented nature of Sialkot's sports goods industry, this finding reflects the increasing pressure of international buyers and global market standards on firms to implement sustainable supply chain practices.

The strongest impact was observed for implementation of EMS, emphasizing the critical role of formal environmental management frameworks in improving sustainability performance. Firms that establish structured environmental policies, monitoring mechanisms, compliance systems, and sustainability targets are more capable of controlling environmental impacts and continuously improving operational sustainability. Although waste management initiatives did not emerge as an independent predictor in regression analysis, their positive correlation suggests that waste reduction and recycling remain important supportive practices. It is likely that waste management contributes more effectively when integrated within broader environmental management systems rather than functioning as an isolated initiative.

Practical Implications

The results of this study provide important implications for industrial practitioners, managers, and policymakers. Manufacturing managers should prioritize investment in environmental management systems and sustainable supply chain integration, as these were identified as the strongest predictors of sustainability performance. Policymakers

should encourage adoption of environmental certification systems and provide incentives for firms implementing structured sustainability frameworks. Additionally, industry stakeholders should continue promoting energy conservation awareness and technological upgrades to improve energy efficiency across manufacturing operations. These actions will help sports goods manufacturers meet international environmental standards and maintain competitiveness in export markets.

Conclusion

This study examined the impact of green manufacturing practices on environmental sustainability in sports goods manufacturing firms in Sialkot, Pakistan. The findings indicate that green manufacturing practices significantly improve environmental sustainability by enhancing resource efficiency, reducing waste, lowering emissions, and promoting environmentally responsible production systems. Specifically, energy conservation practices, waste management initiatives, environmentally responsible supply chain practices, and implementation of environmental management systems were all found to positively influence environmental sustainability.

Among these factors, environmental management systems and environmentally responsible supply chain practices demonstrated the strongest contribution toward sustainable manufacturing performance. The study highlights the importance of adopting structured green manufacturing strategies for improving environmental performance and maintaining competitiveness in export-oriented manufacturing industries. Overall, the findings suggest that green manufacturing is an essential approach for achieving sustainable industrial development in the sports goods sector. This study opens pathways for future research to explore additional green manufacturing dimensions and broader industrial applications to further advance sustainability practices in emerging economies.

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