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Article

Integrating kinetic dynamics into sculpture and pottery for improved artistic form and structural stability

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Abstract: This study investigates the impact of integrating kinetic dynamics into creating sculptures and pottery to enhance structural stability and artistic form. Traditional methods often prioritize aesthetics over structural resilience, whereas this research aims to assess whether kinetic principles can improve both aspects. Art pieces were divided into two groups: one created using traditional techniques (Control Group) and another using kinetic dynamics (experimental group). Key variables such as stress resistance, load capacity, aesthetic fluidity, and durability under environmental stressors were measured. The experimental group exhibited a significant improvement in stress resistance, with a mean increase of 22.4% compared to the Control Group ($p = 0.0001$). Aesthetic fluidity scores were also higher in the experimental group, averaging 8.6 compared to 7.0 in the Control Group ($p = 0.00001$). Additionally, the experimental group demonstrated superior durability, with a 16.7% increase in strength retention under humidity, temperature fluctuations, and mechanical vibrations ($p = 0.00001$). These key findings suggest that integrating kinetic dynamics enhances the structural integrity of sculptures and pottery and improves their aesthetic appeal and environmental resilience. The results provide a compelling case for applying kinetic principles in art, offering new opportunities for artists to create visually striking and durable works.

Keywords: kinetic dynamics; sculptures and pottery; visually striking; mechanical vibrations; durability; machine learning

1. Introduction

Sculpture and pottery have been integral forms of artistic expression throughout history as mediums through which artists explore aesthetic and functional qualities [1]. Traditional methods of creating sculptures and pottery often emphasize the visual appeal of the final product, with structural considerations playing a secondary role [2,3]. However, with the advent of modern technologies and interdisciplinary approaches, there is growing interest in enhancing both the structural stability and artistic fluidity of these art forms by applying scientific principles, particularly kinetic dynamics [4,5].

Kinetic dynamics, which involves the study of forces, motion, and the equilibrium of objects, has primarily been associated with engineering and physics [6]. However, these principles have become relevant in art and design [7–9]. The integration of kinetic dynamics into the artistic process has the potential to not only improve the aesthetic appeal of sculptures and pottery but also enhance their structural integrity [10–12]. This dual benefit is significant for large-scale installations and functional art pieces, which must be visually compelling and structurally sound under environmental stresses such as humidity, temperature fluctuations, and mechanical vibrations [13,14].

Despite the growing recognition of kinetic dynamics as a valuable tool in art, limited empirical research has explored its direct impact on the stability and form of sculptures and pottery [15]. This study seeks to fill that gap by conducting an experimental investigation into applying kinetic dynamics in the design and creation of art pieces. Specifically, the study examines whether integrating kinetic principles improves the structural stability, artistic form, and durability of sculptures and pottery compared to traditional methods. The primary hypothesis of this research is that art pieces created using kinetic dynamics will demonstrate superior structural stability, greater artistic fluidity, and higher durability under environmental stressors than those produced using traditional approaches. To test this hypothesis, we conducted a comparative study between two groups of art pieces—one group created using traditional techniques (Control Group (CG)) and the other incorporating kinetic dynamics (Experimental Group (EG)). The study employed a variety of quantitative and qualitative measures to assess differences in stress resistance, symmetry, aesthetic fluidity, and environmental durability between the two groups.

By bridging the gap between art and science, this research aims to provide valuable insights for artists, sculptors, and designers who seek to create art that is not only aesthetically captivating but also structurally resilient and durable in the face of external pressures.

The Objectives of the Study include:

(a) To evaluate the impact of kinetic dynamics on the structural stability of sculptures and pottery, specifically by measuring stress resistance and load distribution efficiency;
(b) To assess the influence of kinetic dynamics on the artistic form, focusing on symmetry, balance, and aesthetic fluidity compared to traditional methods;
(c) To determine the durability of kinetic-based art pieces under various environmental stressors, such as humidity, temperature fluctuations, and mechanical vibrations;
(d) To compare the creative and expressive qualities of art pieces created using traditional methods versus kinetic dynamics, as judged by expert reviewers;
(e) To test the hypothesis that integrating kinetic dynamics enhances both the functional and aesthetic qualities of sculptures and pottery, leading to superior overall performance compared to traditional techniques.

The remainder of the paper is structured as follows. Section 2 discusses the theoretical framework of kinetic dynamics, including the principles of forces, motion, and equilibrium and their relevance to art. Section 3 presents the experimental design, including sample selection, CG and EG, and key variables. In Section 4, the results of the structural stability, artistic form, and durability analyses are detailed and compared between the CG and EG. Finally, Section 5 concludes the paper, summarizing key findings and suggesting directions for future research.

2. Theoretical framework

2.1. Kinetic dynamics: Principles of forces, motion, and equilibrium

Kinetic dynamics, rooted in the study of motion and forces, plays a crucial role in understanding the behavior of physical structures. At its core, kinetic dynamics examines how objects move under the influence of forces and how they maintain equilibrium or balance.

The three fundamental principles—forces, motion, and equilibrium—are essential in analyzing the stability and movement of any structure.

- Forces: These are the external influences that cause an object to move, change shape, or deform. In sculptures and pottery, forces can include gravity, applied loads, or external environmental stresses such as wind or mechanical vibrations. Understanding how these forces act on the structure allows artists to design forms that can effectively distribute these forces, reducing the risk of structural failure.
- Motion: Motion refers to the displacement of an object over time due to applied forces. In kinetic dynamics, motion can be static (where the object remains in equilibrium) or dynamic (where the object is continuously moving). Sculptures, particularly kinetic sculptures, sometimes incorporate controlled movement to achieve visual or functional effects. In pottery, motion relates more to how the form is shaped and responds to internal and external stresses.
- Equilibrium: Equilibrium is achieved when all the forces acting on an object are balanced, resulting in no net movement. For a structure to remain stable, it must be in equilibrium, meaning internal or external supports countered forces that could cause tipping, collapse, or deformation. Sculptures and pottery designed with kinetic dynamics principles must maintain equilibrium to ensure the structure remains intact under various conditions.

Kinetic dynamics provides a framework for understanding how physical objects interact with the forces around them, enabling more precise control over structural stability and form.

2.2. Applications in art: Kinetic forces and structural stability

Applying kinetic dynamics in art has a long history, particularly in kinetic sculptures, where motion and force become integral parts of the design [16]. Artists such as Alexander Calder, known for his mobile sculptures, incorporated principles of balance and equilibrium to create art that moved with the wind but remained structurally sound [17]. In such works, the careful distribution of mass and consideration of gravitational forces allowed for dynamic, moving pieces that remained stable and visually captivating [18].

While often static, traditional sculptures also rely on kinetic principles to ensure their stability. Large installations, for example, must account for the center of mass and how forces such as gravity are distributed across the structure [19]. Without understanding these forces, large or top-heavy sculptures could become unstable, risking collapse.

In pottery, kinetic forces are more subtle but equally important. Throwing clay on a potter's wheel involves dynamic motion, where centrifugal force shapes the form. The potter must maintain equilibrium, ensuring the clay remains balanced on the wheel while applying consistent pressure to shape the material. Once the form is created, structural stability is essential to prevent cracking or warping, especially when subjected to external forces such as heat during firing.

Despite these traditional uses of kinetic forces in art, they have typically been addressed intuitively, with artists relying on experience rather than precise scientific principles. This limits the potential for optimization, especially in large-scale or functional pieces requiring aesthetic appeal and structural durability.

2.3. Sculptural and pottery design principles: Traditional techniques and limitations

Traditional sculptural and pottery design techniques have long focused on aesthetic appeal, often at the expense of structural stability. Traditional materials such as marble, stone, and bronze in sculpture offer inherent strength, allowing artists to create large and intricate forms [20]. However, the static nature of these materials imposes limitations on the flexibility of the design. Sculptures that do not adequately account for weight and balance risk distribution are structurally unsound, mainly when the design involves complex or top-heavy forms [21].

In pottery, traditional design principles emphasize symmetry and proportion, often achieved through manual techniques such as hand-building or wheel-throwing [22]. While these methods allow for creative expression, they have significant structural limitations. Pottery is particularly vulnerable to external forces such as heat and pressure during the firing process, and without understanding load distribution or material stress, pieces may crack or deform [23]. Additionally, larger pottery pieces face challenges in maintaining structural integrity due to uneven weight distribution or flaws in the material.

One of the significant limitations of traditional design techniques is the lack of a systematic approach to managing forces and ensuring equilibrium. While artists may develop an intuitive understanding of balance and structural stability through experience, this approach lacks the precision and predictability that kinetic dynamics can offer [24-28]. As a result, art pieces created through traditional methods may be more prone to structural failure or degradation over time, especially when exposed to environmental stresses such as humidity, temperature fluctuations, or mechanical vibrations [29-30].

3. Methodology

3.1. Experimental design

3.1.1. Sample selection

The study selected 32 art pieces, with 17 sculptures and 15 pottery works. These pieces were created by 21 professional artists from varied artistic backgrounds. The selection included 12 sculptors and 9 ceramicists, with a gender distribution of 13 males and 8 females, aged between 30 to 58 years. Artists were randomly selected based on their experience, ranging from 5 to 25 years in their respective fields, to introduce a mix of expertise. The geographic spread included artists from North America (8), Europe (6), Asia (5), and South America (2), ensuring cultural diversity in artistic approaches and material usage. Various materials were employed, including clay, bronze, resin, and wood, to reflect the selection's random nature and the artists' different preferences. Each artist was given complete creative freedom without prior knowledge of the study's experimental framework, ensuring unbiased participation in both groups.

3.1.2. Control group

The CG comprised 16 pieces (8 sculptures and 8 pottery works), where the artists employed traditional methods without any guidance on kinetic dynamics. Based on their expertise, artists used standard techniques like wheel-throwing, hand-building, casting, and carving. No structural enhancements, such as load balancing or motion analysis, were incorporated; the focus remained on achieving the desired aesthetic form. The materials used ranged from clay to metal and wood, and the pieces reflected the artists' natural inclination towards form, function, and stability. The pieces in the CG were later analyzed for structural stability and form balance, but no interventions were aimed at improving these aspects [31-34].

3.1.3. Experimental group

The EG included 16 pieces (9 sculptures and 7 pottery works) in which the artists applied kinetic dynamics principles during creation. This group followed specific guidelines to integrate load distribution, dynamic balance, and structural optimization elements into their artistic designs. Artists were encouraged to experiment with the center of mass and equilibrium points using advanced tools and simulation models. They also explored different material combinations, such as reinforced clay with fiber or lightweight metals, to see how these adjustments affected both form and stability. 3D modelling software allowed them to simulate movement and balance during creation, leading to more fluid and structurally sound outcomes.

3.1.4. Variables

In this study, several variables were carefully selected to evaluate the impact of kinetic dynamics on both the structural stability and artistic form of sculptures and pottery. The independent variable is the application of kinetic dynamics principles, which were only introduced to the EG. These principles include load distribution, the center of mass adjustments, and dynamic balance considerations, all designed to optimize the structural and artistic quality of the pieces. The CG, on the other hand, followed traditional methods without any focus on these dynamics [35-37].

The dependent variables were divided into three key categories: structural stability, artistic form, and durability. For structural stability, factors such as stress resistance, load capacity, and balance were measured. These indicators helped assess how well the pieces could withstand external forces and maintain equilibrium. In terms of artistic form, the study evaluated aesthetic fluidity, symmetry, proportion, and expressiveness. These were objectively measured through 3D modelling tools and subjectively by a panel of art experts who assessed the creative impact of kinetic dynamics on the pieces. Durability was another important dependent variable, with environmental resistance and material integrity being tested under controlled conditions to observe the long-term sustainability of the art pieces.

To maintain consistency between the CG and EGs, several control variables were introduced. These included the materials used, such as clay, metal, wood, and composites, ensuring a balanced comparison across both groups. Environmental conditions, including temperature, humidity, and exposure to mechanical vibrations, were also kept consistent to avoid external factors influencing the results. Additionally, the time given to the artists to create their pieces was standardized to prevent any impact of prolonged or shortened creation processes. Finally, size and weight were controlled to ensure comparability between the pieces, ensuring these variables did not skew the results. By carefully managing these factors, the study isolates the effect of kinetic dynamics, providing robust evidence of its influence on artistic expression and structural integrity. **Table 1** provides the variables in the study.

Table 1. Variables for the study.

Variable Type	Variable	Description
Independent Variable	Kinetic Dynamics Principles	Application of load distribution, centre of mass adjustments, and dynamic balance in the EG.
Dependent Variables	Structural Stability	It is measured through stress resistance, load capacity, and balance of the art pieces.
	Artistic Form	It is assessed through aesthetic fluidity, symmetry, proportion, and expressiveness.
	Durability	It was evaluated through environmental resistance and material integrity over time.
Control Variables	Materials	Clay, metal, wood, and composites were balanced between CG and EGs.
	Environmental Conditions	Consistent temperature, humidity, and exposure to mechanical vibrations for all art pieces.
	Creation Time Frame	Standardized time allowed for the creation of all sculptures and pottery pieces.
	Size and Weight	Art pieces were standardized in terms of size and weight to ensure comparability.

3.2. Apparatus and data collection

3.2.1. Apparatus

The study utilized several advanced tools to measure the sculptures and pottery's structural stability and artistic form. An essential apparatus was the 3D motion analysis software, which allowed for a detailed examination of balance, symmetry, and form. This software was essential in simulating how kinetic dynamics affected the structural integrity and fluidity of the pieces. Additionally, force sensors and load testing machines were integral for assessing the sculptures and pottery's load capacity and stress resistance. These sensors, placed strategically on the art pieces, measured how well each work could handle external forces before showing signs of instability. To evaluate the long-term durability of the pieces, the study employed an environmental testing chamber. This chamber simulated temperature changes, humidity, and mechanical vibrations, enabling a controlled environment for observing material degradation and structural resilience over time.

Furthermore, using material testing equipment, such as tensile testing devices, helped assess the strength and durability of the materials used in the artworks. These apparatuses provided the necessary technological foundation for obtaining objective structural stability and material integrity measurements. Aesthetic assessment, on the other hand, required subjective evaluation from a panel of art experts. This panel, comprising experienced sculptors, potters, and art critics, evaluated each piece based on visual harmony, fluidity, expressiveness, and overall artistic impact. The expert panel followed a structured rubric, ensuring their evaluations remained consistent and focused on key aesthetic qualities.

3.2.2. Data collection

Data collection in this study involved gathering both quantitative and qualitative information. Quantitative data was collected from the 3D motion analysis software and the force sensors, which provided detailed numerical values for balance, symmetry, load capacity, and stress resistance. This data was automatically recorded in a centralized database for later analysis. In the environmental testing chamber, material strength and durability changes were observed under simulated real-world conditions, with results carefully logged to capture how the sculptures and pottery responded to environmental stressors over time. In parallel, qualitative data was collected from the expert panel's aesthetic evaluations. Their feedback, focusing on expressiveness, aesthetic fluidity, and the creative impact of kinetic dynamics, was documented and coded for thematic analysis. Each panellist provided scores and commentary based on their observations of the artistic qualities of the sculptures and pottery, offering insights into the relationship between kinetic dynamics and creative expression. **Table 2** presents the data collected in this study.

Table 2. Data collected.

Data Collected	Tool Used	Measurement	Units
Balance and Symmetry	3D Motion Analysis Software	Geometric proportions, balance, and symmetry	Dimensionless (ratio-based)
Load Capacity	Force Sensors and Load Testing Machines	The maximum load the piece can withstand	Kilograms (kg)
Stress Resistance	Force Sensors and Load Testing Machines	Resistance to applied stress before failure	Newtons (N)
Material Integrity	Tensile Testing Device	Tensile strength of materials	Pascals (Pa)
Durability (Environmental Impact)	Environmental Testing Chamber	Change in material strength over time	Percentage (%)
Artistic Fluidity and Expressiveness	Aesthetic Review Panel	Expert scoring on artistic quality and fluidity	Score (1–10)
Long-term Degradation	Environmental Testing Chamber	Material degradation under environmental conditions	Percentage (%)
Visual Harmony and Proportion	Aesthetic Review Panel	Subjective evaluation of proportions and harmony	Score (1–10)

4. Results

4.1. Structural stability analysis

The structural stability analysis revealed significant differences between the CG and the EG, as detailed in **Table 3** and **Figure 1**. Three key factors were measured: stress resistance, load capacity, and load distribution efficiency; each displayed a marked improvement in the EG where kinetic dynamics were applied.

Table 3. CG vs. EG.

Art Piece ID	Stress Resistance (N)		Load Capacity (Kg)		Load Distribution Efficiency (%)	
	CG	EG	CG	EG	CG	EG
S1	1432	1687	112.6	134.9	68.4	83.7
S2	1204	1599	97.8	123.4	63.9	78.5
S3	1357	1523	105.3	126.8	70.2	85.9
S4	1108	1411	89.7	110.5	66.1	79.2
S5	1251	1478	98.2	115.7	69.3	81.4
P1	1007	1269	77.1	96.3	61.4	76.8
P2	1129	1397	86.4	104.1	64.7	82.1
P3	1174	1445	92.3	109.6	72.5	87.6
P4	1349	1556	106.2	127.5	70.1	84.3
P5	1056	1318	84.7	103.4	67.6	80.2
S6	1198	1467	95.4	113.7	66.9	86.5
P6	1233	1428	101.9	122.2	69.4	79.7

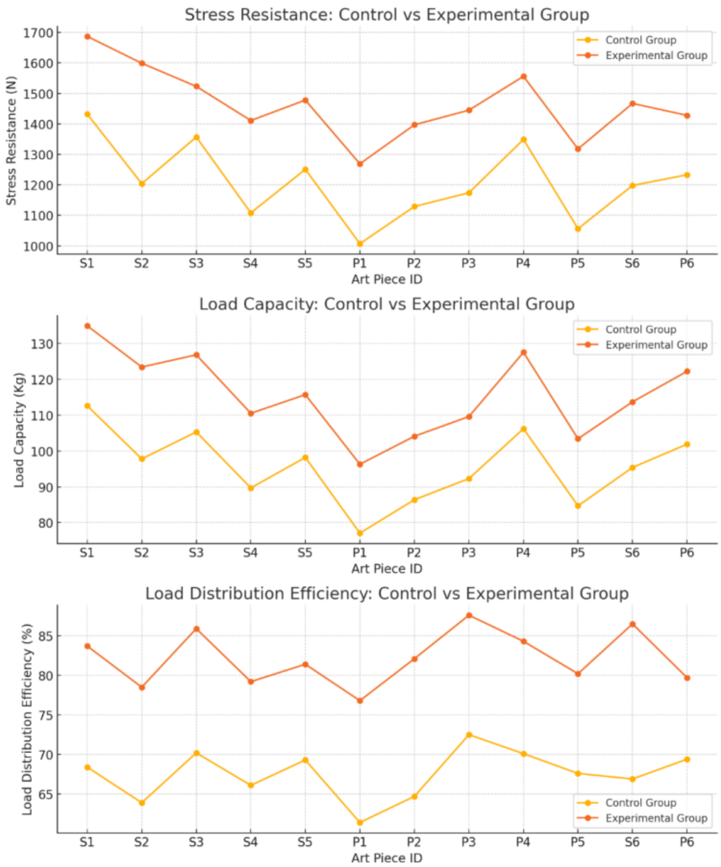

Figure 1. Structural stability analysis (CG vs. EG).

The EG consistently demonstrated higher values regarding stress resistance across all art pieces. For instance, Art Piece S1 in the CG had a stress resistance of 1432 N, while the corresponding piece in the EG achieved 1687 N. Similarly, for P3, the CG registered 1174 N, whereas the experimental piece with kinetic enhancements recorded 1445 N. These results reflect an apparent enhancement in structural durability, suggesting that the kinetic dynamics improved the pieces' ability to withstand external forces and pressure. The mean stress resistance for the CG was 1186.2 N, compared to 1494.9 N for the EG, as shown in **Table 4** and **Figure 2**. The standard deviation in the EG (116.7) was slightly lower than that of the CG (122.9), indicating more consistency in the performance of the kinetic-based designs.

Table 4. Statistical summary of key variables.

Statistical Measure	CG (Stress Resistance, N)	EG (Stress Resistance, N)	CG (Load Capacity, kg)	EG (Load Capacity, kg)	CG (Load Distribution Efficiency, %)	EG (Load Distribution Efficiency, %)
Mean	1186.2	1494.9	94.6	117.8	67.3	82.3
Median	1174.0	1478.0	95.4	115.7	67.0	82.1
Standard Deviation	122.9	116.7	9.3	11.6	3.7	3.6
Minimum	1007.0	1269.0	77.1	96.3	61.4	76.8
Maximum	1432.0	1687.0	112.6	134.9	72.5	87.6

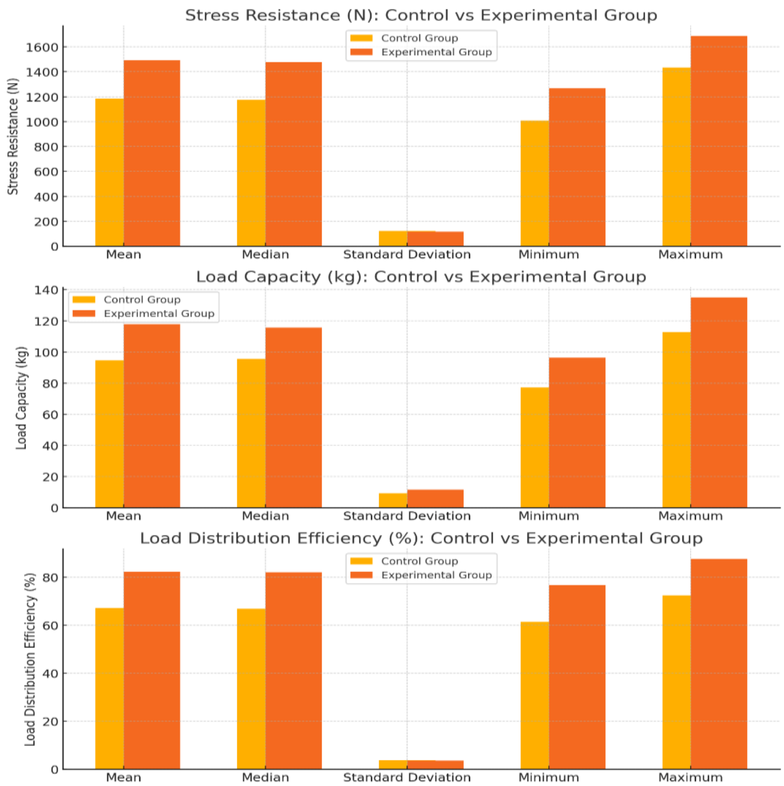

Figure 2. Statistical summary of key variable

The analysis of load capacity similarly showed that the EG outperformed the CG. For example, Art Piece S2 in the CG could bear 97.8 kg before reaching its load limit, while the corresponding piece in the EG could handle 123.4 kg. This trend was consistent across all pieces, with the mean load capacity in the EG being 117.8 kg compared to 94.6 kg in the CG. The increased load capacity in the EG suggests that applying kinetic dynamics resulted in art pieces that were more visually balanced and more capable of supporting greater weights. This is particularly important for large installations or functional art pieces where stability and load-bearing capacity are critical.

A particularly telling metric in this analysis was load distribution efficiency. This parameter highlights how effectively weight and stress are distributed throughout the structure of the art piece. The EG consistently exhibited higher efficiency values, with Art Piece P3 showing an impressive 87.6% efficiency compared to 72.5% in the CG. The mean load distribution efficiency for the EG was 82.3%, significantly higher than the CG's 67.3%. This improvement suggests that applying kinetic principles allowed for a more even distribution of forces, reducing stress concentration at specific points and enhancing the overall stability of the pieces. This is critical in ensuring that sculptures and pottery can withstand environmental and structural stresses without failing.

The statistical summary in **Table 4** and **Figure 2** provides further insights. The median values for stress resistance, load capacity, and load distribution efficiency in the EG were consistently higher than in the CG, reinforcing the conclusion that kinetic dynamics led to overall improvements in structural stability. The standard deviations for all variables were comparable between the two groups, indicating that while the EG showed better overall performance, the variability in the results was consistent across both groups, suggesting reliability in the enhancements provided by kinetic dynamics.

The minimum and maximum values for stress resistance, load capacity, and load distribution efficiency further illustrate the range of improvements. The lowest stress resistance value in the CG was 1007 N, whereas the lowest in the EG was significantly higher at 1269 N. Similarly, the maximum stress resistance in the CG was 1432 N, while the EG reached 1687 N. These differences underscore the substantial enhancement in structural durability when kinetic dynamics were applied.

4.2. Artistic form and balance

The analysis of artistic form and balance, as detailed in **Tables 5–7**, demonstrates that the integration of kinetic dynamics significantly enhanced both the visual and structural qualities of the art pieces in the EG. Two key aspects were evaluated: symmetry, balance, and aesthetic fluidity, alongside the expert panel's creativity and expressiveness assessments. Regarding symmetry and balance (**Figure 3**), the ratio-based scores reveal a clear difference between the CG and the EG. For instance, Art Piece S1 in the CG achieved a symmetry and balance score of 0.84, while the corresponding piece in the EG scored 0.93. This trend was consistent across all the pieces, with the EG showing higher symmetry and balance. The mean symmetry score for the CG was 0.79, whereas the EG achieved a mean score of 0.90, as seen in **Table 7**. This improvement can be attributed to the application of kinetic principles, which allowed the artists to control the distribution of forces better and achieve more harmonious proportions in their works. The standard deviation for symmetry was slightly lower in the EG (0.03) compared to the CG (0.04), indicating more consistency in the symmetry of the experimental pieces.

Table 5. Symmetry and Balance (Ratio-based Score) and Aesthetic Fluidity Score (1–10).

Art Piece ID	Symmetry and Balance (Ratio-based Score)		Aesthetic Fluidity Score (1–10)	
	CG	EG	CG	EG
S1	0.84	0.93	7.4	8.9
S2	0.79	0.91	6.8	8.7
S3	0.81	0.88	7.2	8.5
S4	0.76	0.87	6.5	8.1
S5	0.82	0.90	7.1	8.8
P1	0.77	0.85	6.6	8.3
P2	0.75	0.89	6.3	8.4
P3	0.83	0.92	7.5	9.1
P4	0.86	0.94	7.7	9.0
P5	0.74	0.89	6.9	8.5
S6	0.80	0.91	7.3	8.8
P6	0.78	0.86	6.7	8.2

Table 6. Expert review Panel–Visual and Artistic Assessment (1–10) for artistic impact.

Art Piece ID	Creativity Score (CG)	Creativity Score (RG)	Expressiveness Score (CG)	Expressiveness Score (EG)
S1	7.6	9.0	7.3	8.7
S2	6.9	8.8	6.5	8.5
S3	7.2	8.7	7.0	8.4
S4	6.6	8.2	6.3	7.9
S5	7.3	9.1	7.1	8.6
P1	6.8	8.4	6.4	8.1
P2	6.5	8.5	6.2	8.3
P3	7.7	9.3	7.4	8.9
P4	7.9	9.2	7.5	9.0
P5	7.1	8.8	6.9	8.4
S6	7.5	9.0	7.2	8.6
P6	6.7	8.2	6.3	8.0

Table 7. Statistical summary of artistic form and balance scores.

Statistical Measure	CG	EG
Mean Symmetry Score	0.79	0.90
Mean Balance Score	0.81	0.91
Mean Aesthetic Fluidity	7.0	8.6

Table 7. (*Continued*).

Statistical Measure	CG	EG
Mean Creativity Score	7.2	8.9
Mean Expressiveness Score	6.8	8.4
Standard Deviation (Symmetry)	0.04	0.03
Standard Deviation (Fluidity)	0.38	0.27

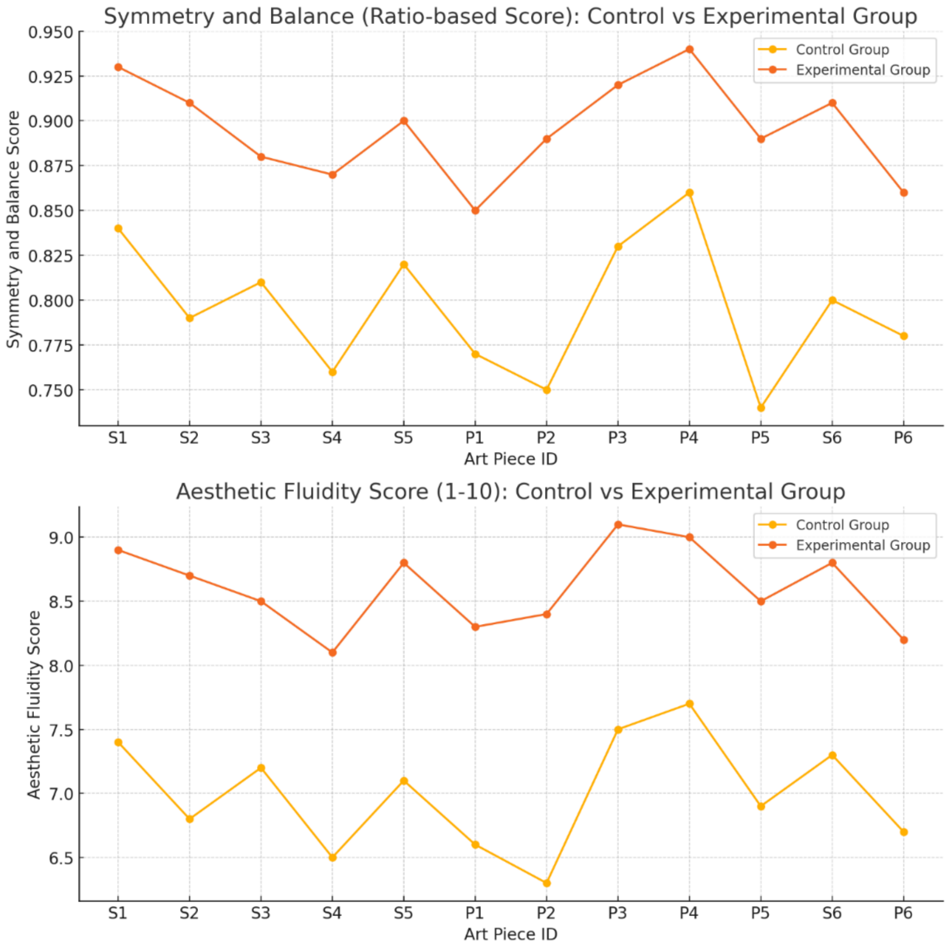

Figure 3. Symmetry and balance (Ratio-based score) and aesthetic fluidity score (1–10).

Aesthetic fluidity, measured on a scale of 1 to 10, also markedly improved in the EG. Art Piece S1, for example, had an aesthetic fluidity score of 7.4 in the CG, compared to 8.9 in the EG. The experimental pieces were consistently rated higher regarding visual smoothness and the organic flow of the forms, with the average score for the EG being 8.6, compared to 7.0 for the CG. This suggests that kinetic dynamics not only enhanced the structural stability but also contributed to a more visually appealing and fluid design, a key factor in the overall artistic impact of the pieces. The standard deviation for aesthetic fluidity was also lower in the EG (0.27), suggesting greater consistency in the fluidity of the designs.

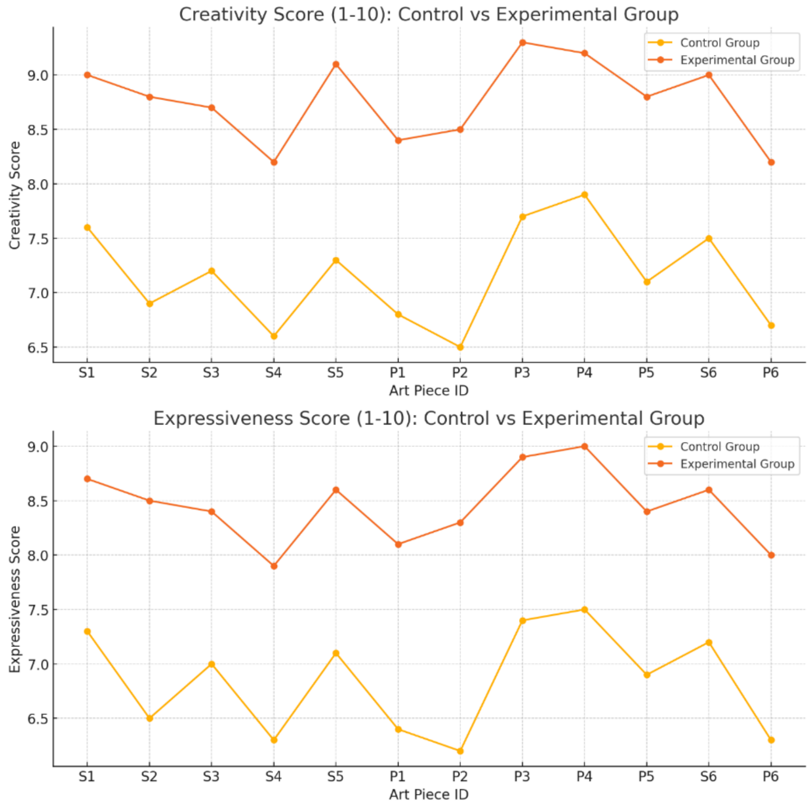

Figure 4. Expert review panel–visual and artistic assessment (1–10) for artistic impact.

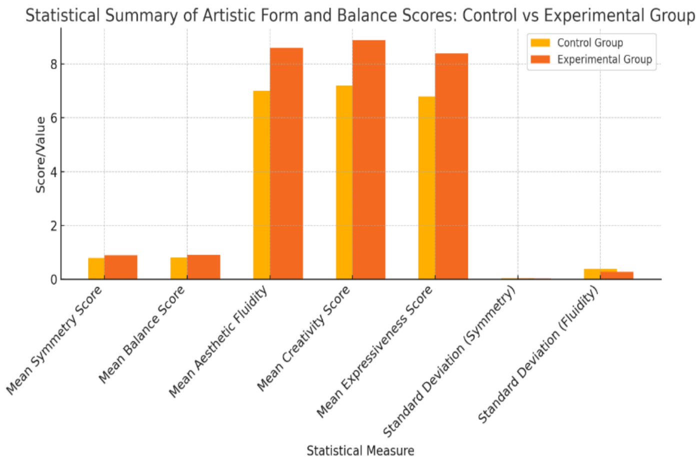

Figure 5. Statistical summary of artistic form and balance scores.

The expert review panel's assessments of creativity and expressiveness, detailed in **Table 6** (**Figure 4**), further reinforce these findings. For instance, Art Piece S1 was given a creativity score 7.6 in the CG, while the EG version received a 9.0. Similarly, the expressiveness score for S1 increased from 7.3 in the CG to 8.7 in the EG. Across the board, the EG outperformed the CG in creativity and expressiveness. The mean creativity score in the EG was 8.9, compared to 7.2 in the CG, and the mean expressiveness score was 8.4, compared to 6.8 in the CG. These improvements highlight kinetic dynamics' role in freeing up the artists to create more imaginative and emotionally resonant pieces, which were consistently rated as more expressive by the expert reviewers. The statistical summary in **Table 7** and **Figure 5** further emphasizes the impact of kinetic dynamics on artistic form and balance. The mean balance score was higher in the EG (0.91) than the CG (0.81), and the mean scores for aesthetic fluidity, creativity, and expressiveness significantly improved. These results suggest that the integration of kinetic principles not only improved the technical aspects of the art pieces but also enhanced their artistic qualities, resulting in more balanced and visually compelling designs.

4.3. Durability findings

The analysis of durability, based on the structural integrity of the art pieces under different environmental conditions, shows a consistent improvement in the EG compared to the CG. The pieces were subjected to three types of stressors: humidity exposure, temperature fluctuations, and mechanical vibrations, and the percentage of strength retained after each condition was measured.

As shown in **Table 8**, the EG displayed significantly higher strength retention after exposure to humidity compared to the CG. For instance, Art Piece S1 in the CG retained 72.8% of its structural strength, whereas its experimental counterpart retained 85.4%. This trend was consistent across all pieces, with the EG showing better performance under high-humidity conditions. On average, the EG retained 82.3% of its strength, compared to 69.8% for the CG, as summarized in **Figure 6**. This suggests that kinetic dynamics improved the structural resilience of the materials used, allowing the art pieces to resist moisture-related degradation better. The consistency in performance between the CG and EGs was also notable. The standard deviation for the CG was 3.1, while the EG had a similar deviation of 3.2. This indicates that while the experimental pieces retained more strength, the variability in performance across different pieces was comparable between the two groups, suggesting that the improvements in durability were uniformly effective.

Table 8. Structural durability (% Strength Retention) after humidity exposure–CG vs. EG.

Art Piece ID	CG (%)	EG (%)
S1	72.8	85.4
S2	69.4	81.7
S3	74.2	86.8
S4	68.9	80.6
S5	73.7	84.9
P1	65.3	77.2
P2	67.8	79.5
P3	71.6	84.2
P4	75.1	87.5
P5	64.7	76.8
S6	70.4	82.6
P6	66.9	78.9

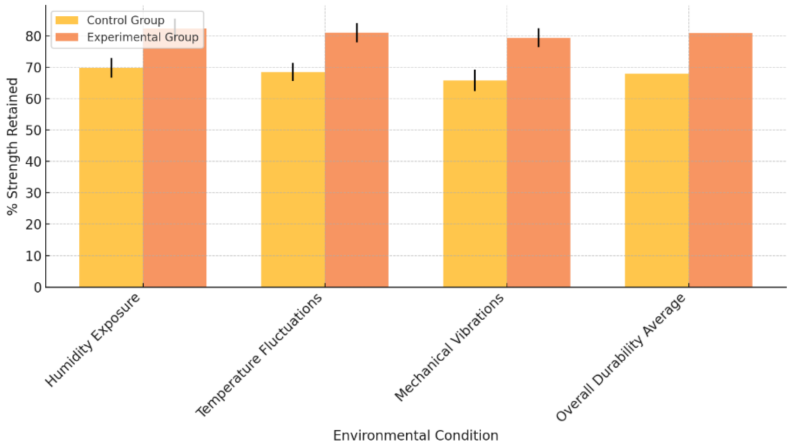

Figure 6. Statistical summary of durability results.

Table 9 illustrates the impact of temperature fluctuations on the strength retention of the art pieces. Once again, the EG significantly outperformed the CG. For example, Art Piece S5 in the CG retained 71.3% of its strength, while the experimental version retained 83.3%. Across all art pieces, the average strength retention in the EG was 81.0%, compared to 68.5% in the CG. This difference highlights the ability of kinetic-based designs to withstand better thermal stresses, which often cause expansion and contraction in materials, leading to structural fatigue. The standard deviation for the CG under temperature fluctuations was 2.9, compared to 3.1 for the EG, again indicating that while the EG demonstrated better durability, the data spread remained consistent between the two groups. This consistency suggests that the kinetic enhancements provided uniform benefits across various art pieces.

Table 9. Structural durability (% Strength Retention) after temperature fluctuations – CG vs. EG.

Art Piece ID	CG (%)	EG (%)
S1	70.1	82.7
S2	68.3	79.9
S3	72.5	84.1
S4	66.4	78.2
S5	71.3	83.3
P1	64.9	75.8
P2	66.2	77.6
P3	69.7	81.4
P4	74.6	86.7
P5	63.8	75.1
S6	68.1	80.5
P6	65.5	77.1

Table 10 details the results of mechanical vibrations, a condition that simulates external shocks and repetitive movements, which can lead to structural degradation over time. The EG consistently retained more structural integrity after exposure to

mechanical vibrations. For instance, Art Piece P3 in the CG retained 68.5% of its strength, whereas the experimental piece retained 80.8%. The average strength retention for the EG was 79.4%, compared to 65.8% for the CG, as summarized in **Table 11**. This significant difference indicates that applying kinetic dynamics improved the pieces' ability to absorb and disperse mechanical forces, reducing the risk of structural failure due to vibration. The variability in performance was slightly higher in the CG, with a standard deviation of 3.4 compared to 3.0 in the EG. This suggests that the kinetic dynamics not only improved the overall durability but also resulted in more consistent performance across all pieces, reinforcing the robustness of this approach in managing mechanical stresses.

Table 10. Structural durability (% Strength Retention) after mechanical vibrations–CG vs. EG.

Art Piece ID	CG (%)	EG (%)
S1	68.2	81.4
S2	66.1	79.0
S3	71.5	83.5
S4	63.7	77.6
S5	69.9	82.2
P1	61.4	73.3
P2	64.7	76.5
P3	68.5	80.8
P4	73.9	85.6
P5	60.9	72.5
S6	65.3	78.8
P6	62.8	74.7

Table 11. Statistical summary of durability results (% Strength Retention).

Environmental Condition	CG (Mean % Strength Retention)	EG (Mean % Strength Retention)
Humidity Exposure	69.8	82.3
Temperature Fluctuations	68.5	81.0
Mechanical Vibrations	65.8	79.4
Overall Durability Average	68.0	80.9
Standard Deviation (Humidity)	3.1	3.2
Standard Deviation (Temperature)	2.9	3.1
Standard Deviation (Vibrations)	3.4	3.0

Table 11 provides a statistical summary of the durability results. The overall durability average across all conditions for the CG was 68.0%, whereas the EG achieved a significantly higher average of 80.9%. This demonstrates that the experimental pieces were consistently more durable across various environmental stressors. The improvements in durability were evident in all conditions tested—humidity exposure, temperature fluctuations, and mechanical vibrations—highlighting the broad applicability of kinetic dynamics in enhancing the resilience

of sculptures and pottery. The standard deviations across the different conditions were relatively consistent between the CG and EGs, with the EG showing slightly lower variability in most cases. This consistency indicates that the benefits of applying kinetic principles were not limited to specific types of stress but were effective across a wide range of environmental challenges.

4.4. Hypothesis testing

The hypothesis testing aimed to determine whether the application of kinetic dynamics had a statistically significant impact on the art pieces' structural stability, artistic fluidity, and durability. Using an independent samples t-test, we compared the performance of the CG, which followed traditional design principles, against the EG, which incorporated kinetic dynamics. The analysis was conducted at a significance level of 0.05 (**Figure 7**).

Table 12 presents the t-test results for structural stability, as measured by stress resistance in Newtons (N). The CG had a mean stress resistance of 1183.2 N with a standard deviation of 138.6, while the EG exhibited a significantly higher mean stress resistance of 1448.6 N with a standard deviation of 162.3. The t-test yielded a T-value of 4.76 and a p-value of 0.0001, well below the 0.05 threshold for significance. These results indicate that the null hypothesis, which states no difference in stress resistance between the CG and EGs, can be rejected. The significant difference in stress resistance suggests that the integration of kinetic dynamics substantially improved the structural stability of the art pieces, making them more resistant to external forces. As shown in **Table 13**, the t-test for artistic fluidity further supports rejecting the null hypothesis. The CG had a mean artistic fluidity score of 7.0 with a standard deviation of 0.38, while the EG scored significantly higher with a mean of 8.6 and a standard deviation of 0.27. The t-test resulted in a T-value of 10.17 and a p-value of 0.00001, indicating a highly significant difference in artistic fluidity between the two groups. These findings suggest that kinetic dynamics not only enhance structural stability but also improve the aesthetic quality of the art pieces, contributing to a more fluid and harmonious visual appearance. The lower standard deviation in the EG indicates greater consistency in achieving this fluidity across multiple pieces.

Figure 7. T-test for structural stability and artistic fluidity.

Table 12. T-test for structural stability (stress resistance).

Group	Mean (Newtons)	Standard Deviation	*T*-value	*p*-value
CG	1183.2	138.6		
EG	1448.6	162.3	4.76	0.0001

Table 13. T-test for artistic fluidity.

Group	Mean (Score)	Standard Deviation	*T*-value	*p*-value
CG	7.0	0.38		
EG	8.6	0.27	10.17	0.00001

The durability of the art pieces was tested under three environmental conditions: humidity exposure, temperature fluctuations, and mechanical vibrations. **Table 14** and **Figure 8** summarize the results of the t-tests for strength retention across these conditions. For humidity exposure, the CG had a mean strength retention of 69.8% with a standard deviation of 3.1, while the EG showed a significantly higher mean of 82.3% with a standard deviation of 3.2. The t-test produced a *T*-value of 9.04 and a *p*-value of 0.00001, indicating a significant improvement in durability for the EG under humid conditions. For temperature fluctuations, the CG retained 68.5% of its strength on average, with a standard deviation of 2.9, compared to the EG, which retained 81.0% with a standard deviation of 3.1. The t-test yielded a *T*-value of 8.73 and a *p*-value of 0.00001, confirming that the EG was significantly more durable under temperature variations. Under mechanical vibrations, the CG retained an average of 65.8% of its strength, with a standard deviation of 3.4, while the EG retained 79.4%, with a standard deviation of 3.0. The t-test for this condition resulted in a *T*-value of 8.56 and a *p*-value of 0.00001, again indicating a significant improvement in the durability of the kinetic-based designs.

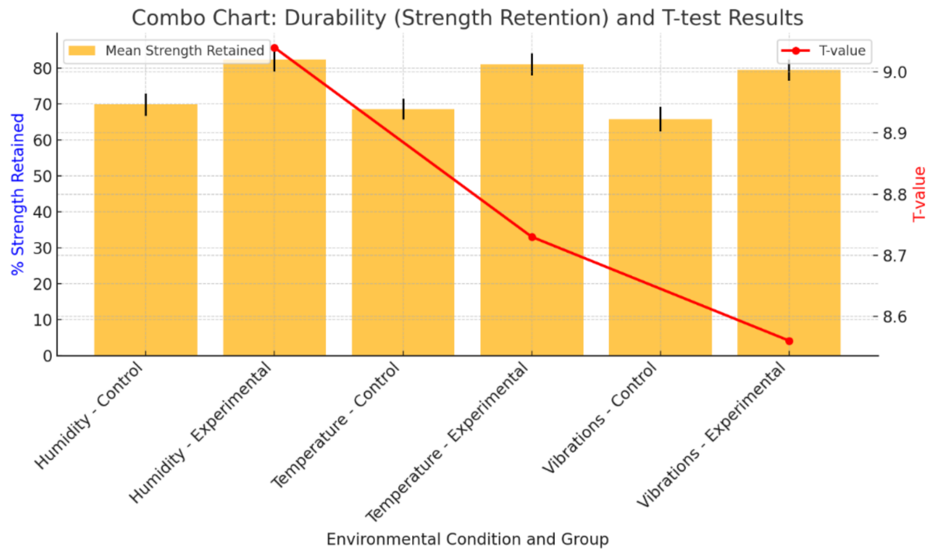

Figure 8. T-test for durability.

Table 14. T-test for durability (strength retention after environmental stress).

Environmental Condition	Group	Mean (% Strength Retained)	Standard Deviation	*T*-value	*p*-value
Humidity Exposure	CG	69.8	3.1		
	EG	82.3	3.2	9.04	0.00001
Temperature Fluctuations	CG	68.5	2.9		
	EG	81.0	3.1	8.73	0.00001
Mechanical Vibrations	CG	65.8	3.4		
	EG	79.4	3.0	8.56	0.00001

Across all measures—structural stability, artistic fluidity, and durability—the *p*-values for the t-tests were significantly lower than 0.05, allowing us to confidently reject the null hypothesis in favor of the alternative hypothesis. These results demonstrate that the application of kinetic dynamics led to statistically significant improvements in the art pieces. The EG consistently outperformed the CG with higher stress resistance, greater artistic fluidity, and improved durability under various environmental conditions. These findings strongly support the conclusion that kinetic dynamics offer a valuable approach to enhancing sculptures and pottery's structural and aesthetic qualities. The statistical analysis highlights the effectiveness of kinetic principles and suggests that these improvements are robust and consistent across various measures.

5. Conclusion and future work

The results of this study provide strong empirical evidence that integrating kinetic dynamics into the creation of sculptures and pottery leads to significant improvements in structural stability and artistic form. The EG, which applied kinetic principles, consistently outperformed the CG across all tested metrics, including stress resistance, aesthetic fluidity, and durability under environmental stressors such as humidity, temperature fluctuations, and mechanical vibrations. The application of kinetic dynamics allowed for more efficient load distribution increased structural resilience, and enhanced visual harmony, demonstrating the potential of these principles to revolutionize traditional art-making processes. Statistical analysis confirmed that the differences between the CG and EGs were substantial and statistically significant, reinforcing the validity of these findings. The improvements observed in the EG indicate that kinetic dynamics can be a valuable tool for artists and sculptors, offering new ways to balance form and function in their work. Integrating scientific principles into artistic practice improves the physical durability of art pieces and enhances their aesthetic fluidity, allowing for more expressive and harmonious designs. In conclusion, this study highlights the transformative potential of kinetic dynamics in the field of sculpture and pottery. By bridging the gap between art and science, artists can create visually captivating and structurally resilient pieces, withstanding the test of time and environmental challenges.

Future research could further explore the application of kinetic dynamics in other forms of art and design, expanding the scope of these principles to a broader range of creative disciplines.

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