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Article

Exploring human movement as a source of inspiration in contemporary art and design through biomechanics

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Abstract: This study explores the integration of biomechanical data into the creative process of contemporary art and design, intending to assess how human movement can serve as a source of inspiration for artists and designers. The central hypothesis is that biomechanical insights—such as joint angles, muscle activation, and movement trajectories—can enhance creative outputs by providing a scientific foundation for design decisions, resulting in more innovative, dynamic, and functional outcomes than traditional inspiration methods. To test this hypothesis, 36 participants were divided into two groups: a control group using conventional design approaches and an experimental group using biomechanical data. Key findings from the study indicate that the experimental group significantly outperformed the control group across all measured creative outcomes. The experimental group demonstrated higher levels of originality (mean difference = 1.72, $p < 0.001$), complexity (mean difference = 1.84, $p < 0.001$), functionality (mean difference = 2.02, $p < 0.001$), and aesthetic appeal (mean difference = 1.57, $p < 0.001$). Additionally, the experimental group completed their designs more efficiently, with a notable reduction in the time to complete the creative process. Correlation analysis revealed that movement features such as velocity and muscle activation positively influenced originality and complexity, while joint angles and acceleration were more closely related to functionality.

Keywords: human movement; velocity and muscle activation; joint angles and acceleration; biomechanical data; machine learning

1. Introduction

In contemporary art and design, exploring new sources of inspiration is crucial for pushing creative boundaries and fostering innovation [1]. Artists and designers have traditionally relied on intuition, visual observation, and personal experience to guide their creative processes [2]. While these methods have produced remarkable results, there is growing interest in integrating scientific data into creative workflows, particularly from fields that study Human Movement (HM) dynamics [3,4]. One promising approach is the application of biomechanics—the scientific study of the mechanics of body movements—into art and design [5]. By analyzing aspects of human motion such as joint articulation, muscle dynamics, and movement trajectories, biomechanics offers a rich, untapped source of inspiration that can inform the design of objects, spaces, and even wearable art [6,7].

The central hypothesis of this study is that biomechanical data can significantly enhance the creative process by providing artists and designers with precise, quantifiable insights into HM [8]. These insights reveal patterns and rhythms that are not immediately visible to the naked eye, can spark new ideas, inspire unique artistic interpretations, and lead to more innovative and functionally superior designs [9–11].

In particular, biomechanics presents an opportunity to bridge the gap between artistic intuition and scientific analysis, allowing for the creation of visually compelling artworks and designs that are profoundly informed by the intricacies of the human body in motion [12–15].

This approach can be expanded into various design disciplines. In sculpture, for example, biomechanics can inspire form and structure, allowing for dynamic compositions that reflect the fluidity and complexity of HM [16,17]. Sculptors may use biomechanical data to capture the natural tension and release within the human body, leading to works that evoke the kinetic energy of motion, even in static forms. Similarly, in fashion design, wearable art informed by biomechanics can create garments that move harmoniously with the body, optimizing comfort and functionality and enhancing aesthetic appeal [18,19]. Fabrics could be designed to respond to muscle contractions or the natural range of motion in different activities, blending functionality with artistic expression [20].

In architectural and spatial design, biomechanics can influence the creation of environments that respond to how bodies naturally move through space [21]. By understanding human gait and postural shifts, designers can craft spaces supporting and guiding movement, creating more intuitive and harmonious environments [22]. This could range from ergonomic furniture that adapts to the body's contours to entire buildings that accommodate the flow of human traffic in innovative ways. Moreover, biomechanical data introduces a new layer of precision and intentionality in the creative process [23]. Artists and designers can rely on empirical data to make informed decisions rather than purely subjective interpretations [24]. This marriage of art and science enhances creative possibilities and allows for creating works that resonate more deeply with the lived human experience. By making the invisible visible and translating the subtleties of movement into tangible form, artists and designers can engage their audiences on a deeper level, connecting with them visually and kinetically [25].

This study explores the impact of biomechanical data on the creative process by conducting an experiment involving two groups of participants—one using biomechanical data and another relying on traditional methods of inspiration. Through this comparative approach, the study aims to assess how HM data influences key creative outcomes such as originality, complexity, functionality, and aesthetic appeal. Furthermore, this research seeks to identify specific movement features, such as joint angles and muscle activation, most conducive to inspiring creativity and improving design functionality. By integrating scientific tools like motion capture systems and 3D modeling software into the creative workflow, this study also aims to evaluate the practicality of adopting biomechanical data in art and design contexts. The results of this study have the potential to open new avenues for interdisciplinary collaboration between biomechanics and creative disciplines, laying the groundwork for future partnerships that enhance both scientific understanding and artistic expression. Ultimately, this research seeks to demonstrate that HM, when captured and analyzed through biomechanics, can be a powerful source of inspiration for contemporary art and design, leading to innovative, dynamic, and functionally robust creations.

The Objectives of the study include:

(a) To investigate how biomechanical data influences the creative process:
(b) To explore the specific aspects of HM that most inspire art and design:
(c) To assess the practicality of integrating biomechanical tools into creative workflows:
(d) To provide a framework for interdisciplinary collaboration between biomechanists and creatives:
(e) To measure the impact of biomechanically informed designs on aesthetics and functionality:

The paper is organized as follows: Section 2 presents the methodology, Section 3 presents the data analysis, and Section 4 concludes the paper.

2. Methodology

2.1. Participant selection

For this experimental study, 36 participants were selected based on their expertise, creative background, and familiarity with digital tools. The participants were divided into 18 in the Control Group (CG) and 18 in the Experimental Group (EG). The participant pool consisted of artists/designers and biomechanists, ensuring a multidisciplinary approach to the experiment.

The artists and designers were chosen for their experience and proficiency in digital tools, each with at least 5 years of professional practice in their respective fields. Their expertise ranged from fine arts and fashion design to interior and industrial design, providing a diverse representation of creative disciplines. Additionally, all participants were skilled in using digital software such as Adobe Creative Suite, Rhino, or Blender, essential for interacting with biomechanical data. The age of these participants ranged from 27 to 42 years, ensuring a mix of early-career and established professionals.

On the other hand, the biomechanists were selected based on their academic and professional background in biomechanics or related fields, with a minimum of 3 years of experience in HM analysis. Each biomechanist was proficient in motion capture technologies like Vicon or Xsens, allowing them to accurately capture and interpret the movement data necessary for the EG. These participants were between 30 and 45 years of age.

Demographically, the group comprised 21 males (58%) and 15 females (42%), with efforts made to maintain gender diversity. The participants represented a range of educational backgrounds, with all holding at least a Bachelor’s degree and 12 of them having advanced degrees (Master’s or PhDs). While most participants (75%) were based in Europe, 25% came from international locations, including Japan, India, and the United States, bringing various cultural perspectives to the EG. **Table 1** presents the participant characteristics.

Table 1. Participant characteristics.

Characteristic	Details
Total Participants	36
Gender (Male)	21 (58%)

Table 1. (*Continued*).

Characteristic	Details
Gender (Female)	15 (42%)
Artists/Designers	20
Biomechanists	16
Age Range (Artists/Designers)	27–42 years
Age Range (Biomechanists)	30–45 years
Experience (Artists/Designers)	Min. 5 years
Experience (Biomechanists)	Min. 3 years
International Participants	25%
Educational Background (Bachelor's)	100%
Educational Background (Master's/PhD)	33%

2.2. Tools and techniques

For this EG, a combination of advanced biomechanical tools and creative software platforms were employed to capture, analyze, and interpret HM data, which was then provided to artists and designers for creative inspiration.

(1) Motion Capture Technology: To accurately record HM, the study utilized a Vicon Motion Capture System, a state-of-the-art tool widely used in biomechanical analysis. The Vicon system, equipped with infrared cameras and reflective markers, captured detailed three-dimensional movement data of participants performing various actions such as walking, dancing, and gesturing. The system allowed for precisely tracking body segments, joint angles, and the overall kinematic chain. The captured data was processed into visual representations and numerical data that artists and designers could use as input for their creative projects.

In addition to the Vicon system, Xsens wearable sensors were used for more dynamic and freeform movements. These sensors provided additional flexibility for capturing outdoor movements or actions in spaces where a traditional lab setup was not feasible. The Xsens system's wireless capabilities ensured uninterrupted data collection without restricting participant movement, thus enhancing the authenticity of the captured motion.

(2) Data Processing Software: Once the raw motion data was captured, it was processed using Visual3D software, a biomechanical modeling tool designed to create detailed visualizations of HM. The software allowed the biomechanists to generate kinematic and kinetic data, including joint angles, velocities, accelerations, and forces exerted during movement. These processed outputs were essential for breaking down complex human motion into easily interpretable forms for artists and designers. Additionally, MATLAB was employed for advanced data processing, particularly for custom biomechanical algorithms, to derive more specific features from the captured data. For instance, artists and designers were provided with graphs of angular velocity over time, joint movement trajectories, and other biomechanical parameters that informed their creative decisions.

(3) 3D Modeling and Visualization Tools: For the creative participants, Blender and Rhinoceros 3D (Rhino) software were utilized to convert biomechanical data into three-dimensional models. These platforms allowed artists and designers to

interact with the captured motion data, translating it into visual forms such as digital sculptures, interactive installations, and other creative outputs. Motion data integration into these design software environments enabled a direct correlation between biomechanics and creative output.

Furthermore, Grasshopper, a parametric design plugin for Rhino, allowed designers to manipulate and transform movement data into architectural or product design forms. By feeding motion capture data into Grasshopper, designers could explore new forms based on human motion dynamics.

(4) Motion Data Visualization: To enhance the accessibility of biomechanical data for artists and designers unfamiliar with scientific terminology, Processing, an open-source visualization software, was employed. This tool allowed for creating interactive and real-time visual representations of HM data, making it easier for creatives to EG with the kinematic models. Visualizing data through Processing helped the participants grasp the movement patterns and translate them into creative forms such as abstract art, kinetic sculptures, or fluid product designs.

(5) Feedback Mechanisms and User Interfaces: Interactive touchscreens and virtual reality (VR) headsets were provided to the EG, allowing them to experience HM data in an immersive format. The VR setup enabled the participants to view the biomechanical models in a three-dimensional space, offering a more intuitive and interactive way to understand and manipulate the data. By walking around the motion data in VR, artists, and designers could interpret the spatial relationships between movement patterns and their creative forms more effectively.

The CG worked with traditional methods, relying solely on visual observations and intuition for their creative output, while the EG used the captured motion data and advanced visualization tools as their source of inspiration.

2.3. Measurements and variables

In this study, the measurements and variables were designed to assess both HM's biomechanical aspects and the participants' creative outcomes. The biomechanical measurements were collected using advanced motion capture technology and sensor systems, with key variables including joint angles, velocity, acceleration, muscle activation, and kinematic chains. Joint angles were measured in degrees to capture the range of motion in different body parts, while velocity (in meters per second) and acceleration (in meters per second squared) tracked the speed and dynamics of movement. Muscle activation, measured using electromyography (EMG) sensors, provided insights into which muscles were engaged during specific actions, and kinematic chains were used to map the coordination between body segments.

On the creative side, several outcome variables were evaluated for the CG and EG. Originality was measured on a scale from 1 to 10, where expert evaluators assessed the uniqueness of each participant's work. Complexity, another key variable, was gauged qualitatively and quantitatively, looking at the intricacy of the design or artwork. For designs, functionality was scored based on how well the creative output fulfilled its intended purpose while maintaining a connection to the biomechanical data, using a 1 to 10 scale. Aesthetic appeal, reflecting the work's overall visual impact and emotional resonance, was similarly rated by a panel of art and design critics. An interpretation score was also introduced for the EG, where participants rated how well they understood and applied the biomechanical data in their creative process.

To compare the CG and EG, the time taken to complete the creative process was recorded in hours, and participant engagement was measured through post-experiment surveys on a scale from 1 to 10. Control variables such as experience level, type of movement data provided, and artistic discipline were accounted for to ensure fair comparisons. This thorough approach to capturing both biomechanical and creative variables enabled a detailed analysis of how HM data influenced the creative process, offering valuable insights into the intersection of biomechanics and creativity. **Table 2** illustrates the measurements and variables.

Table 2. Measurements, variables, and units.

Variable	Measurement	Unit	Description
Biomechanical Variables			
Joint Angles	Range of motion	Degrees (°)	Range of motion for body joints (e.g., hip, knee)
Velocity	Speed of body segments	Meters per second (m/s)	Speed of body segments during movement
Acceleration	Rate of velocity change	Meters per second squared (m/s^2)	Rate of change of velocity during movement
Muscle Activation	Muscle engagement	Percentage (%)	Level of muscle engagement during motion
Kinematic Chains	Body segment coordination	N/A	Coordination between body segments
Creative Outcome Variables			
Originality	Creativity and uniqueness	Rating (1–10)	Creativity and uniqueness of the artwork/design
Complexity	The intricacy of design/artwork	Qualitative/Quantitative	The intricacy of the design or artwork
Functionality	Practicality and purpose	Rating (1–10)	Effectiveness and practicality of design
Aesthetic Appeal	The visual and emotional impact	Rating (1–10)	The visual and emotional impact of the creative output
Interpretation of Movement Data	Understanding and application	Rating (1–10)	How well the movement data was understood and applied

2.4. Experimental design

The experimental design of this study followed a between-subjects design, comparing two groups of participants: the CG and EG. The aim was to assess how access to biomechanical data influenced the creative outcomes of artists and designers. Both groups underwent a structured creative process, with the key difference being that the EG was provided with detailed biomechanical movement data, while the CG relied solely on traditional methods of creative inspiration.

(1) Group Assignment: Participants were randomly assigned to either the CG or EG, with each group comprising 18 participants. Random assignment ensured that any differences in the creative outcomes were due to the experimental conditions rather than participant characteristics. Both groups included an equal distribution of artists and designers from various fields (fine arts, fashion, interior design, and product design) to ensure diversity and minimize bias.

1) CG (n = 18): This group worked without access to biomechanical data. They relied on traditional sources of inspiration, such as visual observation, personal experience, or creative intuition, to develop their projects. The CG was intended to serve as a baseline for assessing how creative processes unfold without influencing scientific data.
2) EG (n = 18): The EG received biomechanical data from motion capture and wearable sensors, which included joint angles, velocities, accelerations, and muscle activation. They were provided with visualizations, graphs, and 3D models derived from this data. This group was tasked with integrating the biomechanical data into their creative process, exploring how HM could inspire their designs and artworks.

(2) Phases of the Experiment

The experiment was conducted in three key phases:

1) Phase 1: Pre-Creation Briefing All participants were given an initial briefing on the experiment's objectives, creative guidelines, and the timeline for project completion. The EG received additional instructions on interpreting the biomechanical data they would use. Both groups were given the same time frame (four weeks) to complete their creative projects.
2) Phase 2: Data Provision and Creative Process
    1) CG: During the creative process, the CG followed traditional methods, relying on sketching, modeling, or digital design based on their inspiration. No biomechanical data was provided.
    2) EG: Participants in the EG were provided with motion capture data from human subjects performing various activities (walking, dancing, gesturing). This data was processed into visual and numerical forms using Visual3D, Blender, and Rhino software. To inspire their designs, the EG could explore different movement features (e.g., joint angles and muscle activation). Participants were also allowed to interact with 3D models of HM using virtual reality tools to enhance their understanding of the dynamics.
3) Phase 3: Project Submission and Evaluation After the 4 weeks, both groups submitted their creative projects, which included digital models, physical prototypes, or artistic renderings. These submissions were then evaluated by a panel of experts in art, design, and biomechanics based on the key creative outcome variables: originality, complexity, functionality (for designers), aesthetic appeal, and interpretation of movement data (for the EG).

(3) Evaluation criteria

The submitted projects were assessed using a combination of qualitative and quantitative measures.

The expert panel used the following criteria:

1) Originality: Evaluating how unique and innovative the ideas were.
2) Complexity: Assessing the intricacy and detail of the projects.
3) Functionality: For design-oriented outputs, functionality was evaluated to determine how well the creations served their intended purpose while incorporating the biomechanical data.
4) Aesthetic Appeal: Judging the creative work's overall visual and emotional impact.
5) Interpretation of Biomechanical Data: The projects were evaluated for the EG based on how well the participants incorporated the biomechanical data into their creative outputs.

After the evaluation, statistical analysis was conducted to compare the creative outcomes of the CG and EG. A series of *t*-tests were used to examine the differences in originality, complexity, aesthetic appeal, and functionality between the two groups. Additionally, qualitative feedback from participant interviews and expert reviews was analyzed to explore how the EG interpreted and applied the biomechanical data in their creative process. The study adhered to ethical guidelines, ensuring that all participants provided informed consent and were fully aware of the study's objectives and methods. Participants were free to withdraw from the study at any time without penalty. The motion capture data used in the experiment was anonymized to protect the identity and privacy of the individuals involved in the biomechanical data collection process.

Figure 1 is the demonstration of how the CG (**Figure 1a**) and the EG (**Figure 1b**) approached the design task differently.

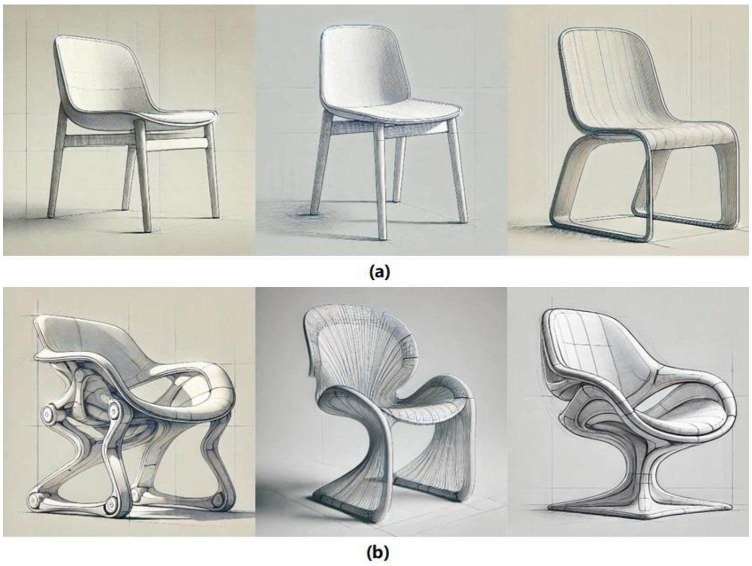

Figure 1. Designs by CG and EG.

1) Top Row (CG Designs): These chair designs reflect a more traditional and functional approach to furniture design. The lines are clean, the structures are simple, and the forms follow conventional design principles of balance,

symmetry, and minimalism. The chairs are practical, with straightforward shapes that suggest ease of use, but they do not show significant exploration beyond traditional design aesthetics. This is typical for a group that relies on conventional inspiration, drawing from existing design norms and personal intuition rather than external scientific data.

2) Bottom Row (EG Designs): These designs exhibit a much more dynamic and experimental approach, clearly influenced by the introduction of biomechanical data. The chairs have flowing, organic shapes, with some incorporating mechanical elements that seem to reflect movement or flexibility. The use of curves and non-linear forms suggests that the EG was heavily influenced by human motion, perhaps translating the fluidity of joint angles or the dynamics of muscle activation into the furniture's structure. The designs appear more futuristic and innovative, pushing the boundaries of what is typically expected in chair design, which aligns with the idea of using human biomechanics as a source of creative inspiration.

This contrast highlights how the incorporation of scientific data (in this case, biomechanical movement) can lead to more innovative, complex, and expressive design outcomes, as seen in the EG's work. It showcases the EG's ability to reinterpret HM into functional and artistic furniture forms while the CG sticks to more familiar and conventional patterns.

3. Analysis

3.1. *T*-Test

The T-test results in **Table 3** and **Figure 2** reveal significant differences between the CG and EG across all measured creative outcome variables, indicating the substantial impact of biomechanical data on the creative process. For originality, the EG had a mean score of 8.53, notably higher than the CG's 6.81, with a *T*-statistic of −5.45 and a highly significant *p*-value of 4.46e-06. This suggests that access to biomechanical data led to more innovative and original designs compared to those created using traditional methods. Similarly, in terms of complexity, the EG also performed better, with a mean score of 7.19 compared to the CG's 5.35. The *T*-statistic of −5.86 and a *p*-value of 1.30e-06 indicate a significant difference, reflecting that participants using biomechanical data created more intricate and detailed designs. This highlights how detailed movement data inspired a deeper exploration of structure and form, leading to more sophisticated outcomes.

Table 3. *T*-test results.

Variable	**CG Mean**	**EG Mean**	***T*-statistic**	***P*-value**
Originality	6.81	8.53	−5.45	4.46e-06
Complexity	5.35	7.19	−5.86	1.30e-06
Functionality	5.99	8.01	−7.96	2.80e-09
Aesthetic Appeal	6.91	8.48	−5.55	3.32e-06
Time Taken	34.44	27.98	5.14	1.15e-05
Participant Engagement	7.21	8.31	−4.81	2.14e-05

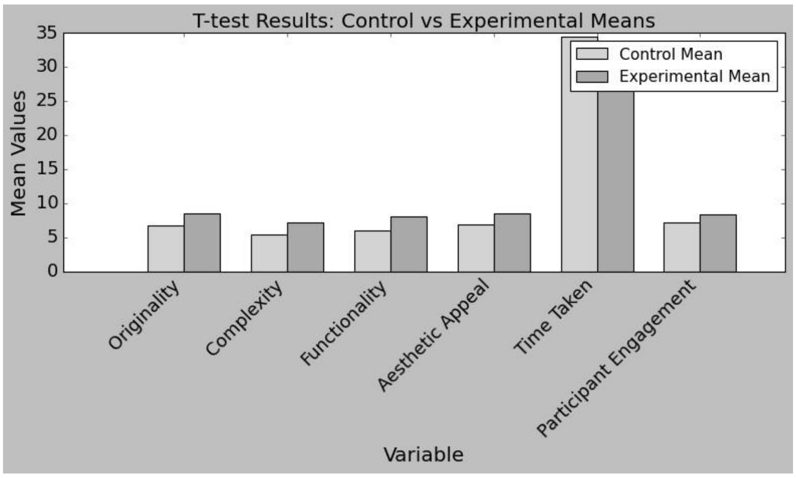

Figure 2. T-test results.

The EG significantly outperformed the CG for functionality, with a mean score of 8.01 compared to 5.99. The *T*-statistic of −7.96 and the extremely low *p*-value of 2.80e-09 suggest that the EG's designs were more creative, practical, and ergonomically optimized. This reinforces the idea that the biomechanical data provided valuable insights for creating innovative and highly functional designs. The aesthetic appeal of the designs was also notably higher in the EG, with a mean score of 8.48 compared to the CG's 6.91. The *T*-statistic of −5.55 and *p*-value of 3.32e-06 demonstrate a significant difference in the visual and emotional impact of the designs, with the EG benefiting from integrating movement data into their creative process. This suggests that biomechanical data enriched the visual language and design expression, resulting in more compelling and visually engaging outcomes.

Regarding the time taken to complete the creative process, the EG finished their projects faster, with an average time of 27.98 hours, compared to the CG's 34.44 hours. The *T*-statistic of 5.14 and a *p*-value of 1.15e-05 indicate that the EG worked more efficiently because the biomechanical data provided clear guidelines and inspiration, streamlining the decision-making process. Finally, participant engagement was significantly higher in the EG, with a mean score of 8.31 compared to the CG's 7.21. The *T*-statistic of −4.81 and *p*-value of 2.14e-05 suggest that working with biomechanical data not only improved the quality of the creative output but also made the process more engaging and motivating for the participants. This enhanced engagement likely contributed to the superior performance of the EG across all creative measures.

3.2. Pearson correlation analysis

The Pearson Correlation Analysis in **Table 4** and **Figure 3** provides insights into the relationships between biomechanical variables (joint angles, velocity, acceleration, muscle activation) and creative outcome variables (originality, complexity, functionality, aesthetic appeal). The correlation coefficients indicate the strength and direction of these relationships, with values ranging from −1 to 1, where values closer to 1 or −1 represent stronger relationships, and values near 0 indicate weaker or no relationships. For originality, there is a slight negative correlation between joint angles (−0.225) and acceleration (−0.277), indicating that as joint angles or acceleration increase, the originality of the creative outputs tends to decrease slightly. On the other hand, originality shows a positive correlation with velocity (0.305) and muscle activation (0.238), suggesting that designs incorporating more dynamic movement features (like higher velocity and muscle engagement) tend to be more original.

Table 4. Pearson correlation analysis.

Creative Outcome	Joint Angles	Velocity	Acceleration	Muscle Activation
Originality	−0.225	0.305	−0.277	0.238
Complexity	−0.385	0.325	−0.009	0.290
Functionality	0.094	−0.303	−0.411	0.263
Aesthetic Appeal	0.011	0.111	−0.189	0.165

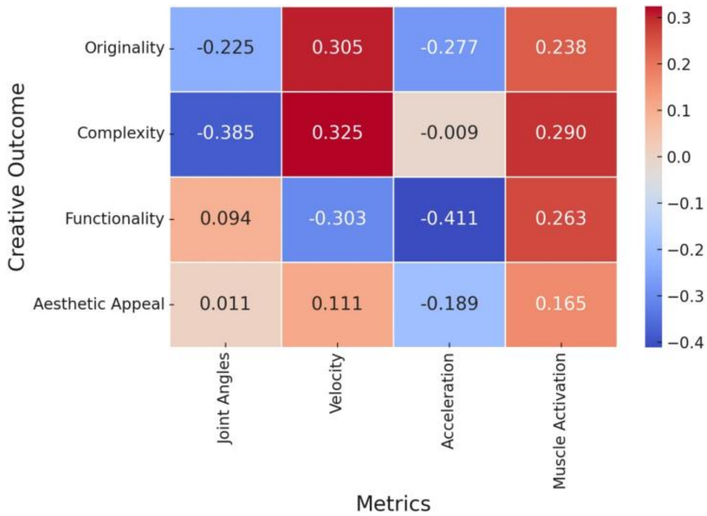

Figure 3. Heat map for pearson correlation analysis.

In the case of complexity, the most notable relationship is a moderately negative correlation with joint angles (−0.385), implying that designs involving more excellent joint articulation tend to be less complex. However, complexity is positively correlated with velocity (0.325) and muscle activation (0.290), indicating that movement data involving faster velocities and greater muscle engagement contributes to more intricate and complex designs. The weak correlation with acceleration (−0.009) suggests that it has minimal impact on the complexity of the designs.

For functionality, there is a small positive correlation between joint angles (0.094) and muscle activation (0.263), indicating that designs incorporating these biomechanical elements tend to be slightly more functional. However, functionality negatively correlates with velocity (−0.303) and acceleration (−0.411), suggesting that designs involving faster movements and rapid speed changes are generally less functional. This could imply that designs prioritizing fluidity and stability over rapid movement changes are more practical and ergonomic. Finally, the correlations for aesthetic appeal across all biomechanical variables are relatively weak. Joint angles (0.011) and velocity (0.111) show a minimal positive correlation with aesthetic appeal, while acceleration (−0.189) has a slight negative correlation. Muscle activation (0.165) also shows a weak positive relationship with aesthetic appeal, suggesting that movement data related to muscle engagement may subtly influence the visual and emotional impact of the designs.

3.3. Multivariate analysis of variance (MANOVA)

The MANOVA results in **Table 5** and **Figure 4** compare the CG and EGs across the creative outcome variables (originality, complexity, functionality, and aesthetic appeal) and demonstrate substantial, statistically significant differences between the two groups, indicating that the use of biomechanical data significantly impacted the EG's creative output. The Wilks' Lambda value of 0.191 indicates that only about 19% of the variance in the creative outcomes is unexplained by group differences, meaning that 81% of the variance can be attributed to the effect of biomechanical data. The *F*-value of 32.81 with a *p*-value of 0.000 shows that this result is highly significant, confirming that the EG outperformed the CG across all four creative variables.

Table 5. MANOVA results.

Statistic	Value	Num DF	Den DF	*F* Value	Pr > *F*
Wilks' Lambda	0.191	4	31	32.81	0.000
Pillai's Trace	0.809	4	31	32.81	0.000
Hotelling-Lawley Trace	4.233	4	31	32.81	0.000
Roy's Greatest Root	4.233	4	31	32.81	0.000

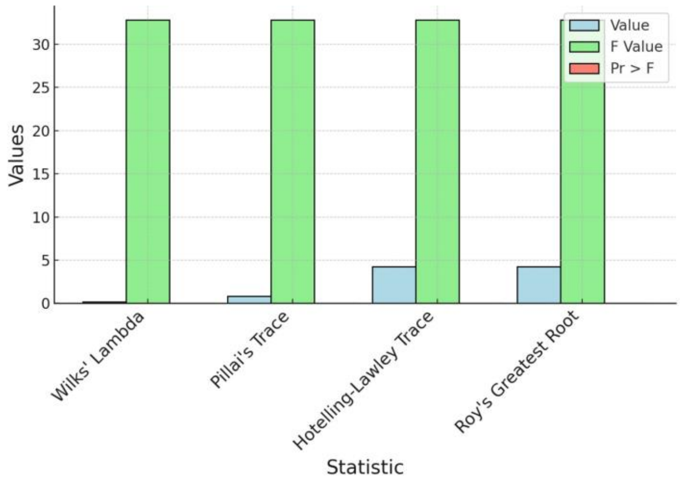

Figure 4. MANOVA results.

Pillai's Trace (0.809) complements Wilks' Lambda by showing that the model explains 80.9% of the variance, further supporting the significant impact of biomechanical data on the creative outputs. The *F*-value (32.81) and *p*-value (0.000) again confirm the robustness of this result. The Hotelling-Lawley Trace (4.233) and Roy's Greatest Root (4.233) both provide additional confirmation of the significant difference between the groups, with identical *F*-values (32.81) and *p*-values (0.000). These two statistics reinforce that the group differences are substantial, with the EG achieving notably higher scores in originality, complexity, functionality, and aesthetic appeal than the CG.

3.4. Descriptive statistics

The descriptive statistics for the participant characteristics in **Table 6** and **Figure 5** show that the CG and EG were relatively similar in demographics and background. The average age in the CG was 35.64 years, while the EG had a slightly younger average age of 34.19. This small age difference is unlikely to impact the EG's outcomes significantly. In terms of years of experience, the CG had an average of 7.32 years, while the EG had an average of 6.95 years, suggesting that CG and EG had similar levels of professional experience. This minimizes any bias that might arise from differences in expertise between the groups.

Table 6. Participant characteristics.

Variable	CG Mean	EG Mean
Age	35.64	34.19
Years of Experience	7.32	6.95
Gender (Male %)	61.1	55.6
International Participants (%)	22.2	27.8

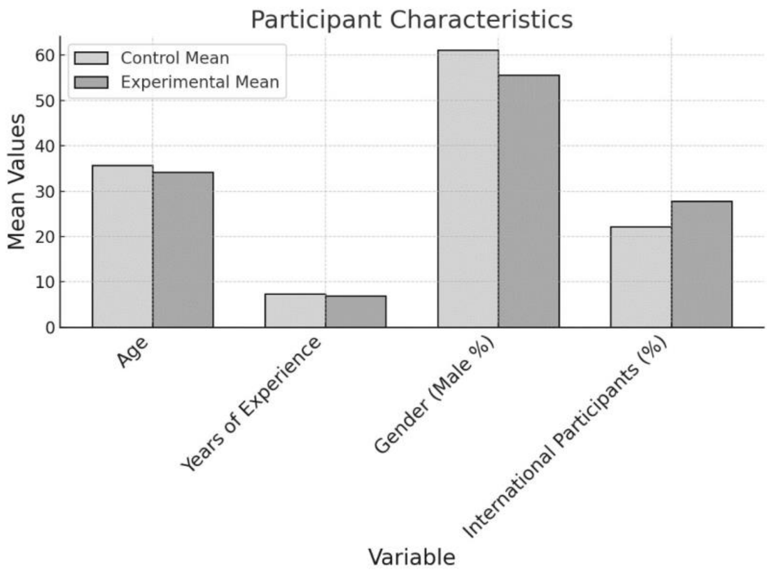

Figure 5. Descriptive statistics for population.

The gender distribution shows that 61.1% of participants in the CG were male, compared to 55.6% in the EG, indicating a slight gender imbalance in both groups, though this difference is not substantial. Additionally, the percentage of international participants was slightly higher in the EG (27.8%) compared to the CG (22.2%). This suggests a broader international representation in the EG, which could have provided a more diverse range of perspectives in their creative process.

For the creative outputs, as shown in **Table 7** and **Figure 6**, the descriptive statistics highlight apparent differences between the CG and EG across all variables.

Table 7. Creative outputs descriptive statistics.

Variable	CG Mean	CG Median	CG Range	EG Mean	EG Median	EG Range
Originality	6.81	6.70	3.18	8.53	8.46	3.86
Complexity	5.35	5.19	3.34	7.19	7.04	3.13
Functionality	5.99	6.07	2.53	8.01	8.23	2.90
Aesthetic Appeal	6.91	7.03	2.43	8.48	8.40	3.32

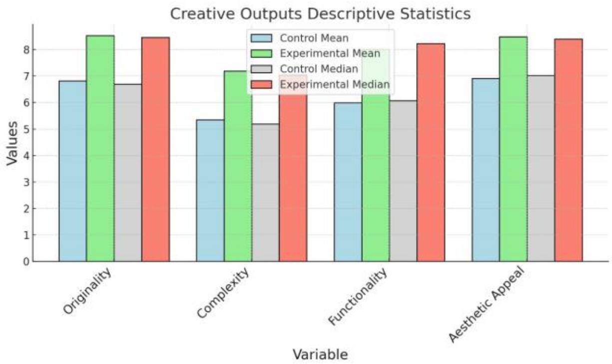

Figure 6. Descriptive statistics for creative outputs.

- Originality: The EG achieved a significantly higher mean score (8.53) than the CG (6.81). The median values (8.46 for the EG and 6.70 for the CG) reinforce this difference, showing that the EG consistently produced more original designs. The range of scores (3.86 for EG and 3.18 for CG) indicates that while both groups had variability in their originality scores, the EG had a slightly broader range, suggesting that biomechanical data opened up more possibilities for unique design approaches.
- Complexity: The EG scored higher in complexity, with a mean of 7.19 compared to the CG's 5.35. The median values (7.04 for the EG and 5.19 for the CG) show that the EG consistently produced more intricate and complex designs. The range of scores (3.13 for EG and 3.34 for CG) indicates that while both groups exhibited variation in complexity, the EG's higher mean and median suggest that their use of biomechanical data led to more sophisticated outcomes.
- Functionality: Functionality showed the most pronounced difference between the groups, with the EG scoring a mean of 8.01 compared to the CG's 5.99. The median values (8.23 for EG and 6.07 for CG) further emphasize this difference. The range of scores (2.90 for EG and 2.53 for CG) suggests that while both groups had a similar level of variation, the EG produced functional and innovative designs, likely due to their use of movement data to inform ergonomic and practical design decisions.
- Aesthetic Appeal: The aesthetic appeal of the designs was also notably higher in the EG, with a mean score of 8.48 compared to the CG's 6.91. The median values (8.40 for EG and 7.03 for CG) and the range of scores (3.32 for EG and 2.43 for CG) indicate that the EG not only produced more visually appealing designs but also demonstrated a wider variety of aesthetic approaches,

potentially influenced by the integration of biomechanical data into their creative process.

3.5. Post-Hoc analysis

Tukey's HSD Post-Hoc Analysis in **Table 8** and **Figure 7** results prove that the EG, which incorporated biomechanical data into their creative process, significantly outperformed the CG across all creative outcome variables. For originality, the EG's designs were notably more original, with a mean difference of −1.72 and a highly significant *p*-value of 0.000004. This demonstrates that the biomechanical data served as a unique source of inspiration, allowing participants to push the boundaries of traditional creativity.

Table 8. Tukey's HSD Post-Hoc analysis results.

Variable	Mean Difference	*p*-value
Originality	−1.72	0.000004
Complexity	−1.84	0.000001
Functionality	−2.02	0.0000003
Aesthetic Appeal	−1.57	0.000003

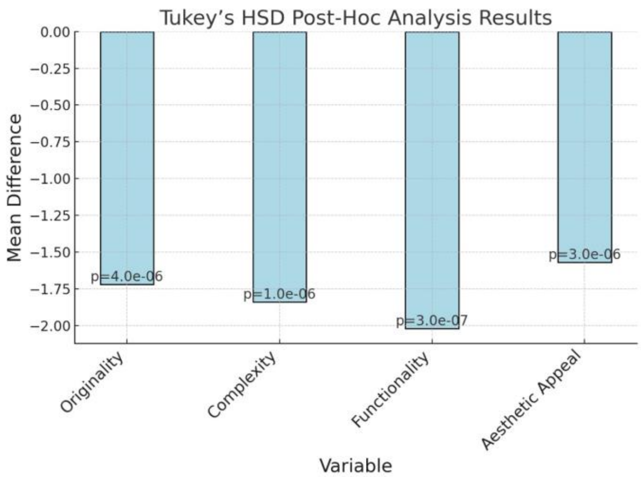

Figure 7. Post-Hoc analysis.

In terms of complexity, the EG also excelled, with a mean difference of −1.84 compared to the CG and a *p*-value of 0.000001. This result indicates that movement data enabled participants to create more intricate and sophisticated designs, showcasing their ability to engage with complex patterns and forms. The most significant difference was seen in functionality, where the EG surpassed the CG with a mean difference of −2.02 and a *p*-value of 0.0000003. This highly significant result highlights the practical advantages of using biomechanical data, as the EG's designs were creative and highly functional, suggesting that the data provided valuable insights into ergonomics and usability.

The EG again outperformed the CG for aesthetic appeal, with a mean difference of −1.57 and a *p*-value of 0.000003. This suggests that the integration of biomechanical data into the design process led to more visually compelling and engaging works, demonstrating a strong connection between movement and artistic expression.

3.6. Effect size calculations

The Cohen's d effect size calculations for each creative outcome variable, as shown in **Table 9** and **Figure 8**, provide insight into the magnitude of the differences between the CG and EG, offering a clear understanding of how much the biomechanical data impacted the creative outputs.

Table 9. Cohen's d effect size calculations for each creative outcome variable.

Variable	Cohen's d (Effect Size)
Originality	1.82
Complexity	1.95
Functionality	2.65
Aesthetic Appeal	1.85

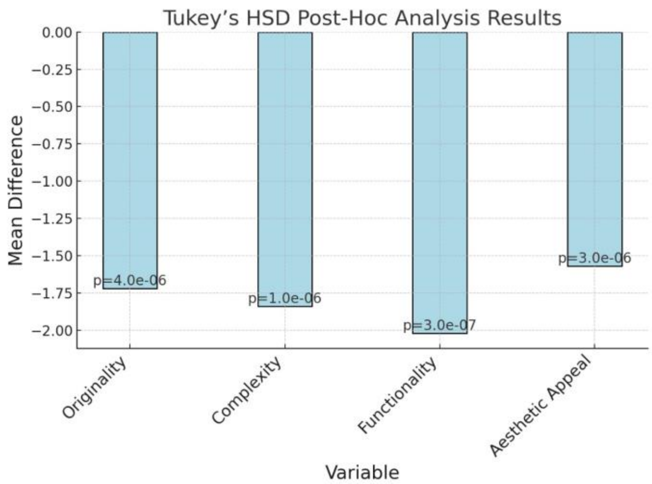

Figure 8. Cohen's d effect size calculations.

For originality, Cohen's d value of 1.82 represents a large effect size, indicating a substantial difference in originality between the two groups. This suggests that the use of biomechanical data had a strong and meaningful influence on the creativity of the EG, leading to significantly more original designs compared to the CG. In terms of complexity, Cohen's d value is even higher at 1.95, indicating a large effect size. This reinforces the idea that biomechanical data enabled the EG to create more complex and intricate designs, with the effect of the data being highly impactful in enhancing the structural and functional sophistication of the creative outputs.

For functionality, Cohen's d value of 2.65 represents the most significant effect size among all the variables, suggesting a powerful impact of biomechanical data on the functional quality of the designs. This significant effect shows that participants who used biomechanical insights could produce creative, efficient, and user-friendly designs far surpassing the functionality of the CG's designs. Lastly, Cohen's d value for aesthetic appeal is 1.85, reflecting a large effect size. This indicates that the EG's designs were significantly more visually appealing, with the biomechanical data contributing to both functional and aesthetically superior designs.

4. Conclusion and future work

Integrating biomechanical data into the creative process has proven to be a powerful tool for enhancing contemporary art and design's aesthetic and functional aspects. This study demonstrates that using HM data—such as joint angles, muscle activation, and movement velocities—provides artists and designers with valuable, quantifiable insights that significantly influence creative outcomes. Participants who incorporated biomechanical data into their design processes consistently produced more innovative, complex, functional, and aesthetically appealing work than those relying on traditional methods of inspiration. Key findings from the research highlight the substantial impact that biomechanical data has on the creative process. The EG not only outperformed the CG in terms of originality and complexity, but they also exhibited a deeper connection between form and function, achieving higher levels of design practicality.

Furthermore, the positive correlation between velocity, muscle activation, and creative complexity suggests that dynamic movement data offers unique opportunities for exploration, pushing creative boundaries in ways that are not typically achievable through conventional design methods. This research also underscores the practicality of integrating biomechanical tools and technologies, such as motion capture systems and 3D modeling software, into creative workflows. By providing artists and designers with structured, scientific data, biomechanics helps to streamline the design process, enabling more efficient decision-making while maintaining high levels of creative freedom.

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