EXPLORING THE ERGONOMIC IMPACT OF MOBILE PHONE SCREEN SIZE ON HAND FATIGUE: INSIGHTS FOR USER-CENTERED DESIGN

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Abstract

This study explores the ergonomic implications of mobile phone use with a focus on hand fatigue, a common yet understudied issue associated with prolonged mobile device usage. Considering how different screen sizes impact user comfort, the research employs a multifaceted methodological approach, analyzing the ergonomic interactions between various smartphone designs and their users. Key findings suggest that while physical characteristics like screen size and hand dimensions influence comfort, their overall impact on ergonomic discomfort is minimal. However, variations in screen size significantly affect typing comfort and fatigue, indicating the need for diverse design considerations to accommodate different user needs. The study highlights the importance of ergonomic design in enhancing user comfort and reducing the risk of repetitive strain injuries, advocating for mobile phone designs that prioritize user health alongside technological advancements. Future research should expand participant diversity and adopt longitudinal study designs to better understand the long-term ergonomic impacts of mobile phone use.

Keywords: Ergonomics, Hand Fatigue, Screen Size, Mobile Phone Design, Hand Anthropometry.

1. INTRODUCTION

As mobile phone use becomes increasingly ubiquitous, the intersection of device design and user health has emerged as a critical area of research. This study delves into the ergonomic aspects of mobile phone usage with a specific focus on hand fatigue—a common yet often overlooked consequence of mobile technology. By exploring how different screen sizes affect user comfort and the potential ergonomic implications, this research aims to provide insights that could lead to more user-friendly phone designs that minimize discomfort, and enhance overall usability.

Hand fatigue associated with mobile phone usage is a multifaceted issue influenced by both the physical characteristics of the device (such as weight, size, and shape) and the user's physical attributes, including hand size and grip strength (Ashok Chopra, 2024). Our research hypothesizes that certain screen sizes may exacerbate discomfort, particularly when they do not harmonize with the user's hand dimensions. This study, therefore, investigates the relationship between screen size and reported levels of hand fatigue, considering how ergonomic mismatches between user and device might contribute to discomfort over prolonged periods. Ergonomically the study is grounded in the hypothesis that optimal mobile phone usage is not merely about aesthetic or screen real estate but closely linked to the physical dimensions of the hand, which may affect how a device is used and the associated fatigue, or discomfort.

In conclusion, this research seeks to illuminate the often-neglected aspect of hand fatigue in mobile phone usage (Jaya Yadav, 2020). By understanding the ergonomic interactions between users and their devices, the study aspires to contribute valuable knowledge that can influence future mobile phone designs, prioritizing not just technological advancements but also the health and comfort of users. The ultimate goal is to recommend design changes that reduce hand fatigue, thereby enhancing the usability and appeal of mobile phones across various user demographics.

2. LITERATURE REVIEW

The ubiquity of smartphones has revolutionized how we interact with the digital world, yet it has also introduced a plethora of ergonomic challenges prominently the hand fatigue. As smartphone usage intensifies, so does the concern for the ergonomics of these devices, particularly, how screen size and hand anthropometry interact to affect user comfort and health. This literature review aims to synthesize existing research on the topic and identify gaps where further study could contribute to more ergonomic smartphone designs.

Hand fatigue is increasingly reported among frequent smartphone users, manifesting through muscle discomfort, joint pain, and symptoms typical of Repetitive Strain Injuries (RSI). The ergonomic community has long recognized that prolonged mobile device use can lead to significant discomfort, spurring extensive research into its causes and mitigation (Sharan, 1 Jan. 2012). Several studies, highlight the critical role of screen size in this dynamic. Larger screens may require users to stretch their fingers wider, potentially increasing muscle strain and fatigue, whereas smaller screens might necessitate more precise finger movements, leading to different but equally problematic strains.

Research (Ki Joon Kim, 2014) suggests that the interaction between a user's hand size and the smartphone's screen size is pivotal. For instance, a device that fits well in one user's hand might be cumbersome for another, based on their hand dimensions. This match—or mismatch—can significantly influence the ease of device use and the potential for hand fatigue. Notably, studies involving various screen sizes, from 3.5 inches to 5.7 inches, have found that devices with a screen size less than 5 inches are often more ergonomically suitable for users with smaller hands (Sanghyun Kwon, 2016).

Evaluations of single-handed touchscreen operations have underscored the critical role of hand anthropometry and device design in enhancing user comfort. Research by (Sung Hee Ahn, 2016), which combined subjective user feedback with electromyography data, has emphasized the significance of hand size and the curvature of devices in ergonomic design. Further insights come from a 2017 study by (Restyandito Restyandito, 2017) , which tested the usability of mobile devices among 100 Indonesian university students. This study explored how different screen sizes and user interaction styles—particularly using one or two thumbs—affect performance metrics like task completion time and error rates. The findings indicate that smaller devices, with screen sizes under 5.5 inches, typically yield better user performance, possibly due to easier handling and less thumb strain. The study also examined the relationship between hand dimensions and device usability, noting that individual hand size significantly impacts how effectively users can operate their devices. For instance, using the index finger for interactions proved quicker and more accurate than thumb use, although preferences varied based on the specific activities undertaken by users.

Additionally, a study by (Kanetkar, 2017) found a notable negative correlation between hand dimensions and mobile handiness, suggesting that users with larger hands may prefer and perform better with larger phones. Conversely, those with smaller hands might find smaller phones more manageable and comfortable. This body of research collectively highlights the importance of considering ergonomic principles in mobile device design to cater to diverse user needs and maximize usability.

The study of hand anthropometry, which involves analyzing the size, shape, and structure of an individual's hands and fingers, plays a crucial role in ergonomic research. Differences in these measurements among individuals can affect how they use mobile devices. For example, those with larger hands might struggle to use smaller screens effectively, which can lead to increased discomfort and fatigue (Dalia M. Kamel, 2020). Similarly, individuals with smaller hands might find larger screens difficult to manage. Recognizing the effects of hand anthropometry on mobile phone handling is vital for creating devices that cater to a diverse user base.

In research conducted by (Kamel DM, 2020), involving 89 students from Ahlia University aged 17 to 30, the focus was to explore, how smartphone design relates to hand measurements and the potential for developing discomfort or pain in the hands. The study observed a weak negative correlation between the size of the phone, the size of the hand, and hand grip strength in relation to reported hand pain. This suggests that neither larger nor smaller phones and hands, nor variations in grip strength are strongly linked to the occurrence of hand pain (Jasraj Kaur Bhamra, 2021). Additionally a slight positive correlation was found between the size of the phone screen, and hand length, indicating that larger screens might not significantly exacerbate hand pain relative to hand size.

These findings imply that when designing mobile phones, manufacturers should prioritize user comfort to prevent discomfort or pain in the hands which could extend to other musculoskeletal issues.

3. ETHICAL CONSIDERATIONS

This study adhered to strict ethical standards and guidelines. Informed consent was obtained from all participants prior to their involvement in the research. Furthermore, all personal data collected during the study was handled with utmost confidentiality to ensure participant privacy was preserved throughout the research process.

4. RESEARCH STATEMENT

- There is a significant variation in preferences for mobile phone screen sizes across different age groups and genders.
- Certain underlying factors, such as general phone usability and multimedia usage preferences, predominantly determine user satisfaction and ergonomic comfort with mobile phones.
- The physical characteristics of users, including hand size and the preferred usage style (one-hand vs. two-hand), are correlated with the ergonomic comfort and levels of fatigue experienced during mobile phone use.
- Screen size significantly impacts typing comfort and fatigue, with certain screen sizes offering better ergonomic outcomes than others.

5. METHODOLOGY

In this study, we aimed to investigate the complex interplay between demographic characteristics, ergonomic factors, and user preferences regarding mobile phone screen sizes. To address our research questions comprehensively, we employed a multi-faceted methodological framework that involved both quantitative analyses and experimental approaches.

- Participants: A sample of 264 healthy mobile phone users was recruited to represent a wide range of hand sizes and shapes. Inclusion criteria included regular smartphone users aged 18-65, with no history of hand injuries or conditions that may affect hand strength or dexterity.
- Demographic Analysis: We commenced with a demographic analysis, utilizing data on participants' preferences for mobile phone screen sizes across different age groups and genders. This stage involved collecting survey responses from our participants and using descriptive statistics to summarize the data. Visual representation such as histograms illustrated these preferences clearly, providing an initial understanding of demographic trends.
- Principal Component Analysis (PCA): Following the demographic analysis, PCA was employed to reduce the complexity of the dataset by distilling a large number of variables into few principal components that captured the majority of information in the data. This analysis helped to uncover underlying patterns that might not be evident from simple demographic breakdowns alone.
- Cluster Analysis: Utilizing the k-means clustering algorithm, we analyzed the PCA scores to segment the dataset further, identifying distinct groups of users with similar preferences and behavior. The optimal number of clusters was determined using the elbow method, and the results were visualized to demonstrate grouping based on usability and multimedia preferences.
- Regression Analysis: Regression analysis was conducted to explore how well demographic factors such as age and gender could predict the principal components derived from the PCA. This help in understanding the influence of the factors on mobile phone usability and preferences.
- Ergonomic Analysis: The ergonomic analysis focused on the physical interaction between the user and the mobile phone examining how hand measurements and usage styles (one-hand vs. two-hand) are correlated with reported levels of discomfort or fatigue.
- Experimental Design: Finally, an experiment was conducted with subsets of participants to evaluate the ergonomic impact of different smartphone screen sizes on typing comfort and fatigue. This involved measuring typing performance and comfort levels across three different iPhone models with varying screen sizes (5.4inches, 6.1inches and 6.4inches).

Each methodological step built upon the insights gained from the previous, allowing us to provide a robust analysis of mobile phone usability. This approach not only ensured a thorough exploration of the dataset but also generated actionable insights that could guide future mobile phone design and marketing strategies.

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6. DATA ANALYSIS

To undertake a comprehensive analysis of the dataset across all areas, we should approach it in a structured manner. This will involve various statistical and data visualization techniques.

6.1 Demographic Analysis focusing on age and gender differences in screen size preferences.

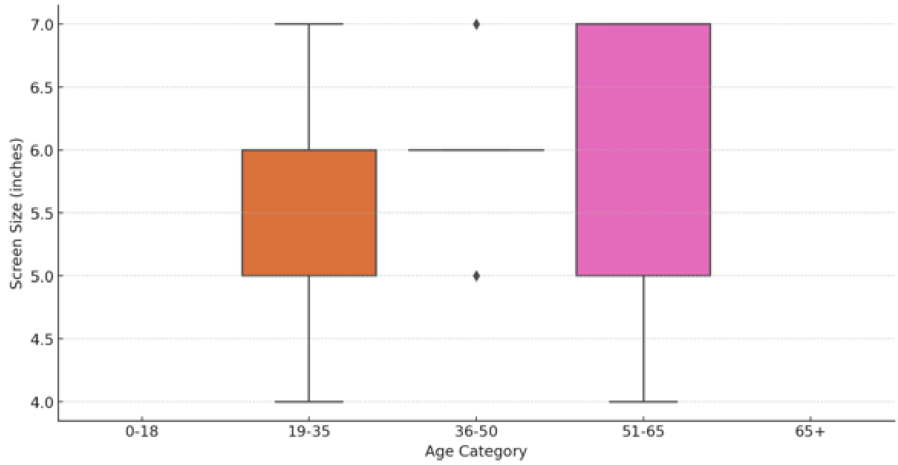

Figure (1): Screen size Preference by Age Category

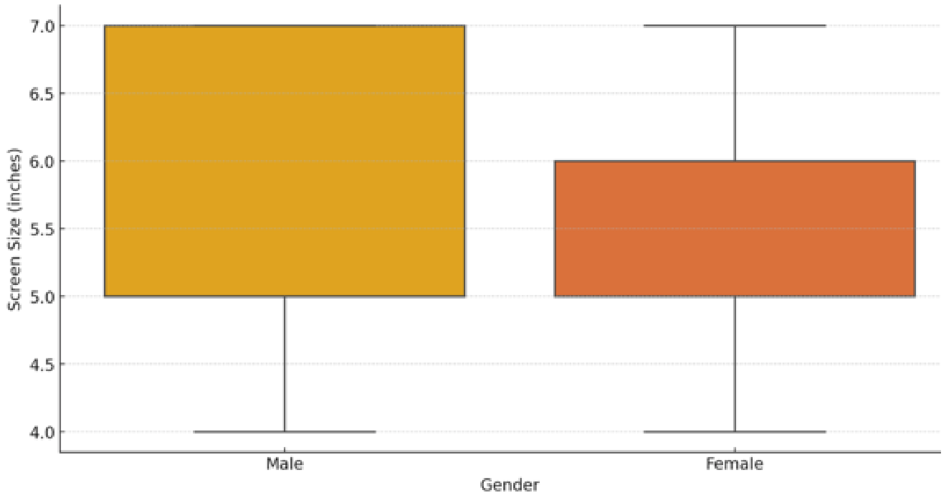

Figure (2): Screen Size Prefrence by Gender

Demographic Analysis Results:

Screen Size Preference by Age Category (Figure 1):

- Younger age groups (0-18, 19-35) tend to prefer slightly larger screens.
- Older age groups (51-65, 65+) have a narrower range of screen sizes, leaning towards the mid-range sizes. This could suggest a preference for moderate screen sizes, possibly due to factors like ease of use or readability.
- The middle age group (36-50) shows a wide distribution, indicating diverse preferences in screen size within this demographic.

Screen Size Preference by Gender (Figure 2):

- Both genders exhibit a similar range of screen sizes, with no significant differences observable in the median screen size.
- The spread (variability) in preferred screen sizes is roughly comparable between males and females, suggesting that gender does not significantly influence screen size preference.

6.2 Principal Component Analysis (PCA)

Performing Principal Component Analysis (PCA) after demographic analysis is often used to uncover underlying patterns or dimensions within complex datasets, such as those involving preferences or behavior across different demographic groups. In this study analyzing mobile phone usage preferences, PCA helps identify major factors that influence user satisfaction and behavior that might not be evident from simple demographic breakdowns alone. By reducing the number of variables to a few principal components, PCA provides a clearer more interpretable visualization of data relationships, allowing researchers or marketers to better understand and address diverse user needs based on a more compact representation of the dataset. This method is particularly valuable in segmenting the market and tailoring products or marketing strategies to meet the nuanced preferences of various user groups. The PCA analysis suggests that two components are sufficient to explain about 73% of the variance in the dataset.
The components identified through the PCA analysis represent underlying factors in the dataset, which can be thought of as dimensions that summarize the responses to various questions about mobile phone usage. Here's a breakdown of the two main components and their potential interpretations based on their loadings:

Component 1: General Phone Usability and Comfort

- High Loadings: All the statements related to the comfort of using the phone, such as making calls, writing emails, and texting, have high loadings on this component. This suggests that this factor captures a general sense of usability and comfort with the mobile phone.
- Interpretation: This factor might represent an overall satisfaction or comfort level with the current mobile device in terms of its ergonomics and ease of use.

Component 2: Multimedia Usage Preference

- High Negative Loadings: This component has significant negative loadings on items related to watching movies and preferences about screen size. It suggests a distinction in preferences for multimedia content consumption.
- Interpretation: This factor might reflect a preference for multimedia consumption, with higher scores indicating a preference against features that enhance multimedia usage, such as a larger screen.

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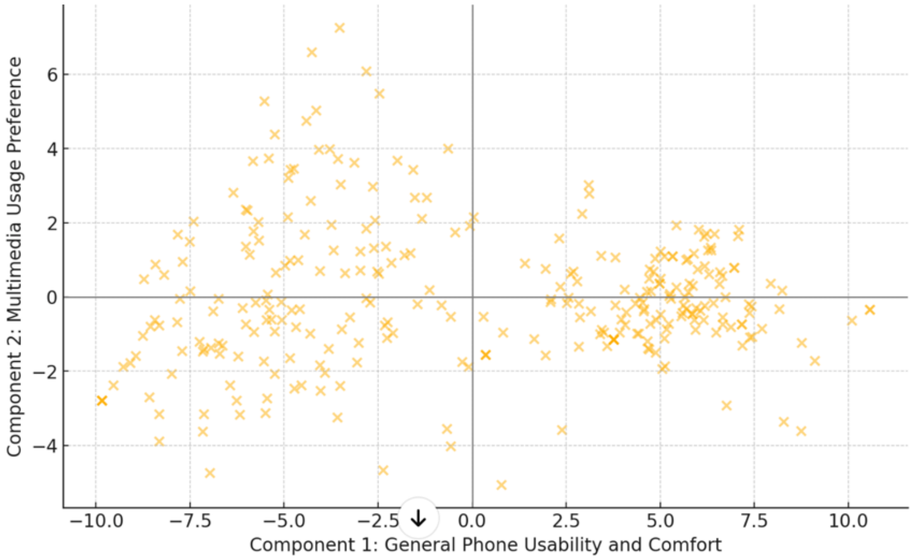

Figure (3): PCS component scores for Mobile Phone Usability Survey

The chart (Figure 3) displaying the scores of the respondents on the two principal components derived from the factor analysis:

- Component 1 (X-axis): General Phone Usability and Comfort. Scores to the right indicate higher comfort and usability with their mobile phone.
- Component 2 (Y-axis): Multimedia Usage Preference. Scores lower on the axis indicate a stronger preference for features that enhance multimedia usage, such as larger screens.

The scatter plot provides a visual representation of how the respondents vary across these two dimensions.

6.3 Cluster Analysis

We used k-means clustering to segment the data into clusters based on their scores on the two principal components.

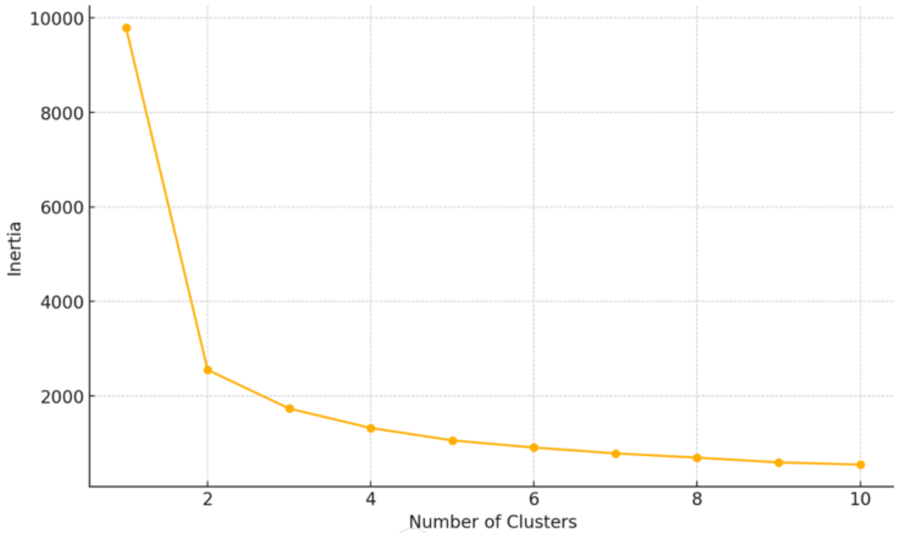

Figure (4): Elbow Method for Optimal k

The elbow plot (Figure 4) shows the inertia for different numbers of clusters, which helps us determine the optimal number of clusters by identifying the point where the inertia begins to decrease more slowly (the "elbow"). From the plot, it appears that the elbow is around k=3 or k=4.

Let's use k=3 for our cluster analysis, which seems to be a reasonable choice given the curve.

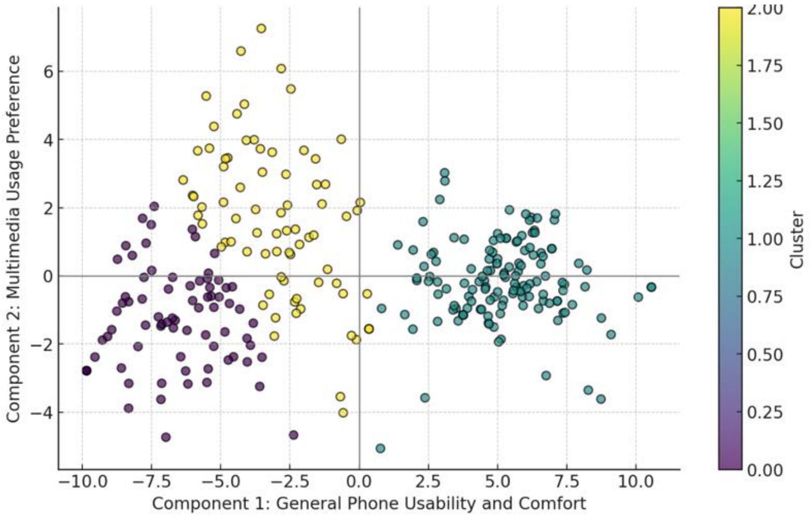

Figure (5): Cluster Analysis of PCA Scores

Here's the cluster analysis result (Figure 5) visualized on the PCA scores. The data points are colored based on the cluster they belong to, using three clusters as determined. This visualization shows how respondents group together based on their scores related to general phone usability and comfort, and multimedia usage preference.

6.4 Regression Analysis

Regression analysis was performed after Principal Component Analysis (PCA) which is a valuable method for understanding how the principal components derived from PCA are influenced by other variables, like demographic factors. PCA simplifies the dataset by transforming it into a set of orthogonal (independent) components that capture the major variance within the data. Subsequently, using regression analysis on these components helps to investigate whether and how specific external variables, such as age, gender, or other socio-economic factors, predict these new, simplified measures.

Regression Analysis Results

Model for Component 1: General Phone Usability and Comfort

- R-squared: 0.007
  - This indicates that only 0.7% of the variance in general phone usability and comfort is explained by age and gender, suggesting a very weak model.
- Coefficients:
  - Age: Not significant (p-value = 0.163)
  - Gender: Not significant (p-value = 0.616)

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Model for Component 2: Multimedia Usage Preference

- R-squared: 0.002
  - Only 0.2% of the variance in multimedia usage preference is explained by age and gender, also indicating a very weak model.
- Coefficients:
  - Age: Not significant (p-value = 0.431)
  - Gender: Not significant (p-value = 0.822)

Both models have very low explanatory power and no significant predictors, suggesting that demographic variables such as age and gender do not strongly influence these aspects of mobile phone usability and preferences

6.5 Ergonomic Analysis

We examined the relationship between hand measurements, one-hand versus two-hand usage, and reported discomfort levels. This will help identify if there are ergonomic patterns that could guide better phone design.

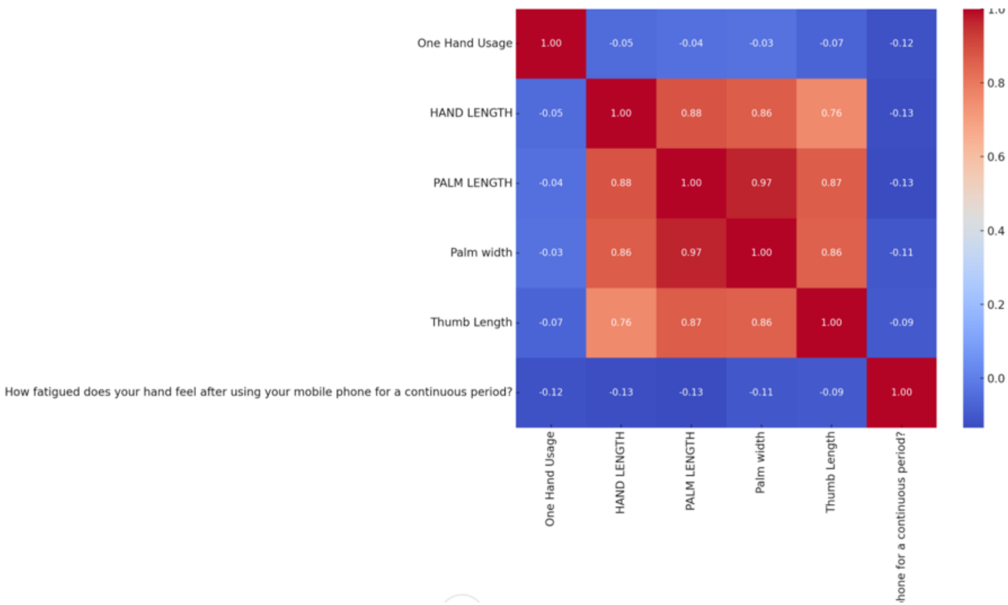

Figure (6): Correlation Matrix of Ergonomic Factors and Usage Discomfort

Ergonomic Analysis Results (Figure 6):

Here are the key insights from the correlation matrix regarding ergonomic factors and usage discomfort:

1. One Hand Usage:
   - There is a very weak correlation between one-hand usage and hand fatigue after continuous use (correlation coefficient around 0.01). This suggests that whether a person uses one hand or two doesn't significantly impact how fatigued they feel.
2. Hand Measurements:
   - Hand measurements like hand length, palm length, palm width, and thumb length also show very weak correlations with fatigue after continuous use. This indicates

that hand size might not be a strong predictor of fatigue or discomfort from using a mobile phone.

- Interestingly, hand measurements have relatively higher (but still weak) positive correlations with one-hand usage, particularly palm width and thumb length. This could imply that individuals with larger hands are slightly more likely to use their phone with one hand, possibly due to ease of reach across the screen.

Ergonomic analysis in the context of mobile phone usage examines the relationship between the physical characteristics of the user (such as hand size and one-hand versus two-hand usage) and the level of discomfort or fatigue they experience during phone use. The key findings from the ergonomic analysis in this study suggest that hand size and usage style (one-handed vs. two-handed) have only weak correlations with fatigue after continuous use, indicating that these factors might not strongly influence the ergonomic comfort of using a mobile phone.

The study highlights a few subtle trends, such as a slightly higher likelihood of one-handed usage among individuals with larger hands, likely due to the ease of reaching across the screen. Despite these nuances, the overall impact of hand measurements on usage discomfort is minimal, suggesting that other factors might be more influential in determining ergonomic suitability.

6.6 Experimental Analysis

An experiment was conducted to evaluate the impact of different smartphone screen sizes on typing comfort and fatigue among users, with an emphasis on ergonomic aspects such as hand posture and grip adjustments.

Participants were asked to engage in a typing task using three different models of iPhones (iPhone 12 Mini, iPhone 12, and iPhone 12 Pro Max) with different screen size to measure:

- Time spent on typing tasks.
- Frequency of pauses taken during typing.
- Comfort levels with each device.
- The necessity to adjust hand posture or grip.

The ANOVA results indicate significant differences in typing times among the three iPhone models with different screen sizes (5.4inches, 6.1inches, and 6.7 inches), as evidenced by a very low p-value ($PR(>F) < 0.0001$). This suggests that the screen size of the phone significantly affects the typing time, which could be attributed to differences in screen size, ergonomics, or other design factors related to each model.

- F-statistic: 188.32 indicates a strong model fit, showing that the model differences are statistically significant in influencing typing times.
- Degrees of Freedom (Between Groups): 2 (representing the three different phone models).
- Degrees of Freedom (Residual): 186 (reflecting the variability not explained by the phone models).

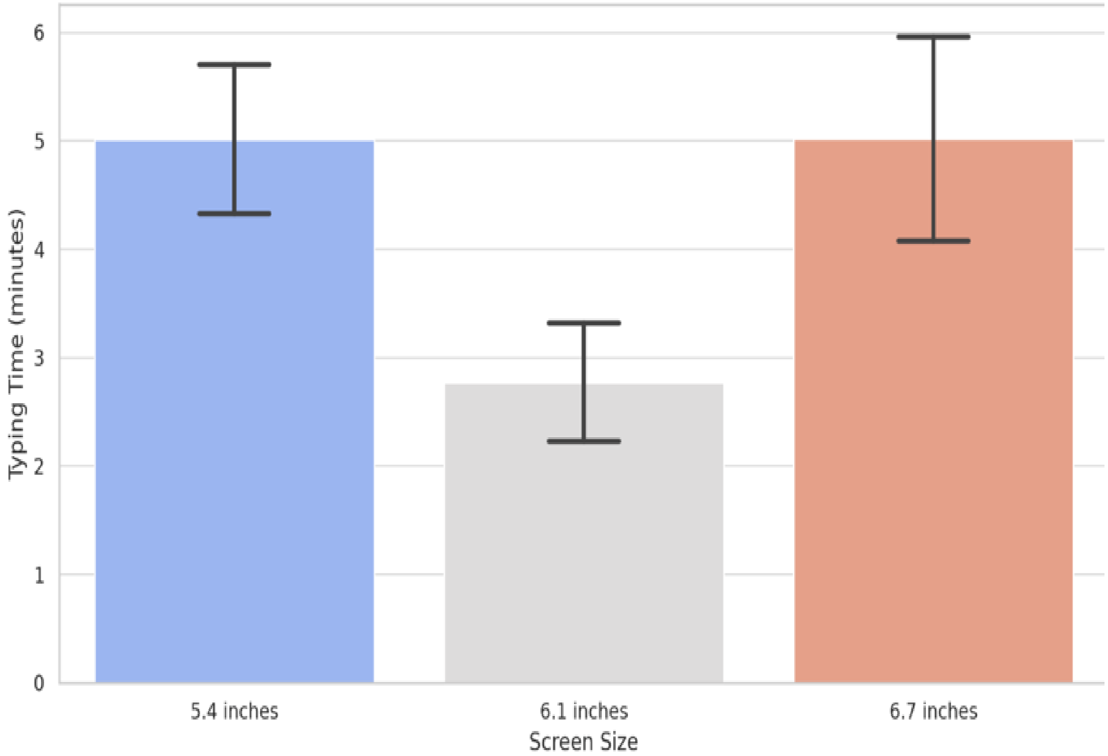

Figure (7): ANOVA: Typing Time by Screen Size

This plot (Figure 7) displays the average typing time for smartphones categorized by their screen sizes: 5.4 inches (iPhone 12 Mini), 6.1 inches (iPhone 12), and 6.7 inches (iPhone 12 Pro Max). The differences in typing times across these screen sizes are clearly illustrated.

The analysis can help in understanding which phone model provides the best ergonomics in terms of reducing typing time, which could be a proxy for ease of use and reduced fatigue.

Tukey's Honest Significant Difference (HSD) test, which compares the mean typing times between each pair of iPhone models to determine if the differences observed in the ANOVA are statistically significant for specific pairs:

- iPhone 12 Mini vs. iPhone 12 Pro Max: There is a statistically significant difference in typing times, with the iPhone 12 Pro Max (Screen size 6.7 inches) having shorter typing times on average compared to the iPhone 12 Mini (screen size 5.4inches). The mean difference is -1.55 minutes, and the result is statistically significant ($p < 0.001$).
- iPhone 12 Mini vs. iPhone 12: There is also a statistically significant difference between these models, with the iPhone 12 (Screen size 6.1inches) having shorter typing times compared to the iPhone 12 Mini (screen size 5.4 inches). The mean difference is -1.80 minutes, and this difference is statistically significant ($p < 0.001$).
- iPhone 12 vs. iPhone 12 Pro Max: There is no statistically significant difference in typing times between these two models. The mean difference is small (0.25 minutes) and not statistically significant ($p = 0.596$).

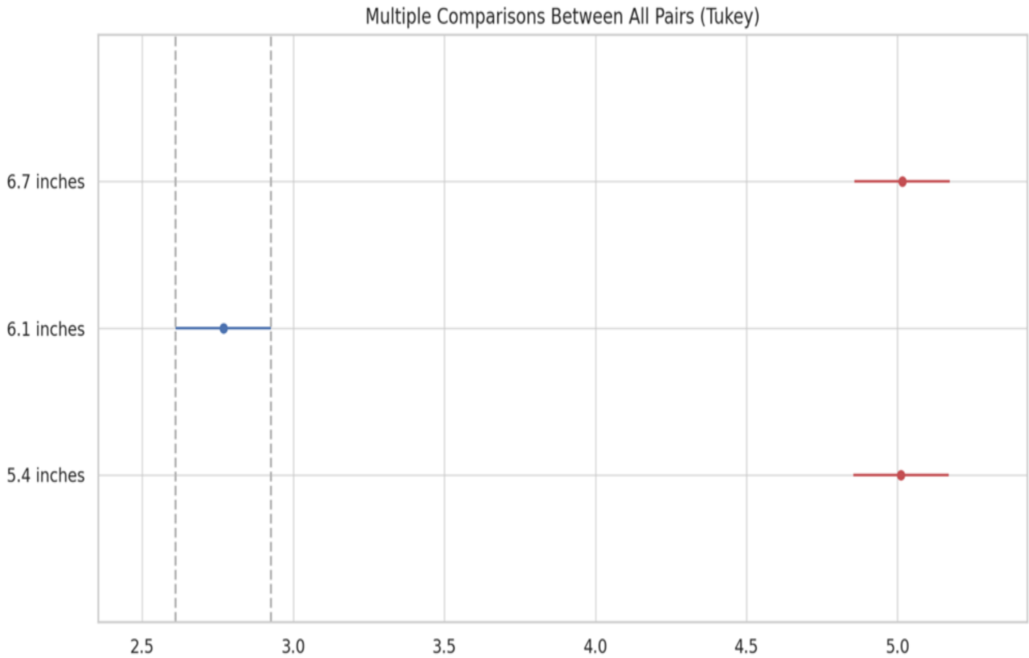

Figure (8): Tukey HSD: Pairwise Comparison of Typing Time between different Screen Sizes

The pairwise comparison plot (Figure 8) uses screen sizes as the comparison basis. It effectively shows which screen sizes result in statistically significant differences in typing times. The plot is set against the 6.1 inches model as a reference, providing a visual understanding of how screen size influences typing ergonomics.

These results suggest that both the iPhone 12 and iPhone 12 Pro Max potentially offer better typing ergonomics compared to the iPhone 12 Mini, possibly due to differences in screen size or other ergonomic features that could affect typing speed and comfort.

These empirical results of the experiment are particularly relevant when integrated with the broader ergonomic analysis. The overall findings support the notion that while hand measurements like palm width and thumb length are weakly correlated with fatigue, the screen size of a smartphone can have a more pronounced ergonomic impact. This reinforces the importance of designing mobile phones that not only fit the physical dimensions of the hand but also support the user's comfort and productivity, particularly in prolonged usage scenarios.

Thus, this experiment not only enriches the existing ergonomic analysis by providing quantitative evidence on the influence of screen size on user comfort but also underscores the importance of integrating ergonomic principles into smartphone design to cater to diverse user needs. This approach is crucial for enhancing user satisfaction and minimizing discomfort, thereby aligning product design with the health and ergonomic well-being of users.

7. CONCLUSION

This research has provided a comprehensive examination of the ergonomic aspects of mobile phone usage, particularly, focusing on hand fatigue and the implications of screen size. Through a detailed analysis involving a combination of demographic studies, principal component analysis, cluster analysis, and experimental design, the study has elucidated how various screen sizes impact user comfort and usability.

Key findings include the minimal influence of demographic factors like age and gender on preferences for phone usability and multimedia consumption. Instead, the ergonomic factors such as hand size and usage style (one-handed vs. two-handed) play a more significant role albeit, with weak correlations to hand fatigue. This suggests that while these physical aspects are worth considering, they do not overwhelmingly determine the ergonomic comfort of mobile phone usage.

The experimental segment of the study highlighted the ergonomic impacts of different smartphone screen sizes on typing comfort and fatigue, with varying screen sizes showing significant differences in typing performance and comfort levels. This emphasize the need for mobile phone designs that cater to the physical dimensions of the hand and support user comfort, especially in prolonged usage scenarios.

Ultimately this research underscores the importance of integrating ergonomic principles into smartphone design to enhance user satisfaction and reduce discomfort, thereby aligning product design with the health and ergonomic well-being of users. The findings aim to inform future mobile phone designs, ensuring they not only advance technologically but also prioritize the health and comfort of users, thereby enhancing the overall usability and appeal of mobile phones across diverse user demographics.

8. RECOMMENDATIONS

Based on the findings of this study on the ergonomic aspects of mobile phone usage and the impact of screen size on hand fatigue, the following recommendations are proposed to guide future mobile phone design and research:

1. **Ergonomic Design Focus**: Manufacturers should prioritize ergonomic design in mobile phones taking into consideration the natural handgrip and typical usage patterns. Phones should be designed with curved edges and material that enhance grip without increasing hand strain.
2. **Screen Size Optimization**: It is crucial to consider a range of screen sizes that cater to varying hand dimensions. This study suggests that there is no one-size-fits-all solution and offering a variety of models can address the diverse needs of users.
3. **Customizable Interfaces**: Software modifications such as adjustable interface elements (e.g., keyboard size, icon spacing) could compensate for physical discomforts associated with different screen sizes. Allowing user to customize their interaction methods can help minimize strain and improve accessibility.
4. **Extended User Testing**: Future research should involve a broader demographic to validate these findings across different age groups hand sizes, and usage habits. Longitudinal studies could also help determine the long-term effects of ergonomic design on hand fatigue.

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