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Experimental Design for User-Centric Kitchen Customisation Based on Anthropometric Data

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ABSTRACT

This paper presents an experimental design aimed at evaluating the ergonomic benefits of kitchen cabinet customisation based on individual anthropometric data. The study adopts a within-subjects protocol, in which participants perform a series of typical kitchen tasks — including reaching, chopping, distributing ingredients, lifting, and stirring — in both standard-dimension kitchens and kitchens customised according to each participant' s body measurements. Key anthropometric parameters, such as stature, standing elbow height, and functional reach, are measured to inform the user-specific kitchen configurations, resulting in two experimental conditions with the same set of tasks performed in each. During both conditions, data are collected using Electromyography (EMG), Galvanic Skin Response (GSR), Electrocardiogram (ECG), and motion capture systems. By comparing participants' physiological responses between the two kitchen environments, the study quantitatively assesses differences in muscle workload, physiological stress, and range of motion. The experimental protocol, sample size calculation, and data collection methods are all designed to enable rigorous, quantitative comparison of ergonomic outcomes in different kitchen settings. This experimental design establishes a basis for developing guidelines to help designers integrate anthropometric data and minimise ergonomic risks in customised kitchen design.

Keywords: *Kitchen Customisation, Anthropometric Data, Experimental Design, Electromyography (EMG)*

1 INTRODUCTION

China has a long-standing tradition encapsulated in the saying "food is the paramount necessity of the people," highlighting its rich culinary culture centred around grains and encompassing various cooking methods such as frying, boiling, frying, stewing, steaming, and roasting (Gao Yang & Miaoxing, 2023). Cooking is a meticulous activity that follows structured procedures and comprehensive guidelines (Kamal Baharin, Ahmad Nizam, Mohd Faharul, Azizan, & Mohd Nordin, 2025). Today, the kitchen has evolved from a mere cooking space to the heart and centre of family life (Man & Chongxi, 2021).

With the rise in household consumption in China, consumers' demands for personalisation have also surged (Qian, 2022). Modern homeowners are not just looking for standard kitchens; they seek spaces that resonate with their own personalised needs and characteristics, adapt to their unique lifestyles, and contribute to their overall well-being. Traditional standardised products struggle to meet these increasingly diverse and personalised needs (Li Ruiqi, Ji Tingyu, Han Li, Guotao, & Chengran, 2021).

To address this challenge, mass customisation in furniture production has emerged. This method uses advanced technologies such as information technology, new materials, and flexible manufacturing to successfully reconcile the contradiction between mass production and personalised customisation (Zhi-hui, 2016).

Anthropometrics, a key aspect of ergonomics, is crucial for kitchen customisation. Accurate measurements of users' body dimensions and habits enable designers to craft layouts that enhance both comfort and efficiency. This ensures cabinets' dimensions align with user needs, minimising the risk of injuries from repetitive tasks. As demand for personalised kitchens grows, integrating anthropometrics more effectively into design processes becomes vital. Future research should focus on methods facilitating the transition to mass-customised production systems, addressing the practical challenges highlighted by Da Silveira, Borenstein, & Fogliatto (Da Silveira, Borenstein, & Fogliatto, 2001). While the trend leans towards customisation, many current practices overlook anthropometrics and user-centric design. By leveraging anthropometrics and technological advancements, we can elevate the kitchen customisation process to be both ergonomic and user-friendly.

When designing and developing products, we shoulder pay attention to the aspects of visual design, storytelling, and user interaction (Nazri et al. 2025). Design operates as a culturally mediated practice, reflecting and shaping the values of society (Yang et al. 2025). It is important to explore ergonomic factors in household kitchens, considering diverse user needs influenced by physical characteristics (Chen et al., 2024). While the 2010 revision of China's "Kitchen Furniture" standard (QB/T 2531 — 2010) provides valuable reference points, mere compliance with technical guidelines does not ensure an optimal design. (J. Chen, 2023). Industry- standard guidelines like the NKBA offer valuable insights for home kitchen design, just focusing on functionality and aesthetics within minimal dimensional requirements (H. Chen et al., 2024). However, Jinwang et al. reveals that some cabinet designs, especially integrated ones, use a uniform height across all these workspaces (Jinwang et al. 2019). Some methods may propose ideal kitchen dimensions, yet they may not satisfy all users due to individual size variations (H. Chen et al., 2024). Charu's study of 200 participants found that standard kitchen designs often don't match anthropometric measurements, leading to joint and back pain (Amit Bhatia, 2019). Similarly, research by Sultana and Prakash showed that ergonomic kitchen design can significantly reduce discomfort and musculoskeletal problems (Sajida & Chitra, 2014). While technical guidelines provide a starting point, following them alone does not guarantee an optimal design. The different evaluation results of different samples indicate the necessity of customised requirements (Chen, 2023). Given demographic differences, it is crucial to provide users with personalised and optimised measurements, especially for those who exceed anthropometric thresholds (Krishna & Mehta, 2021). Based on the above content, the following problems has been identified:

1. The discrepancy between standard customisation kitchen designs and individual anthropometric measurements, leading to discomfort and pain.
2. The challenge lies in understanding the relationship between physical fatigue resulting from kitchen activities and the design height of the kitchen, which contributes to ergonomic risks.
3. There is a lack of a comprehensive guideline for designers in the customisation design process by integrating anthropometric measurements, optimising design proposals according to user needs, and minimising primary ergonomic risks.

1.1 Research Objectives

Based on the above three problems, three corresponding objectives were proposed.

1. Examine the prevalent use of standard dimensions in kitchen customisation design reveals a neglect of the diverse anthropometric needs of users, leading to primary ergonomic risks.
2. Examine the use of user-specific dimensions in kitchen customisation design can reduce primary ergonomic risks.
3. Propose a guideline to assist kitchen customisation designers in the design process by integrating anthropometric data.

1.2 Hypotheses

In order to achieve research objective i, H1-H5 is proposed. In order to achieve research objective ii, H6-H10 is proposed. Based on the comparison of the verification results of H1-H5 and H6-H10, H11 is proposed to achieve objective iii, as follows:

- H1: In customised kitchens using universal standard dimensions, performing kitchen activities involving repetitive or sustained awkward postures may result in biomechanical stress and physical fatigue.
- H2: In customised kitchens using universal standard dimensions, high frequency of repetitive kitchen tasks may result in biomechanical stress and physical fatigue.
- H3: In customised kitchens using universal standard dimensions, maintaining static postures for long periods of time while performing kitchen activities may result in biomechanical stress and physical fatigue.
- H4: In customised kitchens using universal standard dimensions, kitchen activities that require force may cause biomechanical stress and physical fatigue.
- H5: In customised kitchens using universal standard dimensions, kitchen activities involving contact stress may result in biomechanical stress and physical fatigue.
- H6: In customised kitchens incorporating user-specific dimensions, performing kitchen activities involving repetitive or sustained awkward postures may result in less biomechanical stress and physical fatigue than in a kitchen with universal standard dimensions.
- H7: In customised kitchens incorporating user-specific dimensions, performing high-frequency repetitive kitchen tasks may result in less biomechanical stress and physical fatigue than in a kitchen using universal standard dimensions.
- H8: In customised kitchens incorporating user-specific dimensions, prolonged kitchen activities in static postures may result in less biomechanical stress and physical fatigue than in a kitchen with universal standard dimensions.
- H9: In customised kitchens incorporating user-specific dimensions, exerting force in kitchen activities may result in less biomechanical stress and physical fatigue than in a kitchen with universal standard dimensions.
- H10: In customised kitchens incorporating user-specific dimensions, performing kitchen activities with contact stress may result in less biomechanical stress and physical fatigue than in a kitchen using universal standard dimensions.
- H11: Integrating anthropometric guidelines can help designers create customised kitchen designs that are more ergonomic and increase design efficiency.

2 LITERATURE REVIEW

2.1 Kitchen Customisation

Driven by the discrepancy between customer demands and production constraints, mass customisation (MC) has emerged as a solution to balance mass production with personalised customisation. Davis first introduced the concept of MC as a means to offer uniquely tailored products through flexible and integrated processes, aiming balance user needs with large-scale production (Davis, 1989). Pine argues that the goal of mass customisation is to offer customers a wide range of product choices and services, enabling them to purchase products that meet their specific needs at reasonable prices. He defines mass customisation as a production method that uses high-efficiency, low-cost design, production, and service techniques to fulfil individual customer needs within a product category through mass production (Pine, 1999). This definition underscores two key features of mass customisation: large-scale production and personalised needs fulfilment. For products like home appliances, bicycles, clothing, furniture, and computers, which are stable in quality, easy to standardise, and mature, mass customisation is more achievable (Zhang & Ju, 2002).

Whole-house customisation treats the overall living environment as the central focus for design and renovation. When crafting the overall design and individual components, it's essential not only to maintain a consistent style but also to balance functionality, ergonomics, and aesthetic (Rui et al. 2017). Ergonomics is instrumental in optimising kitchen spaces for both comfort and efficiency. This discipline focuses on the interaction between individuals and their working environments, aiming to ensure safety and minimise risks (Hrovatin et al. 2015). In the realm of kitchen design, ergonomics takes into account the entire work system, processes, and outcomes. The objective is to enhance movement efficiency and mitigate injuries resulting from repetitive actions (Chen et al. 2024). Practices in kitchen ergonomics are geared towards improving movement efficiency and reducing the strain caused by repetitive tasks during cooking, thereby preventing potential injuries. Furthermore, these practices also strive to enhance user interactions within the kitchen space during culinary activities (Occupational Health and Safety Agency for Healthcare in British Columbia, 2003).

2.2 Anthropometry In Kitchen Customisation

Kitchen tasks generally follow the sequence of "washing vegetables — chopping — cooking — washing dishes," primarily utilising three workspaces: the sink, countertop, and stove（Chen, 2023）. Common kitchen actions like bending over to chop vegetables or reaching into cabinets to fetch items can cause fatigue and lead to musculoskeletal disorders due to lifting and sustained poor posture. Awkward postures during kitchen tasks can lead to MSDs (Fatima et al. 2023; Mondal & Bhattacharjee, 2017).

In 1927, a German designer, Erna Meyer, proposed that to improve comfort in kitchen chores, the kitchen design should be adjusted to suit the user's height (Meyer, 1926), as illustrated in Figure 1.

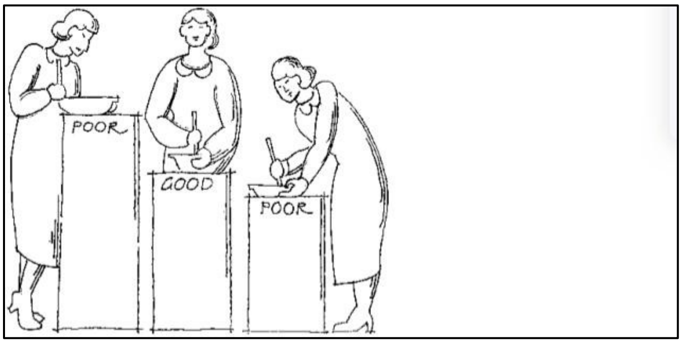


Figure 1 Kitchen Furniture Adjusted to the height of its Users
(Sources: Meyer,1926, Copyright Consent: Permissible to Publish)

Generally, the stove and the countertop are at the same height. However, since women typically use the stove for longer periods, to avoid shoulder and neck pain from holding their arms too high, the stove height should be lower than the countertop height. The sink height is often too low, causing lower back strain with prolonged use. Therefore, the sink height should be raised so users can wash dishes comfortably while standing upright (Li, 2007). Dong suggested that the stove surface height should account for the combined height of the stove and pots. For tabletop stoves, the height should be 200 mm lower than the regular countertop, making it between 600 mm and 650 mm. For built-in stoves, it should be 100 mm lower, resulting in a height between 700 mm and 750 mm.

Researchers proposed the recommended countertop heights for women of different heights are shown in Table 1 (Li, 2007). This has significant implications for the ergonomic study of kitchens, as it identifies the correlation between women's height and comfortable countertop heights, with small size intervals. However, it does not reveal the intrinsic relationship between them. While height provides some guidance on countertop height, it is more directly related to the elbow height in a standing posture.

Table 1 The Most Comfortable Operating Height Corresponding to the Different Stature

Stature	150cm	153cm	155cm	158cm	160cm	163cm	165cm	168cm	170cm
Operating height	79cm	80cm	81.5cm	83cm	84cm	85.7cm	86.5cm	88cm	89cm

(Source：(Li, 2007)

The general principles for selecting human body dimensions percentiles in product design are as follows (Baoxiang, 2017):

- For general products, the 95th and 5th percentiles (P95 and P5) are commonly chosen, or alternatively, P90 and P10 may be selected as appropriate.
- For products related to health and safety, the 99th and 1st percentiles (P99 and P1) are selected, or alternatively, P95 and P5 as appropriate.
- For products used by both adult men and women, the larger percentile is chosen based on the male P90, P95, or P99, and the smaller percentile based on the female P10, P5, or P1.

Since the kitchen is a product used by both genders, choosing the female P10 to the male P95 percentile (GB/T 10000-1988) range can satisfy 85% of the adult population in China (Table 2). According to data, the 10th percentile stature (P10) for Chinese adult females (aged 18-55) is 1503 mm, and the 95th percentile stature (P90) for Chinese adult males (aged 18-60) is 1775 mm. Therefore, the appropriate height range is 1500 mm to 1800 mm.

Table 2 Main Body Dimensions (GB/T 10000-1988) (Unit: mm)

Age group	**Men (18 to 60 years old)**							**Women (18 to 55 years old)**						
Measuring items	**1**	**5**	**10**	**50**	**90**	**95**	**99**	**1**	**5**	**10**	**50**	**90**	**95**	**99**
1.1 Height	1543	1583	1604	1678	1754	1775	1814	1449	1484	1503	1570	1640	1659	1697
1.2Weight /kg	44	48	50	59	70	75	83	39	42	44	52	63	66	71
1.3Upper arm length	279	289	294	313	333	338	349	252	262	267	284	303	302	319
1.4Forearm length	206	216	220	237	253	258	268	185	193	198	213	229	234	242
1.5Thigh length	413	428	436	465	496	505	523	387	402	410	438	467	476	494
1.6Calf length	324	338	344	369	396	403	419	300	313	319	344	370	375	390

(Sources: Baoxiang, 2017)

The design methods for various functional areas are as follows (Jun, 2009):

- Sink height = elbow height - 50 mm
- Stove height = elbow height - (100-150) mm
- Countertop height = Stature x 6/11

This study reveals the true relationship between various human body measurements and kitchen cabinet dimensions, providing very valuable guidance for this thesis. Using the provided formulas, the appropriate heights of different kitchen countertops can be accurately calculated for each user.

In summary, anthropometry in ergonomics is crucial for custom kitchen design. Previous studies have explored the relationship between countertop heights and human measurements, providing a reference for future research. However, the heights of various countertops used in current kitchen customisation processes are still designed according to standardised dimensions, without considering individual differences. This can lead to physical discomfort for users. Addressing this gap will be the focus of this thesis.

3 METHODOLOGY

The research design utilises a quantitative approach to data collection and analysis. Objective numerical data on physical workload and task efficiency are obtained through anthropometric measurements, Xsens motion capture, surface Electromyography (EMG), Galvanic Skin Response (GSR), and Heart Rate monitoring. The primary ergonomic risk factors in the kitchen are frequent task repetition, forceful movements, extended or repetitive awkward postures, prolonged static positions, and pressure from contact. Tasks such as chopping vegetables, bending during food preparation, reaching for items on shelves or in upper cabinets, and lifting utensils and pots are commonly carried out in the kitchenette (Bhatia & Singla, 2019). To examine the relationship between dimensional design and ergonomic risk in kitchen, five experimental tasks were designed: reaching for items on high cabinets, chopping vegetables, distributing ingredients into different containers or bowls, lifting heavy pots, pans, and containers, and stirring ingredients in pots and pans, simulating a complete cooking process in the kitchen. The five experiments were conducted in both customised kitchens using standard dimensions and those using user-specific dimensions, resulting in ten experiments in total. Table 3 illustrate the specific tasks conducted in each kitchen setup.

Table 3 The Specific Tasks Conducted in Each Kitchen Setup (Sources: The Author, 2025)

The primary ergonomic risk factors	Task
Extended or repetitive awkward postures	Accessing items from upper shelves
Frequent task repetition	Cutting and preparing vegetables
Prolonged static positions	Transferring ingredients to different containers
Forceful movements	Handling and moving heavy kitchenware
Pressure from contact	Mixing and stirring contents in pots

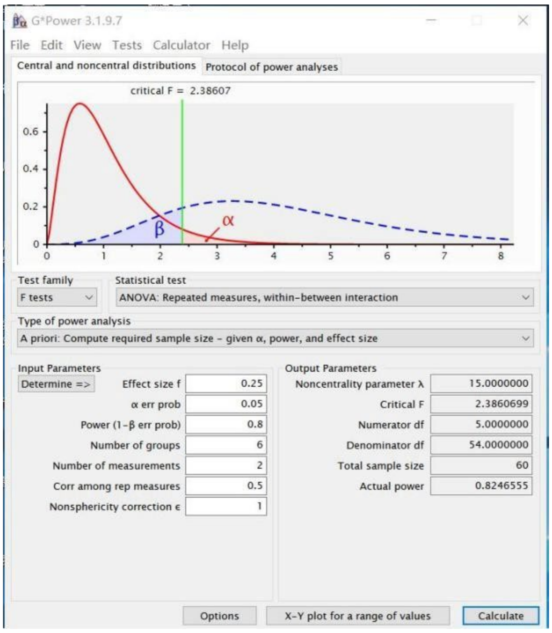
3.1 Sampling

3.1.1 Participant Recruitment

Inclusion criteria required participants to be free from severe musculoskeletal disorders, willing to participate, and have prior experience with common kitchen tasks such as cooking, chopping, and cleaning. Exclusion criteria included physical conditions that might impede safe task execution and professional cooking experience.

3.1.2 Sample Size Determination

In order to ensure adequate statistical validity of the study, the sample size was predicted using G*Power 3.1.9.7 software. G*Power (Erdfelder et al. 1996) is a free and highly versatile software for conducting statistical power analysis, and has become a standard tool in social and behavioural sciences. The latest release, G*Power 3.1.9.7, significantly enhances its previous capabilities by supporting a comprehensive array of statistical tests—including t, F, χ^2, z, and several exact tests—across both Windows and Mac OS platforms. The software features improved effect size calculations, flexible input parameters, and robust power analysis options, making it an indispensable and practical resource for researchers seeking rigorous sample size estimation and study planning (Faul et al. 2007). The statistical analysis was conducted using an F test, specifically a repeated measures analysis of variance (ANOVA) incorporating a within-between interaction. An a priori power analysis was performed with the following parameters: a significance level (α) of 0.05, a target statistical power of 0.80, a between-subjects factor representing height group (six groups), and a within-subjects factor representing the configuration of the operating table (two conditions: standard height and individualised height). Based on these specifications, the power analysis determined that a minimum total sample size of 60 participants is necessary to ensure sufficient statistical power for detecting meaningful effects. The calculation interface of G*Power 3.1.9.7 is shown in Figure 2.



Test family: F tests
Statistical test: ANOVA: Repeated measures, within–between interaction
Type of power analysis: A priori: Compute required sample size – given α, power, and effect size

Input Parameters
Effect size f: 0.25
α err prob: 0.05
Power (1–β err prob): 0.8
Number of groups: 6
Number of measurements: 2
Corr among rep measures: 0.5
Nonsphericity correction ϵ: 1

Output Parameters
Noncentrality parameter λ: 15.0000000
Critical F: 2.3860699
Numerator df: 5.0000000
Denominator df: 54.0000000
Total sample size: 60
Actual power: 0.8246555

Figure 2 The Calculation Interface of G*Power 3.1.9.7
(Source: The Author, 2025)

In accordance with the GB/T 10000-1988 standard for Chinese adult anthropometry, participants were divided into six stature-based groups spanning from 1500 mm to 1800 mm (1500–1550, 1550–1600, 1600–1650, 1650–1700, 1700–1750, and 1750–1800 cm), ensuring coverage of approximately 85% of the adult Chinese population. A total of 60 participants (10 per group) were recruited, as determined by a priori power analysis using G*Power.

4 FINDINGS

Based on the literature review, the Conceptual Framework is proposed and showed in Figure 3.

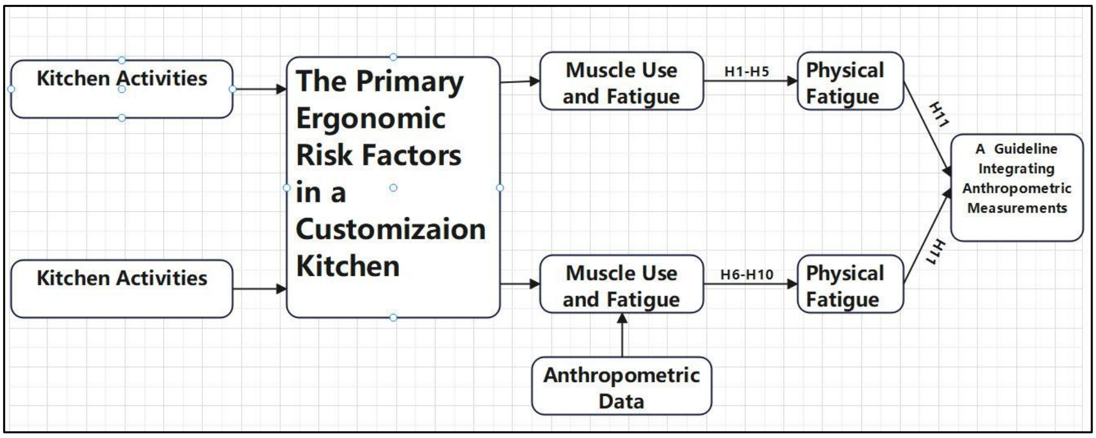


Figure 3 The Conceptual Framework
(Source: The Author, 2025)

Figure 4 shows the research process. basically, the research has divided into 3 phases after a pilot test. Phase 1 is conducted through experiments with tasks in customised kitchens with standard kitchen dimension, Phase 2 is conducted through experiments with tasks in customised kitchens with user-specific dimension, and Phase 3 is verified through in-depth interviews.

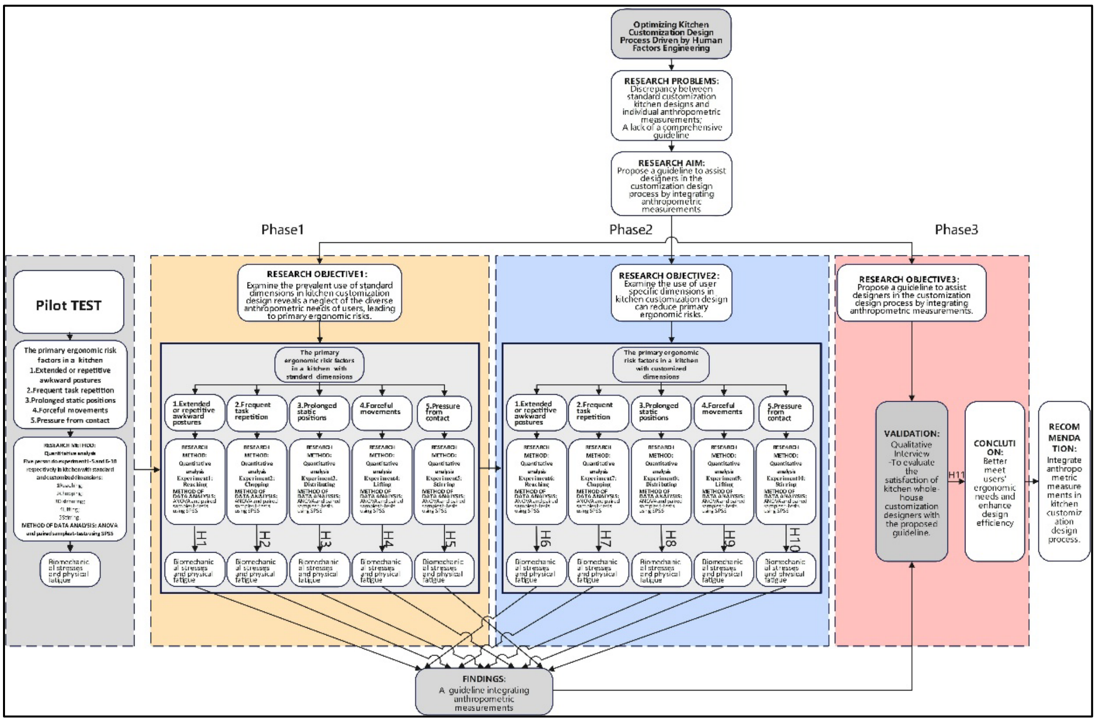


Figure 4 Research process
(Source: The Author, 2025)

3.2 Experimental Setup

Based on anthropometric measurements, two types of kitchen operating environments were established for each participant to enable subsequent ergonomic comparison experiments:

3.2.1 Customised kitchens with standard kitchen dimension

This configuration employed industry-standard kitchen dimensions commonly used in whole-house customisation, without considering individual user differences. Specifically, the operating table height was set at 820 mm, the stove height was achieved by placing a 50 mm stove support on top of the countertop, and the bottom height of the hanging cabinet was set at 1900 mm (vertical distance from the floor). This group served as the control condition, simulating the prevalent practice of applying uniform dimensions regardless of user variability.

3.2.2 Customised kitchens with user-specific dimension

This configuration was tailored for each participant according to their individual anthropometric data, with the aim of optimising ergonomic comfort and operational efficiency while reducing muscle load.

Operating table height was set as: Elbow height (with shoes) minus 100 mm. This approach ensures the user's forearms rest comfortably with a slight downward angle (approximately 5°–15° above the table surface), facilitating shoulder relaxation and horizontal wrist alignment, while minimising upper limb muscle strain. The height of the stove was set as the participant' s standing elbow height minus 200 mm, with a wok placed on a 50 mm stove support.

Hanging cabinet bottom height was set as: Functional arm reach height (with shoes) minus 150 mm. This ensures participants can access both lower and upper shelves comfortably while standing flat-footed, reduces excessive shoulder elevation, and helps prevent postural overcompensation or safety hazards such as frequent head bumps or unstable reach manoeuvres.

These two experimental setups allow for direct comparison of a conventional standardised kitchen and a user-specific, ergonomically optimised kitchen environment. This provides a robust methodological basis for evaluating physiological and behavioural differences across conditions, in line with a user-centred approach to kitchen customisation. The configurations of the two kitchens are shown in the Figure 5.

Figure 5 The Configurations of the Two Kitchens
(Source: The Author,2025)

3.3 Testing Process

3.3.1 Pilot Test

The pilot test aimed to validate the feasibility, reliability, and clarity of the experimental protocol prior to the main study.

Seven participants were recruited for the pilot: one “zero participant” for initial process calibration, and one participant from each of six distinct height groups to ensure anthropometric diversity. All participants were free from severe musculoskeletal disorders and had no professional cooking experience.

This pilot test ensured that all procedures, measurement tools, and data collection methods were appropriate and effective, providing a solid foundation for the subsequent full-scale experiment.

3.3.2 Phase 1

3.3.2.1 Procedure

Each participant received a detailed briefing on the study’ s objectives, procedures, and task requirements before providing written informed consent, in accordance with institutional ethical approval. Anthropometric data — including stature, standing elbow height, and functional overhead reach — were collected using standardised instruments. Participants then completed a standardised sequence of five kitchen tasks (reaching, chopping, distributing, lifting, and stirring) in customised kitchens configured to standard dimensions.

3.3.2.2 Data Collection Instruments

During all tasks conducted in customised kitchens with standard dimensions, full-body motion data were recorded using the Xsens MVN Link IMU-based system. Surface EMG sensors measured muscle activity to assess workload and fatigue, while heart rate monitoring and galvanic skin response (GSR/EDA) were used to evaluate physical exertion, autonomic arousal, and stress. These physiological measures provided comprehensive data on participants’ responses under standardised kitchen conditions.

3.3.3 Phase 2

3.3.3.1 Procedure

Customised kitchen dimensions — including countertop, cabinet, work surface, and stovetop heights—were calculated for each participant based on their anthropometric measurements, ensuring ergonomic alignment with individual body dimensions. Participants then performed the same standardised sequence of five kitchen tasks in these user-specific kitchen environments.

3.3.3.2 Data Collection Instruments

Motion capture, electromyography (EMG), heart rate monitoring, and galvanic skin response (GSR) were still used to collect participants’ physiological data during this experimental phase. The wearing effect on participants is shown in the Figure 6.

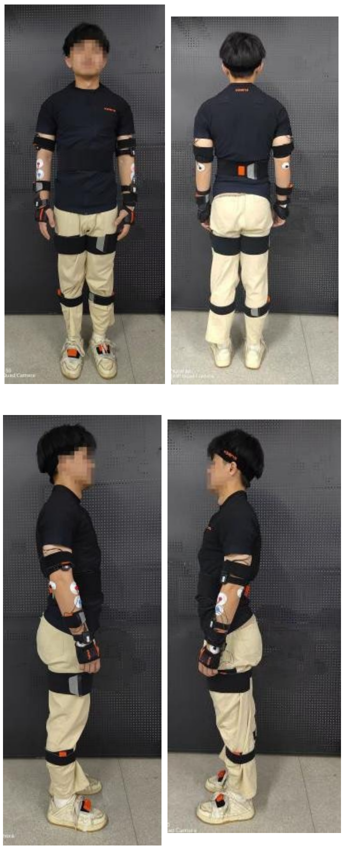


Figure 6 The wearing effect on participants
(Source: The Author,2025)

3.3.4 Phase 3

Three experienced kitchen customisation designers (minimum 5 years' professional experience) will be recruited for in-depth interviews to assess the proposed design guidelines. After obtaining informed consent, participants will provide feedback on guideline effectiveness, feasibility, and user impact, guided by open-ended interview questions. Only designers with ergonomic kitchen experience will be included. This process aims to gather expert insights and suggestions for further improvement.

CONCLUSION

This research outlines a comprehensive research approach aimed at addressing effective customisation challenges in kitchen design, meeting user ergonomic needs, and ensuring their physical health during kitchen activities. A research method incorporating quantitative method was proposed through experiments. The research design focuses on identifying the main ergonomic risk factors and designing experiments to verify hypotheses related to standards and user specific kitchen sizes. By comparing two types of kitchen environments through experiments, the aim is to provide guidance for designers to better meet the ergonomic needs of users. The development process of research instruments includes designing experiments, and conducting pilot tests to improve experimental procedures. The formal experiment is divided into the first and second stages, focusing on customised kitchen design in different aspects. The first stage studied the use of standard sizes, and the second stage explored the application of user specific sizes. This experimental design provides a foundational framework for proposing guidelines that assist designers in integrating anthropometric measurements, optimising customisation according to user needs, and minimising ergonomic risks in kitchen design.

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AUTHOR CONTRIBUTIONS

Each author contributed equally in this research.

CONFLICT OF INTEREST

The author declares no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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