4-8-2024

Kitchen ergonomics in health and healthcare: A rapid scoping review

Haozhi Chen
Purdue University, chen1809@purdue.edu

Nicholas Anton
Purdue University, anton5@purdue.edu

Richard J. Holden
Indiana University

Denny Yu
Purdue University, dennyyu@purdue.edu

Human Factors in Healthcare 5 (2024) 100069

Contents lists available at ScienceDirect

Human Factors in Healthcare

journal homepage: www.elsevier.com/locate/hfh

Review

Kitchen ergonomics in health and healthcare: A rapid scoping review

Haozhi Chen [a], Nicholas Anton [a], Richard J. Holden [b,c], Denny Yu [a,*]

[a] Purdue University, 315 N. Grant St, West Lafayette, IN 47907, USA
[b] Indiana University Bloomington, Bloomington, IN, USA
[c] Regenstrief Institute, Inc., Indianapolis, IN, USA

ARTICLE INFO

Keywords:
Ergonomics
Sociotechnical systems
Home kitchen
Health

ABSTRACT

Although traditional workplace settings such as hospitals and clinics are well-studied, non-clinical areas like home kitchens, which connect clinical healthcare with the care provided in daily living settings, have received less attention. During the early stages of the global pandemic, there has been an increase in home cooking activities due to widespread isolation and restrictions imposed on dining publicly. Ergonomics is at the intersection between work environments and human task performance, and kitchen ergonomics informs knowledge on effective, safe, and efficient cooking practices while maintaining the desired kitchen functionality. Numerous contributions across various disciplines have added knowledge to the kitchen ergonomics area, and this rapid scoping review aims to synthesize the knowledge from these diverse disciplines and further understanding of user interactions with home kitchens. Adopting the Systems Engineering Initiative for Patient Safety model, relevant research publications were synthesized into four major themes: Kitchen layout, arrangement, and environment; Kitchen tools and technology; Design criterion for users with special needs; Risks & Hazards related to kitchen activities. These themes summarizes the current state and gaps in kitchen ergonomics. In addition, these themes help identify future engineering opportunities for supporting health-related cooking activities in the home environment.

Introduction

Healthcare environments are central to the outcomes of healthcare processes (Holden et al., 2013). Although there are many settings where healthcare tasks are performed, traditional healthcare settings often studied in human factors projects include environments such as hospitals, clinics, pharmacies, and operating rooms (Carayon et al., 2006). Less studied are the non-clinical settings such as the home and home kitchen environments. Although not a traditional workplace setting, the home kitchen also plays an important role in a person's daily living, influences patient health, and warrants attention from the human factors healthcare community.

Kitchens are commonplace among US households and serve a critical role in daily activities, primarily food preparation. At home, Americans may spend 60% of their waking time in the kitchen (Severson, 2017). A longitudinal study (2003–2016) found an increase in the percentage of adults cooking at home, especially among college-educated men (Taillie, 2018). Such trends were the result of the pursuit of a healthier dietary pattern (Mills et al., 2017) and the acceptance of cooking as a form of pleasure rather than labor, concomitant with the increased popularity of food-associated media such as TV channels, smartphone applications, and social media (Holmberg et al., 2016; de Solier, 2005; Hearn et al., 2014). Moreover, restrictions imposed on US restaurants during the Coronavirus Disease 19 (COVID-19) global pandemic (Lucas, 2020) further accelerated the rise in families dining at home (Wilkins, 2020). With the increased trend of home cooking, the need to understand how home kitchens can affect users' health and health-related activities has become more critical.

Kitchen ergonomics focuses on the intersection between kitchen environments and cooking-related performance. It provides theories, concepts, and guidelines that can support successful home cooking activities. Examples of kitchen ergonomics practices include optimizing movement and minimizing repetitive motions during the cooking process to prevent injuries caused by cooking tasks and improving the interactions between the users performing cooking tasks in the kitchen environment (Occupational Health and Safety Agency for Healthcare in British Columbia, 2003). Ergonomics in the kitchen environment centers around topics that ensure effective, safe, and efficient cooking practices.

* Corresponding author.
E-mail address: dennyyu@purdue.edu (D. Yu).

https://doi.org/10.1016/j.hfh.2024.100069
Received 2 March 2023; Received in revised form 26 February 2024; Accepted 29 February 2024
Available online 23 March 2024

Contributions across numerous disciplines are relevant to kitchen ergonomics, including but not limited to industrial design, which enhances the user-friendliness of kitchen by optimizing kitchen space layout (Overhill, 2014); physical ergonomics, which uses anthropometry principles to evaluate kitchen design for risk mitigation and safety (Silvana et al., 2015; Ward, 1974); environmental psychology, which studies how the ambient environment of the kitchen affects users (Tong et al., 2021); and smart systems, which advance human-kitchen interaction through autonomous and smart technologies (Ceccacci et al, 2015). However, very few studies exist that aggregate these diverse disciplines and synthesize their intersections and remaining gaps. Thus, there is a need to scope the current state of the literature on kitchen ergonomics with a specific focus on the cooking process to better understand user interactions within the home kitchen space while performing cooking tasks.

This rapid scoping review summarizes the relevant disciplines and topics of kitchen ergonomics that have contributed to domestic kitchen design. Literature from various disciplines is synthesized to identify intersections and gaps for improving ergonomics in the kitchen.

Method

Relevant research publications were identified using the Google Scholar, PubMed, and ScienceDirect databases. The literature review was conducted in three steps. As the first step, a broad search was conducted using the search term "kitchen + ergonomics" to serve as a scoping review of relevant literature. The second step was to examine the reference lists from the articles selected from step one; non-duplicated articles with relevant information in the title were selected from the reference lists. The final step was a forward citation search to obtain non-duplicated literature that cited the previously identified papers from the first and second steps.

For step one of the literature review, the abstracts of the articles found were screened and narrowed down using the following inclusion criteria: 1) studies published in the English language, 2) application area was home kitchens, 3) contributed to knowledge on the relationship between the kitchen work environment and the user, and 4) was published in peer-reviewed journals, conference proceedings, industrial standards, or technical reports.

The initial review (Step 1) resulted in 59 publications that met the inclusion criteria, the second review (Step 2) identified 30 additional publications, and the third review (Step 3) identified 21 additional publications. To reduce the scope of this rapid review and maintain the relevancy of all articles, the full texts of the 110 identified articles were further screened on their relevance to the home cooking process and ergonomic considerations for kitchen users. The 110 articles were screened, and 78 of them were included in the results of this scoping review.

The Systems Engineering Initiative for Patient Safety (SEIPS) model was used to guide the organization of the included paper into constructs (Holden et al., 2013; Carayon et al., 2006). The SEIPS model evolved from sociotechnical systems theory, which emphasizes the interaction between people (social system) and technology (technical system) within an organization. It was designed to analyze and explain the healthcare system by focusing on the interactions between the work system, processes, and healthcare outcomes. According to SEIPS 2.0, the work system has six interacting components: person(s), tasks, tools and technologies, organization, internal environment, and external environment (Holden et al., 2013). The SEIPS 2.0 model was used to organize the emerging themes from our review. The findings of our scoping review were mapped onto this sociotechnical framework as follows (Fig. 1). Kitchen ergonomics can be classified into the work system (i.e., characteristics and needs of potential home kitchen users, the layout and environment of the kitchen, and kitchen tools and equipment), processes (i.e., acts directly related to cooking), and outcomes (i.e., user safety, usability, and performance).

Results

The number of manuscripts primarily associated with the key sociotechnical constructs are shown in Table 1 and are synthesized in the following sections.

Table 1
Articles associated with the various constructs from the sociotechnical model (Fig. 1).

Constructs	Articles identified
Kitchen layout, arrangement, and environment	27
Kitchen tools and technology	21
User characteristics and needs	19
Outcomes	11

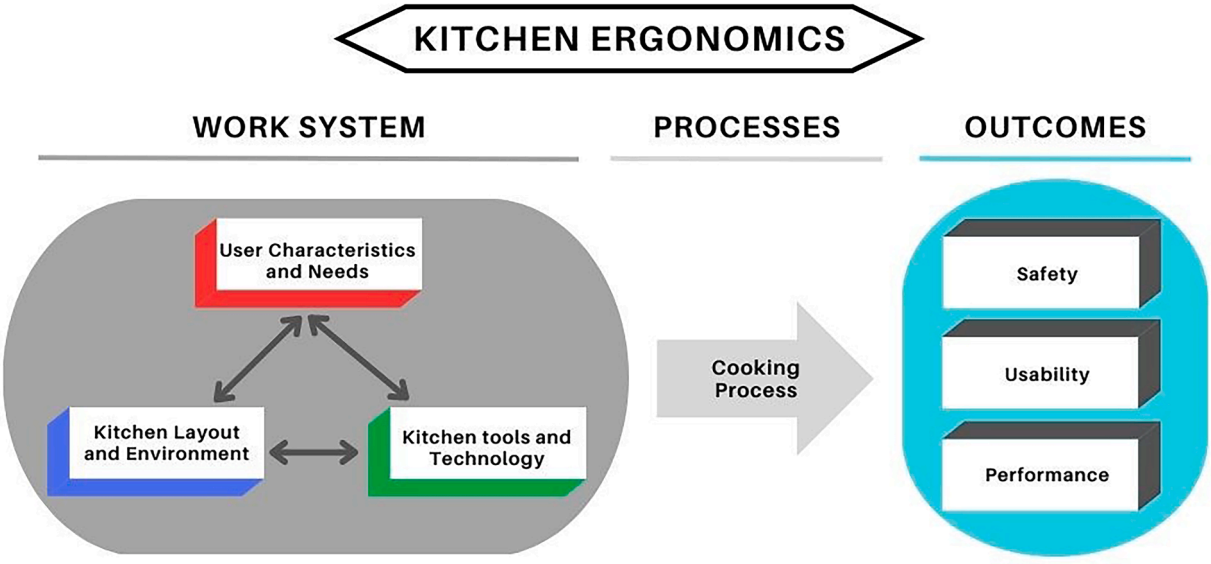

Fig. 1. Sociotechnical Framework of Kitchen Ergonomics based on SEIPS 2.0 (Holden et al., 2013).

Work system

Kitchen layout and environment

In the context of kitchen ergonomics, the kitchen layout and environment construct includes kitchen space, positioning of kitchen elements, and the relationship between those elements. Five concepts were concluded for Kitchen Layout and Environment as indicated in Fig. 2.

The 1st concept, the work triangle, was developed by kitchen designers and architects to achieve the optimal configuration of the kitchen space between the stove, fridge, and sink. The work triangle focused on the placement of the stove, fridge, and sink in a triangle formation with the intention of positioning all elements at distances that minimize traffic in the path and avoid excessive movement volume (Chen et al., 2021; Maguire et al., 2014; NKBA, 2016; Hoag & van Dyke, 1975). Traditional kitchen triangle concepts was found to neglect the significance of body volume and the accommodation of the "size" of a moving body (Overhill, 2014). An ideal kitchen triangle with smooth, uninterrupted work traffic was recommended as a top consideration in kitchen design for home builders (Hoag & van Dyke, 1975).

Kitchen shape was the 2nd key concept related to the kitchen layout component in this sociotechnical system. In contrast to the "kitchen triangle" that described the configuration of the stove, fridge, and sink, the "kitchen shape" concept described the room shape of the kitchen. Commonly recognized kitchen shapes (Fig. 3) included One-wall, Corridor, l-shaped, U-shaped, Peninsula, and Island (Ayşe Yazıcıoğlu, 2014). By placing the appliances on three sides and eliminating traffic passes through the work triangle, the U-shaped layout was associated with the shortest movement volume between appliances during cooking tasks (Chen et al., 2021; Bonenberg, 2013; Kapple, 1964). One-wall type kitchen was identified as the most prominent option with kitchen space being small ($< 5m^2$) with the least amount of total activity area (Ayşe Yazıcıoğlu, 2014; Kapple, 1964). As suggested by the Kitchen Planning Standard, the space available and the proper fitting of cabinets and appliances should be considered to select the best shape. Applying a kitchen shape inappropriately could cause limited space and occupancy of the kitchen and potentially interrupt workflow and traffic (Ayşe Yazıcıoğlu, 2014; Kapple, 1964; Ferdinand et al, 2019).

While the kitchen triangle and kitchen shape concepts were largely discussed in the design and architecture fields, papers from the anthropometry field focused on the workstation dimensions (e.g., countertops, storage, and shelves) as the 3rd concept. Counter dimensions were shown to directly impact a user's ability to cook safely, and poorly designed work counter dimensions would lead to non-neutral postures and, even more so, musculoskeletal injuries (Hoag & van Dyke, 1975; Kishtwaria et al., 2007). Four critical anthropometric measures were identified for working surface height in the domestic kitchen: stature, floor-to-elbow height (standing), floor-to-elbow height (seated), and seat-to-elbow height (Ward & Kirk, 1970). Additionally, literature emphasized that specific tasks and functions performed on work surfaces could vary and require varying work heights (e.g., sink for cleaning tasks, stovetop for cooking tasks, and counter for food preparation tasks) (Ward & Kirk, 1970; Yang & Yu, 1990; Ward, 1971; Sandhu et al., 2008; Patil & Rajhans, 2018). Therefore, adjustability of the counter height, if possible, was frequently proposed as an important design consideration in contemporary kitchens (Hoag & van Dyke, 1975; Bonenberg et al., 2019; Pheasant & Haslegrave, 2006;). In addition to counter height, some other relevant workspace dimensions (e.g., counter depth and area) were also discussed to enhance the user's performance. (Hoag & van Dyke, 1975; Mark R & Steven J, 2012; Ceccacci et al, 2015; Chahal, 2021).

The 4th concept synthesized in this scoping review was storage space, a concept that was often a top priority for designers (Yazıcıoğlu & Kanoğlu, 2016). Cabinet space was critical for food, utensils, and appliance storage and organization (NKBA, 2016; Kapple, 1964). Placement of the space can affect user task performance and safety. For example, studies found that upper and lower storage units that minimized reaching and bending exertions reduced the risk of falls and biomechanical stresses on users' arms and shoulders (Bonenberg et al, 2019; Chen et al., 2021; Pheasant & Haslegrave, 2006). Another study indicated that cabinet height decisions for overhead cabinets also affected accessibility (if placed too high) or visibility/mobility (i.e., overhead cabinets placed too low reduced the interspace between the worktop and overhead cabinet base) (Silvana et al., 2015).

Finally, the last concept identified in the kitchen environment construct was the ambient environment. Studies showed that adequate lighting was critical in the kitchen and enabled users to visualize their workspace well and avoid injuries such as lacerations (Maguire et al., 2014). Example guidelines included having at least one wall-switch-controlled light to provide general illumination of the kitchen area and well-illuminated work surfaces with multiple light sources with level adjustability (NKBA, 2016). Illuminance was shown to affect the performance of kitchen tasks, especially on tasks that rely heavily on visual ability (Mcguiness et al, 1983). While illumination was the most common ambient environment topic, other ambient environment topics with significant effects on users included temperature, air quality, and acoustic level (Ward, 1974; Tong et al., 2021; Kim et al., 2015). A study showed positive effects of natural sound masking on the perception of noise produced by range hood and emotion valence in home kitchens (Tong et al., 2021). Another study showed a positive correlation between indoor air pollution caused by poor ventilation in home kitchens and the risk of lung cancer (Kim et al., 2015).

Kitchen tools and technology

The next construct in the kitchen work system is kitchen tools and technologies (Fig. 4). Literature summarized in this construct primarily focused on usability and the kitchen tool design process; the hand-tool interface was especially emphasized.

The 1st identified concept was the physical properties of kitchen hand tool design; it encompassed kitchen tools' shape, size, and material. For example, studies found that the spatula handle dimensions and lift angle on food-frying, food-turning, and food-shoveling tasks significantly impacted the cooking task performance and perceived exertion

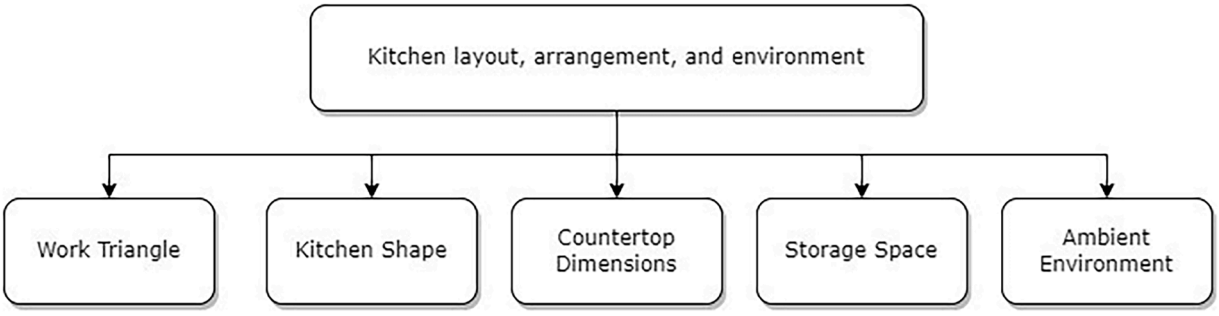

Fig. 2. Six key concepts within the Kitchen Layout and Environment construct.

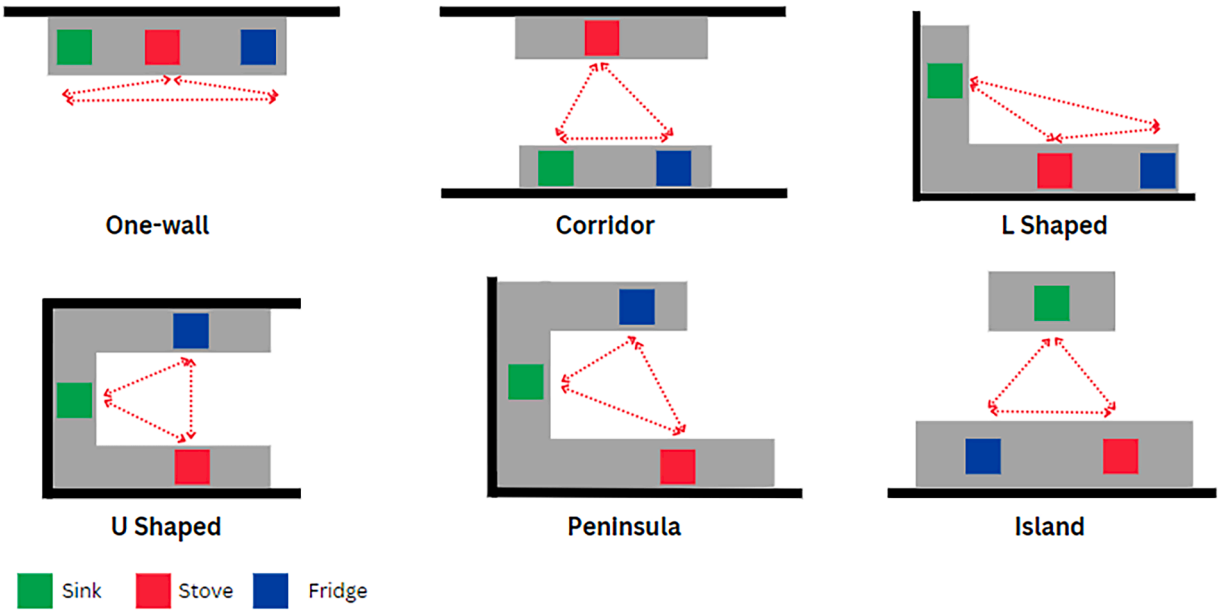

Fig. 3. Kitchen shapes and kitchen triangle with example arrangements of sink, stove, and fridge (note that sink, stove, and fridge locations are interchangeable).

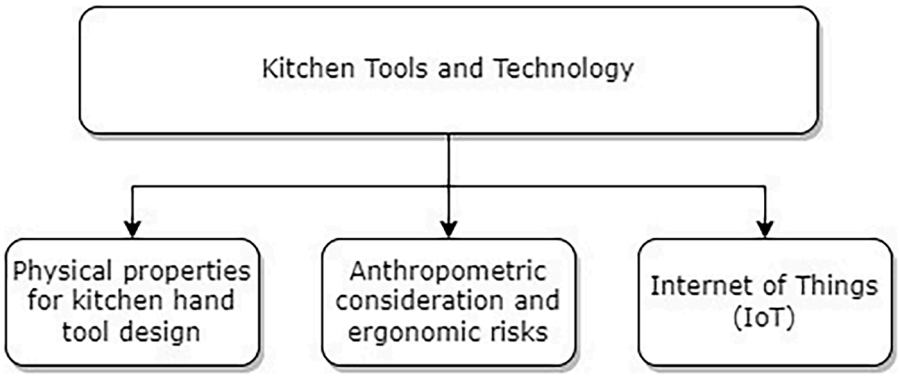

Fig. 4. Three concepts within the Kitchen Tools and Technology construct.

(Hsu et al., 1994; Wu & Hsieh, 2002); a similar study has also studied the effects of potato peeler shapes on peeling task efficiency (Drejer et al., 2021). Materials of kitchen tools were also found to have different effects on kitchen task performance. Improving knife sharpness reduced upper limb muscular stresses in meat-cutting tasks (Claudon & Marsot, 2006) but did not have any effect on vegetable-cutting tasks (Stone et al., 2018). In summary, task performance was the key focus of tool design studies.

The 2nd concept identified from the scoping review was the anthropometric consideration for kitchen hand tools. Light product weight, easy grasping mechanism, convenient tool length, slip-resistant grasp surfaces, edges to be rounded or curved, and avoiding stress related to tissue compression were common recommendations provided in the literature (Zubaidi et al., 2019; Wu & Hsieh, 2002; Su, 2016; Lakshmi & Kumari, 2016; Ritzel & Donelson, 2001). Studies grouped within this anthropometry concept also included research on anthropometry assessment methods for cooking-related tasks, and several studies demonstrated a wearable sensors approach (McGorry et al., 2003; Pereira et al., 2020). Kitchen-related injuries related to improper kitchen hand tool designs (i.e., Tenosynovitis and Carpal Tunnel Syndrome) was commonly reported (Su, 2016; Wu & Hsieh, 2002). Finally, the physiological cost associated with kitchen tools and tasks was also frequently addressed in studies related to this anthropometric concept (Sandhu, 2003; Kelsheimer, 2000; Kumari et al., 2017).

As "smart" homes become increasingly popular, IoT (Internet of Things) becomes an emerging concept in the kitchen tools/technology literature. According to a survey conducted to examine preferences for technology versus human assistance and control in the context of Quality-of-Life Technology (QoLT), most respondents were inclined to utilize technology in their environment (Beach et al., 2014). The main objective of a "smart" kitchen was to increase comfort, efficiency, and usability by improving the purchase, storage, and preparation of food as much as possible, making tasks simpler for the user through effective human–machine–environment interaction (Ceccacci et al, 2015; Ferrero et al., 2019; van den Eijnde, 2020). Many studies identified the home automation system as a critical component of the smart kitchen concept due to its contribution to improved functionality, ergonomic layout, and environmental safety. Researchers also found reduced physiological costs incurred during kitchen-based activities with the implementation of human automation systems (i.e., an automated kitchen cabinet system that could directly provide a targeted item in closer reach and alert the user for retrieval (Ceccacci et al, 2015; Ficocelli & Nejat, 2012; Gullà et al, 2016; Ständer et al., 2012; Žarić et al., 2021). Despite the innovations suggested in this area, this topic remains more theoretical to date and has not been widely implemented.

User characteristics and needs

The construct "user characteristics and needs" refers to the needs,

both physical and psychological, of individuals who perform tasks in the kitchen environment (Fig. 5). The focus was to understand the ergonomics considerations in domestic kitchens for various users since individual needs may vary depending on physical and psychological characteristics.

Many kitchen-related studies identified were focusing on design considerations for older adults . Several studies described the diminished sensory and physical abilities in older adults and how these could adversely affect their ability to perform cooking-related tasks (Maguire et al., 2014; Pinto et al., 2000; Ibrahim & Davies, 2012; Özalp, 2020). For example, the physiological decline in the older adult population could make common postures in meal preparation (e.g., bending, lifting, reaching, carrying, stooping) a risk for physical injuries as those postures and tasks could result in biomechanical stresses and force requirements that exceed the user's strength capability (Czaja et al, 1993; Ibrahim & Davies, 2012). Design considerations, including both operational assistance (e.g., interventions that support physical activities like chopping, stirring, and carrying aimed at reduced strength and dexterity) and organizational assistance (e.g., coordination of different cooking tasks with smooth transitions between tasks, a monitoring system for the cooking process to optimize progression of simultaneous cooking tasks and minimize unnecessary movements) were proposed to help address these concerns (Kuoppamäki et al., 2021).

The "users" and "kitchen layout" constructs of the kitchen work system were closely interrelated. The top four concepts from the kitchen layout section (i.e., Work Triangle, Kitchen Shape, Countertop Dimensions, and Storage Space) were often considered in the context of older adults. Some studies recommended some layout (i.e., U-shaped) to minimize total movement volume for older adults (Chen et al., 2021; Özalp, 2020). It was suggested that such layouts ensured placing the sink and stove within a close range of the worktop to avoid unnecessary movement in the kitchen triangle (Hrovatin et al., 2012; Ibrahim & Davies, 2012). Studies also described needed changes in the workspace dimensions and storage space placement to enhance users' ability to perform cooking tasks and accommodate differences in anthropometric measurements in the elderly. Work surface height between 700 - 900 mm with some adjustability to avoid excessive bending and stress on the upper limb region was recommended (Bonenberg et al., 2019; Kirvesoja et al, 2000; Özalp, 2020). Lower utilization rates of higher cabinets and storage units under worktop areas were commonly mentioned to reduce awkward postures for reaching, bending, and lifting (Câmara, 2010; Chen et al., 2021; Ibrahim & Davies, 2012; Kirvesoja et al, 2000; Fielo & Warren, 2001). To facilitate reach, wall-mounted cabinet units placed at the lowest possible level with easy access to the handle were recommended, along with the reduction in cabinet depth. Pull-down shelves or cupboards with height adjustability were also suggested as solutions to better accommodate older populations (Chen et al., 2021; Maguire et al., 2014; Bonenberg, 2013; Bonenberg et al., 2019).

The 2nd concept was accident prevention for older adults. Fall was the top reported concern for the elderly population in the domestic environment, along with risks of burns, bumps, and cuts due to impaired mobility and visibility (Devito et al., 1988; Kłos et al., 2014; Lucht, 1971; Özalp, 2020). Studies concluded the primary causes of falls to be poor lighting, slippery floors, and unstable objects, which were common issues found in kitchens when the environment failed to accommodate the needs of older adults (Maguire et al., 2014; Hrovatin et al., 2012; Câmara, 2010; Hrovatin et al., 2016). It was recommended to install extra lighting above the floor space, worktop, and inside storage units; tools should be placed at places where sufficient lighting could be provided (Maguire et al., 2014; Bonenberg et al., 2019; Câmara, 2010). Other literature suggested fixing furniture to the floor, adding raised edges to the stove, placing storage within reach, and maintaining a dry floor surface to improve safety for older adults in the kitchen (Câmara, 2010; Devito et al., 1988; Pinto et al., 2000). In general, preventing accidents remained a priority in kitchen design for elderly users, along with ease of meal preparation, adjustability, and access to household appliances (Maguire et al., 2014; Bonenberg et al., 2019).

The 3rd concept identified from the scoping review on potential users included users with disabilities and potential considerations for restricted mobility and reduced physical abilities. Important design considerations were related to the ease of meal preparation, adjustability of work surfaces and storage, and easy access to appliances (Bonenberg et al., 2019). Given that some individuals with disabilities use wheelchairs, it was recommended to prioritize uninterrupted space between work surfaces and ensure continuity in the cooking process. One study suggested the term "optimal access points" to allow the user to perform multiple kitchen activities without the necessity of moving (Bonenberg, 2015).

The 4th concept referred to operational assistance for users with reduced physical abilities. The operational assistance required conforming to the working principles of existing designs with individuals with disabilities or older adults' biomechanics (Stuparu & Bârsan, 2012). Adopting sound alerts and brighter finishing colors was suggested for appliances to accommodate users with visual impairments (Kłos et al., 2014), and kitchenware was designed to be lighter and more versatile for reducing wrist bending and increasing grip force and pivots (Wu et al., 2015; Zubaidi et al., 2019; Atreya & Agarwal, 2019). By promoting home automation and reducing the need for physical manipulation, smart kitchens were also suggested as adaptable solutions to support the meal preparation process and improve usability for users with impairments (Gullà et al, 2016).

The last concept was the personalization and optimization of user-specific measurements. The demographic difference among users was identified as an important factor since choosing limited measurements would not be appropriate for users exceeding anthropometric thresholds (Chahal, 2021; Pant et al., 2021). Another important issue was gender, as many studies performed on the relationship between kitchen layout and anthropometric data used women as the main subject of study (Hoag & van Dyke, 1975; Ward & Kirk, 1970; Chahal, 2021; Pant et al., 2021; Singh & Khan, 2021). As a result, adjustability was frequently emphasized to address personalization to individual anthropometry in modern kitchen design (Chen et al., 2021; Maguire et al., 2014; Bonenberg, 2013; Pheasant & Haslegrave, 2006; Bonenberg et al., 2019).

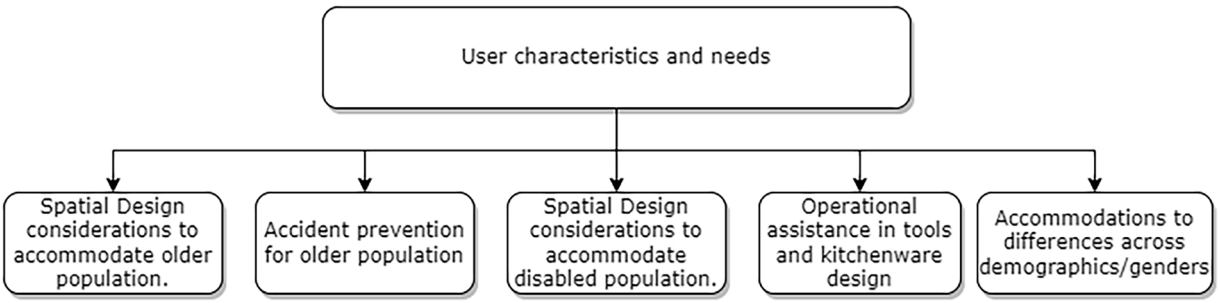

Fig. 5. Concepts within user characteristics and needs.

Outcomes

Safety, usability, & performance

The goal of improving the kitchen work system is ultimately to improve the safety and usability of the kitchen as a workspace and users' performance. Common accident factors that cause injuries in kitchens included burns, slips, falls, lacerations, and punctures. Laceration resulting from knife use was identified as a predominant domestic injury type for all users (Smith, 2013; Adeyemi, 2021), while falls and burns were additional risks more common for older users (Devito et al., 1988; Pinto et al., 2000; Câmara, 2010). Burns also contributed to a large number of injuries to children in domestic kitchens (Puthumana et al., 2021; Drago, 2005).

Usability of domestic kitchens and performance during cooking focused on kitchen layout selection and tool design (i.e., interrupted workflow, poor wrist postures, or reduced access to storage space) (Silvana et al., 2015; Kapple, 1964; Wu & Hsieh, 2002). The main concerns identified by some studies were musculoskeletal disorders (MSD) and cumulative trauma disorders (CTD) due to misuse and overuse of muscles and bones, repetition of unnatural postures, and repetitive and intensive hand-related jobs (Mondal (Ghosh) and Bhattacharjee, 2017; Mondal, 2012). In everyday kitchen activities, users engaged in walking, bending, kneeling, stooping, and reaching; adopting awkward postures for extended periods could lead to the development of MSDs, thus making the kitchen a potential area for MSDs in domestic environments (Ibrahim and Davies, 2012; Mondal, 2012; Zaheer et al., 2021). Rapid upper limb assessment surveys were commonly utilized to evaluate exposure to common risk factors such as movement, static, force exertion, postures, and working time in kitchen activities (Mcatamney & Corlett, 1993; Zaheer et al., 2021). Repetitive usage of kitchen hand tools in cooking tasks (e.g., chopping, stirring) with poorly designed weight, length, and grip was shown to apply stress on hands and lead to CTDs (Adeyemi, 2021; Su, 2016; Wu & Hsieh, 2002).

Food hygiene was identified as another important outcome for cooking-related tasks, as cross-contamination leading to food poisoning has been shown to take place during the food preparation process (Azevedo et al., 2014). Touching raw meat during the food preparation process without properly washing hands afterward was one of the main sources identified for cross-contamination (Didier et al., 2021). One study was conducted to examine the correlation between sink placement and hygienic practices during food handling in five European countries, demonstrating that cross-contamination events were more likely to occur when the sink–countertop distance was greater than one meter. The authors recommended replacing the traditional food triangle concept with the safety triangle (formed by the apexes of the sink, countertop, and stove) with a perimeter of less than four meters to compromise food hygiene and work efficiency in kitchens (Mihalache et al., 2022). In general, outcomes of cooking processes in domestic kitchens can be improved by implementing the ergonomic design criteria for layout, environment, and tools discussed in the work system section.

Discussion

Home cooking has a close and important connection with healthcare. For example, the infinicare framework integrates activities across both clinical and daily living contexts to emphasize the interdependence of clinical-based care and daily living; it proposes that there should be a continuum between clinical healthcare and care provided in daily living settings (Ozkaynak et al., 2018). A kitchen can serve a purpose beyond just preparing daily meals; home kitchens become the hubs of informal caregiving, where foods are prepared as primitive remedies for basic treatments. Moreover, healthcare received in formal care institutions can influence patients' current diets (i.e., adequate carbohydrate and essential amino acids intake to address surgical stress response support recovery after Orthopedic Surgery) (Hirsch et al., 2021), and these changes must be executed in home kitchens. Patients often bear the responsibility beyond formal care institutions, and their dietary practices can significantly impact the outcome of formal healthcare.

In preventive care, home kitchens can play a crucial role in primary prevention, where a broad range of activities is initiated to prevent disease before it ever occurs (Simeonsson, 1991). Cooking at home is often associated with better health, and evidence has shown the potential dietary benefits of home-cooked meals (Mills et al., 2017). With increased attention given to integrating nutrition from food into medication and providing nutritional support for chronic diseases (Downer et al., 2020; Gropper, 2023), consuming home-cooked meals can be an effective way to prevent various chronic diseases, largely due to the control individuals have over the ingredients. There is a strong association between frequent consumption of home-cooked meals and cardio-metabolic health, including lower adiposity, cholesterol levels, and diabetes risk (Mills et al., 2017). In both the informal care and prevention stages, self-care emerges as a critical theme. The home kitchen serves as a cornerstone of self-care, where individuals can control their diet, experiment with foods that benefit their unique health conditions, and establish a connection to formal healthcare practices.

Given that home cooking promotion can be an essential part of public health initiatives, it is critical to promote an ergonomic home kitchen environment and include it as an important environment for healthcare. Four major topics in kitchen ergonomics were summarized in this review: kitchen layout, kitchen tools and technology, potential users, and outcome. As presented in the results section, each topic was interconnected. This intricacy and interdependency of the topics related to kitchen ergonomics were highlighted and organized with our adapted sociotechnical model to scope the current state of the literature on kitchen ergonomics.

Much of the current literature on physical kitchen ergonomics focused on proposing ergonomic design solutions by relating anthropometry measures to the kitchen layout and appliances or getting subjective preferences/fitting trials with a targeted group of users with determined demography (Silvana et al., 2015; Kishtwaria et al., 2007; Ward, 1971). This general approach was effective in proposing the optimum dimension in design or identifying the gap or mismatch between the current kitchen setup and the user group's needs. However, limitations could also apply to different user groups. Recommendations for kitchen layout dimensions were rarely proposed as a single value because the "optimal" dimension differed across the users or the cooking-related tasks being performed. An ergonomically optimized kitchen layout can reduce the risk of musculoskeletal problems resulting from awkward postures and repetitive motions, such as back pain and repetitive strain injuries. These safety risks adversely impact the physical health of individual users and may create barriers, both physical and potentially mental, when it comes to pursuing diet and nutritional aspects of healthcare.

While some industry-standard guidelines, such as the National Kitchen & Bath Association (NKBA) guidelines, can offer valuable insights and measurements for home kitchen design, they primarily serve the purpose of creating functional and aesthetically pleasing kitchen spaces within the minimally allowable dimensional and clearance requirements. These guidelines can be general and may not address the specific needs of every user. They also struggle to keep pace with the trends in smart kitchens and evolving technology. Finally, sustainability is not a priority in the design practices outlined by these guidelines despite its significant role in modern smart home kitchens.

In addition to the physical layout, the ambient environment can also impact the performance of kitchen tasks (Mcguiness et al., 1983), physical health (Maguire et al., 2014), and the mental state of users (Tong et al., 2021). While adequate lighting has been a widely discussed topic in domestic kitchen ergonomics, fewer published articles have systematically studied and made recommendations on other environmental factors, such as noise or ventilation. However, these factors still

play a significant role in human-environment interactions and have a considerable impact on users' physical and mental health. All these characteristics should be included in future research to create a more ergonomic and health-conscious home kitchen space that prioritizes both functionality and well-being.

Given the increase in domestic kitchen usage, kitchen-related accidents highlighted by previous literature may further increase during or immediately after societal events (e.g., pandemic and inflation) that impact access to eating out. While common home kitchen-related incidents that lead to negative health outcomes and hospital visits have been identified (e.g., falls, burns, lacerations), very few studies holistically analyzed the causes and prevention strategies in a domestic environment. Additional research is needed to better measure and understand injuries in the domestic environment and to develop evidence for current design recommendations aimed at preventing negative health impacts and emergency department visits.

Although kitchen ergonomics has been emphasized in this review as an area for enhancing health, there can be a negative impact on health if a macro ergonomics view is not considered. As foodborne infectious diseases become a major health concern for the home environment (Taché & Carpentier, 2014; Byrd-Bredbenner et al., 2013; Borrusso & Quinlan, 2017), effective ergonomic considerations should also encompass safe food handling practices and conditions. The home kitchen often becomes a reservoir for various foodborne pathogens due to unsafe food handling and storing practices (Borrusso & Quinlan, 2017). Both food preparation surfaces and storage units can serve as sources of cross-contamination and foodborne infections resulting from improper cleaning, storage temperature, and mishandling of raw and cooked food (Taché & Carpentier, 2014). The physical layouts and placement of worktops and storage units can affect users' accessibility to them (Silvana et al., 2015; Chen et al., 2021; Bonenberg et al., 2019), significantly affecting their likelihood and ability to perform proper cleaning procedures regularly. The placement of the sink in the kitchen can potentially affect the rate of cross-contamination events (Didier et al., 2021). Furthermore, smart kitchen technology can elevate safe food handling practices in the home kitchen environment with developments in food status monitoring systems and temperature control for food storage.

Many studies only tackled the issues faced by older adults or individuals with disabilities in the kitchen environment due to their reduced physical and mental ability or existing health issues. Furthermore, current studies may be limited in generalizability across genders. For instance, 9 out of 13 studies using anthropometry data related to kitchen design exclusively used female dimensions. Limited studies have been performed with users who do not belong to the above demographic groups to understand the issues facing this population in the kitchen environment as well. A study focused on food safety described both men and adults younger than age 30 years as kitchen users who are most likely to make food handling errors that lead to certain foodborne illnesses and adverse health outcomes (Byrd-Bredbenner et al., 2013). In summary, the user populations of focus in current literature may not reflect all users of the kitchen.

Studies in this review included papers published on populations around the world. However, cultural differences may affect the themes and concepts described by the presented sociotechnical model. Cultural differences may affect the frequency/type of cooking tasks performed and the dimensions/preferences of kitchen layouts. Studies conducted in Asia reported kneading and rolling dough as an important task to be considered in worktop height designing (Kishtwaria et al., 2007; Sandhu et al., 2007), while a study conducted in the West did not identify this issue (Ward, 1971). With a diverse population of people with different cultural backgrounds across the United States, multicultural study is a gap that warrants further research. Similarly, a comparative study among the different kitchen designs internationally can potentially enable researchers and designers to consider different perspectives and identify solutions to counter common issues.

Limitations and future work

This paper is a rapid scoping review that was conducted with selected sources. Although it was able to capture the general themes and concepts prevailing in the current research space, the scoping review method prioritized breadth of coverage over depth of analysis. Additionally, "kitchen + ergonomics" was the only search term, and all the articles included were either directly from the initial search, the reference list, or the forward citation search. This abbreviated nature of the search process could introduce selection bias, which could cause some applications or domain knowledge to be neglected. The scope of this paper has been limited to domestic kitchens; thus, many studies on professional and commercial kitchens were excluded. Finally, only studies published in English were included in this review and may exclude studies conducted in some other nations. A more detailed, systematic review is needed to further examine the full body of work done for each of the proposed constructs in the kitchen ergonomics framework (Fig. 1); explicitly exploring work done for each of the identified constructs can yield additional, more domain-specific suggestions to improve kitchen ergonomics holistically. In terms of connecting kitchen ergonomics to healthcare, future work should consider the special accommodations needed by patients with chronic diseases in food preparation. Another benefit is to study how essential services offered by clinical dietitians also impact people's dietary choices within households and communities, leading to revolutionized home cooking habits.

Conclusion

This rapid scoping review synthesized literature published on domestic kitchen performance to develop a framework of kitchen ergonomics with four major constructs: kitchen layout, arrangement, and environment; kitchen tools and technology; user characteristics and needs; and outcomes and risks related to kitchen activities. This framework proposes a novel way to categorize concepts in user interactions within the domestic kitchen and demonstrates the need for more studies on domestic kitchen ergonomics to fill current research gaps.

Although not a formal workplace where care is delivered, non-traditional environments such as the home kitchen influence patient health and warrant attention from the human factors healthcare community. While this study focused on home kitchens, there are many other non-workplace settings where health-related activities are performed. We urge additional healthcare human factors reviews and investigations of not only kitchens but also other non-traditional environments where health-related work occurs.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

References

Adeyemi, H. O. (2021). Development of an intelligent ergonomic model for Hazards predictions in Domestic Tasks. *IOP Conference Series: Materials Science and Engineering, 1043*(2). https://doi.org/10.1088/1757-899X/1043/2/022001

Atreya, S., & Agarwal, S. (2019). *Re-designing an Indian kitchen for the elderly using REVIT* (1st ed.). Gurgaon, India: CRC Press https://doi.org/10.1201/9780429444272.

Ayşe Yazıcıoğlu, D. (2014). A statistical data analysis for increasing the kitchen design performance. *A/Z : ITU journal of Faculty of Architecture, 11*(1), 174–184 [Online]. Available https://www.researchgate.net/publication/289785077.

Azevedo, I., Albano, H., Silva, J., & Teixeira, P. (2014). Food safety in the domestic environment. *Food Control, 37*(1), 272–276. https://doi.org/10.1016/j.foodcont.2013.09.058

Beach, S. R., Schulz, R., Matthews, J. T., Courtney, K., & Dabbs, A. D. V. (2014). Preferences for technology versus human assistance and control over technology in the performance of kitchen and personal care tasks in baby boomers and older

adults. *Disability and Rehabilitation. Assistive Technology, 9*(6), 474–486. https://doi.org/10.3109/17483107.2013.832412
Bonenberg, A. (2013). Shaping an Integrating Kitchen Space with Gesture-Based Control System. In: Stephanidis, C., Antona, M. (eds) Universal Access in Human-Computer Interaction. Applications and Services for Quality of Life. UAHCI 2013. Lecture Notes in Computer Science, 8011, pp. 12-21. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-39194-1_2.
Bonenberg, A. (2015). Designing a functional layout of a kitchen for persons with disabilities – Concept of optimal access points. *Procedia Manufacturing, 3*, 1668–1675. https://doi.org/10.1016/j.promfg.2015.07.490
Bonenberg, A., et al. (2019). Designing for human use: Examples of kitchen interiors for persons with disability and elderly people. *Human Factors and Ergonomics in Manufacturing, 29*(2), 177–186. https://doi.org/10.1002/hfm.20772
Borrusso, P. A., & Quinlan, J. J. (2017). Prevalence of pathogens and indicator organisms in home kitchens and correlation with unsafe food handling practices and conditions. *Journal of Food Protection, 80*(4), 590–597. https://doi.org/10.4315/0362-028X.JFP-16-354
Byrd-Bredbenner, C., Berning, J., Martin-Biggers, J., & Quick, V. (2013). Food safety in home kitchens: A synthesis of the literature. *International Journal of Environmental Research and Public Health, 10*(9), 4060–4085. https://doi.org/10.3390/ijerph10094060
Câmara, J. J. D. (2010). Analysis and ergonomics of houses for elderly people. *Periodicum Biologorum, 112*(1), 47–50 [Online]. Available https://hrcak.srce.hr/file/80495.
Carayon, P., et al. (2006). Work system design for patient safety: The SEIPS model. *Quality & Safety in Health Care, 15*(1). https://doi.org/10.1136/qshc.2005.015842
Ceccacci, S., Menghi, R., & Germani, M. (2015). Example of a new smart kitchen model for energy efficiency and usability. In *The Fourth International Conference on Smart Systems, Devices and Technologies* (pp. 12–18) [Online]. Available https://www.semanticscholar.org/paper/Example-of-a-New-Smart-Kitchen-Model-for-Energy-and-Ceccacci-Menghi/14b06373ece0ffa77a4ffea28427744505c5c08e.
Chahal, P. K. (2021). Study of human factors in rural kitchen design. *International Journal of Social Sciences, 10*(2), 99–107. https://doi.org/10.46852/2249-6637.02.2021.2
Chen, M., He, C., Wang, M., Yin, Q., & Wang, Y. (2021). Function layout of adaptive aging population kitchen design based on trace observation. *Lecture Notes in Networks and Systems, 261*, 564–570. https://doi.org/10.1007/978-3-030-79760-7_67
Claudon, L., & Marsot, J. (2006). Effect of knife sharpness on upper limb biomechanical stresses - A laboratory study. *International Journal of Industrial Ergonomics, 36*(3), 239–246. https://doi.org/10.1016/j.ergon.2005.11.007
Czaja, S. J., Weber, R. A., & Nair', S. N. (1993). A human factors analysis of ADL activities: A capability-demand approach. *The Journals of Gerontology, 48*, 44–48. https://doi.org/10.1093/geronj/48.special_issue.44
de Solier, I. (2005). TV dinners: Culinary television, education and distinction. *Continuum (Society for Social Work Administrators in Health Care), 19*(4), 465–481. https://doi.org/10.1080/10304310500322727
Devito, C. A., Lambert, D. A., Sattin, R. W., Bacchelli, S., Ros, A., & Rodriguez, J. G. (1988). Fall injuries among the elderly community-based surveillance. *Journal of the American Geriatrics Society (JAGS), 36*(11), 1029–1035. https://doi.org/10.1111/j.1532-5415.1988.tb04371.x
Didier, P., et al. (2021). Washing hands and risk of cross-contamination during chicken preparation among domestic practitioners in five European countries. *Food Control, 127*, Article 108062. https://doi.org/10.1016/J.FOODCONT.2021.108062
Downer, S., Berkowitz, S. A., Berkowitz, S. A., Harlan, T. S., Olstad, D. L., & Mozaffarian, D. (2020). Food is medicine: Actions to integrate food and nutrition into healthcare. *The BMJ, 369*. https://doi.org/10.1136/bmj.m2482
Drago, D. A. (2005). Kitchen scalds and thermal burns in children five years and younger. *Pediatrics, 115*(1), 10–16. https://doi.org/10.1542/peds.2004-0249
Drejer, Å.B., Enstad, T., Fog, E.R.M., Viken, T.O.F., Medola, F.O., & Sandnes, F.E. (2021). A Comparison of Three Potato Peeler Designs. Human Systems Engineering and Design III. IHSED 2020. Advances in Intelligent Systems and Computing 269. 10.1007/978-3-030-58282-1_56.
Ferdinand, R. T., Gunanata, S., Widayati, N., Lianto, F., & Susetyarto, M. B. (2019). Effectiveness and efficiency of kitchen space reviewed from the kitchen triangle concept in small flats case study 'Rusunawa' Manis Jaya, Tangerang city, Banten. *IOP Conference Series Materials Science and Engineering, 508*(1), Article 012032. https://doi.org/10.1088/1757-899X/508/1/012032
Ferrero, R., Vakili, M. G., Giusto, E., Guerrera, M., & Randazzo, V. (2019). Ubiquitous fridge with natural language interaction. In *2019 IEEE International Conference on RFID Technology and Applications, RFID-TA 2019* (pp. 404–409). Institute of Electrical and Electronics Engineers Inc.. https://doi.org/10.1109/RFID-TA.2019.8892025
Ficocelli, M., & Nejat, G. (2012). The design of an interactive assistive kitchen system. *Assistive Technology, 24*(4), 246–258. https://doi.org/10.1080/10400435.2012.659834
Fielo, S. B., & Warren, S. A. (2001). Home adaptation Helping older people age in place. *Geriatric Nursing, 22*(5), 239–246. https://doi.org/10.1067/mgn.2001.119473
Gropper, S. S. (2023). The role of nutrition in chronic disease. *Nutrients, 15*(3). https://doi.org/10.3390/nu15030664
Hearn, G., Collie, N., Lyle, P., Choi, J. H. J., & Foth, M. (2014). Using communicative ecology theory to scope the emerging role of social media in the evolution of urban food systems. *Futures, 62*, 202–212. https://doi.org/10.1016/j.futures.2014.04.010
Hirsch, K. R., Wolfe, R. R., & Ferrando, A. A. (May 01, 2021). Pre-and post-surgical nutrition for preservation of muscle mass, strength, and functionality following orthopedic surgery. *Nutrients, 13*(5). https://doi.org/10.3390/nu13051675
Holden, R. J., et al. (2013). SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients. *Ergonomics, 56*(11), 1669–1686. https://doi.org/10.1080/00140139.2013.838643
Holmberg, C., Chaplin, J. E., Hillman, T., & Berg, C. (2016). Adolescents' presentation of food in social media: An explorative study. *Appetite, 99*, 121–129. https://doi.org/10.1016/j.appet.2016.01.009
Hrovatin, J., Pišot, S., & Plevnik, M. (2016). Healthy ageing at home: Ergonomic adaptations of interior design and self-assessed quality of life of older adults of the municipality of Ljubljana. *Annales Kinesiologiae, 7*(2), 139–152.
Hrovatin, J., Širok, K., Jevšnik, S., Oblak, L., & Berginc, J. (2012). Adaptability of kitchen furniture for elderly people in terms of safety. *Drvna Industrija, 63*(2), 113–120. https://doi.org/10.5552/drind.2012.1128
Hsu, S. H., Wu, S. P., & Peng, Y. (1994). The optimum lift angle for the culinary spatula (turning shovel). *Ergonomics, 37*(2), 325–332. https://doi.org/10.1080/00140139408963649
Ibrahim, N. I., & Davies, S. (2012). Aging: Physical difficulties and safety in cooking tasks. *Work, 41*, 5152–5159. https://doi.org/10.3233/WOR-2012-0804-5152
Hoag, L. L., & van Dyke, R. H. (1975). A human factors evaluation of the American kitchen. *Proceedings of the Human Factors Society Annual Meeting, 19*(1), 120–124. https://doi.org/10.1177/154193127501900124
Gullà, F., Ceccacci, S., Menghi, R., & Germani, M. (2016). An adaptive smart system to foster disabled and elderly people in kitchen-related task. Proceedings of the 9th ACM International Conference on PErvasive Technologies Related to Assistive Environments (PETRA ,16), 27, 1. https://doi.org/10.1145/2910674.2910678.
Kapple, W.H. (1964). Kitchen planning standards. Circular Series Index No. C5.32. Small Homes Council-Building Research Council. University of Illinois at Urbana-Champaign. [Online]. Available. http://hdl.handle.net/2142/54612.
Kelsheimer, H. L. (2000). Older Adult Women Find Food Preparation Easier with Specialized Kitchen Tools. *Journal of the American Dietetic Association, 100*(8), 950–952. https://doi.org/10.1016/S0002-8223(00)00273-X
Kim, C., et al. (2015). Home kitchen ventilation, cooking fuels, and lung cancer risk in a prospective cohort of never smoking women in Shanghai, China. *International Journal of Cancer, 136*(3), 632–638. https://doi.org/10.1002/ijc.29020
Kirvesoja, H., Vak, S., & Hak, A. (2000). Three evaluations of task-surface heights in elderly people's homes. *Applied Ergonomics, 31*(2), 109–119. https://doi.org/10.1016/s0003-6870(99)00044-7
Kishtwaria, J., Mathur, P., & Rana, A. (2007). Ergonomic evaluation of kitchen work with reference to space designing. *Journal of Human Ecology, 21*(1), 43–46. https://doi.org/10.1080/09709274.2007.11905949
Kłos, R., Fabisiak, B., & Kaczmarek, M. (2014). Analysis of human needs in kitchen design for people with visual impairment. *Drvna Industrija, 65*(1), 43–50. https://doi.org/10.5552/drind.2014.1329
Kumari, P., Kumar, A., & Dayal, R. (2017). Ergonomic assessment of the existing design of selected kitchen tools. *Technofam, 6*(2), 35–40 [Online]. Available https://www.researchgate.net/publication/353430989.
Kuoppamäki, S., Tuncer, S., Eriksson, S., & McMillan, D. (2021). Designing kitchen technologies for ageing in place. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 5*(2). https://doi.org/10.1145/3463516
Lucas, A..). Coronavirus outbreak prompts growing number of states to ban dining in at restaurants. https://www.cnbc.com/2020/03/16/coronavirus-outbreak-prompts-states-to-ban-restaurant-dining.html.
Lakshmi, D., & Kumari, P. (2016). Ergonomics of bread making tools – a review. *International Journal of Scientific Research, 5*(10), 185–191 [Online]. Available: https://www.researchgate.net/publication/327221803_Ergonomics_of_Bread_Making_Tools-A_Review.
Lucht, U. (1971). A prospective study of accidental falls and resulting injuries in the home among elderly people. *Acta socio-medica Scandinavica, 3*(2), 105–120 [Online]. Available https://about.jstor.org/terms.
Maguire, M., et al. (2014). Kitchen living in later life: exploring ergonomic problems, coping strategies and design solutions. *International Journal of Design, 8*(1) [Online]. Available https://www.researchgate.net/publication/289297557_Kitchen_Living_in_Later_Life_Exploring_Ergonomic_Problems_Coping_Strategies_and_Design_Solutions.
Mark R, L., & Steven J, L. (2012). Design of work areas, tools, and equipment. In *Introduction to human factors and ergonomics for engineers* (Second Edition,, *ch. 3* pp. 85–133). Boca Raton, FL, USA: CRC Press.
Mcatamney, L., & Corlett, E. N. (1993). RULA: A survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics, 24*(2), 91–99. https://doi.org/10.1016/0003-6870(93)90080-s
McGorry, R. W., Dowd, P. C., & Dempsey, P. G. (2003). Cutting moments and grip forces in meat cutting operations and the effect of knife sharpness. *Applied Ergonomics, 34*(4), 375–382. https://doi.org/10.1016/S0003-6870(03)00041-3
Mcguiness, P. J., Boyce, P. R., & Harker, S. D. P. (1983). The effects of illuminance on tasks performed in domestic kitchens. *Applied Ergonomics, 15*(1), 9–24. https://doi.org/10.1177/096032718301500102
Mihalache, O. A., et al. (2022). Kitchen layouts and consumers' food hygiene practices: Ergonomics versus safety. *Food Control, 131*. https://doi.org/10.1016/j.foodcont.2021.108433
Mills, S., et al. (2017). Health and social determinants and outcomes of home cooking: A systematic review of observational studies. *Appetite, 111*, 116–134. https://doi.org/10.1016/j.appet.2016.12.022
Mills, S., Brown, H., Wrieden, W., White, M., & Adams, J. (2017). Frequency of eating home cooked meals and potential benefits for diet and health: Cross-sectional analysis of a population-based cohort study. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1). https://doi.org/10.1186/s12966-017-0567-y
Mondal (Ghosh), J., & Bhattacharjee, T. (2017). A Review on Domestic Injuries among Housewives. *International Journal of Nursing Research and Practice (IJNRP), 4*(1). https://doi.org/10.15509/ijnrp.2017.4.1.339

Mondal, J. (2012). A review on mechanical & physical hazards at domestic kitchen. International Journal of Occupational Safety and Health, 2(1), 7-10. [Online]. Available http://nepjol.info/index.php/IJOSH.

National Kitchen and Bath Association. (2016). Nkba Kitchen and Bathroom Planning Guidelines with Access Standards. John Wiley & Sons, Incorporated.

Occupational Health and Safety Agency for Healthcare in British Columbia. (2003). *An ergonomics guide for kitchen in healthcare*.

Overhill, H. (2014). Apple pie proxemics: Edward T. Hall in the kitchen work triangle. *Design Issues, 30*(2), 67–82. https://doi.org/10.1162/DESI_a_00263

Özalp, B. T. (2020). Determination of domestic kitchen characteristics for elderly Turkish women: A comprehensive ergonomics approach. *Open Journal of Safety Science and Technology, 10*(02), 53–67. https://doi.org/10.4236/ojsst.2020.102005

Ozkaynak, M., Valdez, R., Holden, R. J., & Weiss, J. (2018). Infinicare framework for integrated understanding of health-related activities in clinical and daily-living contexts. *Health Systems, 7*(1), 66–78. https://doi.org/10.1080/20476965.2017.1390060

Pant, G., Vyas, N., Pradesh, H., Vishwavidayalaya, K., Rana, A., & Sharma, S. (2021). Ergonomic assessment of kitchen interiors in relation to human health and safety in the region of Uttarakhand. *The Pharma Innovation Journal*, (7), 490–498 [Online]. Available http://www.thepharmajournal.com.

Patil, A. S., & Rajhans, N. R. (2018). Human factors in designing workspace: Customizing kitchen counter design. *Advances in intelligent systems and computing* (pp. 286–294). Springer Verlag. https://doi.org/10.1007/978-3-319-60828-0_29

Pereira, D., Morassut, A., Tiberi, E., Dario, P., & Ciuti, G. (2020). Forces and torque measurements in the interaction of kitchen-utensils with food during typical cooking tasks: Preliminary test and evaluation. 29th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), 1171–1177. 10.1109/RO-MAN47096.2020.9223457.

Pheasant, S., & Haslegrave, C. M. (2006). *Bodyspace: Anthropometry, Ergonomics and the Design of Work* (3rd Edition). CRC Press. https://doi.org/10.1201/9781315375212.

Pinto, M. R., de Medici, S., van Sant, C., Bianchi, A., Zlotnicki, A., & Napoli, C. (2000). Ergonomics, gerontechnology, and design for the home-environment. *Applied Ergonomics, 31*(3), 317–322. https://doi.org/10.1016/s0003-6870(99)00058-7

Puthumana, J. S., Ngaage, L. M., Borrelli, M. R., Rada, E. M., Caffrey, J., & Rasko, Y. (2021). Risk factors for cooking-related burn injuries in children, who global burn registry. *Bulletin of the World Health Organization, 99*(6), 439–445. https://doi.org/10.2471/BLT.20.279786

Ritzel, K., & Donelson, T. (2001). Human factors gets cooking. *Ergonomics in Design, 9*(1), 15–19. https://doi.org/10.1177/106480460100900104

Sandhu, P. (2003). Reduction in energy costs of doing selected household work by using efficient gadgets and applying ergonomics in homes. *Journal of Human Ecology, 14*(5), 323–327. https://doi.org/10.1080/09709274.2003.11905632

Sandhu, P., Malik, M., & Kaur, H. (2007). Analysis of gap between existing and formulated kitchen work counters in selected households of Wdhiana city. *Foods & H.S, 26*(1), 42–47.

Sandhu, P., Malik, M., & Kaur, H. (2008). Study into problems faced by Punjabi housewives while working on existing kitchen work spaces. *Journal of Human Ecology, 23*(4), 331–337. https://doi.org/10.1080/09709274.2008.11906086

Severson, K. (2017). *Kitchen of the future: Smart and fast but not much fun*. https://www.nytimes.com/2017/10/13/dining/smart-kitchen-future.html (accessed Dec. 20, 2022).

Silvana, P., Oblak, L., & Ravnik, D. (2015). Ergonomic suitability of kitchen furniture regarding height accessibility. *Collegium Antropologicum, 39*(1), 185–191 [Online]. Available https://www.researchgate.net/publication/275954955.

Simeonsson, R. J. (1991). Primary, secondary, and tertiary prevention in early intervention. *Journal of Early Intervention, 15*, 124134. https://doi.org/10.1177/105381519101500202

Singh, R., & Khan, S. (2021). Ergonomics in the kitchen of working women of MIG families (a study of Aligarh city). In *Proceedings of HWWE: International Conference on Humainzing Work and Work Environment* (pp. 83–89). https://doi.org/10.1007/978-981-15-9054-2_9

Smith, G. A. (2013). Knife-related injuries treated in United States emergency departments, 1990-2008. *Journal of Emergency Medicine, 45*(3), 315–323. https://doi.org/10.1016/j.jemermed.2012.11.092

Ständer, M., Hadjakos, A., Lochschmidt, N., Klos, C., Renner, B., & Mühlhäuser, M. (2012). A smart kitchen infrastructure. In *2012 IEEE International Symposium on Multimedia, ISM 2012* (pp. 96–99). https://doi.org/10.1109/ISM.2012.27

Stone, R. T., Janusz, O., & Schnieders, T. (2018). Ergonomic analysis of modern day kitchen knives. In , *62. Proceedings of the Human Factors and Ergonomics Society 2018 Annual Meeting* (pp. 1338–1342). https://doi.org/10.1177/1541931218621306

Stuparu, D., & Bârsan, L. (2012). Research on kitchen products for people with disabilities. *Bulletin of the Transilvania University of Braşov Series I: Engineering Sciences, 5*(54), 47–52.

Su, Y. (2016). *Pleasure of manual kitchen products: A checklist for designing manual kitchen tools*. Auburn University [Online]. Available https://etd.auburn.edu//handle/10415/5042.

Taché, J., & Carpentier, B. (2014). Hygiene in the home kitchen: Changes in behaviour and impact of key microbiological hazard control measures. *Food Control, 35*(1), 392–400. https://doi.org/10.1016/j.foodcont.2013.07.026

Taillie, L. S. (2018). Who's cooking? Trends in US home food preparation by gender, education, and race/ethnicity from 2003 to 2016. *Nutrition Journal, 17*(1). https://doi.org/10.1186/s12937-018-0347-9

Tong, Y., Zhang, R., Liu, Z., & Tan, Z. (2021). Effect of natural sounds masking on perception of noise in the kitchen environment. In Rebelo, F. (Ed.), AHFE 2021. Lecture Notes in Networks and Systems: 261. Advances in Ergonomics in Design (pp. 521-528). Cham: Springer. 10.1007/978-3-030-79760-7_62.

van den Eijnde, J. (2020). The human touch in kitchen technology: how technology changes our relationship with food in the rational and ritual kitchen. *APRIA Journal, 2*(1), 68–84. https://doi.org/10.37198/apria.02.01.a9

Ward, J. S. (1971). Ergonomic techniques in the determination of optimum work surface heights. *Applied Ergonomics, 2*(3), 171–177. https://doi.org/10.1016/0003-6870(71)90043-3

Ward, J. S. (1974). Critical ergonomics factors in domestic kitchen design. *Ergonomics, 17*(2), 233–240. https://doi.org/10.1080/00140137408931342

Ward, J. S., & Kirk, N. S. (1970). The relation between some anthropometric dimensions and preferred working surface heights in the kitchen. *Ergonomics, 13*(6), 783–797. https://doi.org/10.1080/00140137008931206

Wilkins, J. L. (2020). Challenges and opportunities created by the COVID-19 pandemic. *Journal of Nutrition Education and Behavior, 52*(7), 669–670 (Online). Available https://www.npr.org/2020/04/07/.

Wu, F. G., Sun, H. H., & Lin, Y. C. (2015). Innovative Aid Design of Moving Kitchenware for Elders. *Procedia manufacturing, 3*, 6266–6273. https://doi.org/10.1016/j.promfg.2015.07.795

Wu, S., & Hsieh, C. (2002). Ergonomics study on the handle length and lift angle for the culinary spatula. *Applied Ergonomics, 33*(5), 493–501. https://doi.org/10.1016/s0003-6870(02)00024-8

Yang, G., & Yu, L. (1990). The determination of optimum heights for Chinese kitchen facilities. *Ergonomics, 33*(7), 945–957. https://doi.org/10.1080/00140139008925302

Yazıcıoğlu, D. A., & Kanoğlu, A. (2016). A systematic approach for increasing the success of kitchen interior design within the context of spatial user requirements. *Advances in Social Sciences Research Journal, 3*(1). https://doi.org/10.14738/assrj.31.1804

Zaheer, A., Fatima, A., & Rowson, J. (2021). Evaluating and managing MSDs in domestic tasks through ergonomics. *Journal of Engineering Research, 11*(1B), 186–196. https://doi.org/10.36909/jer.11843

Žarić, N., Radonjić, M., Pavlićević, N., & Žarić, S. P. (2021). Design of a kitchen-monitoring and decision-making system to support aal applications. *Sensors (Basel, Switzerland), 21*(13). https://doi.org/10.3390/s21134449

Zubaidi, A. M. F., Sumitro, M. K., & Husna, A. S. (2019). EASILY (easy to use kitchen utilities) designing cutting boards sets for elderly and arthritis sufferers with quality function deployment. *IOP Conference Series. Materials Science and Engineering, 530*(1). https://doi.org/10.1088/1757-899X/530/1/012055