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Creative Design and Conceptual Development of a Portable Camping Cooking Workstation Based on Human Factors Engineering

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Abstract **Original Research Article**

With the rapid proliferation of outdoor camping culture, camping equipment has expanded from the professional adventure sector to mainstream leisure scenarios. However, camping cooking equipment currently available on the market often suffers from inadequate human factors consideration—users frequently encounter challenges such as disorganized workspaces, awkward operating postures, excessive cognitive load under low-light conditions, and equipment assembly/disassembly processes that deviate from natural mental models, all of which directly impact camping safety and overall experience quality. This study focuses on the design of portable camping cooking workstations and employs a dual research methodology combining "literature review" and "real-world fieldwork": on one hand, it systematically reviews relevant theories and existing research in human factors engineering, outdoor equipment design, and cognitive ergonomics; on the other hand, it conducts field observations and semi-structured interviews with a total of 26 participants—including members of university outdoor clubs and random campsite users—to document typical cooking task sequences and pain-point scenarios.

The study identifies five major core human factors issues: abnormal static lumbar flexion resulting from insufficient work surface height; a mismatch between the storage space for small objects and the search strategies employed; a significant degradation in the operability of fasteners under conditions of low flexibility or when wearing gloves; spatial relationships between fuel and heat sources that contradict risk perception intuition; and the lack of zoned cooking workflows, which poses risks of cross-contamination and burns. Based on task analysis and human-machine interface principles, this study proposes a creative conceptual design for a "Folding/Unfolding Modular Cooking Workstation," which integrates five key human factors: adjustable work height, magnetic quick-release storage, tactile-coded controls, a heat source isolation duct system, and a single-handed operable snap-fit mechanism. The value of this paper lies in integrating structured human factors engineering analysis methods into a creative, exploratory product design process, demonstrating that human factors principles are not merely a remedial tool for "improving existing products," but rather a core driver of innovation during the conceptualization phase.

Keywords: Human factors engineering; Camping equipment; Creative conceptual design; Task analysis; Cognitive ergonomics.

1. Introduction

Over the past decade, outdoor camping in China has evolved from an extreme adventure subculture into an important component of mass leisure consumption. Relevant market reports indicate that the number of camping participants continues to grow, with "premium camping" and "road-trip camping" attracting a large number of non-professional individuals to engage in outdoor activities. However, the growth rate of the equipment industry far outpaces systematic research into users' actual usage behaviors—most camping products adhere to the traditional "lightweight–durability" dual design logic common in mountaineering gear, yet overlook the cognitive capabilities and physical endurance limits of general users under non-ideal conditions. As users transition from trained mountaineers to ordinary students, families, or white-collar professionals, human factors issues—once overshadowed by the perception of "professionalism" —become extensively exposed.

Preliminary observations have revealed that the cooking phase of camping activities is one of the most frequently used stages, featuring the longest operational sequence and the highest risk of underestimation. A typical dinner preparation workflow includes the following steps: fetching water → lighting the fire → setting up the cooking pot → preparing ingredients → cooking → serving and serving back → cleaning → storing equipment – involving multiple risk factors such as high temperatures, fuel, cutting tools, water, and uneven terrain. Currently, consumer-facing cooking solutions on the market can be broadly categorized into two types: the minimalist approach and the modular approach. The minimalist approach involves simply placing a picnic mat and a portable stove on the ground to cook; users then perform all tasks while squatting or bending over. The modular approach, on the other hand, involves assembling various separate items – such as folding tables, storage boxes, windbreakers, vegetable wash basins, and seasoning racks – like "building blocks" on the spot, with no fixed spatial arrangement; after use, these items often leave the area in a disorganized state.

The shared essence of both approaches is that they do not view cooking as a "human–machine system" that requires systematic spatial planning, but rather as the arbitrary stacking of various items. As a result, users are compelled to perform what should be a seamless task through unnatural postures, nonlinear search paths, and temporary layouts that impose high cognitive load.

The core tenet of human factors engineering is "designing for people – within their capabilities, within their limitations, and within safe boundaries." Integrating human factors principles into the innovative design of camping and cooking equipment is, at least in three respects, irreplaceable.

At the biomechanical level, outdoor users are often in a state of fatigue—whether after hiking, in low-temperature environments, or after fasting—during which their muscular tolerance window narrows; inappropriate working heights or postural requirements can accelerate musculoskeletal strain or even lead to acute injuries.

At the cognitive ergonomics level, conditions such as low light, wind or rain, or wearing gloves can drastically limit the available perceptual channels; when interfaces and controls lack appropriate encoding, they become fertile ground for human error.

At the task–space matching level, cooking is a multi-step sequential task; if the workspace does not support workflow zoning or the "proximity principle" for tools, both efficiency and safety will collapse simultaneously.

2. Research and Methods

2.1 Literature Review

This section maps out the academic discourse across three dimensions, providing a theoretical anchor point for subsequent analyses.

1) Human factors engineering and outdoor equipment evaluation research: Existing studies have shown that there is a substantial body of ergonomics-related literature on the evaluation of "load-bearing and sheltering" equipment—such as backpacks, sleeping bags, and tents. For example, Zadry et al. used surface electromyography and electrocardiography measurements on hiking backpacks to demonstrate that the muscle activation levels across different carrying systems differed significantly from the locations of subjective discomfort (90% for the shoulders, 60% for the waist), indicating that the geometric design and contact interfaces of the equipment directly influence the human biomechanical load. This same logic applies to the "work surface height – trunk flexion angle – lumbar spine load" chain in cooking workstations; however, it has been rarely applied to

the camping kitchen scenario.

2) Research on User Experience and Demand Modeling for Camping Products: In recent years, China has seen the emergence of multiple research trajectories in camping product design driven by the KANO model, affective engineering, and situational analysis methods. A common finding across these studies is that the focus of demand among mainstream camping users is shifting from "being able to make do" to "low cognitive burden + high emotional value" – while aesthetics remain important, predictability and operational ease are the underlying factors that determine repeat purchases and word-of-mouth. In other words, human factors are becoming the fundamental logic behind experiential quality.

3) Cognitive Ergonomics and Field Operation Interface Research: The key constraints that distinguish field operations from indoor kitchen settings include: degraded perceptual channels (e.g., light attenuation, gloves reducing tactile sensitivity, wind noise interfering with auditory feedback), fragmented attention (the need to simultaneously monitor fire, water, food, and children), and reduced fault tolerance (in the field, there is no hot water faucet to immediately rinse off a burn). Research on "Usability Heuristics" within cognitive ergonomics consistently emphasizes that when environmental pressure increases, products must rely on natural mapping, forced functionality, and multi-channel feedback to reduce working memory load.

2.2 Real-world scenario research

1) Research subjects and methodology

This study employs a mixed-methods approach combining non-participatory observation with semi-structured interviews; the research subjects span two distinct scenario categories.

The first scenario involves a campus setting: two weekend camping events organized by a university's mountaineering and wilderness survival club, held at a campsite located near a suburban reservoir; observers recorded the activities from a distance of 3–5 meters away from the activity zone, without interfering with the participants' natural behavior.

The second scenario involves public camping sites. During the evening cooking peak period (17:00–20:00) at suburban commercial camping sites within the city, on-site interviews were conducted with voluntarily participating camping groups, each lasting 3–8 minutes.

A total of 8 valid observation records were collected, and interviews were conducted with 18 participants; the cohort comprised 11 males and 7 females, aged between 20 and 35 years, with camping experience ranging from first-time participants to those with over five years of experience.

2) Research Record Framework

For each observation, field notes should be taken focusing on the following variables:

First, decomposition of the cooking task chain: segment-based timing and operation counting from "retrieving equipment" to "complete storage"; capturing snapshots of the user's body posture to record the frequency and duration of transitions between squatting, kneeling, bending over, and standing positions.

Second, the search path length and the number of failures for the "find something" task are used as proxy indicators of cognitive load.

Third, obvious signs of discomfort, such as massaging the waist, swinging the arms, making a "sigh–" sound, or blowing on the fingers.

Fourth, emergency incidents—such as being scalded, a knife slipping, seasonings falling over, or the stove top being knocked over.

2.3 Determination of Human Body Dimensional Benchmarks

The human body dimensional data used in this design are derived from the current national standard GB/T 10000-2023 "Human Body Dimensions for Chinese Adults," which came into effect on March 1, 2024, replacing the previous GB 10000-88 version. This standard applies to ergonomic design scenarios involving consumer products, home furnishings, workspaces, and safety protection. Considering that the camping user base encompasses a broad spectrum of adult males and females, this document adopts the age range of 18–60 years for males and 18–55 years for females as the baseline age range, and determines the values using the percentile method—specifically, using three reference lines—P5 (suitable for users with smaller body sizes/effective reduction after wearing thick clothing and gloves), P50 (median/optimal design target), and P95 (upper limit for larger body sizes/safety envelope)—to jointly constrain the feasible design domain. The following two tables' present excerpts of the percentile values for key human body dimensions in both standing and sitting postures.

Table 2-1: Percentile Values of Key Human Body Dimensions in Standing Posture

Measurement Items	Sexual Distinction	P5	P50	P95	Remarks
elbow height	male(18–60)	954	1024	1096	Natural standing position ,nude value，mm
elbow height	female(18–55)	899	960	1023	Natural standing position ,nude value，mm
shoulder height	male	1281	1367	1455	mm
High hand function	male	680	741	801	mm
High hand function	female	650	704	757	mm

Table 2-2: Percentiles of Key Human Body Dimensions in Sitting Posture

Measurement Items	Sexual Distinction	P5	P50	P95	Remarks
Sitting elbow height	male	228	263	298	nude value， mm
Sitting elbow height	female	215	251	284	nude value， mm

Sitting elbow height	male	858	908	958	mm
Sitting elbow height	female	809	855	901	mm
Lower leg plus foot height	male	383	413	448	Footprint, mm (≈ Vertical clearance control for the lower level)

3. Analysis and Discussion

3.1 Task Analysis – The Task Chain and Key Interaction Interfaces for Camping Cooking

By breaking down camping cooking into a hierarchical task structure, it can be described as the following sequence:

Phase A Deployment: Site selection and leveling → Define operational area → Install furnace/fuel → Arrange windbreaks → Establish water supply route.

Phase B – Ingredient Preparation: Remove food from refrigerated container → Clean → Cut and prepare → Apply seasonings.

Phase C – Cooking: Ignite → Control temperature → Stir/Flip → Remove from heat → Maintain temperature.

Phase D Closure: Extinguish all ignition sources → Initial equipment cleaning → Return equipment to designated storage areas → Dispose of waste.

In this chain, nodes A and D represent the spatial assembly and disassembly logic, testing folding mechanisms and storage topology; nodes B and C represent the continuous operation logic, testing work surface height, storage accessibility, and risk isolation. Both phases share the same core challenge: the user's lack of a "A truly functional workbench" in field conditions.

3.2 Problem Identification

Based on the analysis of observational and interview data, recurring challenges can be categorized into five interconnected human factors-related issues.

1) Lack of work surface height → Abnormal static lumbar flexion

Among the 8 groups, 7 groups had an actual work surface height ranging from 15–35 cm, including picnic mats, low fold tables, vehicle tailgate covers, etc. This indicates that during the prepping and cooking stages, the trunk was essentially in a continuous forward-leaning or squatting posture. One respondent with a history of lumbar disc disease stated: "Just cutting a potato tells me I won't be able to sleep well tonight." From a biomechanical perspective, when trunk flexion exceeds 60° and persists for more than 2 minutes, the intradiscal pressure at the L4–L5 lumbar vertebral segment increases significantly; in outdoor environments, this posture is often maintained for 15–30 minutes, and since the core muscles are already in a "low-preload" state due to the energy expenditure from hiking, the risk of musculoskeletal strain is systematically amplified.

2) Disordered storage topology → Excessive cognitive friction during search

The question "Where is this item?" represents the most frequently encountered micro-interruption during the cooking phase. Users tend to place seasonings, tableware, or tools into a deep storage box or multiple zippered bags – under low-light conditions with gloves on, visual searching degenerates into blind hand groping; such searches can take anywhere from 30 seconds to 2 minutes.

During interviews, 12 participants mentioned "simply spreading out items on the floor" as a coping strategy; however, this approach, in turn, occupies additional storage space and increases the risk of tripping or contamination. At its core, this reflects a mismatch between the information architecture used for organizing items (grouping, encoding, visibility) and human spatial memory capabilities.

3) Operational degradation of fasteners → The "finger warfare" scenario under glove-or low-ligancy conditions

The spring latch on the folding table, the tightening valve at the stove gas cylinder interface, and the small knob cap on the seasoning bottle – these interfaces feel smooth when manipulated in a laboratory setting, but are widely criticized by users in the real-world scenario of wearing thin gloves at 5°C with numb fingertips. The human factors engineering principle regarding "operational margin" explicitly states that when the fifth percentile hand size of the target user group – adjusted for the thickness of gloves – is used for reverse calculation, the minimum operational aperture and lever travel of many products fail to meet the required standards. As a result, users are forced to rely on their teeth, keys, or stones for assistance, leading to a stepwise increase in the probability of human error.

4) Lack of spatial isolation in heat source management → The intuitive risk perception is violated

Heating elements deployed by multiple workgroups are positioned right next to the edge of plastic storage boxes, beside tissue packs, or along the main workflow path. This is not due to "user recklessness," but rather the absence of a predefined heat source isolation zone – since the workbench's layout assumes that all areas are equally accessible, workers naturally occupy the unoccupied spaces. This violates the human factors principle of defensive space: high-risk components must actively signal "do not approach" through form, height difference, or tactile boundaries, rather than relying on the user's constant vigilance.

5) Unzoned cooking workflows → cross-contamination and "wet–dry" conflict

In low-standards kitchens, the cleaning area (for dirty water or fresh food residues) and the ingredient preparation area (for dry, clean chopped ingredients) often share the same cloth for reuse; users may simply wipe the surface twice with a wet wipe and consider this a "switch." From a behavioral perspective, this indicates that task transitions lack a physical anchor to trigger a psychological reset in users – in conventional indoor kitchens, this transition is naturally facilitated by the rigid separation between the sink and the countertop, whereas this structural feature is absent in outdoor camping scenarios.

Table 3-1 below provides a concise summary of the five major issues in camping and cooking, along with their ergonomics-based root causes.

Table 3-1: Five Major Issues in Camping Cooking and Their Ergonomic Root Causes

serial number	Phenomenon Description	direct consequence	Human Factors Engineering Dimension	Human Factors Root Cause Analysis
1	The work surface height is too low （15-35cm）	Continuous bending and squatting exercises can cause a significant increase in lumbar spine stress	Biomechanical workspace	Worktop height not aligned with the percentile range for elbow height in both standing and sitting postures
2	Deep and opaque storage space	Long search time and high cognitive friction under low-light conditions	Cognitive Ergonomics, Information Architecture	Contradicts the principles of "visualization" and "proximity"; lacks location encoding
3	The connector or control size is too small	High operational failure rate when wearing gloves	Human-Machine Interface Ergonomics	Does not account for the 5th percentile hand size or the glove thickness allowance
4	The heat source area lacks physical isolation	Prone to burns and may ignite nearby objects	Cognition and behavior, risk perception	Lack of "defensive space" design; reliance on users' proactive vigilance
5	Combined washing, cutting, and cooking areas	Cross-contamination; chaotic workflow	Task Analysis Workspace	Lack of task sequence-based physical partitioning and behavioral guidance

3.3 Human factors analysis

By mapping the aforementioned issues back to the classic human factors engineering modules, the following conclusions can be drawn.

First, the Human-Machine Interface Layer: The controls lack a unified tactile coding system (making blind operation impractical), the operation direction mapping is unnatural (the tightening/loosening actions do not align with the arrow indications), and the connection margin is too small (due to glove incompatibility) – these issues represent a classic case of interface–operator channel mismatch.

Second, the Task Analysis Layer: The entire cooking workflow lacks standardized, three-phase scripting support (i.e., "unfolding, operating, and collapsing"); each operation involves an improvised reconfiguration – this implies that the product should incorporate built-in topological memory (where, upon unfolding, the positions of the components are fixed and self-evident), thereby liberating users from

the need to "re-invent the layout."
Third, the Cognitive and Behavioral Layer: The difficulty in low-light search reflects a disconnect between the way information is presented (from inside the take in box to being invisible outside) and human spatial cognitive preferences (visual and positional cues> pure memory); whereas the intrusive presence in the heat source area indicates the need for passive behavioral guidance—letting the shape itself speak, rather than relying on warning signs.
Fourth, the workspace layer: The effective working surface height should be approximately 10–15 cm below the elbow level (i.e., around 85–95 cm for standing workstations or 65–75 cm for seated workstations); however, current mainstream solutions typically offer a height of nearly zero – a consequence of the complete neglect of human-scale data.
Fifth, the biomechanical layer: the combined posture of bending over to chop vegetables and performing squats while watching the stove directly places the lumbar spine and knee joints within a high-risk range during the fatigue window – necessitating adjustable-height support or, at the very least, elevating the reference plane.

4. Design Improvement Plan

4.1 Design Based on Core Principles

This proposal is named "HEARTH (Hearth-side Ergonomic Adaptive Ready-to-deploy Cooking Hub)" – a creative exploratory concept proposal that does not aim for the precision required in mass-production engineering drawings; instead, it uses the comprehensive integration of human factors principles as the criterion for assessing its conceptual validity.
The target user profile consists of general consumers primarily engaged in self-driving trips or suburban camping (excluding extreme alpine climbing), typically traveling in groups of 2–4 people, with each cooking session lasting between 20 and 50 minutes; the typical operating environment ranges from dusk to night, may involve light breezes, and features slightly uneven ground.
The five human factors design principles serve as the foundational framework for the solution; the principles are described below.
1) Elevated and stable work surface – the effective countertop height shall be no less than the upper edge of the seated thigh (approximately 45–50 cm for the lowest setting); it features a two-stage adjustable height range of 65–85 cm, ensuring that the elbow is close to 90° when preparing ingredients in a standing position; the support leg is equipped with spiral grounding holes and an expanded base plate to accommodate uneven grassy surfaces.
2) Topological clarity – fixed positioning of each zone upon unfolding: the left-side cleaning and draining area, the central cooking and heating area, and the right-side drying and ingredient preparation area; the zones are naturally demarcated by the raised and recessed edges of the bent steel plate combined with color coding (warm colors for the cooking area, cool colors for the cleaning area), rather than by any stickers or signage.
3) Structuring stored items – Replace deep-bottom storage bins with a transparent front-mounted magnetic compartment paired with an elastic hanging strip system: seasonings bottles are hung upside down and secured by the hanging strip (visibly positioned, allowing single-handed removal); kitchen tools are placed in magnetic knife slots (protected by a transparent barrier to prevent accidental contact); small items are stored in shallow, compartmented trays (placed in areas not obscured by deep bottoms). The core principle is "See = Find."
4) User-friendly controls – All snap-fit mechanisms have been replaced with large rotary dial locks (dial handle ≥30 mm); folding joints now utilize spring-loaded release pins instead of finger-clamping; an additional tactile stop has been added next to the air cylinder interface (enabling proper alignment even when handling by touch); key knobs feature a diamond-patterned texturing with a diameter of ≥40 mm.
5) Risk-Driven Compulsory Isolation – The hot zone is recessed by 3–5 cm (created by a natural lip formed through steel plate bending) and is equipped with a rear fixed windbreak panel (which also serves as a spark shield); the gas pipeline runs along a dedicated channel rather than being suspended and dragged; a sufficient "no-parking zone" is reserved ahead of the hot zone (a 8 cm wide silicone anti-slip strip is printed as a visual boundary – providing a

tactile reminder when the user steps on it).

4.2 Conceptual Shape Description – Expanded Configuration

The main component of HEARTH is a lightweight steel-aluminum alloy composite countertop with a three-section folding design (expanded dimensions approximately 90 × 55 cm); the four corners of the base feature telescopic support legs (with two-section locking mechanism). The countertop is not a single flat surface but incorporates three functions through its edge notched flanges: the upwardly folded flange creates a rollover prevention lip; the embedded magnetic guide rails within the flange allow accessories to be slidably mounted; and the angular folding of the flanges themselves serve as a zero-component separation boundary between the "hot zone" and "clean zone."

The left section features a foldable shallow trough tray (equipped with a folding silicone water bag attachment ring); the central section contains a recessed stove base (with three-sided windshields that fold out seamlessly from the countertop); the right section has a flat material preparation surface covered with a food-grade PE non-slip mat. The magnetic seasoning bottle holder, towel clip, and small tool clamp are clearly visible on the front mounting strip.

Folding configuration: The countertop folds neatly into a rectangular shape measuring approximately 30 × 55 × 12 cm; the leg tubes are stored within the protective sleeve; the seasoning rack is removed and inserted into the internal slot – this storage topology ensures that "every component has its designated place," eliminating the cognitive confusion that often arises when organizing items and not knowing where to put them. The total folded volume is roughly equivalent to that of a carton of milk; the target weight is set at 5–7 kg (for the aluminum alloy version) or 8–10 kg (for the steel-aluminum composite version).

4.3 Task Flow Rewriting Verification

Execute the task script in the sequence "Expand → Prepare Materials → Cook → Withdraw" to validate human factors improvements:

Unfold: Open the Butterfly Lock → The countertop will automatically level itself (the edge bending stiffness ensures no manual alignment is required) → Pull out the legs and engage the locking mechanism → Lower the sink tray (a single movable tab) → Complete. The entire process requires no reading of the instruction manual, as the design permits only one correct unfolding sequence (forced functionality).

Material preparation: Use the right hand to chop vegetables in the right-side area; adjust the countertop height so that the elbow forms an angle of approximately 90° and the lumbar spine remains in neutral position; place the knife in the magnetic slot on the right edge – simply pull it out to use; keep the seasonings on the front-mounted strip – simply glance at the strip to identify the target.

Cooking: Use your left hand to monitor the stove (located within the central recess, where the flame is surrounded on three sides); keep your body upright – there is no need to bend down or reach down to adjust the heat; the wind shield prevents side winds, and a safe clearance between the pot edge and the countertop rim is geometrically guaranteed.

Disassembly: Pour water into the sink → Remove the stopper from the seasoning bottle and insert it back into the internal slot (close the circuit for storage) → Fold the countertop together → Retract the legs → Close the butterfly latch. No parts left over.

4.4 Qualitative expectations for human factors indicators

Based on inferences derived from human factors theory, qualitative assertions regarding improvement directions can be formulated: the countertop elevation should reduce the cumulative lumbar flexion duration—from the observed mean of approximately 18–25 minutes per meal—to a level where sustained deep flexion (occasional bending for ≤3 minutes) is virtually eliminated; and the trunk posture should transition from "bent–static" to "upright–occasional slight tilting."

The magnetic mounting strip combined with a transparent storage compartment reduces the average search frequency – which previously ranged from approximately 4–6 searches per meal – to nearly zero (each item has a fixed visual location).

The large blade lock and tactile stop reduce the occurrence probability of the "operating with gloves failed/seeking assistance with dental tools" event from a high frequency to a marginal case.

The triple-structure design—combining heat-zone depression, lip edge, and windscreen—substitutes the verbal safety directive "be careful" with the physical form itself; this captures the essence of how human factors engineering has evolved from individual safety guidance to systematic safety assurance.

5. Conclusion and Outlook

5.1 Conclusion

This study takes the camping cooking scenario as a starting point and, through a dual-track research approach combining literature review and fieldwork, reveals a seemingly mundane yet long-neglected reality within the industry: the core challenge for mass camping does not lie in whether one possesses the necessary equipment, but in the lack of an organizational structure among the equipment that is grounded in the human body's physical dimensions and cognitive patterns. The five major human factors identified through this research—abnormal waist flexion posture, friction during storage and retrieval, operational degradation under glove-wearing conditions, lack of spatial isolation for heat sources, and unzoned movement paths—correspond to five classic areas of concern in human factors engineering: work space design, information architecture, interface margin, defensive space, and task zoning. The HEARTH Foldable Modular Cooking Workstation concept, developed based on these analyses, does not derive its innovation from any flashy mechanical mechanism, but rather from integrating human factors principles as the underlying logic for conceptual design—rather than as mere post-design embellishments: the countertop height is derived inversely from human body percentile data; zoning is achieved through the integrated forming of a folded-line flange rather than through labeling; the storage topology features a closed-loop system that eliminates cognitive ambiguity; and the control component dimensions are calibrated according to the hand shape of the 5th percentile individual when wearing gloves.

This study demonstrates that integrating human factors engineering into creative exploratory product design does not constrain creativity; instead, it eliminates pseudo-ideas that may look cool but are actually counterintuitive for human use, channeling design efforts toward initiatives that genuinely enhance the human experience.

5.2 Research Limitations

This study employs a relatively small field survey sample size (8 observation sessions + 18 interview sessions) and is confined to suburban environments during weekends; thus, it does not cover human performance under extreme operating conditions—such as high-altitude cold climates or heavy rain-induced muddy terrain. The design approach remains at the conceptual and qualitative validation stage; no functional prototype has been developed yet for usability testing or electromyographic/pose-based quantitative validation. Additionally, the trade-off between lightweight design, cost, and stiffness (i.e., the engineering feasibility boundary) identified in the conceptual design requires further collaborative development in conjunction with material selection and manufacturing processes.

5.3 Engineering and Management Implications

From an engineering management perspective, the camping equipment sector is currently experiencing a transitional window – shifting from a "functional component pile up" model to a "experience-driven system" model. By advancing human factors engineering from mere "compliance checks" during the quality inspection phase to serving as design principles and a creative filter during the concept generation stage, companies can reap benefits in two key areas: 1) reducing hidden costs arising from after-sales complaints and minor injuries; and 2) building a brand perception premium based on the notion of "effortless use" – which represents the decisive factor for the next phase of the mass camping consumer market. Future research could build upon this framework by incorporating Digital Human Modeling tools (e.g., Jack/Siemens UGS) for standard postural simulation, or conducting comfort comparison experiments on prototypes using the

Nordic Body Map scale, thereby transforming qualitative human factors diagnostics into tangible data assets.

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