

Toward Finding an Optimal Balance between Function and Comfort in the Most Intimate Human Environment

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The interaction between the human body and the environment has always been a key issue of Ergonomics. The nearest environment that continuously interacts with the human body, regardless of place, time and tasks, is clothing, which directly covers and moves along with the human body. People interact with their surroundings through clothing, socially and physically. In particular, in unfavorable or dangerous work environments, the impact of clothing on the wearer's comfort, safety, and performance is enormous. For example, firefighters' outfits and ballistic body armor are the only protection that they can rely on in extremely dangerous work environments. In this sense, clothing functions as a portable shelter or barrier attached to or supported by the human body to provide protection from challenging environments.

With advancements in technology, protective clothing and sports apparel have evolved into a system that provides enhanced protection to consumers. However, the increased protection, in many cases, tends to have negative effects on comfort. For instance, the recently developed enhanced ballistic protection body armor made of multiple layers of nonwoven composites or Kevlar make soldiers more vulnerable to heat stress because of the increased thermal insulation and impermeability which prohibits evaporative cooling and, as a result, accelerates increases in body temperature. In addition, that enhanced ballistic protection increases the weight of body armor and body coverage, which significantly limit soldiers' mobility and combat readiness by increasing physical strains and risk of musculoskeletal injuries.

It is also possible that protection in a clothing system introduces new challenges that may be more dangerous than the external threat for which the initial design was meant. This is a paradoxical situation. For example, heat and flame protection for firefighters' outfits requires sufficient air gaps as thermal barriers to minimize the external heat impact on the body. This entails increased bulkiness and weight of the garment. As a result, firefighters suffer from not only extreme temperature hazards but also physical strains due to limited body movement. Statistics indicate that heart attacks brought on by over-exhaustion and heat stress are a major cause of on-duty deaths and injuries in firefighters. The main reason for this is cardiovascular malfunction; body temperature and heart rate increase because of the physical strains of high metabolism and restricted body movement inside the excessive thermal insulation of protective gear, which is originally designed to protect the wearer from external heat hazards, not from body heat inside the garment.

Finding an optimal balance between improved function and comfort should be the most important consideration in implementing more effective clothing design. After all, clothing is the most intimate environmental interaction with the human body. Designing an entire clothing system with a well-defined purpose of use and priorities is critical to the wearers' performance and safety. Then the question would be how to do this. It can be done with problem-solving design approaches based on a thorough understanding of human and environment factors. A closed-loop stepwise design process suggested by Koberg and Bagnall [1] has been widely used in many fields. The design process includes 7 steps: accepting problems; analyzing

problems; defining the most critical problem(s) and setting goals; generating ideas for solutions; selecting feasible and effective options; implementing ideas and evaluation.

I would like to emphasize a few things in the design process to achieve the ultimate goal that of finding an optimal balance between function and comfort. First of all, the problem-solving design process should start with accepting existing challenges and problems. Designing a clothing system includes not only literature review but also observation of the interaction between body and design features, lab testing, and interviews. Getting input from the wearers is critically important in this process because it can help researchers or designers set priorities and design criteria with clearly defined design goals; then they can solve problems and improve functions and comfort based on an understanding of the wearers' unique needs and challenges.

Second, when selecting ideas, one should consider possible advantages and disadvantages based on analyses of priority matrix and feasibility. In this way, designers or researchers can set clear criteria for implementation and evaluation. Third, the effectiveness of a design should be evaluated by scientifically valid methods because it is important to make progress in design and to communicate with consumers based on objective and valid evidence to make a broader impact of new design and research outcomes. Recent accusations and lawsuits about misleading information in the advertising of a few sportswear items show the importance of valid evaluation (for example, some companies were accused of deceitful advertising about the effect of design on muscle enhancement and body shaping in their toning shoes and compression sportswear).

Last, I would like to emphasize the importance of close communication among the industry, researchers and consumers to improve our ability to find the optimal balance between function and comfort in clothing. How can new technologies be incorporated into clothing available in the market to better enhance human comfort, work efficiency and safety? How can new technologies and materials found in the lab reach consumers in the form of wearable or usable products? What would be reliable and valid standards for evaluating the effectiveness of new design and technologies? The answer lies in active collaboration across the boundaries of research, manufacturing and marketing in order to enhance safety, work efficiency and performance.

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Received August 27, 2012; Accepted August 28, 2012; Published August 30, 2012

Citation: Park H (2012) Toward Finding an Optimal Balance between Function and Comfort in the Most Intimate Human Environment. J Ergonomics 1:e114. doi:10.4172/2165-7556.1000e114

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Finding the optimal balance between improved function and comfort in our clothing, which is the most intimate environment, will be one of the paths to improved human well-being.

Reference

1. Koberg D, Bagnall J (2003) *The Universal Traveler: A soft-systems guide to: creativity, problem-solving, and the process of reaching goals*. Los Altos, CA: William Kaufmann 128.