

# Experimental analysis of firefighters crossing multiple obstacles under smoke and heat environment

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**Abstract** Firefighter movement experiments were conducted in a multi-factor coupled environment (dense smoke and high temperatures) to examine movement characteristics and influencing factors when crossing various obstacles. The study analyzed the effects of obstacle types and crossing postures on movement speed and explored the relationship between movement time and ten individual characteristics, categorized into three groups: basic information, firefighting experience, and psychological factors. The findings provide valuable insights for optimizing firefighting operations and improving firefighter safety training.

**Keywords** Smoke and heat environment, Multi-obstacle, Firefighter, Movement characteristics

## Introduction

The firefighting and rescue environment is characterized by dense smoke, high temperatures, and complex obstacles, posing significant risks to firefighter safety. Existing research on firefighter movement primarily focuses on three aspects: (1) the effects of equipment load and carrying methods on mobility [1], (2) the relationship between air consumption and task intensity when using self-contained breathing apparatus (SCBA) [2], (3) the influence of search formations, spatial cognition, and information demands on wayfinding behavior [3]. However, existing experimental studies are conducted in simplified environments that differ significantly from actual firefighting and rescue scenarios. The combined effects of dense smoke, high temperatures, and multiple obstacles have not been adequately considered, leading to data and conclusions that may not effectively support firefighting operations.

## Experimental setup

Based on these considerations, an experiment was conducted at the Bishan Fire and Rescue Division training facility in Chongqing, China (Fig.1(a)). This facility simulates complex firefighting environments, incorporating dense smoke, high temperatures, and multiple obstacles. Artificial smoke was released to reduce visibility to 0.5 meters, while high-power heating devices elevated the ambient temperature to 40 centigrade. The experimental route featured 13 obstacles, none of the participating firefighters had prior training on this route (Fig.1(d)). A total of 50 firefighters participated, all wearing full firefighting protective gear, including fire-resistant clothing, helmets, and self-contained breathing apparatus (SCBA), in accordance with operational requirements (Fig.1(b)). Each firefighter completed the experiment individually, with the process monitored and recorded using thermal imaging (Fig.1(c)). Data collection included movement time and SCBA air consumption. Additionally, a questionnaire was conducted to obtain individual characteristic data across three categories: basic information (years, BMI, physical fitness), firefighting experience (years of firefighting service, number of firefighting incidents, smoke and heat training, firefighter skill), and psychological factors (fear of darkness, fear of dense smoke, fear of unfamiliar and unknown)—encompassing ten variables.

## Experimental analysis

In this study, five typical obstacles were selected to analyze movement speed under varying conditions, including differences across obstacle types and the impact of crossing postures on the same obstacle, as

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shown in Fig.2. It was observed that obstacles requiring crawling or squeezing through, such as transverse barriers, significantly reduced movement speed. Similarly, obstacles that necessitated bending or crawling, such as height-restricted barriers, also imposed notable movement constraints. Additionally, for the same obstacle, the choice of crossing posture had a significant effect on movement speed. Building upon these findings, the relationship between individual characteristics and movement time was further examined. A correlation analysis was conducted on ten individual characteristics to assess their impact on movement time.

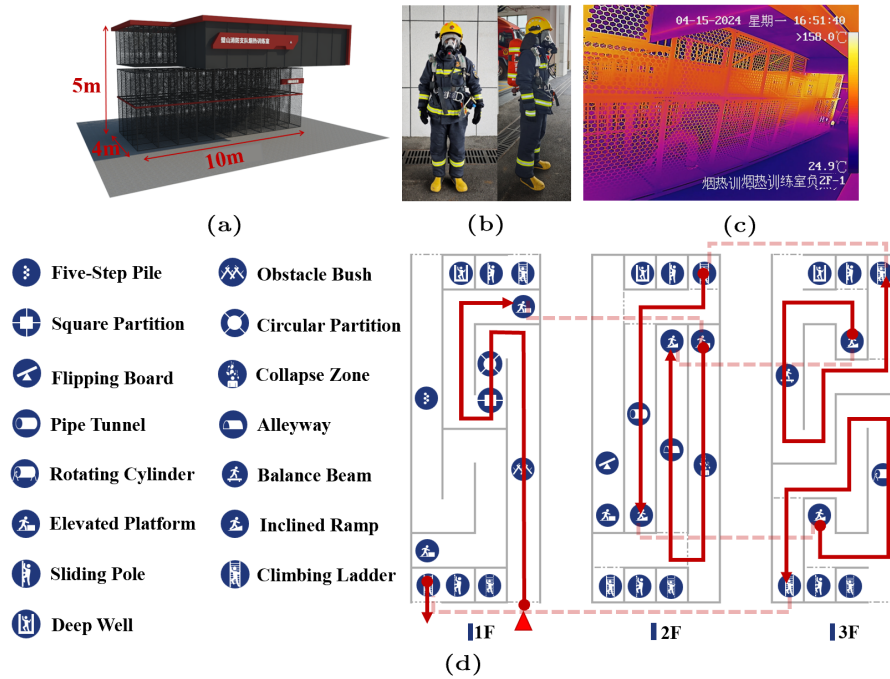


Figure 1: Experimental Overview.(a) Facility.(b) Firefighter gear.(c) Movement process.(d) Experimental route.

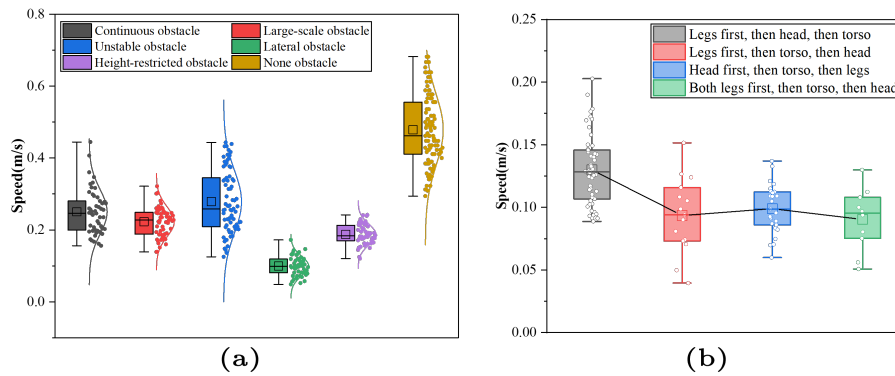


Figure 2: Experimental Analysis. (a) Movement speed across different obstacles. (b) Movement speed under different crossing postures for partitions.

## Bibliography

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