

A Study on the Standard Size of Fire and Rescue Helmets and a Question-naire-Based Improvement Plan

Dongmin Shin¹, Minjeong Park², Gangbok Lee³,
Seungyong Kim⁴, ByungJun Cho⁵, Minju Kang⁶,
Sangyol Shin⁷, Jaehan Jeong⁸, and Yongtaek Han^{9*}

¹Dept. of Paramedic Science,
Korea National Univ. of Transportation
61 Daehak-ro, Jeungpyeong-gun,
Chungbuk 368-701, KOREA
dmshein@ut.ac.kr¹

²4dm Design Management Creative Director
B-3213, 1, Jeongjail-ro, Bundang-gu,
Seongnam-si, Gyeonggi-do, 13616, Korea
parthenonn@naver.com

³IoT Convergence Research Department,
Electronics and Telecommunications
Research Institute Daejeon, Korea
kblee@etri.re.kr

⁴Dept. of Management Information System,
Korea National Univ. of Transportation
50 Daehak-ro, Chungju-si, Chungbuk
380-702, Korea
sykim@g.ut.ac.kr

⁵Dept. of Emergency Medical Technology,
Kangwon National University

Kuydong Samcheok City,
Kangwondo 245-711, Korea

⁵cho6451@gmail.com

⁶Dept. of Paramedic Science,
Korea National Univ. of Transportation
61 Daehak-ro, Jeungpyeong-gun,
Chungbuk 368-701, KOREA

⁶llllrrrr22@naver.com

⁷Dept. of Emergency Medical service,
Howon University 64 Howondae 3gil,
limpi, Gunsan city, Jeollabuk-do, KOREA

⁷since2000@howon.ac.kr

⁸Korea Fire Institute,
331 Jisamro, Giheung-gu, Yongin-si,
Gyeonggi-do, 17088, Korea

⁸cjh@kfi.or.kr

⁹Korea Fire Institute,
331 Jisamro, Giheung-gu, Yongin-si,
Gyeonggi-do, 17088, Korea

⁹rthan102@hanmail.net

Abstract

Background/Objectives: In this study, we derived an optimized size for fire and rescue helmets as personal safety equipment for firefighters. We also identified priorities for advanced IoT technologies that need to be attached to Fire and Rescue Helmets by implementing a questionnaire.

Methods/Statistical Analysis: In recent years, Fire and Rescue Helmets with advanced technology have been developed overseas, but they have not been much researched or developed in Korea. As a result, various products of this kind do not exist in Korea.

Findings: Based on the average size of Korean men's heads, we derived an optimized size for fire helmets. The

optical width of this product would be 200 mm, the length would be 260 mm, and the height would be 150 mm. Also, we verified that this size meets the requirements of the authorizing certification institution. According to our questionnaire results, what firefighters most need in helmets is lighting functionality. Next, were communication and information transmission features. After that, firefighters indicated a need for a combination of GPS features, lighting, and various sensors. We have developed a conceptual design for fire and rescue helmets based on this research.

Improvements/Applications: We expect this research to be the basis for developing an even more sophisticated and functional fire helmet than those that currently exist.

Key Words : Fire Helmet, Rescue Helmet, Standard Size, IoT Technology, Survey.

1 Introduction

Firefighters use many firefighting tools, from head to foot, to minimize harm from heat, smoke, and pressure while they are working at various fire and accident sites. They also use tools to increase their work efficiency. More than anything else, the safety of firefighters must be protected for a firefighting operation to be completed successfully. Therefore, enhancing the functionality and technology of the safety equipment possessed by each firefighter is a major technical issue¹.

Fire and rescue helmets protect the head, the most important part of the human body. This study develops an improvement plan for Korean fire and rescue helmets including optical, sensor, lighting, and communication technology that represents an improvement over existing options, with the proposed design based on optimal ergonomics.

The favorite brands of foreign firefighters include Casco, Cromwell, DNA, Pacific, MSA, Drager, Bullad, Protos, and Rosenbauer. In terms of structure and design, a more relaxed standard than that of the Korea Fire Institute is often applied by these foreign producers.

Previous studies include research on air circulation inside helmets and the development of new materials for the head part. Re-

garding color, products with higher legibility have recently been launched. For helmet housing, some designs include a hole in the outer part of the helmet so heat generated during a rescue operation can be dis-charged. Smart helmets to which other necessary equipment can be attached are also under development. Materials used in smart helmets include ultem, kevlar, complex polyamide, aramid, etc. for their high flame resistance. At the same time, the active manufacture of smart helmets that employ harmonized IoT technologies and high-tech devices has also begun. In figure 1(a) shows various foreign fire and rescue helmets in terms of color, performance, and design, while In figure 1(b) shows helmets with advanced technology.



(a) Various Fire and Rescue Helmets from Overseas

(b) IoT Fusion Helmets with Advanced Technology

Figure 1: High-Tech Helmets and Firefighting Helmets Used Overseas

Although fire helmets are a key component for protecting the heads of firefighters at disaster sites, there has been a lack of relevant systematic research in Korea^{2,3}. Because the small businesses that produce helmets are relatively small, relatively little formal research has been done on helmets in Korea. However, it has been predicted that the latest 3D printing technology will make it possible to produce highly detailed, bespoke helmet designs. Therefore, various designs and enhanced technology are becoming more important in this field^{4,5}.

In this study, we derived the optimal helmet size for Korean firefighters and identified a suitable priority for related high-tech components as required during a real mission based on questionnaire results. This information is expected to contribute to the development of Korean-style rescue helmets than contain smart technology to enable communication between high-tech devices (lights, headsets, communicators, goggles, sensors, night vision goggles, GPS, flashers and visual equipment) and the outside. We suggest a concept design for fire and rescue helmets and provide basic information regarding the development process for smart rescue helmets including installation of optional devices⁶.

2 Research Method

2.1 Standard Head Size for Korean

To determine a standard size for helmets, we gathered standard data for men between 25 and 59 years old, which is the general age range of adult Korean men working in industrial areas or as firefighters.

The average head width obtained was 167.3 mm, the circumference was 576 mm, the horizontal length from glabella and occiput was 192 mm, and the length from one trignon to the other through the vertex was 357.28 mm. Furthermore, the width between each external ear was 158.9 mm and the horizontal length from glabella to trignon was 97.23 mm. The horizontal length from sellion to occiput was 208.5 mm, the length from glabella to occiput through the vertex was 290.57 mm, the height of the head was 237.3 mm, and the vertical length from vertex to glabella was 101.2 mm. Finally, the linear length from trignon to lips was 141.5 mm. In figure 2 indicates these lengths in a graphic form⁷.

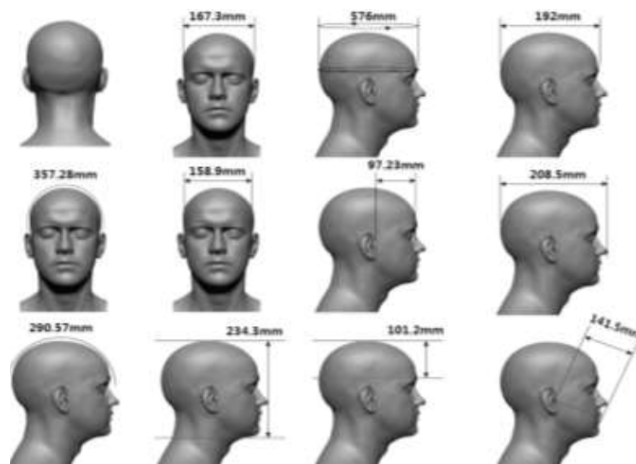


Figure 2: The Standard Length of Each Section of a Korean Head⁸

According to certified standards by the Korea Fire Institute, the vertical clearance between the inside of a helmet and the head must be greater than 55 mm and less than 25 mm. In turn, the clearance between a helmet and its internal fittings must be greater than 5 mm. In figure 3 shows this standard spacing between a helmet and head with reference to the Korea Fire Institute's guidelines⁹.

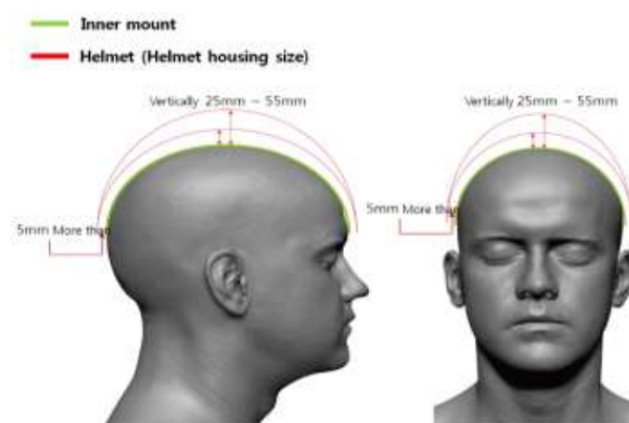


Figure 3: Standards Approved by the KFI: Spacing Between a Helmet and Head

2.2 General Questionnaire Information from Fire fighters

In this study, we used a questionnaire to research preferences of firefighters regarding the general details of fire and rescue helmets and related high-tech equipment that can be installed on these helmets. We collected 184 questionnaires with the cooperation of fire departments in Seoul City, Gyeonggi-do Province, Gangwon-do Province, Busan City and Chungcheongbuk-do Province.

Respondents were composed 100% of males and 26.1% had careers of more than five and less than 10 years. Furthermore, 33.7% had careers of more than 10 years and 9.8% had careers of less than one year. Finally, 9.2% had careers of more than one and less than three years. With regard to age, 48.4% were in their thirties, 22.8% were in their forties, 12.5 % were in their twenties, and 15.8% were in their fifties. The degree of trust respondents expressed in the safety of their helmets was slightly higher than average. As shown in table 1 displays the characteristics of respondents to the questionnaire.

Table 1. Respondent Characteristics

Gender	Male	184 (100%)
	Female	0 (0%)
Working area	Structures	184 (31.6%)
Length of Career in Rescue Work	Less than one year	18 (9.8%)
	More Than 1 Year-Less Than 3 Years	17 (9.2%)
	More Than 3 Years-Less Than 5 Years	38 (20.7%)
	More Than 5 Years-Less Than 10 Years	48 (26.1%)
	More Than 10 Years	62 (33.7%)
Age	Twenties	23 (12.5%)
	Thirties	89 (48.4%)
	Forties	42 (22.8%)
	Fifties	29 (15.8%)
	Central Rescue Team	23 (12.5%)

Rescue team	Special Rescue Team	80 (43.5%)
	Rescue Team Member	81 (44%)

3 Research Results

3.1 Standard Korean Head Size and Helmet Size with Reference to Certification by the Korea Fire Institute

The standards for firefighting helmets as certified by the Korea Fire Institute and the range of helmet sizes in reference to standard Korean head size are as follows. The width of the forward portion of the inner face of the helmet must not be less than 202 mm, the width of the outer side of the helmet must not be less than 177.3 mm, and the vertical length of the inside of the helmet must be between 126.2 mm and 156.2 mm. In figure 4 and 5 indicate the results according to these measurements.

Therefore, according to the range of helmet sizes in reference to standard head size, the width of the forward portion of the inner face of the helmet must not be less than 202 mm, the width of the outer side of the helmet must not be less than 177.3 mm, and the vertical length of the inside of the helmet must be between 126.2 mm and 156.2 mm. Figure 4 and 5 indicate the results according to these measurements.

In figure 6 and 7 compare the size of helmets produced in Korea with one of typical foreign helmets. The variations observed were not large. We also found that all helmets considered had sizes consistently within the standards certified by the Korea Fire Institute (including foreign helmets).

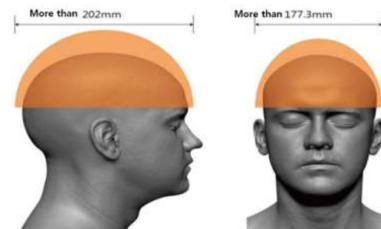


Figure 4: Standard Korean Head Size and Range of Helmet Width with Reference to the Certifications of the KFI

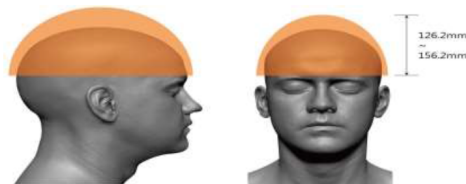


Figure 5: Standard Korean Head Size and Vertical Helmet Length with Reference to the Certifications of the KFI

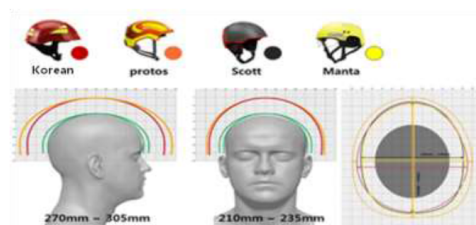


Figure 6: Comparison Survey of Korean and Foreign Helmet Sizes (Width)

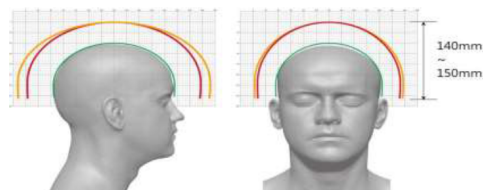


Figure 7: Comparison Survey of Korean and Foreign Helmet Sizes (Vertical Length)

3.2 Questionnaire Regarding Basic Factors of Helmets and High-tech Equipment

Through this questionnaire, we identified basic structural features of helmets, needs for high-tech equipment, and the priority that should be given to equipment, as below. Basic characteristics include safety, weight, hardness, shockproof features, pollution source detectors, suitable fit to the head, fire resistance, attachment satisfaction, helmet size, and the general necessity of high-tech helmets. As shown in table 2 shows the results of the question-naire.

Table 2: Priority of Firefighting Helmet Features According to Questionnaire Results

Safety	Not At All	10 (5.4%)
	Not Really	18 (9.8%)
	Average	65 (35.3%)
	A Little	61 (33.2%)
	Very Important	30 (16.3%)
Weight	Not At All	35 (19%)
	Not Really	68 (37%)
	Average	46 (25%)
	A Little	31 (16.8%)
	Very Important	4 (2.2%)
Hardness and Safety	Not At All	7 (3.8%)
	Not Really	30 (16.3%)
	Average	79 (42.9%)
	A Little	53 (28.8%)
	Very Important	15 (8.2%)
Shockproof	Not At All	7 (3.8%)
	Not Really	39 (21.2%)
	Average	93 (50.5%)
	A Little	41 (22.3%)
	Very Important	4 (2.2%)
	Not At All	10 (5.4%)
	Not Really	49 (26.6%)

Pollution Source Detector	Average	79 (42.9%)
	A Little	39 (21.2%)
	Very Important	7 (3.8%)
Korean Head Size	Not At All	30 (16.3%)
	Not Really	73 (39.7%)
	Average	53 (28.8%)
	A Little	23 (12.5%)
	Very Important	5 (2.7%)
Attachment	Not At All	9 (4.9%)
	Not Really	42 (22.8%)
	Average	78 (42.4%)
	A Little	47 (25.5%)
	Very Important	8 (4.3%)
Helmet Size	Not At All	16 (8.7%)
	Not Really	36 (19.6%)
	Average	62 (33.7%)
	A Little	49 (26.6%)
	Very Important	21 (11.4%)
Need for High-Tech Helmets	Not At All	9 (4.9%)
	Not Really	9 (4.9%)
	Average	24 (13%)
	A Little	31 (16.8%)
	Very Important	111 (60.3%)

In addition to the basic characteristics of fire and rescue helmets, we established a priority ranking for nine high-tech devices deemed necessary for firefighting. In figure 8 shows the results.

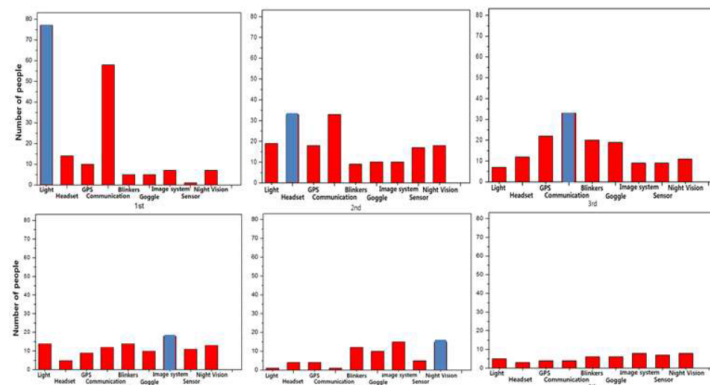


Figure 8: Priorities for Installing High-Tech Devices

According to the results, the first thing firefighters wanted added to helmets was a light. The second thing they preferred was a headset for personal communication. Third was a communication device for the transmission of various information with the commanding headquarters. Forth was better visual equipment, and fifth was night-vision goggles. For other equipment, there was no statistically significant difference in preference. However, many respondents did not answer questions further down the list. According to these results, the high-tech equipment most required on fire and rescue helmets were lights, communication devices, information transmission devices and devices to ensure a clear view during both day and night. Besides these, firefighters indicated a need for GPS and various other sensors. Through these surveys, it was concluded that it is most reasonable to design and manufacture high-tech, structural fire helmets in a way that enables firefighters to flexibly install the equipment they regard to be important. By adding various IoT devices, the heads-up display can increase rescue efficiency by sharing additional information with on-site fire crews. As the communication device is connected to the helmet, firefighters will be able to work more efficiently by communicating simultaneously with headquarters and the fire department¹⁰.



Figure 9

In figure 9 indicates optimal helmet size given standard head size for Korean. It also shows a conceptual design for a fire and rescue helmet that is combined with high-tech devices. We have derived the optimal size for the helmet. The width should be 200 mm, the length between the front and back of the helmet should be 260 mm, and the height should be 150 mm. Also, the front part of the helmet is designed to hold light and visual devices, including a flasher. These devices will be installed in a way that allows the firefighter to look forward. Considering the overall balance of weight, the antenna, battery, and communication devices are designed to be installed on the back. At the same time, it is possible to put an additional antenna to ensure smooth communication using an auxiliary battery. The above design is only a conceptual reference that takes into consideration optimal size and necessary high-tech devices, not a picture of a real helmet.

4 Conclusion

Fire and rescue helmets protect the head, the most important part of the human body. This study established a plan for the improvement of Korean fire and rescue helmets, which can be made better than existing rescue helmets based on our research on firefighter priorities for IoT technology, also deriving the optimal size of firefighting helmets. The results can be summarized as follows.

1. In foreign countries, the use of various fire helmets combined with advanced technology is increasing. On the other hand, insufficient systematic development of high-tech fire helmets has been completed in Korea.
2. We have derived the optimal helmet size given average Korean male head size. The width should be 200 mm, the length

should be 260 mm, and the height should be 150 mm. This is similar to the size approved by the Korea Fire Institute.

3. According to a questionnaire completed by rescue crews in the field, firefighters prioritize lighting, communication and information transmission devices. After these, they demand the installation of various sensor devices, such as GPS, flashers, etc.

4. In order to ensure the efficiency and safety of operations, we have suggested an optimal helmet size and conceptual design. We have also suggested a fire and rescue helmet that ensures convenience.

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