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Girl on Fire – Links between sex, firefighters' clothing, safety, confidence and wear and tear

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ABSTRACT

Firefighters are exposed to high risks and hazards, such as flames and smoke, in their daily lives. To be protected against these risks, firefighters wear protective clothing. As an employer, it is the duty to provide firefighters with good protection according to DIN EN 469. To do so, it is necessary to select, procure and maintain suitable firefighters' protective clothing. In order to identify weaknesses in the above steps and to develop and present proposals for remedying the identified weak points, an empirical study was conducted. In preparation for this study, interviews were first conducted with members of fire brigades. Based on the interviews, the relevant standards and regulations for fire fighters´ clothing were classified and areas of tension between the standards and regulations as well as their design in everyday fire brigade life were identified. Based on this, a standardized quantitative survey was conducted and the answers of the respondents were empirically evaluated. The evaluation examined both the respondents' answering behavior and the dependency between the answering behavior for different questions due to demographic differences. A key finding is that women firefighters are less satisfied with their firefighting clothing compared to men firefighters. The firefighters' clothing fits them worse. They do not feel as safe and comfortable. Moreover, woman have less confidence in the protective clothing. There is a correlation between the fit of the clothing and the satisfaction, confidence and feeling of protection

1 Introduction

The workload in the German fire brigades is increasing. In the period from 1997 to 2018, the number of fire brigade operations has increased by about 50%, while the number of volunteers active in the volunteer fire brigades has decreased by about 22% [1,2]. Daily availability has also decreased [3 p. 3, 4 p. 10; 40-41]. As a result, the members of the volunteer fire brigade are under great strain. To compensate, some municipalities have set up compulsory or voluntary professional fire brigades.

In order to ensure fire protection in the municipalities in the long term, a sufficient number of firefighters must be available. One way to increase the number of firefighters is to increase the proportion of women firefighters [5 p. 2].

The diversity of members is also beneficial for the performance of the individual units [6 p. 32–37, 7, 8].

All fire brigades have the duty not to treat applicants differently for extraneous reasons [9 § 8 II] In the case of professional fire brigades and volunteer fire brigades as part of the state authority, it is also a constitutional duty to provide equal access for women and men [10 Art. 33 II].

The proportion of female members in volunteer fire brigades has increased from 5.7% in 2000 to 9.9% in 2020 [2,11,12]. Despite intensive efforts, the volunteer fire brigades are thus lagging behind the comparable German Federal Agency for Technical Relief (Bundesanstalt Technisches Hilfswerk) (share of women in 2020: 15.7% [13 p. 3]).

The volunteer fire brigades have potential in this regard. In the period from 2010 to 2018, 26.0 % of girls were active in the youth fire brigades; however, only 21.2 % of those who transferred to the operational departments are girls [14 p. 12–13, 15 p. 12–14, 16 p. 12–14, 17 p. 13–15, 18 p. 13–15, 19 p. 13–15, 20 p. 13–15, 21 p. 13–15, 22 p. 13–15]. If girls were to join the fire brigade as often as boys, there would be about 1,500 more young fire fighters available in Germany each year [23 p. 5].

In 2012, the German Sport University Cologne developed a recruitment sports test on behalf of the German Association of Cities, which was used to reduce sporting hurdles for women in the best possible way without endangering their ability to work [24-27].

The requirements for firefighters' protective clothing are specified in DIN EN 469 [28] and in the manufacturing and testing description for universal firefighters' protective clothing (Herstellungs- und Prüfungsbeschreibung für eine universelle Feuerwehrschutzbekleidung, HuPF) [29-32] for firefighters' jackets and trousers. In the HuPF, size specifications and cut sizes are also given, whereby men's measurements are assumed as far as possible; comparison tables are available for women's measurements. Fig. 1 shows some examples of ill-fitting firefighters' protective clothing: a jacket that cannot be fully closed, a trouser leg that is too long and trousers that are too tight at the hips.

Fig. 1 Example of misfitting firefighting clothing among women [33].

It is permitted to deviate from the specifications stated in the HuPF as long as this does not impair the protective clothing for firefighters. Exceeding the specifications or producing a variety of cut shapes is certainly desirable. Some manufacturers make use of this possibility and have explicitly women's models in their portfolio. Nevertheless, fire brigades only very rarely introduce protective firefighting clothing for women. The reasons given are [34]:

- Many manufacturers had too little choice for firefighters' protective clothing in various cuts.
- Many intermediaries do not stock unusual sizes and do not have a complete portfolio for wearer trials.
- When introducing new models, many fire brigades take too little time for selection and hardly have the time to carry out extensive wearer trials with models from different manufacturers in all available cuts and sizes.
- Many municipalities shy away from the higher procurement costs of a balanced range of protective firefighting clothing.

Therefore, firefighters' protective clothing is looked at more closely with a view to the needs of women firefighters.

2 Method

First, interviews were conducted with members of volunteer fire brigades, a professional fire brigade and a plant fire brigade. The aim of the interviews was to determine the focus of the subsequent nationwide, questionnaire-based survey.

A survey of German fire brigade members was then conducted between 7 August 2021 and 14 October 2021 using the SoSci Survey tool from SoSci Survey GmbH, Munich. In the process, 101 questions from 61 question clusters were asked. 1,734 persons participated in the survey, 1,223 data sets are complete [35].

- Questions were asked in the areas of [36 p. 28]:
- Demography and constitution of the subjects
- Selection and introduction of new firefighting clothing
- Maintenance, wear, upkeep and retirement of firefighters' clothing
- Satisfaction with current fire brigade clothing
- Evaluation of selected suggestions for the improvement of firefighters' clothing

The high response rates (approx. 1.3 ‰ of the total line group) and the low dropout rate of 29.5% from surveys already started were achieved with several measures [36 p. 28–29]:

- The survey was optimized for both desktop and mobile devices so that participants could take part immediately after receiving the survey.
- Participants could choose between a shortened basic survey of about 15 minutes and the full survey of about 30 minutes, indicating the expected duration. They were asked to complete the survey once they had made a decision for the short or long version of the survey.
- The survey was advertised in a variety of ways. A total of 234 institutions were asked to support the implementation of the survey as multipliers, including:
    - The (as of 2021) 111 German professional fire brigades
    - The Federal Ministry of the Interior, the 16 Land Ministries of the Interior and the Conference of Federal Ministers of the Interior
    - The district governments of the federal states, insofar as they have set them up
    - The fire brigade schools of the federal states, if they have established any
    - The German Fire Brigades Association (Deutscher Feuerwehrverband e. V.), Berlin, and its 16 state associations
    - The German Fire Brigades Union (Deutsche Feuerwehrgewerkschaft e. V.), Solingen, and its 13 regional associations

- Other public service unions, including the German Civil Servants' Association (Deutscher Beamtenbund), Berlin, and the Association of German Armed Forces Fire Brigades (Verband der Bundeswehrfeuerwehren e. V)., Haltern am See
- The four fire brigade accident insurance funds and the German Social Accident Insurance (Deutsche Gesetzliche Unfallversicherung) as well as professional associations from the processing industry
- Professional organizations, including the Association for the Promotion of German Fire Protection (Vereinigung zur Förderung des Deutschen Brandschutzes e. V.), Münster, the Working Group of the Heads of Professional Fire Departments (Arbeitsgemeinschaft der Leiter der Berufsfeuerwehren) in the German Association of Cities (Deutscher Städtetag) and the Community of Interest of Fire Officers and Promotion Officers of the Higher Fire Service (Interessengemeinschaft der Brandreferendare und Aufstiegsbeamten des höheren feuerwehrtechnischen Dienstes)

In addition to demographic data on gender, age, height, body weight, body proportions, level of training, fire brigade type and settlement structure, respondents were asked about their experiences with their own protective clothing. Likert scales with five choices were used in the majority. To prevent over-selection of the middle field, there was no neutral response option. For questions about satisfaction as well as about fit, the response options were "very satisfied", "satisfied", "somewhat satisfied", "fairly dissatisfied" and "very dissatisfied". Some questions were detached from the Likert scheme. For example, the respondents were asked to rank the clothing issued to them according to satisfaction or to rank the relevance of various protective mechanisms of the firefighters' protective clothing [35].

The results of the survey were then reviewed and checked for validity. Where participants obviously tried to falsify the data, the data set concerned was eliminated. There was no automated elimination of outliers [36 p. 29].

The data was then examined with regard to the demographics of the participants. However, the focus was particularly on looking at dependencies between satisfaction with firefighters' protective clothing and fitting behavior on the one hand, and participants' gender and body shapes on the other.

3 Limitation of the method

The study design and the collected data as well data have methodological limitations [36 p. 113].

The sample composition cannot be controlled. It remains open whether respondents have participated more than once in the digital survey, which is to be completed autonomously, or whether several respondents have completed a joint interview.

The sample does not necessarily have to be representative. It is not possible to check whether the answers given by the individual respondents are representative for the respective fire brigade or the type of fire brigade. Furthermore, it is not possible to check whether the respondents' fire brigades are representative of the fire brigade as a whole. With regard to the sample, it can be determined, for example, that the proportion of members of the professional fire brigade among the test persons is higher than the expected value.

For most of the questions, no objective data was asked, but the respondents were asked for a subjective assessment on a Likert scale [37 p. 47–49] with five answer options. Consequently, the answers of the test persons can only be compared with each other to a limited extent. Due to the size of the sample with a total of 1,734 respondents, it can be assumed that the law of large numbers [38] is valid, so that the total scale of the respective items is sufficiently relevant for the analysis carried out here, since deviations are relativized in the total.

The proportion of female test persons is about 13 times lower than the proportion of male test persons. Statements and evaluations that are explicitly based on statements by female respondents are subject to a significantly greater statistical uncertainty. Comparisons of the overall response behavior with the response behavior of the female respondents are therefore also subject to corresponding uncertainties.

Some test persons gave, presumably intentionally, incorrect data (e.g. a height of 300 cm with a body weight of 200 kg). Where this was obvious, the subjects were removed from the study. However, it cannot be ruled out that deliberately falsified data were not detected and therefore could not be excluded from the study.

The remaining data sets were analyzed.

4 Results

The discussions preceding the surveys revealed that, in relation to firefighters' protective clothing, relevant fields of action do not lie, as expected, in the technology of firefighters' protective clothing itself and approaches to the circular economy, but rather in the consideration of fits, gender equality and wear and tear.

The proportion of male firefighters is 92%, that of female firefighters 7%; three participants stated that they were diverse. Approximately 80% of the participants are active in a volunteer fire brigade. The majority of participants are active in small and medium-sized communities [36 pp. 30–36].

The majority of female firefighters are younger, smaller and slimmer than their male comrades [36 pp. 37–44].

As seen in Fig. 2, approximately 67% of all firefighters are satisfied or very satisfied with the protective firefighting clothing they currently use. However, the overall satisfaction with the firefighters' protective clothing differs between women and men. Men are about twice as often very satisfied with their protective clothing [36].

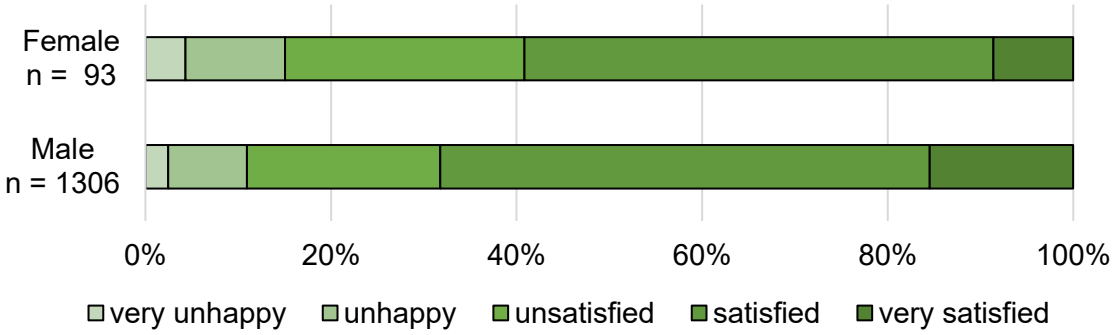

Fig. 2 Satisfaction of the firefighters in the firefighting protective clothing.

However, if the individual components of the personal protective equipment are considered, then there are sometimes considerable differences in satisfaction and the fitting behavior between women and men firefighters. For example, the response behavior for the statement "very satisfied" differs between female and male firefighters for the firefighter jackets (exemplary in Fig. 3), the firefighter trousers (exemplary in Fig. 4) and the gloves for technical assistance by about 10 percentage points each; for the other clothing elements (jacket for technical assistance, fire protection gloves, boots, helmet and flame protection bonnet) the difference is about 5 percentage points [36 p. 63].

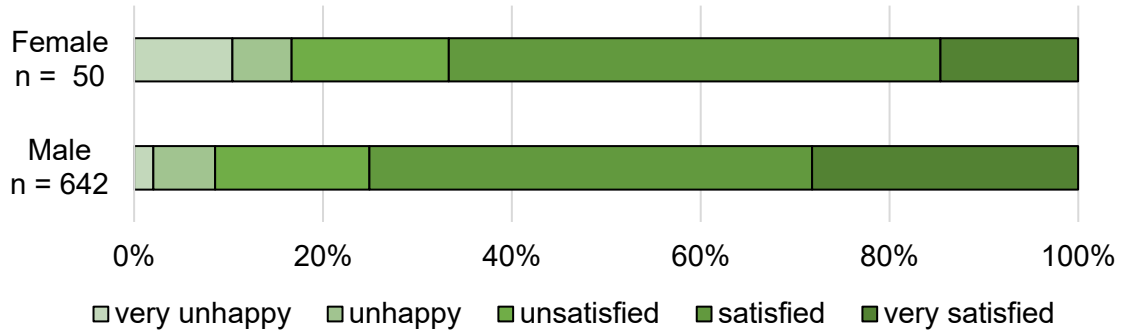

Fig. 3 Satisfaction of firefighters with the firefighter jacket.

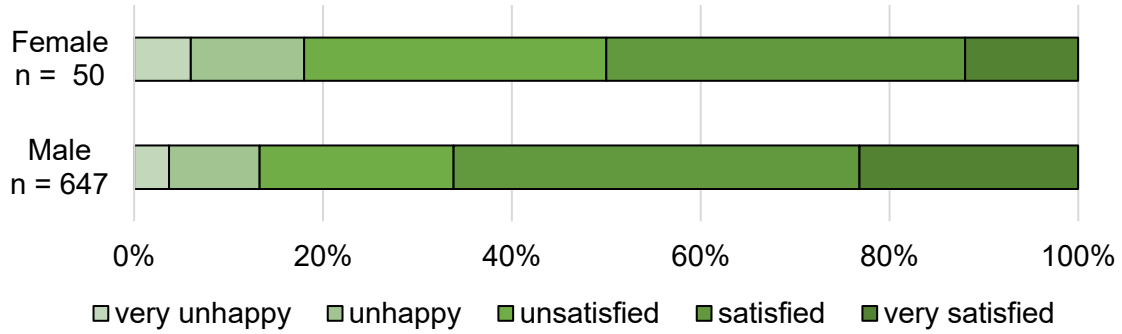

Fig. 4 Satisfaction of firefighters with the firefighter trousers.

The greater dissatisfaction of women firefighters compared to men firefighters becomes clear when participants are asked to sort the items of clothing issued to them according to satisfaction. If for male firefighters the fire jacket is ranked 2nd and the fire trousers 6th, for female firefighters the fire jacket is ranked 7th and the fire trousers 9th [36 p. 65]. Since not all items of clothing are issued in the individual fire brigades, it is first standardised accordingly with the number of times a particular item of clothing was selected in the first place. In comparison, the importance of a single piece of equipment as indicated by the test persons: At the same time, the fire brigade jacket and the fire brigade trousers are evaluated as the most important clothing items [36 p. 66]. This comparison is shown in Table 1.

Table 1. Satisfaction and relevance of the individual clothing elements.

Rank	Satisfaction (men)	Satisfaction (women)	Relevance
1	Rainwear	Rainwear	Firefighter jacket
2	Firefighter jacket	Sportswear	Firefighter trousers
3	Sportswear	Underwear	Boots
4	Underwear	Boots	Helmet
5	Jacket for technical assistance	Jacket for technical assistance	Rainwear
6	Firefighter trousers	Flame protection bonnet	Sportswear
7	Boots	Firefighter jacket	Jacket for technical assistance
8	Flame protection bonnet	Gloves for technical assistance	Underwear
9	Helmet	Firefighter trousers	Flame protection bonnet
10	Fire protection gloves	Helmet	Fire protection gloves
11	Gloves for technical assistance	Fire protection gloves	Gloves for technical assistance

The fit behavior at the different body parts is used for comparison. Depending on the part of the body, the “fits well” between female and male firefighters differed by between 10 and 30 percentage points. Only at the neck and feet is there hardly any difference. It is interesting that the difference in the response “fits well” is greatest at the head, while satisfaction with the helmet is inconspicuous [36 p. 79].

The differences in satisfaction with jackets and trousers based on fit, as shown in Table 1, are compared for women and men as examples in Fig. 5. Relevant areas are marked. Instead of the firefighter’s protective jacket, the garment for technical rescues is worn for better illustration.

As seen in Fig. 6, both women and men feel safe or very safe in firefighters’ protective clothing, with 81% and 83% respectively. The feeling of safety in protective firefighter clothing is generally high. However, it is noticeable that only 20% of female firefighters feel absolutely safe in protective firefighting clothing, compared to 31% of male firefighters.

Trust in firefighters’ protective clothing is basically high. There are almost no men who do not trust their protective clothing. However, 3% of women do not trust their firefighters’ protective clothing absolutely. Furthermore, 2% of women hardly trust their firefighter protective clothing. Among men, only 2% do not trust their firefighters' protective clothing at all or not at all. Absolute trust is also weaker among women firefighters (13.5%) than among men firefighters (28%).

Fig. 5 Contrasting protective firefighting clothing for women and men.

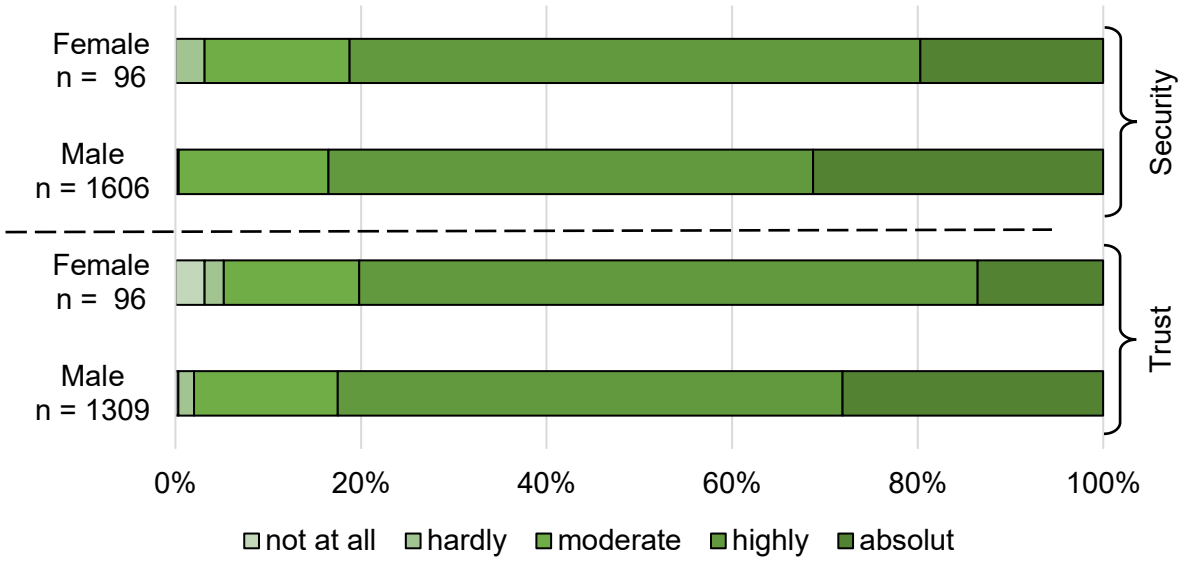

Fig. 6 Trust and a sense of security.

In terms of a sense of security and confidence, firefighters find good conditions. For women firefighters, however, the conditions are only acceptable. Fig. 5 shows, that the fit of fire fighters garment is selected according to men's waist, hip and legs, even in the cut of woman's clothing.

A connection can be established between satisfaction with the firefighter's trousers or jacket on the one hand and the feeling of safety and confidence on the other. The more satisfied firefighters are with the firefighter jacket (see Fig. 7) and the firefighter trousers (see Fig. 8), the greater the feeling of safety and confidence in the firefighter clothing. Each cluster comprises 1/9, i. e. approx. 11% of the data points. The more two-dimensional the image, the greater the scatter within the respective data set.

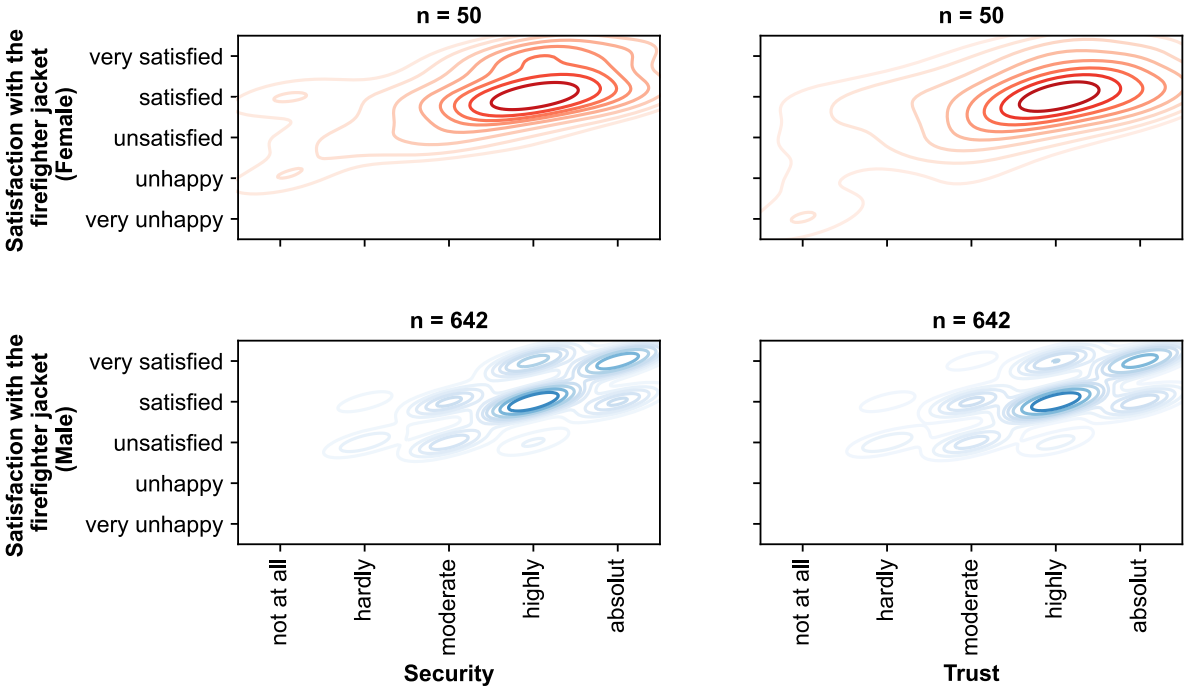

Fig. 7 Correlation between satisfaction with the firefighter jacket and feeling of safety and confidence.

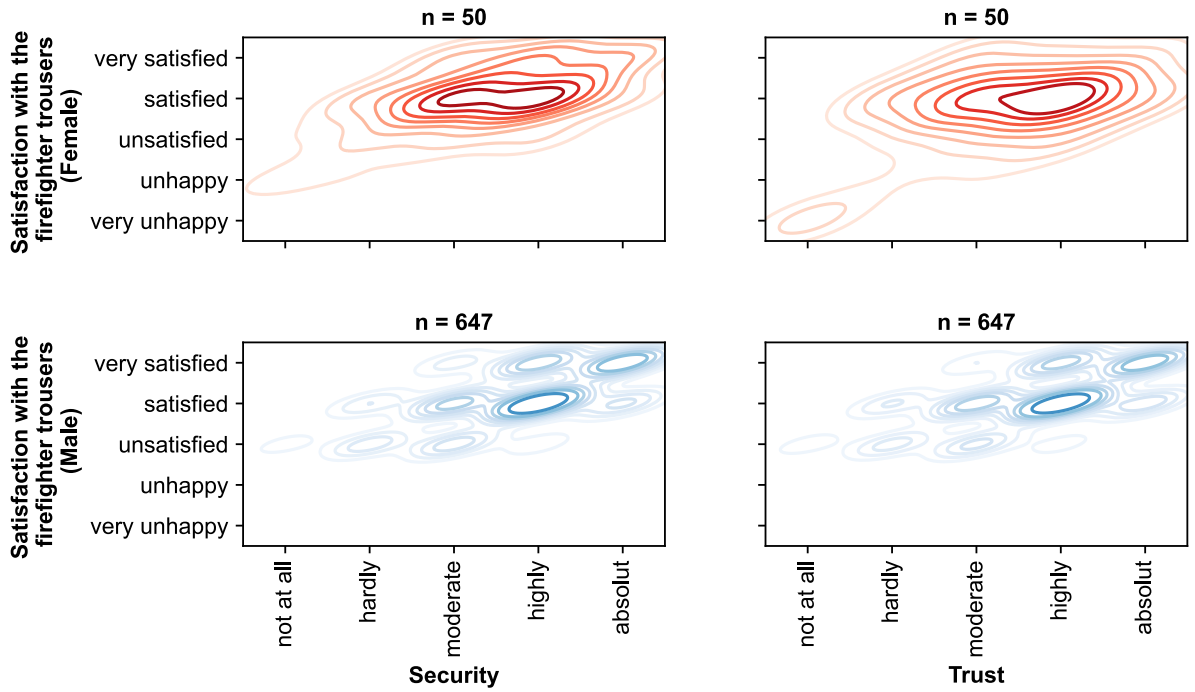

Fig. 8 Correlation between satisfaction with firefighter trousers and feeling of safety and confidence.

However, with the exception of the feeling of safety in the firefighters' trousers, this correlation is weaker for female firefighters than for male firefighters (see Table 2).

Table 2. Correlation between satisfaction with firefighter jacket and firefighter trousers and confidence and feeling of safety.

	Trust		Safety	
	Female	Male	Female	Male
Firefighter jacket	0.553	0.614	0.544	0.649
Firefighter trousers	0.580	0.606	0.622	0.595

The fire brigade authorities are obliged to provide adequate protective clothing for firefighters [39 § 3]. Users should be closely involved in the selection of protective equipment [40 § 14 I].

A close involvement of the users has a positive influence on the satisfaction with the firefighters' protective clothing, while the influence on the feeling of safety and trust is hardly perceptible (see Fig. 9). The calculation of the correlation coefficient is omitted, as a normalization of the different types of wearing tests is not possible.

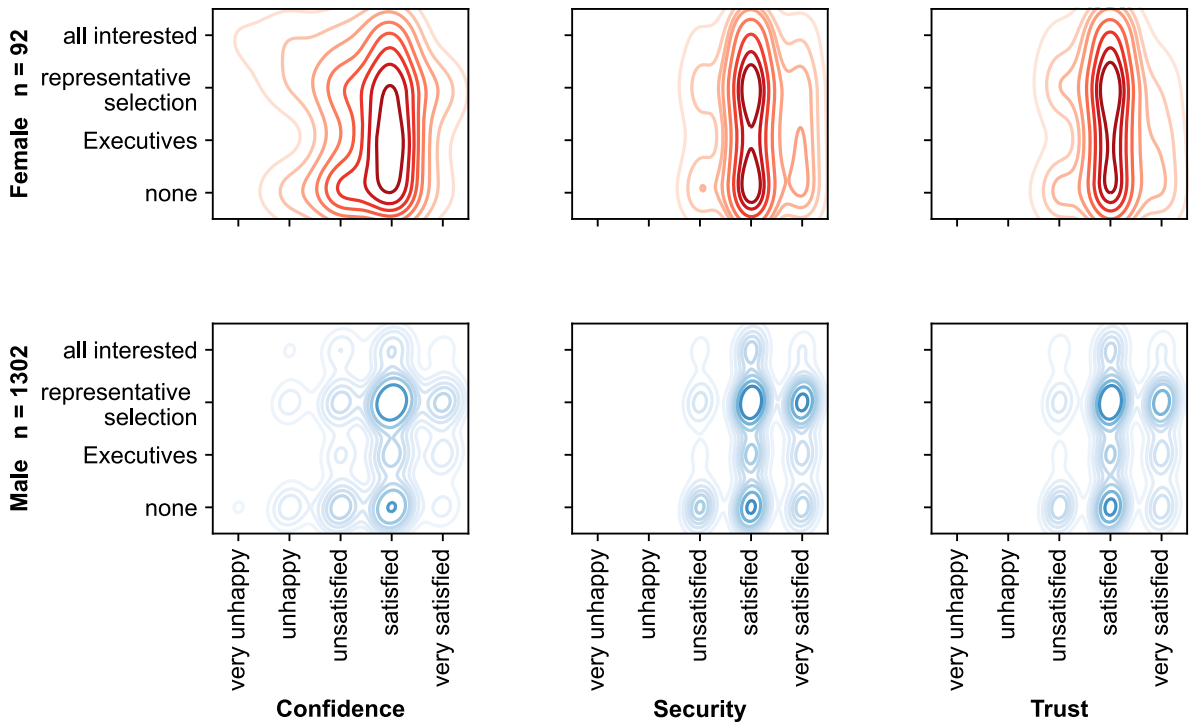

Fig. 9 Impact of wearer trials on satisfaction, sense of safety and confidence.

The protective effect of firefighters' protective clothing depends not only on the fit, but also on wear. A fundamentally good protection can be lost if the clothing wears out more and more over time. Fig. 10 shows the wear behavior of the individual parts of the clothing depending on the gender of the wearer. A low rank means that clothing wears out quickly, a high rank means longevity. The individual positions are sorted according to the difference in the wear behavior of female and male firefighters. Starting on the left with the largest difference, the difference decreases towards the right.

As expected, highly stressed areas, i.e. the knees, reflector strips, boot tops, hook and loop fasteners and the tightness of the boots, wear out fastest. The midfield is led by the openings on the sleeves and on the legs, whereby the openings on the sleeves wear out noticeably faster for women, and the wear on the openings on the legs is moderately higher for firefighters.

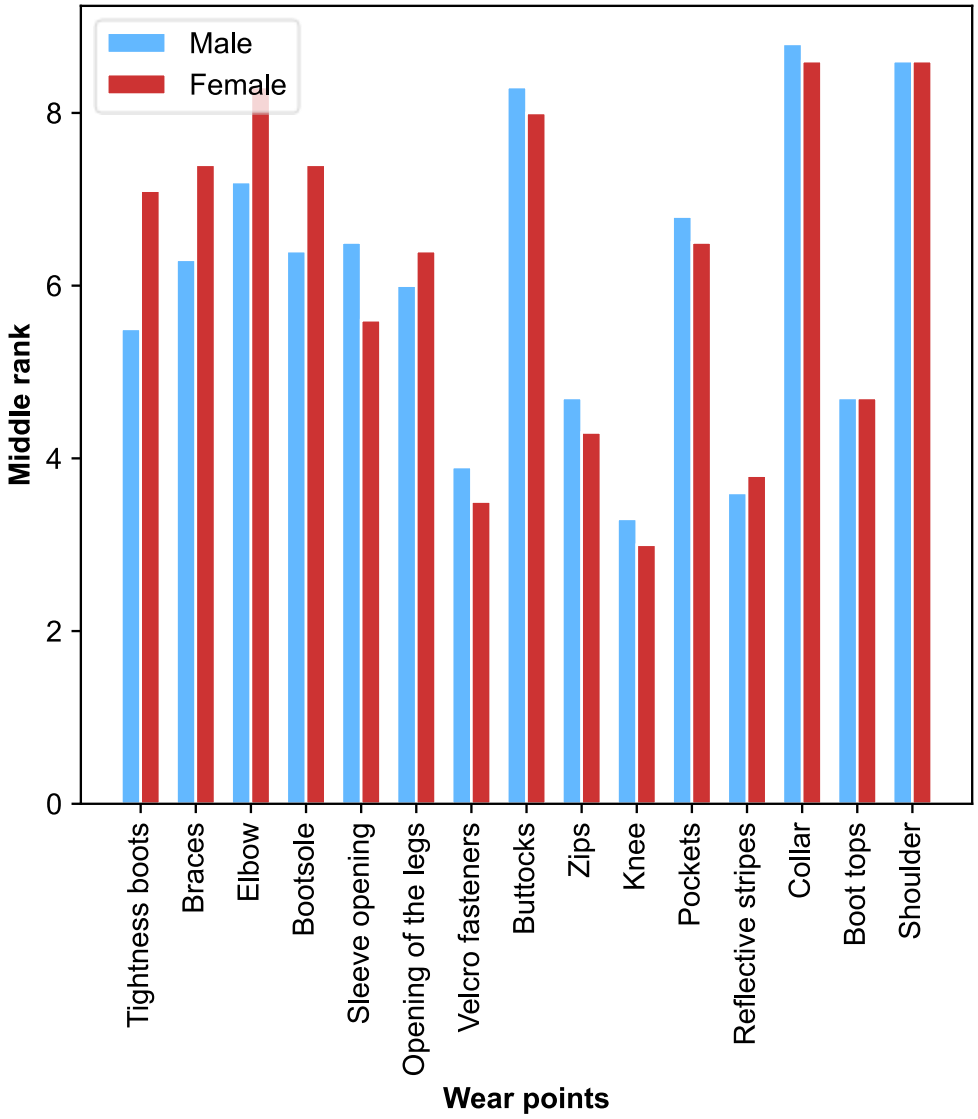

Fig. 10 Wear points and intensity of wear.

Representation is important to the members of fire brigades; The fact that the fire brigade protective clothing of different neighboring fire brigades increasingly differs from each other is not least due to the desire for one's own fire brigade to become a brand of its own [41]. But here, too, there are differences between men and women firefighters (see Fig. 11).

Women do rate their firefighter clothing as somewhat less attractive than firefighters do. But it is also less important to them. For male firefighters, the correlation between the assessment of fashion as relevant and the attractiveness of the current outfit is weak with $r = 0.363$, but significantly stronger than for female firefighters, where this correlation cannot be established with $r = 0.048$.

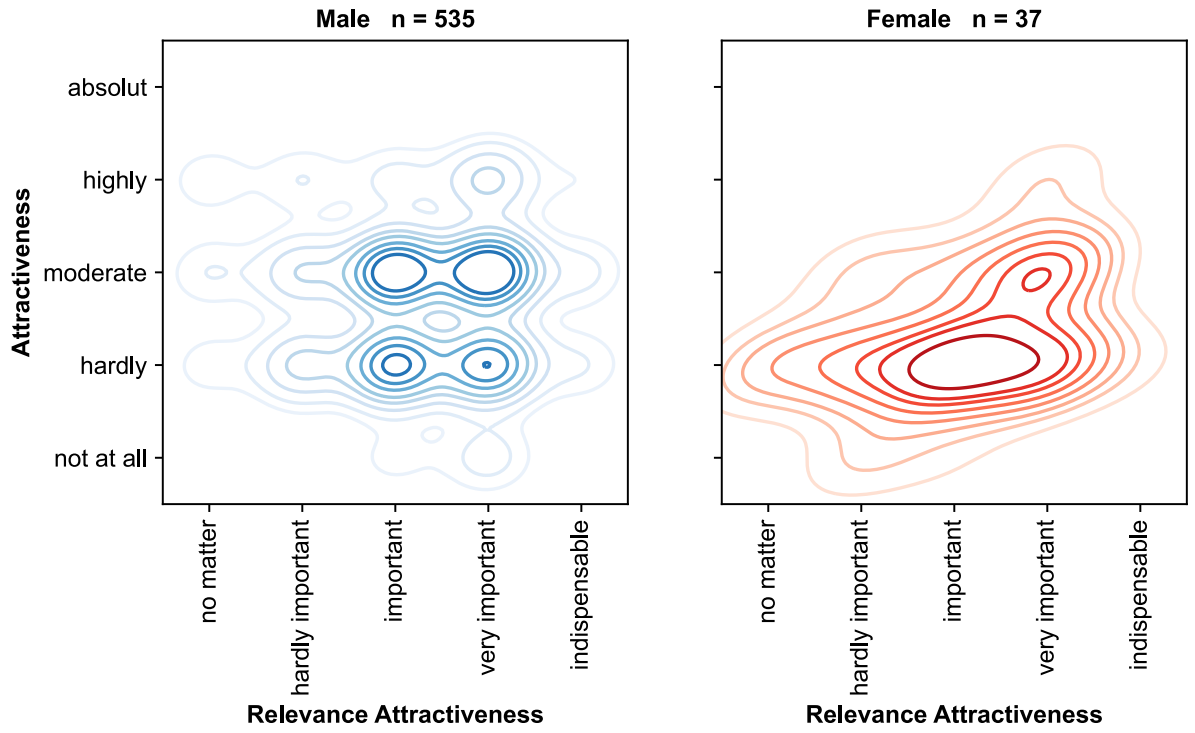

Fig. 11 Relationship between the relevance of attractive firefighter clothing and its perceived attractiveness.

5 Conclusions

The comparatively high dissatisfaction of women firefighters with the firefighter jacket and firefighter trousers, as well as the poor fit, is a cause for concern. Together, the firefighter jacket and firefighter trousers protect most of the body. Only the head, neck, hands and feet remain uncovered by the firefighter jacket and firefighter trousers.

Even if fire operations account for an increasingly smaller proportion of fire brigade operations [11], fire operations are nevertheless particularly dangerous.

Firefighter jacket and firefighter trousers together protect about 80% to 90% of the total body surface; from a burnt body surface of about 25%, life-threatening injuries are assumed to have occurred [42].

If firefighters' clothing is not carefully selected, there is a high potential for injury.

Also of concern is the high wear and tear on the openings of the firefighters' protective clothing on the sleeves and legs. Through the openings, fire smoke can penetrate the firefighters' protective clothing and contaminate the wearers' skin. Such contamination is dangerous as it increases the risk of cancer; accordingly, contamination with fire smoke must be prevented [43-46].

Consequently, the protective clothing for firefighters must fit as well as possible. Only safe, but also comfortable and well-fitting protective clothing for firefighters enables them to carry out their work safely. [41]. To ensure the best possible selection, wear trials should be conducted more frequently than today and the team should be closely involved in the wear trials. For this purpose, the already existing handouts on carrying trials can be made more widely known. [47 pp. 48–50] This is, because air space between the clothing and wearer lead to a higher insulation of heat transmission and therefore less burning injuries.

The HuPF needs to be further developed in view of the increased diversity among fire brigades - especially women firefighters. Since the introduction of the HuPF in 1999, the demographic composition of fire brigades has changed; the proportion of women has increased significantly. The generic firefighter should no longer be the starting point for production regulations [29-32], but the diversity of the fire brigades must also be reflected in the production regulations. Women's measurements are to be added

to the size tables. This will also encourage those municipalities to procure suitable protective firefighting clothing for their women firefighters who currently only procure protective firefighting clothing in accordance with the minimum standards.

6 Outlook

Research is to be conducted to find out whether women firefighters are less able than men to carry out certain activities in everyday firefighting, and in particular whether they have an increased risk of accidents. For this purpose, accident reports from the fire brigades are to be evaluated.

If the impression that women are less well protected than men in the fire service is confirmed, proposals will be developed on how the protection of women firefighters can be improved or the risk reduced.

If this impression is not confirmed and the lower confidence in firefighters' protective clothing and the feeling of poorer protection among women firefighters is subjective, then possible reasons for this should be identified and remedial measures proposed. In this case, competences from the fields of didactics and occupational psychology and physiology should be closely involved.

The previous considerations in the area of firefighter cancer [48-52] should be expanded to include the two aspects of gender equity and the influence of wear and tear.

The firefighters' protective clothing itself should also be further developed. To this end, the manufacturing and testing description for universal firefighters' protective clothing should be adapted to female forms and a corresponding guarantee of the availability of protective firefighters' clothing tailored to women should be included.

The intensively stressed areas of the firefighters' clothing should be reinforced. First approaches to reinforcement with e.g. ceramic particles are already being implemented in industry [53,54].

The overall objective should be to contribute to improving the working conditions of women firefighters, especially in the volunteer fire brigade (the bottleneck for female applicants to the professional fire brigade and the plant fire brigade is the sports test [24-27]), in order to support society in increasing the proportion of women firefighters in the fire brigade and in increasing the number of citizens active in the volunteer fire brigades. There are already many research programs and campaigns in this field [24-27, 55-60]. At present, the aspect of personal protective equipment is treated with restraint.

Beyond the requirements for firefighting clothing, it is possible to evaluate whether female and male firefighters are qualified to perform different tactical tasks to different degrees. The relative weaker quickness of women [61 p. 185; 62 p. 198] (women have about 80% of the absolute strength of men [63 p. 375]), but also their better endurance [64 pp. 189–208] should be pointed out.

Author Contributions

C. Schiffer: conceptualization, methodology, data curation, writing – original draft preparation; R. Krause: supervision, writing – review and editing; J. Kühn: supervision, writing – review and editing; T. Gries: resources. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Oestreicher, S. Deutscher Feuerwehrverband, Ed. *Feuerwehrjahrbuch 2020:* Berlin, 2021.
2. Deutscher Feuerwehrverband, Ed. *Feuerwehrjahrbuch 2001/02:* Bonn, 2001.
3. Rolf, W.; Dehling, J.; Schneider, B. Ministerium für Inneres und Kommunales des Landes Nordrhein-Westfalen; Verband der Feuerwehren in Nordrhein-Westfalen e. V., Eds. *Arbeitsgruppe 2 – Organisation der*

Freiwilligen Feuerwehr – Pilotprojekt „Fahrzeugtechnik“: Ausformulierter Antrag auf ein Pilotprojekt, June 10, 2014.
4. Koß, C.; Penkert, B.; Vehling, H. Ministerium des Innern NRW, Ed. FEUERWEHRENSACHE - Förderung des Ehrenamtes der Feuerwehren in Nordrhein-Westfalen – Abschlussbericht: Düsseldorf, 10.2017.
5. Darmstädter, S.; Jacobs, Sönke, Matticzk, Roland; Trede, M.; Voss, A. Deutscher Feuerwehrverband, Ed. *Frauen lassen nichts anbrennen: Willkommen in der Freiwilligen Feuerwehr*, 04.2007.
6. Dixon-Fyle, S.; Dolan, K.; Hunt, D.V.; Prince, S. Diversity wins: How inclusion matters. https://www.mckinsey.com/featured-insights/diversity-and-inclusion/diversity-wins-how-inclusion-matters (Accessed October 8, 2022).
7. Innovation durch Vielfalt: Deutschlands Feuerwehrsystem als Gegenstand eines neuen Forschungsprojekts an der Universität Paderborn, December 03, 2018.
8. Deutschlands Feuerwehrsystem ist Gegenstand eines neuen Forschungsprojekts an der Universität Paderborn, January 15, 2019.
9. *Allgemeines Gleichbehandlungsgesetz: AGG,* Deutscher Bundestag. BGBl. I S. 1897, August 14, 2006.
10. Grundgesetz für die Bundesrepublik Deutschland: GG, Deutscher Bundestag. BGBl. I S., May 23, 1949.
11. Deutscher Feuerwehrverband, Ed. *Statistische Entwicklung*.
12. Oestreicher, S. Deutscher Feuerwehrverband, Ed. *Feuerwehrjahrbuch 2020:* Berlin, 2021.
13. Zanetti, H.; Schwarz, T. Bundesanstalt Technisches Hilfswerk (THW), Ed. *Jahresbericht 2020:* Bonn, 06.2021.
14. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2010, 2011.
15. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2011, 2012.
16. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2012, 2013.
17. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2013, 2014.
18. Huhn, A. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2014, 2015.
19. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2015, 2016.
20. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2016, 2017.
21. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2017, 2018.
22. Huhn, A. Deutscher Feuerwehrverband, Ed. Statistik der Deutschen Jugendfeuerwehr im Deutschen Feuerwehrverband für das Berichtsjahr 2018, 2019.
23. Schiffer, C. Geschlechterspezifische Anforderungen an Persönliche Schutzbekleidung: Gägelow, October 22, 2022.
24. Kleinöder, H.; Dörmann, U.; Wirtz, N. Physische Eignungsfeststellung für die Berufsfeuerwehr in Deutschland - Offizielles Testhandbuch -.
25. Kleinöder, H.; Dörmann, Ulrike, Haeo, André; Bornholdt, B.; Gerling, I.; Tischer, U.; Wendt, M.; Emberger, D.; Hartmann-Tews, I.; Brixius Klara; Strüder, H.; Mester, J. Physikalische Eignungsfeststellung für die Berufsfeuerwehr in Deutschland: Analyse, Konzeption und Erprobung von geschlechterneutralen Testverfahren – Teil 1. *Zeitschrift für Forschung, Technik und Management im Brandschutz – vfdb*, **2012,** 24–27.
26. Kleinöder, H.; Dörmann, Ulrike, Haeo, André; Bornholdt, B.; Gerling, I.; Tischer, U.; Wendt, M.; Emberger, D.; Hartmann-Tews, I.; Brixius Klara; Strüder, H.; Mester, J. Physikalische Eignungsfeststellung für die Berufsfeuerwehr in Deutschland: Analyse, Konzeption und Erprobung von geschlechterneutralen Testverfahren - Teil 2. *Zeitschrift für Forschung, Technik und Management im Brandschutz - vfdb*, **2012,** 90–95.
27. Kleinöder, H.; Dörmann, Ulrike, Haeo, André; Bornholdt, B.; Gerling, I.; Tischer, U.; Wendt, M.; Emberger, D.; Hartmann-Tews, I.; Brixius Klara; Strüder, H.; Mester, J. Physikalische Eignungsfeststellung für die Berufsfeuerwehr in Deutschland: Analyse, Konzeption und Erprobung von geschlechterneutralem Testverfahren. *Brandschutz deutsche Feuerwehr-Zeitung; Zeitschrift für das gesamte Feuerwehrwesen, für Rettunsdienst und Umweltschutz*, **2012**, *66,* 100–107.
28. Deutsches Institut für Normung. DIN EN 469:2020-12, Schutzkleidung für die Feuerwehr - Leistungsanforderungen für Schutzkleidung für Tätigkeiten der Feuerwehr; Beuth Verlag GmbH: Berlin, 2020. DOI: 10.31030/3147021.

29. Innenministerkonferenz, Ed. Herstellungs- und Prüfungsbeschreibung für eine universelle Feuerwehrschutzbekleidung (Teil 1 - Feuerwehrüberjacke): HuPF - Teil 1, 11.2020.
30. Innenministerkonferenz, Ed. Herstellungs- und Prüfungsbeschreibung für eine universelle Feuerwehrschutzbekleidung (Teil 2 - Feuerwehrhose): HuPF - Teil 2, 11.2020.
31. Innenministerkonferenz, Ed. Herstellungs- und Prüfungsbeschreibung für eine universelle Feuerwehrschutzkleidung (Teil 4 - Feuerwehrüberhose): HuPF - Teil 4, 11.2020.
32. Innenministerkonferenz, Ed. Herstellungs- und Prüfungsbeschreibung für eine universelle Feuerwehrschutzbekleidung (Teil 3 - Feuerwehrjacke): HuPF -Teil 3, 03.2020.
33. Kill, B.; Verband der Feuerwehren in Nordrhein-Westfalen e. V. *Example of misfitting firefighting clothing among women*, 12.2022.
34. Teilnehmerinnen und Teilnehmer des Seminars der Hanseatischen Feuerwehr-Unfallkasse Nord für Bereichs-, Kreis- und Stadt-Sicherheitsbeauftragte sowie Bereichs-, Kreis- und Stadtwehrführer aus Hamburg, Mecklenburg-Vorpommern und Schleswig-Holstein. Gägelow. Personal Communication, October 21, 2022.
35. Schiffer, C. *Nutzerbefragung Feuerwehrbekleidung*, 2021. DOI: 10.18154/RWTH-2021-11526.
36. Schiffer, C. Beitrag zur nutzerzentrierten Weiterentwicklung von Feuerwehrbekleidung: Empirische Analyse von Marktbedürfnissen, 2nd ed.; RWTH Aachen University: Aachen, 2022. DOI: 10.18154/RWTH-2022-01052.
37. Pfaff, D. *Praxishandbuch Marketing: Grundlagen und Instrumente,* 2nd ed.; Campus Verlag: Frankfurt, New York, 2020. ISBN: 9783593444055.
38. Bortz, J. *Statistik für Human- und Sozialwissenschaftler: Mit 242 Tabellen,* 6th ed.; Springer: Heidelberg, 2005. ISBN: 354021271X.
39. Gesetz über die Durchführung von Maßnahmen des Arbeitsschutzes zur Verbesserung der Sicherheit und des Gesundheitsschutzes der Beschäftigten bei der Arbeit (Arbeitsschutzgesetz): ArbSchG, Deutscher Bundestag. BGBl. I S. 1246, August 07, 1996.
40. *Unfallverhütungsvorschrift 49 - Feuerwehr: UVV 49,* Deutsche Gesetzliche Unfallversicherung, 2018.06.
41. Zimmerli, T. Schutz und Komfort von Feuerwehrbekleidung. *Textilveredlung*, 1998, *33,* 52–56.
42. Liehn, M. *OP-Handbuch: Grundlagen, Instrumentarium, OP-Ablauf,* 6th ed.; Springer Berlin / Heidelberg: Berlin, Heidelberg, **2016**. ISBN: 9783662492819.
43. Casjens, S.; Brüning, T.; Taeger, D. Das Krebsrisiko von Feuerwehreinsatzkräften – Ein systematisches Review und Metaanalyse epidemiologischer Studien. *ASU* **2021**, *2021,* 359–366. DOI: 10.17147/asu-2106-9519.
44. Taeger, D.; Koslitz, S. Biomonitoring von Feuerwehreinsatzkräften bei Realbränden. *IPA Aktuell*, 2021.
45. Taeger, D.; Koslitz, S.; Heinrich, B.; Pelzl, T.; Käfferlein, H.U.; Breuer, D.; Brünning, T. Krebsrisiko im Feuerwehrdienst: Studie zum Biomonitoring von Feuerwehreinsatzkräften bei Realbränden abgeschlossen. *IPA-Journal*, **2021,** 8–12.
46. Casjens, S.; Brüning, T.; Taeger, D. Cancer risks of firefighters: a systematic review and meta-analysis of secular trends and region-specific differences. *International archives of occupational and environmental health*, **2020**, *93,* 839–852. DOI: 10.1007/s00420-020-01539-0.
47. Deutsche Gesetzliche Unfallversicherung, Ed. *DGUV-Information 205-014: Auswahl von persönlicher Schutzausrüstung für Einsätze bei der Feuerwehr*; Basierend auf einer Gefährdungsbeurteilung: Berlin, 2016.09.
48. International Agency for Research on Cancer; Word Health Organisation. *Painting, Firefighting, and Shiftwork: IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* Volume 98: Lyon, France, 2010.
49. Casjens, S.; Brüning, T.; Taeger, D. Das Krebsrisiko von Feuerwehreinsatzkräften – Ein systematisches Review und Metaanalyse epidemiologischer Studien. *ASU*, **2021**, *2021,* 359–366. DOI: 10.17147/asu-2106-9519.
50. Taeger, D. Krebsrisiko im Feuerwehrdienst, o. D.
51. Taeger, D.; Koslitz, S.; Heinrich, B.; Pelzl, T.; Käfferlein, H.U.; Breuer, D.; Brünning, T. Krebsrisiko im Feuerwehrdienst: Studie zum Biomonitoring von Feuerwehreinsatzkräften bei Realbränden abgeschlossen. *IPA-Journal*, **2021,** 8–12.
52. Taeger, D.; Koslitz, S. Biomonitoring von Feuerwehreinsatzkräften bei Realbränden. *IPA Aktuell*, 2021.
53. Cao, H. Smart coatings for protective clothing. In: *Active Coatings for Smart Textiles*; Elsevier, 2016; pp. 375–389. ISBN: 9780081002636.
54. Mao, N. High performance textiles for protective clothing. In: *High Performance Textiles and their Applications*; Elsevier, 2014; pp. 91–143. ISBN: 9781845691806.
55. Koß, C.; Penkert, B.; Vehling, H. Ministerium des Innern NRW, Ed. FEUERWEHRENSACHE - Förderung des Ehrenamtes der Feuerwehren in Nordrhein-Westfalen - Abschlussbericht: Düsseldorf, 10.2017.
56. Deutschlands Feuerwehrsystem ist Gegenstand eines neuen Forschungsprojekts an der Universität Paderborn, January 15, 2019.

57. Innovation durch Vielfalt: Deutschlands Feuerwehrsystem als Gegenstand eines neuen Forschungsprojekts an der Universität Paderborn, December 03, 2018.
58. Kastein, M.; Finke, J.; Horwath, I. Florian braucht Mehmet mehr als umgekehrt: Herausforderungen und Potenziale für Inklusion in der Freiwilligen Feuerwehr. *Voluntaris*, 2021, *9,* 135–151. DOI: 10.5771/2196-3886-2021-1-135.
59. Deutscher Feuerwehrverband, Ed. *WILLKOMMEN IM BLAULICHT-MILIEU*.
60. Horwath, Ilona, Kastein, Mara, Finke, Josefine. Herausforderungen und Chancen von Diversität für Sicherheit, Effizienz und Zukunft des Deutschen Feuerwehrsystems.: Schlussbericht im Rahmen des Projektes FORTESY - Organisation, Technik, Diversität: Neue Ansätze für Sicherheit, Effizienz und soziale Integration im Feuerwehrwesen, unpublished.
61. Schnabel, G.; Harre, H.-D.; Krug, J. *Trainingslehre - Trainingswissenschaft;* Meyer & Meyer Sportverlag, 2016. ISBN: 9783840310768. DOI: 10.5771/9783840310768.
62. Ferrauti, A. *Trainingswissenschaft für die Sportpraxis;* Springer Berlin Heidelberg: Berlin, Heidelberg, 2020. ISBN: 978-3-662-58226-8. DOI: 10.1007/978-3-662-58227-5.
63. Weineck, J. *Sportbiologie,* 3rd ed.; Perimed-spitta Med. Verl.-Ges: Erlangen, 1992. ISBN: 3884291327.
64. Gillen, C.M. *The Hidden Mechanics of Exercise: Molecules That Move Us;* Belknap Press of Harvard Univ. Press: Cambridge, Mass., 2014. ISBN: 9780674419919. DOI: 10.4159/harvard.9780674419919.