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Development of a Survey Instrument for Measuring Firefighter Ergonomic Factors in Hose Rolling Activity: A Pilot Study

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ABSTRACT

The hose is an essential piece of equipment for firefighters on the job. Flaking, roll and coil, dutch roll, and figure eight are all methods of rolling the hose. Hose rolling requires a combination of uncomfortable postures, repetitive motions, and forceful exertion, which can be stressful on firefighters' bodies. Several firefighters' work duties include the application of high physical loads to the human body. High force demands require muscles to work harder, increasing tiredness and the risk of Musculoskeletal Disorders (MSDs). The main objective of this paper is to present the development and validation of a survey instrument for measuring firefighter ergonomic factors in rolling activity for a pilot study. A set of survey instruments was developed, which consisted of four sections: the demographic profile of the respondent, the Cornell musculoskeletal discomfort survey (CMDQ), hose rolling activity among firefighters, and the design criteria for ergonomic hose rollers. The survey instruments's content was obtained from extensive literature research and expert input. A pilot study was conducted at Pagoh Fire Station. The reliability and validity of the instrument were determined through Cronbach's alpha, face validity, and content validity. Cronbach's alpha values for each section of the survey instruments range from 0.741 to 0.928, while the value for Cronbach's alpha for all 26 standardized items is 0.854. Finally, the findings suggested that this instrument had appropriate reliability and validity to accomplish its aims. The survey instrument is now complete and ready for the distribution of larger amounts of data.

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1. Introduction

Firefighters face numerous occupational challenges, including physically demanding tasks that can lead to injuries and long-term health issues. One such task is hose rolling, a critical activity performed during and after firefighting operations. The ergonomic factors associated with hose rolling play a vital role in mitigating physical strain and improving firefighters' overall well-being and performance. The study of the relationship between workers and their working environment is known as ergonomics [1]. Ergonomic Risk Factors (ERF) are working situations that trigger body wear and tear and can result in injury, and these include repetition, awkward posture, forceful motion, stationary position, direct pressure, vibration, extreme temperature, noise, and work stress [2]. Hence, the hose rolling activity still requires the firefighter to perform the task manually. The previous research found that, the awkward posture ERF received the highest score, with 56% of respondents experiencing it [3].

The hose is an important piece of equipment for firefighters used on duty. There are several methods of rolling the hose such as flaking, roll and coil, dutch roll, and figure of eight. From the previous research, [4] the Rapid Entire Body Assessment (REBA) scored 10 for this activity, indicating a “high” risk level because firefighters must maintain an awkward position due to repeated torso bending for a long time when storing some of the hoses by rolling them up on the ground, this is because the same firefighters who drain the hoses also roll them up, which could strain the lower back. Working in awkward postures changes the shoulder girdle and glenohumeral biomechanics, decreasing subacromial space and increasing supraspinatus tendon mechanical pressure. [5]. Furthermore, repetitive motions involved in hose rolling further compound the ergonomic challenges. Repetitive motions are movements that are performed repeatedly, and they can relate to performing many tasks with comparable movements that involve the same tissues and muscles [6]. Forceful exertion is work tasks and cycles, that require high force loads on the human body, like heavy lifting, pulling, pushing heavy objects, or excessively squeezing a hand tool such as a hammer [7]. High force loads are applied to the human body throughout several work duties. High force demands cause muscles to work harder, which raises associated fatigue and can cause Musculoskeletal Disorders (MSDs) [8]. The task of unrolling and rolling fire hoses may expose firefighters to the risk of ergonomic diseases such as back discomfort and fatigue [9].

MSDs are soft-tissue injuries caused by sudden or sustained exposure to repetitive motion, force, vibration, and awkward positions [10]. Because firefighting requires a lot of physical labor and continuous physical activity, it is a conventional career with a high incidence of MSDs [11]. The discomfort was measured using the Cornell Musculoskeletal Discomfort Survey (CMDQ) [12]. In the previous research, the CMDQ was used to measure the prevalence of MSDs among respondents [13]. [9] By using CMDQ, 90% of firefighters report having pain in their lower back, 70% in their upper arm, 63% in their thigh, 76% in their knee, and 70% in their shoulder. For every body part of each participant, data was collected regarding how frequently they felt discomfort during the previous work week, how uncomfortable they felt as a result of the discomfort, and whether the discomfort affected their ability to work [14]. The survey instruments can be adapted and utilized to gather valuable information about musculoskeletal discomfort experienced by firefighters during hose rolling tasks. This data can be utilized to create strategies for reducing discomfort and preventing musculoskeletal problems related to this task.

The main objective of this paper is to describe the development and validation of a survey instrument for measuring firefighter ergonomic factors in rolling activity for a pilot study. When it comes to the creation of firefighting equipment and tools, ergonomics is one of the most important factors to consider. For the future, this study aims to evaluate firefighter satisfaction with hose rolling activity because most of the highly significant tasks related to ergonomics exist in the firefighter sector.

2. Methodology

A survey instrument is the most common method of collecting quantitative primary data. A survey instrument allows quantitative data to be collected in a systematic format, ensuring that the data is internally consistent and coherent for analysis [15]. Several sequential steps must be involved in developing reliable and valid survey instruments, including the construction of the survey instrument, validation and verification of the instruments, and pilot study. Figure 1 illustrates the survey survey instrument development process used in this study.

Fig. 1. Illustrates the survey survey instruments development process

2.1 Survey Instruments Design

A survey instrument is a set of questions that are predefined and distributed among numerous respondents [16]. A survey-based research survey instrument provides a set of questions, often known as items, that are used to solve a specified research topic [17]. It is also used to confirm other findings because survey instruments can be helpful confirmation tools when used in conjunction with other studies. After all, participants will only respond honestly if their identities are kept private and confidentiality is adjudicated. Considerable thought must be given to the survey instruments's design to collect usable and pertinent data. It takes research and effort to create a well-designed survey instruments, which must be planned out and refined through several. There are about four different types of survey instrumentss designing for a survey which is contingency questions or cascade format, matrix questions, closed-ended questions, open-ended questions [15].

Planning a survey instrument involves a systematic approach to ensure that it effectively collects the desired information while minimizing potential biases and errors. During the initial consideration stage, it is crucial to define the research objectives and identify the target population. Clearly articulating the purpose of the survey instruments and understanding the characteristics of the intended respondents will help guide subsequent decisions. The next stage involves crafting the question content, phrasing, and response format. Selecting appropriate question types is essential, as different question formats are suited for different types of data. Furthermore, question sequence and layout play a vital role in maintaining respondents' interest and maximizing data quality.

Organizing the questions logically and coherently helps guide participants through the survey instruments smoothly. The pre-test stage involves piloting the survey instruments with a small sample of participants similar to the target population. This allows for the identification of any potential issues, such as unclear questions, confusing response options, or problematic sequencing. The final stage involves finalizing the survey instruments for data collection. All revisions and improvements are incorporated, and attention is given to formatting and aesthetics.

2.2 Survey Instrument Development

The development of a survey instrument entails creating a survey instrument that will effectively collect the data required for a research study. To create a survey instrument, the researcher must first define objectives, which include determining the purpose of the survey and what information must be collected. Following that, the development of research questions that are clear, concise, and specific is the foundation of the survey instrument. In addition, the survey instrument must develop a hypothesis, which is a statement that predicts the relationship between variables. Furthermore, survey instruments are used to collect data about individuals' demographics, personal experiences, knowledge, behavioral patterns, and attitudes [18].

This survey instrument consists of four main sections. They are the demographic profile of respondents (Section A), the CMDQ (Section B), hose rolling activities and knowledge of ergonomics (Section C), and the design criteria for ergonomics hose roller (Section D). The question in Section A is a demographic profile of the respondent, such as gender, age, designation, work experience, working hours, fire station grade, regular exercise, health status, MSDs status injury while firefighter handling a hose, and the uses of any assistive device to roll the hose. Demographic data revealed correlations between certain firefighter demographics such as age, and years of service, with the prevalence of MSDs. This helps identify high-risk groups more prone to these issues. Moreover, in Section B, using CMDQ allows for a systematic assessment of musculoskeletal discomfort experienced by firefighters specifically related to hose rolling. It helps quantify the frequency and severity of discomfort in various body regions. The CMDQ is a 54-item questionnaire containing a body map diagram and questions about the frequency of musculoskeletal ache, pain or discomfort in 18 regions of the body during the previous week [19]. This result was implemented for correlation with certain demographic information. In Section B, the frequency of hose rolling activities and knowledge of ergonomics among firefighters was collected. Understanding the frequency of hose rolling activities provides insight into the extent of exposure firefighters have to this task. This data helped correlate higher frequencies of task engagement with increased risks of MSDs. Furthermore, the result of the knowledge of ergonomics concerning hose rolling can reveal gaps in understanding or adherence to ergonomic practices. It helps identify if firefighters are aware of ergonomic principles that can minimize the risk of MSDs during hose rolling. In Section D, the design criteria for ergonomics hose roller evaluated firefighters' ergonomic needs by capturing their preferences and requirements for a hose roller's design. This data ensures that future designs align more closely with user needs and expectations for future research.

2.3 Validation and Verification

Next for ensuring the consistency and high confidence level of the survey result, validation and verification of the survey instruments were conducted. In this study, face validity was applied to confirm whether the created survey instruments were suitable for the study respondents in terms of customizable language use and item layout [20]. Face validity evaluation is performed on selected respondents to see how readily they understand the items/questions in the survey instruments, including feasibility, style formatting, readability, linguistic clarity, and more [21]. The examination of a new survey instrument for content validity ensures that it includes all of the questions that are necessary and eliminates unwanted items to a certain construct domain [22]. In this research, face, and content validity were secured and reviewed by four (4) panels of experts from firefighter representatives, academic representatives, and NIOSH representatives as shown in Table 1. The survey’s appearance, relevance, and representativeness of its elements were judged. Following these reviews, modification was made to the survey instruments to enhance precision and clarity. When validating and verifying a survey instrument for firefighter research in an ergonomic context, the focus is on ensuring that the instrument accurately measures ergonomic factors relevant to firefighters' work environments and tasks.

Table 1
List of experts for face and content validation

Panel	Expertise	Background
1	Senior Officer of Firefighter	Firefighter
2	Senior Officer of Firefighter	Firefighter
3	Professor at UTHM	Academician
4	Manager in CRDD NIOSH	Ergonomic practitioner

2.4 Ethics Approval

Ethical approval for all relevant aspects of the development process was received from the Universiti Tun Hussein Onn Malaysia (UTHM) Ethics Committee. This ethic was applied under “Firefighter Hose Roller: Ergonomics Assessment and Fabrication (Reference number: UTHM/RMC/100-9/139 Jld. 2 (43))”. This ethical approval respects participant confidentiality and privacy and helps to clearly outline the purpose of the survey instruments and assure the anonymity or confidentiality required. This ethical approval will respect participant confidentiality and privacy, clearly outline the purpose of the survey instruments, and assure the anonymity or confidentiality required.

2.5 Pilot Study

A pilot study can assist in determining the sample size for the main trial [23]. Previously, a pilot study was utilized to assess the feasibility of a large-scale investigation on cardiovascular, musculoskeletal, physical fitness, and occupational performance among active firefighters[24]. A standard rule of thumb is to pilot test the survey with 30 to 100 pilot participants (this number will differ, of course, based on the total number of respondents in your sample; Courtenay 1978) [22]. The Malaysian Fire and Rescue Department now has a strength of nearly 30,000 officers and members across the country [25]. Statistical data from referring Firefighter and Resecure Johor shows that the number of firefighters in Johor as of May 2023 is about 1328 firefighters. Using Krojchie and Morgan's table (1970), the sampling size should be considered as 307 for the sampling population size over 1400 population [26]. Table 2 shows the sample size changes depending on the confidence and accuracy levels. However, some studies recommend over 30 samples per group, while others suggest 12 per group, and a suitable sample size is needed to establish participant recruiting or study design feasibility, not hypothesis testing power[27]. Therefore, in this study, the total number of respondents for the pilot study is 35 respondents participated from Pagoh Fire Station.

Table 2
Table for determining sample size for a given population (adapted from [28])

Size of Population	Sample size (n) for Precision (e) of:			
	±3%	±5%	±7%	±7%
500	a	222	145	83
600	a	240	152	86
700	a	255	158	88
800	a	267	163	89
900	a	277	166	90
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	99
7,000	959	378	198	99
8,000	976	381	199	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	100
>100,000	1,111	400	204	100

a = Assumption of normal population is poor (Yamane,1967). Entire population should be sampled

2.6 Reliability of Survey Instruments

The reliability of the survey instruments was assessed by using Cronbach's alpha (α) considering the Cronbach Alpha coefficient for the accepted value of internal consistency is at least 0.6 to 0.7 [17]. Lee J. Cronbach developed Cronbach's Alpha in 1951, which is now frequently used to assess multi-item scale or survey instrument's internal consistency[29]. The value of Cronbach's alpha was calculated using Minitab software which can be obtained by the formula shown.

$$\alpha = (\frac{K}{K-1})(\frac{Sy^2 - Sum\ Si^2}{Sy^2})$$

α = Cronbach's alpha
K = The number of items in the scale
Si = The sum of the item scores for each item
S = The sum of the total scores for all items

3. Results

3.1 Construction of Question Structure

During the construction phases of constructing the survey instruments, the first step required clearly defining the aim and objectives of the survey instruments, followed by identifying the target respondents, specifically firefighters. Subsequently, there was a careful process of creating clear and specific questions designed to obtain accurate information, organized in a logical order to ensure coherence. Particular attention was paid to formulating questions that were specifically designed for the firefighting domain, taking into consideration the relevant context and language. The survey instrument's validity was ensured by expert validation, which confirmed its appropriateness and relevance.

3.2 Instrument Development and Respondent's Profiles

The pilot study was conducted at Pagoh firefighter station. A total of 35 respondents from firefighters were chosen randomly to participate in the survey. A face-to-face interview session was conducted between the respondents and researchers to fill in the survey instruments. The respondents involved in answering this survey question are firefighters who are actively involved in firefighting operations and at the same time roll hoses while on duty. The demographic profile of the respondents in this study is summarized in Table 3.

Table 3
Table demographic profile of the firefighter involved in the pilot study

Profiles		Demographics	
		Frequency	Percentage (%)
Gender	Male	35	100
	Female	0	0
Age	< 20 years	3	8.6
	20 - 29 years	12	34.3
	30 - 39 years	10	28.6
	40 - 49 years	8	22.9
	> 50 years	2	5.7
Designation	Senior Officer	0	0
	Team Supervisor	4	11.4
	Firefighter	31	88.6
Work experience	< 1 year	3	8.6
	1 – 10 years	19	54.3
	11 – 20 years	4	11.4
	21 – 30 years	7	20
	> 30 years	2	5.7
Working hours	8 hours	4	11.4
	12 hours	31	88.6
Fire station grade	Grade A	0	0
	Grade B	0	0
	Grade C	35	100
Regularly exercise	Everyday	24	68.6
	Once a day	11	31.4
	No exercise	0	0
Health status	Good	35	100
	Have disease	0	0
Musculoskeletal	Yes	1	2.9
Disorders (MSD)	No	34	97.1
Assistive device	Yes	35	100
	No	0	0
If yes	Still there and in use	35	100
	Still there but not used	0	0
	Has been disposed	0	0

3.3 Analysis of the Validity and Reliability of the Survey Instruments

Since the survey instruments could potentially be used to measure and evaluate firefighter satisfaction towards the ergonomic factor in the hose rolling activity, the results for the validity of the survey instruments based on the expert judgment for all questions are positive. Several factors contribute to a survey instrument's face and content validity, such as the panel of experts' ability to comprehend and interpret the questions, the survey instrument's template, style, and response time, and the questions' understanding, clarity, language, topic, and suitability. Minor changes and adjustments to the survey instruments have been made in response to expert feedback to improve the survey instrument's substance. Results for the reliability of the survey instruments are shown in Table 4.

Table 4
Expert comment on the survey instruments for validation

Panel	Comment
1,2,3,4	Format acceptable
3,4	Grammar and typing error
3,4	Unclear wording
1,2	Additional other box for designation and fire station grade
3,4	Need to do corrections in sentence structure
1,2,4	Justify and enlarge the table of body symptom survey
3,4	Suggest having multilanguage

The Cronbach's alpha value ranged from 0.928 for the history of body discomfort and pain (section B). Cronbach's alpha for section C is 0.741 which is this section contains the frequency of hose rolling activity among firefighters and 0.846 for design criteria for ergonomic hose roller in section D. (Table 5). Total Cronbach's alpha (α) for all three sections (B, C, and D) with 26 standard items is 0.854. Cronbach's higher alpha levels are preferable. Depending on the source used, different things make up a decent level of internal consistency, but all suggested values are 0.7 or higher [30]. By considering the generally accepted guideline where values above 0.7 suggest good internal consistency, both individual sections and the combined instrument meet this criterion. Therefore, based on the Cronbach's alpha values provided, the instrument demonstrates adequate internal consistency and passes the threshold for reliability.

Table 5
Cronbach's alpha value

Section	No of items	Cronbach's alpha
Section B Cornell Musculoskeletal Discomfort Survey	12	0.928
Section C Hose rolling activity among firefighter	5	0.741
Section D Design Criteria for Ergonomics Hose Roller	9	0.846
Sections B, C, and D	26	0.854

The survey instruments had been successfully developed. Based on this pilot study conducted, results were successfully generated by using the survey instrument. Hence, it can be blasted for large-scale data collection. Therefore, to test its effectiveness, MSDs analysis has been successfully analyzed using this survey instrument.

For example, from the question in Section B, the body discomfort survey revealed that firefighters commonly experienced aches, pain, and discomfort during various activities. When assessing the extent to which these issues interfered with their ability to work, the survey employed the criterion of "substantially interfere." Figure 2 shows the three highest scores were associated with lower back discomfort at 40, knee pain at 31.4, and thigh discomfort at 25.7.

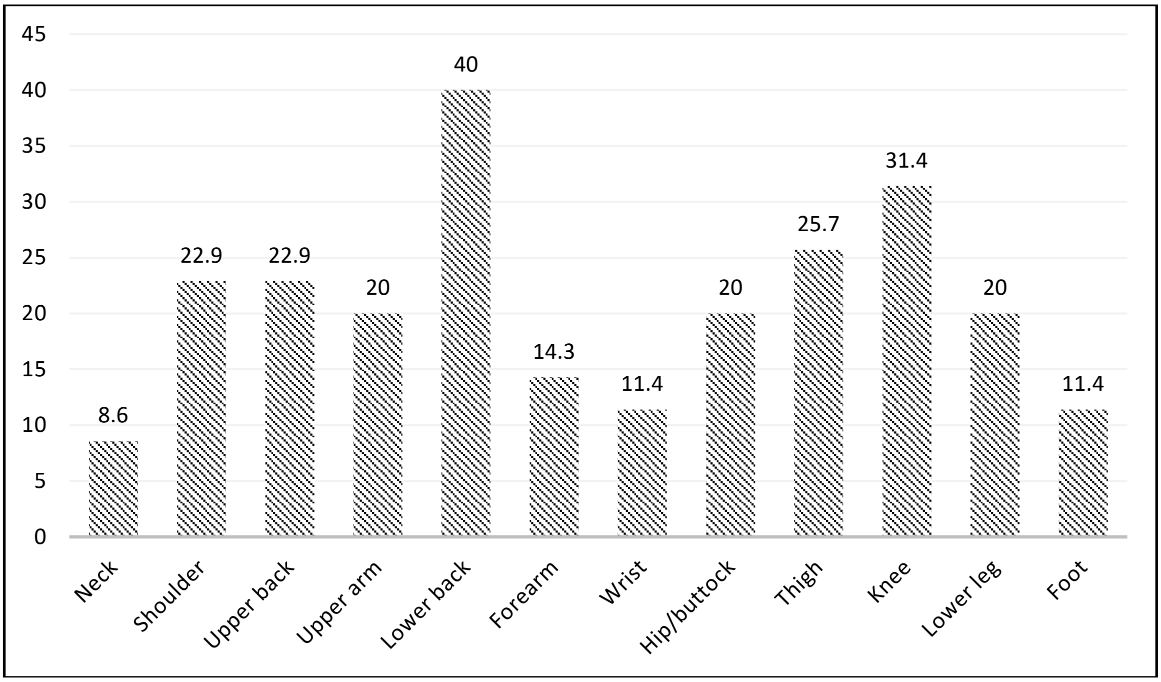

Fig. 2. The result of the body discomfort survey

4. Conclusions

The study concludes with the successful creation of a customized survey tool specifically designed to evaluate important ergonomic parameters associated with firefighters' hose rolling operations. The pilot study provided excellent insights, emphasizing the significant significance of comprehending firefighters' involvement in hose rolling tasks and the aspects that impact their work, ergonomics, and general physical well-being. The assessment of the survey instrument's validity and reliability is important, as it guarantees its precision, consistency, and pertinence in evaluating firefighter ergonomic aspects. The study exhibits significant internal consistency and reliability, as evidenced by the successful demonstration of Cronbach's alpha.

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