THE IMPACT OF TACTICAL PHYSICAL FITNESS ON FIREFIGHTER PERFORMANCE – A CASE STUDY OF FIREFIGHTERS OF MIAOLI COUNTY

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ABSTRACT

Most firefighters used to improve their physical fitness without proper training methods, so they often exerted their strength with wrong postures or their physical fitness could not support them for the whole process of firefighting, resulting in physical injury or failed tasks. Currently as physical exercise becomes a popular trend, firefighters should also exercise their physical fitness in a proper way to complete different kinds of firefighting and rescue with sufficient physical strength. The National Fire Agency has a clear training standard for the physical fitness of firefighters, including firefighters' routine training and annual training, but such standard has been in practice for years without revision over time. It remains questionable whether firefighters trained under this standard can tackle the arduous and dangerous work.

This study mainly explores the impact of tactical physical fitness on the performance of firefighters of Miaoli County. Firstly, by referring to relevant literature and applying the modified Delphi method, this study establishes the influencing factors for firefighters' tactical physical fitness and finds the items of tactical physical fitness training: muscle strength, muscle endurance and cardiopulmonary training. With such items, a hierarchical structure is established and the Analytic Hierarchy Process (AHP) is used to obtain the impact of these three dimensions on the tactical physical fitness of firefighters of Miaoli County. Finally, a weighting system is established.

Keywords: *Tactical physical fitness, modified Delphi method, hierarchical analysis.*

1. Introduction

Firefighters need good physical fitness to be qualified. Faced with the fierce fire, storm and cruel weather, firefighters cannot retreat and must fight on the front line. In addition to psychological bravery, firefighters need adequate physical fitness to tackle disasters. What is the definition of good physical fitness? Firefighters, unlike other athletes, should have the explosive power required by 100-meter race, the cardiopulmonary capacity and endurance necessary for marathon, and the muscle power to lift heavy objects at any time. What firefighters need is tactical physical fitness.

2. Literature Review

What is tactical physical fitness? It is not different at all from general physical fitness regarding the purpose. That is to say, there is no difference among the strong. A strong and well-trained firefighter or a strong and well-trained athlete must be a strong person, first. Firefighters are made out of ordinary people. The muscle strength required by a strong human body is enhanced through the upper limb horizontal push, horizontal pull, vertical push, vertical pull, lower limb push and lower limb pull. The weight bearing of these six training items contributes to developing a strong human body.

2.1 Impact of Physical Fitness on Firefighter Performance

When firefighters are rescueing with fire-fighting clothes, shoes and air respirators, they are in a situation similar to weight-bearing training. They need to perform activities of considerable weight-bearing. The shorter it takes to complete weight-bearing training, the shorter the time of wearing fire-fighting clothes, shoes and air respirators (rescuing) will be, indicating that the training of weight-bearing capacity can enhance firefighters' performance in rescue. The main test is targeted on the combition of muscle strength, muscle endurance and skills. More stress is laid on the training items requiring muscle strength because firefighters do need to improve their physical fitness to tackle unpredictable tasks. However, given that practice skill tests or duty performance is usually carried out in a weight-bearing environment, the time of completing tasks is not only concerned with cardiopulmonary endurance. It is suggested that intermittent exercises with high intensity are performed for the training of different tasks (Huang,

Lee, Yeh, and Lin, 2018).

2.2 Physical Fitness Training Methods to Enhance Capabilities of Firefighting and Rescue

According to the U.S. Fire Administration, apart from skill training, firefighters should also focus on the training of cardiopulmonary fitness, muscle strength and muscle endurance (Huang, Lee, Yeh, and Lin, 2018).

2.3 Summary

This paper only discusses the three dimensions of physical training. These three dimensions are described as follows:

1. Muscle strength training: According to literature review, muscle group training is divided into the following methods: "lying push (chest muscle group)", "squatting (thigh muscle group)", "hard lift (lower back muscle group)", "pull up (back muscle group)", "rowing standing (back muscle group)" and "side flat lift (shoulder muscle group)". These six training methods correspond to the exercise of different muscle groups of the body.

2. Muscle endurance training: According to literature review, muscle endurance training is divided into the following methods for different muscle groups: "lifting body lying on the ground", "sit-up", "prone forward with a bent body", "leg-lifting with abdominal muscles", "shuttle running" and "weight-bearing stair climbing". The main training items are routine training and rescue training.

3. The methods of cardiopulmonary capacity training include "running", "swimming", "rope skipping" and "air breather training". The air breather training is the simulation of a real firefighting operation in which firefighters should wear a full set of firefighting clothes, helmet, shoes and oxygen bottle.

3. Research Method

In order to construct the indicators of influencing factors for the impact of tactical physical fitness on firefighter performance, this study adopts a quantitative and qualitative research method. Firstly, by collecting relevant literature at home and abroad and then carrying out the questionnaire survey with "modified Delphi method", the decision-making hierarchical structure of the impact of tactical physical fitness on firefighter performance is built. Finally, the Analytic Hierarchy Process (AHP) is used to obtain the weighting of each indicator. Their consistency of these indicators is tested and they are ranked.

Chapter 2

3.1 Research Process

As shown in Figure 1, the research process includes the integration of firefighting instructors' opinions and the collection and analysis of firefighting-related literature. The modified Dephi method and Analytic Hierarchy Process (AHP) serve as the theoretical tools of this study. After circulating questionnaires, this study deducts and analyzes impact of tactical physical fitness on firefighter performance, and the relative weight value of the evaluation indicators is obtained.

3.2 Research Subjects

The research subjects of this study included the experts (instructors of routine training and rescue) who take the questionnaire survey that uses the Delphi method in the first stage, and the active firefighters in Miaoli County who take the questionnaire survey that uses the AHP in the second stage. Therefore, the subjects can be divided into two parts as follows:

1. Questionnaires for experts:

Through the semi-open questionnaires for experts with the modified Delphi method, experts fully express their opinions in an anonymous way, and the survey is carried out back and forth till the experts' opinions converge. This aims to define the influencing factors for the impact of tactical physical fitness on firefighters' performance intensity.

2. Subjects for AHP questionnaires:

One of the main subjects of this study is the active firefighters in Miaoli County. The purpose of this study is to understand the sequence of influencing factors for the impact of tactical physical fitness on firefighters' performance intensity, and to understand the preferences of firefighters for tactical physical fitness training. The subjects of this study are the active firefighters in Miaoli County Government Fire Department, who fill in the questionnaires one by one as instructed.

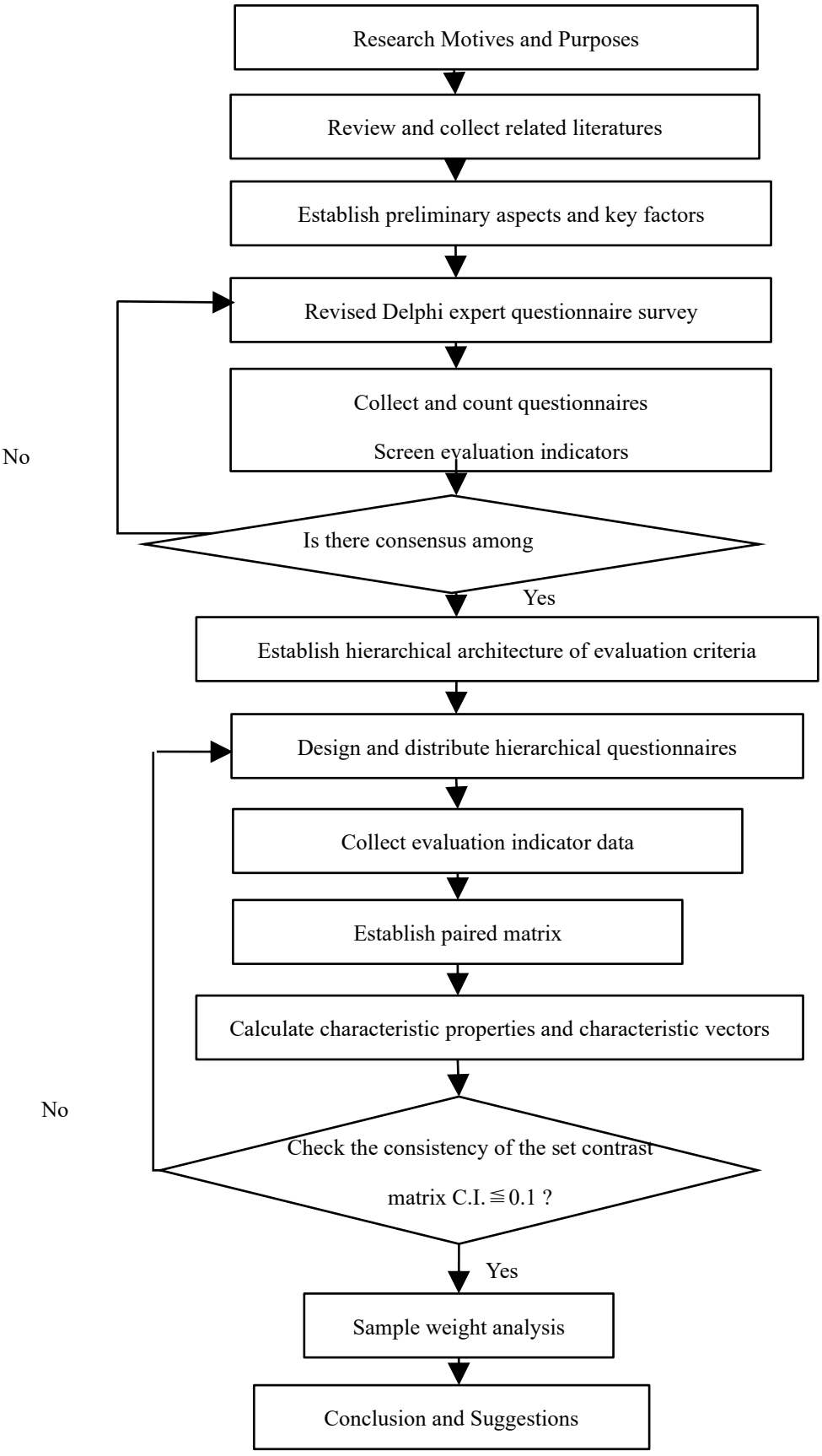

Figure 1. Research flow chart

4. Research Results

1. Results Analysis and Discussion

This study took the active firefighters of Miaoli County Government Fire Department firefighters as the research subjects to explore the key factors for the impact of tactical physical fitness on firefighters' performance. Data were collected, analyzed and discussed through questionnaire survey, based on which the importance and impact of each dimension are understood.

(1) Analysis of the results of the first Delphi questionnaire

1. Under the evaluation dimension of "muscle strength training", the average of "side flat lift" (average of 3.45, standard deviation of 0.93) is lower than 3.5 and was deleted after discussion with experts.

2. Under the evaluation dimension of "muscle endurance training", "sit-up", " prone forward with a bent body", "leg-lifting with abdominal muscles" and "weight-bearing stair climbing" are deleted because their average is lower than 3.5 or their standard deviatoon is greater than 1. They are deleted after discussion with experts and the item of "plank" is added.

3. Under the evaluation dimension of "cardiopulmonary capacity training", all four items meet the criteria. Five of the 16 options in the evaluation criteria of the first questionnaire are deleted because their average is less than 3.5 or the standard deviation is greater than 1, as shown in Table 1.

Table 1: Selection criteria for the first round expert questionnaire evaluation criteria

Target layer	Principal criteria	Statistical results			Secondary criteria (evaluation criteria)	Statistical results			Screening Results
		Average mean	Percentage	Standard deviation		Average mean	Percentage	Standard deviation	
The Impact of Tactical Physical Fitness on Firefighter Performance	muscle strength training	4.45	89	0.69	lying push (chest muscle group)	3.91	78.2	0.83	Retain
					squatting (thigh muscle group)	5	100	0	Retain
					hard lift (lower back muscle group)	4.55	91	0.69	Retain
					pull up (back muscle group)	3.91	78.2	0.83	Retain
					rowing standing (back muscle group)	4.18	83.6	0.75	Retain
					side flat lift (shoulder	3.45	74.6	0.93	Delete

					muscle group)				
	muscle endurance training	4.55	91	0.52	lifting body lying on the ground	3.91	78.2	0.7	Retain
					sit-up	2.82	56.4	1.08	Delete
					prone forward with a bent body	3.45	69	0.69	Delete
					leg-lifting with abdominal muscles	3.45	69	0.82	Delete
					shuttle running	4.0	80	0.89	Retain
					weight-bearing stair climbing	4.27	85.4	1.27	Delete
	cardiopulmonary capacity training	4.64	92.8	0.5	running	4.55	91	0.69	Retain
					swimming	4	80	0.77	Retain
					rope skipping	3.91	78.2	0.7	Retain
					air breather training	4.82	96.4	0.4	Retain

(2) Analysis of the results of the second Delphi questionnaire

The second Delphi questionnaire survey was conducted after the item of "plank" was added according to the opinion of experts in the first round of the questionnaire. The average of 12 evaluation criteria was more than 3.8, and their agreement was more than 70%, representing the convergence of expert opinions, as shown in Table 2.

Table 2: Selection criteria for the second round of expert questionnaire assessment criteria

Target layer	Principal criteria	Statistical results			Secondary criteria (evaluation criteria) Average mean	Statistical results			Statistical results
		Average mean	Percentage	Standard deviation		Percentage	Standard deviation	Average mean	
Physical Fitness on	muscle strength training	4.55	91	0.52	lying push (chest muscle group)	4.0	80	0.77	Retain
					squatting (thigh muscle group)	4.91	98.2	0.3	Retain
					hard lift (lower back	4.64	92.7	0.5	Retain

					muscle group)				
					pull up (back muscle group)	3.91	78.2	0.83	Retain
					rowing standing (back muscle group)	4.09	81.8	0.7	Retain
	muscle endurance training	4.45	89	0.52	lifting body lying on the ground	3.82	76.4	0.6	Retain
					shuttle running	4.09	81.2	0.7	Retain
					plank	3.91	78.2	0.7	Retain
	cardiopulmonary capacity training	4.64	92.8	0.5	running	4.64	92.7	0.5	Retain
					swimming	4.09	81.8	0.7	Retain
					rope skipping	3.91	78.2	0.7	Retain
					air breather training	4.82	96.4	0.4	Retain

(3) Establishing key influencing factors for the effectiveness of the annual training of volunteer firefighters

1. Layer 1 is the main criterion

There are three dimensions including "muscle strength training", "muscle endurance training" and "cardiopulmonary capacity training".

2. Layer 2 is the secondary criterion

The secondary criteria of the dimension of muscle strength training include "lying push (chest muscle group)", "squatting (thigh muscle group)", "hard lift (lower back muscle group)", "pull up (back muscle group)" and "rowing standing (back muscle group)"; the dimension of muscle endurance training includes “lifting body lying on the ground”, “shuttle runnin” and “plank”; the dimension of cardiopulmonary capacity training includes “running”, “swimming”, “rope skipping” and “air breather training”.

(4) Analysis of main criteria

Since the number of main criteria n = 2 and the number 2(2 - 1)/2 = 1 can be regarded as convergence effect, the data consistency meets the criteria.

(5) Analysis of secondary criteria

According to the secondary criterion importance analysis of the dimension of muscle strength training, "squatting (thigh muscle group)" has the greatest impact, reaching 0.381, followed by "lying push (chest muscle group)" accounting for 0.247, "hard lift (lower back muscle group)" accounting for 0.215, "pull up (back muscle group)" accounting for 0.099, and "rowing standing (back muscle group)" for 0.083.

According to the secondary criterion importance analysis of the dimension of muscle endurance training, "lifting body lying on the ground" has the greatest impact, reaching 0.505, followed by "shuttle running" accounting for 0.300 and "plank" for 0.195.

According to the secondary criterion importance analysis of the dimension of cardiopulmonary capacity training, "air breather training" has the greatest impact, reaching 0.417, followed by "swimming" accounting for 0.262, "running" for 0.220 and “rope skipping” for 0.101.

(6) Analysis of the weight of principal (secondary) criterion paired comparison matrix
After comprehensive scoring, the weight ranking can be obtained to further understand the relative importance of each influencing factor, as shown in Table 3.

Table 3: Main (secondary) criteria overall weight ranking

Weight Ranking	Overall Weight	Evaluation Criteria	Principal Criteria Aspect
1	0.185	squatting (thigh muscle group)	muscle strength training
2	0.152	lifting body lying on the ground	muscle endurance training
3	0.120	lying push (chest muscle group)	muscle strength training
4	0.104	hard lift (lower back muscle group)	muscle strength training
5	0.091	shuttle running	muscle endurance training
6	0.089	air breather training	cardiopulmonary capacity training
7	0.059	plank	muscle endurance training
8	0.056	swimming	cardiopulmonary capacity training
9	0.048	pull up (back muscle group)	muscle strength training
10	0.047	running	cardiopulmonary capacity training
11	0.040	rowing standing (back muscle group)	muscle strength training
12	0.021	rope skipping	cardiopulmonary capacity training

5. Conclusions

This study found that the most important influencing factor for the performance of firefighters, according to the opinions of trainers for routine training and rescue, experts and firefighters, is muscle training. This index reveals the fact that muscle training has a great impact on firefighters, so the training should be started from the three basic muscle groups, so that firefighters can improve their own physical fitness, use what they learn in training to tackle various disasters, and prevent themselves from injury when on duty. The second is the dimension of "muscle endurance training". The previous muscle endurance training methods do not fit in the current needs, so it is necessary to review the training methods to enhance the training effectiveness. The weight of "cardiopulmonary training" ranks the lowest among these three dimensions, but this does not mean that this dimension is not important. Fire alarm is the most common disaster faced by firefighters, where the cardiopulmonary capacity is necessary for effective work. Without cardiopulmonary capacity, the strong muscle strength and muscle endurance cannot be used, so the cardiopulmonary capacity training is still of great importance.

According to the above data, the criterion of muscle strength training should focus on squatting (thigh muscle group), lying push (chest muscle group) and hard lifting (lower back muscle group). The major muscle group is the priority of muscle strength training. In the "muscle endurance training", trainees lift themselves lying on the ground to

improve upper body muscle endurance, and then use shuttle running to improve lower body muscle endurance. The cross-training enables firefighters to foster muscle endurance in response tp all kinds of disasters and ensure their safety in work. The "cardiopulmonary ability training" prioritizes the air breather training, in which firefighters work with limited air habitually as if they were in the fire field, so that their working ability in the fire field is enhanced.

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