Evaluation of Risk Factors in the Armed Forces Physical Fitness Test

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Abstract. For the past few years, some officers and soldiers have remained with the Armed Forces for training purposes and for identifying injuries and deaths caused by accidents. This study constructed a research framework through literature review and expert interviews, and then used the decision laboratory method as the basis for network analysis procedures to determine the key factors for assessing risk factors in the national military fitness assessment. Results showed that there were five main influencing criteria, which included 'potential risk factors of physical and mental conditions of officers and enlisted personnel', 'body monitoring equipment', 'medical preparation and knowledge', 'first aid equipment' and 'hazard prevention equipment'. Among them, "Identifying potential risk factors related to the physical and psychological state of officers and soldiers" can be used to improve other key factors. The research results and analyses will be useful for the establishment of a risk assessment mechanism for the effective prevention of accident risks through the national military fitness assessment in combination with new technological devices and systems.

Keywords: Physical fitness · Body Mass Index · Delphi method · DEMATEL-based Analytic Network Process(DANP) · Importance-Performance Analysis

1 Introduction

With regard to physical fitness training and the detection of accidental injuries and fatalities, this study collects statistics from national news reports from the years 2013 to 2016, as shown in Table 1.

According to US military reports, two to three people have died each year since 2010 during physical training (Caitlin 2020). This study uses news media broadcasts to collect statistics from 2017 to 2020, as shown in Table 2.

Especially recently, events such as marathon and triathlon have gradually become national sports, and runners and ordinary people can monitor and adjust their running schedule and training strategy anytime and anywhere (Xu and Zhuang 2018).The data is then transmitted to cloud computing via wired or wireless communication, and the cloud feeds the results back to personal mobile devices, allowing users to obtain necessary information (Chen 2015). To improve the overall effectiveness of the unit's physical

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Table 1. Accidents caused by physical fitness assessment and training in the National Army.

Item	Reporting time	Incident	Result
1	August 7, 2013(Jane Zhengfeng, Li Guanzhi)	A sergeant surnamed Lu from the Kinmen area went to Taoyuan Army Academy for training at the end of July. After classes ended at 5 o'clock in the evening on 7 August, he went jogging with the chief sergeant. After 40 min, he was found lying on the ground, unable to get up, and was rushed to hospital, but he didn't recover	training casualties
2	October 27, 2015 (Wen Yude)	A male major in the Air Force took part in the 3,000 m barehanded running test, but fainted at the end and his heart stopped beating for a while. Fortunately, he was rescued and survived	Detect damage
3	January 7, 2016 (Cai Qinghua)	Colonel Gu, the captain of a certain unit of the Marine Corps, did a 3,000 m unarmed running test. He was sent to hospital after the test when he suddenly fainted during a relaxation exercise	Detect casualties
4	October 11, 2016 (Yang Jiyu)	An NCO surnamed He, who served in a certain naval command, was doing an unarmed 3,000-m run in the camp in the afternoon. When he had finished running and was returning to his dormitory, he suddenly fainted on the stairs. He was pronounced dead	Detect casualties

training and prevent training accidents, the US Marines have developed a physical training APP (2019) to improve the physical fitness level of members and units, as well as to keep track of the injury rate of the entire Marines and which training is more likely to lead to injury (Jiang 2020).

The aim of this study is to examine the existing process of the National Army's physical fitness inspection at the station, reduce the labour cost and inspection time consumption, and establish and improve the risk factor assessment method to effectively monitor the physiological monitoring data generated by officers and soldiers during the inspection. In addition, it effectively analyses and evaluates the accident risk during the

Table 2. US military physical fitness assessment and training accidents.

Item	Reporting time	Incident	Result
1	June 2017(Andy)	The Air Force Times reported that the director of the Air Force Service Center in Denver suddenly collapsed due to physical discomfort during a physical fitness test at Buckley Air Force Base in Colorado, was taken to hospital and died the next day	Detect casualties
2	May 13, 2019 (Meghann)	Likat Ahan, a 51-year-old officer at the U.S. Army War College in New York, reportedly collapsed while running on the campus and was taken to Keller Army Community Hospital for treatment, where he was pronounced dead	Detect casualties
3	October 17, 2019 (Stephen)	Three pilots reportedly died following fitness tests in 2019. Senior pilot Amalia Joseph died on 26 May after suffering a medical emergency while she was running on a track at an Air Force base in South Carolina. Senior pilot Aaron Hall died on 1 June in a similar emergency on another track at the air base. Captain Tranai Rashawn Tanner died on 17 August after being taken to hospital with a medical condition following a physical fitness test at Eglin Air Force Base in Florida on 16 August	Detect casualties
4	July 30, 2020 (Harm)	The Army Times reported that Army National Guard Lt. Robert collapsed after completing a fitness test in preparation for the Basic Officer Leadership Course and was taken to St. Luke's Hospital in Tempe, where he died the next morning	Detect casualties

assessment, so as to reduce the injury and accident incidents during the physical fitness assessment and training.

In recent years, there are still some soldiers who get injured or pass away during physical fitness training or test in National Physical Fitness Test Center or home station. This research focus on reviewing the current procedures of physical fitness test of the ROC Armed Forces, cutting manpower and time, and building a comprehensive way to assess risk in order to monitor the soldier's body performance and status effectively. The goal is to reduce the injuries and casualties during physical fitness test and training.

There are three purposes of our research. The first one is to establish a complete assessment mechanism for the national military to assess risk factors for physical fitness in the garrison, and update the content of the national military physical fitness risk management operation manual and defense regulations to meet the actual implementation needs of the national military. According to the physical and psychological conditions of officers and soldiers during the physical fitness assessment of the National Army, the

introduction of body monitoring equipment can effectively monitor the physiological monitoring data generated by officers and soldiers during assessment and training, and reduce personal injuries and casualties. The third one is to re-formulate the national military physical fitness assessment group and assessment process to reduce manpower expenditure and time consumption of the assessment process.

This research applies the Delphi method to construct framework for risk assessment. The experts selected by this research are professionals who serve as the chief officer of the National Army, the director of the training business department, the physicians and lecturers of the National Military Hospital as the selection conditions, and form an expert group to participate in the revision of the research structure and subsequent filling in order to provide professional opinions. After the literature discussion, the prototype structure was established, and 3 evaluation aspects and 13 evaluation criteria were summarized, and the prototype structure was used to interview the expert group of this study. The final research framework was determined through the results of expert interviews, including 4 evaluation aspects and 9 criteria. And then uses the decision-making laboratory method to identify key factors and results.

2 Review and Discussion of Military Fitness Risk Factors

Literature survey on the risk factors affecting the physical fitness of the national army. Jiang Yaozheng (2011) pointed out that the factors affecting the national military's physical fitness assessment and training cause sports injuries, including (1) demographic characteristics (age, place of residence, education level, parameters such as smoking habits and exercise habits), (2) physiological indicators (height, weight, BMI, body fat percentage, waist and hip circumference and other parameters), (3) sports injury prevention and cognition.

Huang (2012) pointed out the risk factors affecting the physical fitness evaluation of the 3,000 m barefoot running, the evaluation criteria include (1) BMI values, (2) cardiac and respiratory endurance indicators, and (3) human physical condition. Hong (2016) noted that the risk factors that affect physical fitness assessment of the national army, the evaluation criteria are (1) body quality index, (2) weight management, (3) ECG, pulse, systole and diastole blood pressure physical examination index.

Xu 2017) investigated the source of risk in physical fitness training and testing, according to the negligence of personnel, the characteristics of training items, the time of training and testing, the safety of training and venues, the safety of training equipment, and the physical fitness and health status of officers and soldiers. 3 risk factors and 13 risk factors were summarised.

Ye and Su (2018) suggest that understanding fatigue recovery timing and practice in athletic training are key metrics to avoid sports injuries and master effective athletic training. Most of the risk factors come from exercise-induced fatigue, the evaluation criteria are (1) exercise intensity self-perception table, (2) observation method: 1. Self-perception, 2. Perception of others, 3. EMG.

Cai et al. (2018) noted that in the future physical fitness test, wearable devices can be integrated into the physical fitness test equipment of the military to monitor the national.The real-time state of exercise during the physical fitness assessment of

military personnel can reduce the risk of sports injuries and accidental injuries, as well as preventive medical reference. Through the evaluation of 4 criteria, namely (1) mental index, (2) wearable technology, (3) cardiac stress assessment, and (4) data records, it is possible to evaluate whether it is possible to incorporate wearable devices into the military's physical fitness assessment equipment to reduce the risk of sports injuries and accidental injuries.

Zhang et al. (2019) explored the major factors causing sports injuries in army football players, and summarised three dimensions, (1) "weight training", (2) "external environment", and (3) "internal environment". The "environment" criteria include (1) insufficient training time, (2) insufficient training volume, (3) excessive training volume, (4) old training equipment, (5) inadequate equipment, (6) poor site environment, (7) affected by weather, (8) inadequate psychological construction, (9) failure to wear protective gear, (10) failure to warm up before the game, (11) lack of concentration, and other 11 criteria.

Wang (2019) pointed out that risk factors should be analysed and evaluated based on three aspects, namely (1) the "basic quality" of officers and soldiers, (2) the frequency of training, and (3) the relationship between strength and physical fitness. Zhang (2019) pointed out that in order to effectively improve physical fitness and reduce sports injuries, criteria such as (1) heart rate belt, (2) heart rate value, and (3) rating of perceived exertion (RPE) should be combined.

In the above literature analysis, only Xu (2017) literature is based on the compilation rules of the Army Risk Management Operation Manual, and proposes physical fitness risk factors to distinguish personnel, environmental and mechanical factors, which is more consistent with this study's focus. Thus, this study combined some aspects and criteria with the same or similar definitions in the literature, and ultimately constructed a prototype research framework including three aspects and 13 evaluation criteria, and defined each criteria, as shown in Table 3.

Table 3. Aspects and criteria of prototype architecture.

Aspects	Criteria	Definition of Criterion	References
Human Aspects	Training time allocation	Insufficient training time, incorrect warm-up and stretching methods, inaccurate movements, lack of targeted and specificity	Xu (2017), Zhang et al. (2019), Wang 2019)
	Physiological latent risk factors of officers and soldiers	Fatigue, staying up late, injury, illness and injury training, chronic disease, old injury, family inheritance, undetected cause	Xu (2017), Ye and Su (2018)

(*continued*)

Table 3. (*continued*)

Aspects	Criteria	Definition of Criterion	References
	Attention during training	Concerned, play does not listen to command commands, training or inspection of the energy lax	Xu (2017), Zhang et al. (2019)
	Physical and mental state	Substandard body mass index, new recruits, underweight or overweight, lack of exercise habits, insufficient training, improper prescriptions, exhaustion, lack of rest, lack of water, staying up late and working overtime, training hard for a sense of honor	Kong (2011), Huang (2012), Hung (2016), Yip and So (2018), Zhang et al. (2019)
	Training program and organization	The progress of physical fitness training is gradual, the foundation of officers and soldiers is different, the training method is inappropriate, and the result is twice the result with half the effort. During the training, there is no distinction between good and bad, no strength and weakness, and it is impossible to form key supplementary training	Xu (2017), Zhang et al. (2019)

(*continued*)

Table 3. (*continued*)

Aspects	Criteria	Definition of Criterion	References
	Medical readiness and awareness	There are no medical staff, no emergency communication network, delayed medical treatment, improper first aid procedures, and insufficient awareness of the concept of sports injury prevention	Jiang (2011), Xu (2017)
	Exercise intensity self-perception	It is helpful for army trainers to grasp and record the heartbeat rate and self-feeling situation of each individual in the large army, so as to serve as the most immediate reference for evaluating the training effect and fatigue	Jiang (2011), Yip and So (2018), Cheung (2019)
Envirnmental Aspects	Training environment	The runway is uneven, there is no traffic control during the running test, the runway is uneven, the route is not clearly marked, and the field is slippery	Xu (2017), Zhang et al. (2019)
	Training period	Just received the leave and implemented intense training and testing, the risk factor exceeded 40, and the weather changed at that time	Xu (2017), Zhang et al. (2019)
	Weather conditions	Thunderstorms, extreme heat, extreme cold	Xu (2017), Zhang et al. (2019)

(*continued*)

Table 3. (*continued*)

Aspects	Criteria	Definition of Criterion	References
Mechanical Aspects	Protective equipment	There is a shortage of first aid equipment, ambulance stations, and tea supply stations, the planning of the site configuration and movement lines is disordered, security alerts, control and communication are not accurate, and inspections are neglected	Xu (2017), Zhang et al. (2019)
	First aid equipment	Damaged oxygen cylinders, lack of oxygen, expired or shortage of medicines, no ambulance, ambulance breakdown, etc	Xu (2017), Zhang et al. (2019)
	Body monitoring equipment	Based on the definition of relevant criteria, it is possible to measure basic physiological parameters, including heart rate, respiration rate, acceleration, maximum oxygen consumption, temperature, and monitoring of physical activity regardless of the use of heart rate belts and related technological devices	Hung (2016), Yip and So (2018), Cai et al. (2018), Zhang (2019)

3 Research Methodology and Results

3.1 Establishment of a Formal Research Framework

This study makes use of the Delphi method, which is a long-term forecasting technique that was developed by the Rand Corporation in the United States in the 1960s. Pill (1971); Shefer and Stroumsa (1981); Rowe et al.(1991). Through anonymous written discussion

among experts, the Delphi method encourages experts to use their professional knowledge, experience and opinions to reach a consensus on complex issues. Based on the prototype research framework shown in Table 3, this study uses the interview method of experts' experience, intuition and value judgement (Deng 2012), and finally confirms the formal research framework. The experts selected in this study are professionals in the roles of chief officer of the national army, director of the training business department, doctor and lecturer of the national military hospital, who form an expert group to participate in the revision of the questionnaire structure and the filling of the follow-up questionnaire, and provide professional opinions.

The first expert survey on the addition and deletion of the prototype structure was conducted in March 2021. The opinions of the experts were listed. Following this, the dimensions of the prototype structure have been modified according to the modifications proposed by the expert panel, and a second expert interview has been conducted for this prototype framework in April 2021. Finally, after two rounds of expert interview revisions, a formal research framework consisting of four dimensions and nine criteria was finally determined. The formal evaluation levels and definitions were sorted as shown in Table 4.

Table 4. Aspects and criteria of Formal Architecture

Aspects	Criteria	Definition of Criterion
Human Aspects	Training time allocation	Insufficient training time, incorrect warm-up and stretching methods, inaccurate movements, lack of targeted and specificity
	Physiological latent risk factors of officers and soldiers	Fatigue, staying up late, injury, illness and injury training, chronic disease, old injury, family inheritance, undetected cause
	Attention during training	Concerned, play does not listen to command commands, training or inspection of the energy lax
	Physical and mental state	Substandard body mass index, new recruits, underweight or overweight, lack of exercise habits, insufficient training, improper prescriptions, exhaustion, lack of rest, lack of water, staying up late and working overtime, training hard for a sense of honor

(*continued*)

Table 4. (*continued*)

Aspects	Criteria	Definition of Criterion
	Training program and organization	The progress of physical fitness training is gradual, the foundation of officers and soldiers is different, the training method is inappropriate, and the result is twice the result with half the effort. During the training, there is no distinction between good and bad, no strength and weakness, and it is impossible to form key supplementary training
	Medical readiness and awareness	There are no medical staff, no emergency communication network, delayed medical treatment, improper first aid procedures, and insufficient awareness of the concept of sports injury prevention
	Exercise intensity self-perception	It is helpful for army trainers to grasp and record the heartbeat rate and self-feeling situation of each individual in the large army, so as to serve as the most immediate reference for evaluating the training effect and fatigue
Envirnmental Aspects	Training environment	The runway is uneven, there is no traffic control during the running test, the runway is uneven, the route is not clearly marked, and the field is slippery
	Training period	Just received the leave and implemented intense training and testing, the risk factor exceeded 40, and the weather changed at that time
	Weather conditions	Thunderstorms, extreme heat, extreme cold

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Aspects	Criteria	Definition of Criterion
Mechanical Aspects	Protective equipment	There is a shortage of first aid equipment, ambulance stations, and tea supply stations, the planning of the site configuration and movement lines is disordered, security alerts, control and communication are not accurate, and inspections are neglected
	First aid equipment	Damaged oxygen cylinders, lack of oxygen, expired or shortage of medicines, no ambulance, ambulance breakdown, etc
	Body monitoring equipment	Based on the definition of relevant criteria, it is possible to measure basic physiological parameters, including heart rate, respiration rate, acceleration, maximum oxygen consumption, temperature, and monitoring of physical activity regardless of the use of heart rate belts and related technological devices

3.2 Determination of the Causal Relationship and the Key Factors

This study uses the DEMATEL method to clarify the causal relationship between the factors and criteria that influence the risk assessment of the National Military Fitness Assessment. First, through the distribution of questionnaires, a direct influence relationship matrix X based on the results of the questionnaires is generated, and then by normalizing the direct influence matrix and bringing it into the formula $T = X(1 - \mathbf{X})^{-1}$. The total influence relationship matrix T (Total Influence Matrix) established according to the criteria can be obtained as shown in Table 5.

The d value can be obtained by summing each column of the total impact marix in Table 5; the r value can be obtained by summing each row. The row and column sum (d + r) of each item is called "importance", which indicates the relevance of that item to the problem. The rank difference (d-r) of each element is called the "causal degree". If the rank difference is positive, it means that this element is biased towards "active influence" and is classified as a cause; if the rank difference is negative, this element is biased towards "influence". Impact" is classified as effect. According to the overall impact relationship matrix in Table 5, calculate the importance and correlation as shown in Table 6.

Table 5. The total influence relationship matrix

	A1	A2	B1	B2	B3	C1	C2	C3	D1	Column sum (d)
A1	0.190	0.306	0.145	0.212	0.017	0.230	0.277	0.351	0.152	1.882
A2	0.212	0.104	0.052	0.125	0.010	0.151	0.191	0.245	0.068	1.159
B1	0.205	0.159	0.041	0.117	0.010	0.135	0.134	0.235	0.048	1.083
B2	0.156	0.107	0.058	0.055	0.004	0.090	0.094	0.176	0.088	0.828
B3	0.235	0.171	0.104	0.151	0.007	0.140	0.163	0.303	0.126	1.401
C1	0.186	0.183	0.104	0.118	0.010	0.075	0.172	0.210	0.119	1.179
C2	0.187	0.176	0.103	0.108	0.009	0.142	0.078	0.121	0.050	0.974
C3	0.251	0.172	0.042	0.134	0.009	0.070	0.083	0.106	0.051	0.919
D1	0.242	0.174	0.089	0.170	0.011	0.148	0.148	0.294	0.053	1.329
Row sum (r)	1.865	1.553	0.739	1.190	0.087	1.182	1.340	2.042	0.757	

Table 6. Importance and Relevance of Corresponding Criteria

Criteria	d	r	d + r	Ranking	d-r
Hazards in the physical and psychological states of officers and soldiers (A1)	1.88	1.87	3.75	1	0.02
Medical readiness and awareness (A2)	1.16	1.55	2.71	3	−0.39
Assess the site environment (B1)	1.08	0.74	1.82	8	0.34
Detection period (B2)	0.83	1.19	2.02	7	−0.36
Weather conditions (B3)	1.40	0.09	1.49	9	1.31
Hazard prevention facilities (C1)	1.18	1.18	2.36	4	−0.00
First aid equipment (C2)	0.97	1.34	2.31	5	−0.37
Body Monitoring Equipment (C3)	0.92	2.04	2.96	2	−1.12
3,000-m running test standard (D1)	1.33	0.76	2.09	6	0.57

This study adopts the DANP operation framework proposed by Hu et al. (2015), uses DEMATEL's total influence matrix as the unweighted super matrix in ANP operation, normalises the matrix, and self-normalises the results until the fourth convergence, obtaining the limit super matrix shown in Table 7. The relative weight of each criterion can be determined by the limit super matrix.

In order to determine the final overall ranking of the criteria, the importance ranking of DEMATEL and the weight ranking of DANP are used in this study. The sum of the rankings in Table 8 is also called the Borda score. The lower the score, the more important the criterion.

Table 7. Extreme Super Matrix

	A1	A2	B1	B2	B3	C1	C2	C3	D1
A1	0.1831	0.1831	0.1831	0.1831	0.1831	0.1831	0.1831	0.1831	0.1831
A2	0.1501	0.1501	0.1501	0.1501	0.1501	0.1501	0.1501	0.1501	0.1501
B1	0.0674	0.0674	0.0674	0.0674	0.0674	0.0674	0.0674	0.0674	0.0674
B2	0.1117	0.1117	0.1117	0.1117	0.1117	0.1117	0.1117	0.1117	0.1117
B3	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086	0.0086
C1	0.1097	0.1097	0.1097	0.1097	0.1097	0.1097	0.1097	0.1097	0.1097
C2	0.1232	0.1232	0.1232	0.1232	0.1232	0.1232	0.1232	0.1232	0.1232
C3	0.1768	0.1768	0.1768	0.1768	0.1768	0.1768	0.1768	0.1768	0.1768
D1	0.0694	0.0694	0.0694	0.0694	0.0694	0.0694	0.0694	0.0694	0.0694

Table 8. Ranking of criterion weight

Criteria	DEMATEL Importance ranking	DANP sort by weight	Sort and Borda Score	Overall sort
Hazards in the physical and psychological states of officers and soldiers (A1)	1	1	2	★ 1
Medical readiness and awareness (A2)	3	3	6	★ 3
Assess the site environment (B1)	8	8	16	8
Detection period (B2)	7	5	12	6
Weather conditions (B3)	9	9	18	9
Hazard prevention facilities (C1)	4	6	10	★ 5
First aid equipment (C2)	5	4	9	★ 4
Body Monitoring Equipment (C3)	2	2	4	★ 2
3,000-m running test standard (D1)	6	7	13	7

From the results in Table 8, it can be seen that, according to the discussions with the experts, the five most important criteria for assessing the risk factors affecting the physical fitness of the national military are "Identification of potential dangers in the physical and mental state of officers and soldiers (A1)", "Physical monitoring equipment (C3)", "Medical readiness and cognition (A2)", "First aid equipment (C2)" and "Hazard prevention facilities (C1)". And causality diagram between key criteria shows in Fig. 1.

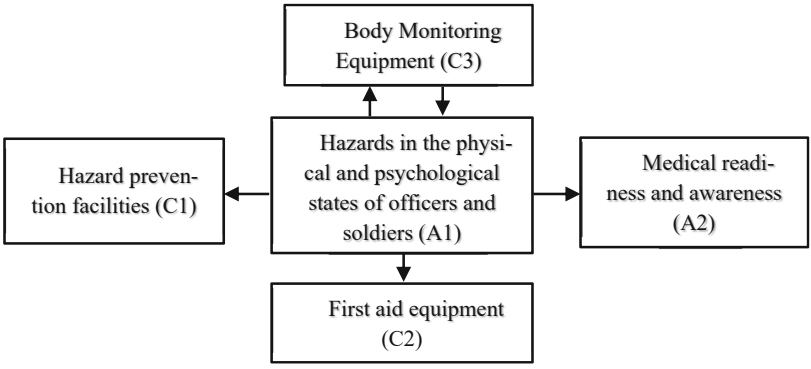

Fig. 1. Causality Diagram Between Key Criteria

4 Conclusions

The results of the research show that the key factors include: "the physiological status of soldiers", "health monitoring device", "medical care preparation and knowledge", "first aid equipment" and risk prevention facility. In addition, the results also indicate that "health monitoring device", "medical care preparation and knowledge", "first aid equipment" and "risk prevention facility" that are key factors for reducing the risk and need to be improved. The cause-effect diagram shows that "identification of potential hazards of soldier's bodies and physiological status" can be used as a source to improve other key factors. Even ROC Armed Forces applies many methods and procedures for monitoring soldiers' mental and physiological status when they take physical fitness test in order to reduce risks some means are still insufficient. The overall results are positive. However, it still needs some enhancement during assessment and evaluation. The current physical fitness test is evaluated by human at home station and no electrical device and health monitoring equipment are used during test for measure solder's basic physiological status. Therefore, many soldiers get injured or die during the test. The results of this research can help the ROC Armed Force combine advanced technologies and devices for physical fitness test and applies the risk assessment to reduce casualties, cut down extra manpower and testing time.

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