Scientific-Expert Journal of Anthropological Aspects of Sports, Physical Education and Recreation

Submitted: 24/02/2024
Accepted: 05/03/2024
Published: 07/03/2024
UDK: 612.74:796.015-053.6

Original article

Could Muscle Power and Muscle Endurance Influence Fire Emergency Response Movement Time in Young Adults?

[1,2]*Bajić Senka, [3]Veljović Dragoljub, [1]Bulajić Borko

[1]*University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy, Novi Sad, Serbia
[2]Umbra Lab, Novi Sad, Serbia
[3]University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia
*Correspondence: email: senka.bajic@uns.ac.rs

Abstract

This research sought to determine whether there was a direct relationship between muscle power, muscle endurance and emergency response times among young adults. While performance capability remains an essential component for emergency teams, this study showed how some physical fitness factors might alter initial emergency response time and lessen the effects of the disaster. Engagement in preparedness exercises, particularly those emphasizing physical activity, offers advantageous health outcomes and enhances disaster response efficacy. These improvements in readiness directly impact the overall outcomes of such disasters. The sample consisted of 21 students, comprising both male and female participants of the same age. Following the American College of Sports Medicine's (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals, the participants were separated into two groups: the physically active group and the physically inactive group. The study's main objective was to determine whether muscle power and muscle endurance of the participants could influence their fire emergency response movement time to a safe location. Additionally, the study sought to find out whether physically active participants responded more quickly than physically inactive ones. The findings of this study indicate a relationship between emergency response time and measurements of muscle endurance and muscle power. Participants who were physically active had shorter movement time to safe location ($p = 0.023$), performed better on the standing broad jump test ($p = 0.001$), and muscle endurance test ($p = 0.004$). Although performance ability is a key component for emergency teams, this study demonstrated how some factors of physical fitness can affect initial emergency response time and help mitigate the effects of the disaster in young adults.

Keywords: Emergency Response, Health and safety, Physical fitness, Disaster preparedness, Fire Emergency, Evacuation

Citation: Bajic, S., Veljovic, D., Bulajic, B. (2024). Could Muscle Power and Muscle Endurance Influence Fire Emergency Response Movement Time in Young Adults? *SportLogia. 20*(1), 1-8. doi: 10.7251/SGIA2420001B

Introduction

The initial moments of an emergency are pivotal for initiating actions that can enhance an individual's response to hazardous situations (Baldwin, 1994). Research indicates that emergency response teams are tasked with mitigating the impact of disasters. However, individuals in perilous situations can still preserve their own lives by taking swift action before aid arrives (Subramaniam, Ali, & Shamsudin, 2012). Recent research have shown that some physical fitness factors could influence faster emergency response in university students (Bajić, Veljović, & Bulajić, 2023).

There are three general ways to survive a fire: trying to put out the flames, taking cover and waiting for help, and evacuation (Tong and Canter, 1985). In this paper, we will assess the evacuation via the measurement of the required evacuation time in a controlled environment. For this study, the controlled environment will represent the already established evacuation route to the predetermined safe location, which is 30 meters outside of the building.

There are some factors that influence how people behave during a fire - the availability of fire safety measures (e.g. fire extinguishers), accessible escape routes, and assistance of professional emergency service. This research focuses primarily on behavior of the young adults in the case of a fire emergency in the form of evacuation time from the site in a controlled manner. Additionally, the research attempted to simulate the actual behavior of an untrained young adults that have never participated in organized evacuation drills.

Strength, endurance, and cardiorespiratory fitness are paramount physical prerequisites for optimal occupational performance (MacDonald, Pope, & Orr, 2016). Better performances in the field of physical fitness can hasten the process of minimizing the effects of disasters, such as lowering the risk of injury and loss of life (Maupin et al., 2018).

The relationship between occupants' emergency tasks and fitness level is clear, and numerous studies have been conducted and found to be reliable regarding the high level of strength and aerobic performance required by specialist police jobs like carrying loads, performing repetitive lifts, and performing a variety of carrying tasks (Robinson et al., 2018). Despite the fact that our study does not specifically address tactical people, various studies suggest that the general community could also gain from having high levels of physical fitness, which is directly associated to faster response times to disasters.

The study's main objective was to determine whether muscle power and muscle endurance of the participants could influence their fire emergency response movement time to a safe location. Additionally, it was hypothesized that the physically active participants will respond more quickly to fire emergency scenario than physically inactive ones.

Methods

Experimental approach to the problem

The objective of the present study is to investigate the potential impact of physical fitness on young adults aged 20 to 30, who were selected randomly for participation. The emergency fire case scenario assumes that the selected participants are attending lectures at the university building during a fire event. The goal is to determine whether participants who were physically active throughout the testing period differed from those who were not in terms of the amount of time they needed to respond to a safe place. Effects of a few fitness factors such as muscular power and muscle endurance were examined and their impacts on emergency response time in the case of fire emergency were compared. The intention was to categorize participants into two groups based on the information obtained from the pre-participation health screening questionnaire. It was hypothesized that significant differences in response times would be observed between the two groups.

Participants

The sample comprised 21 students, consisting of both male and female individuals of the same age, who volunteered for participation in the study. A pre-participation screening questionnaire was prepared by the researchers and used as a data collection form (American College of Sports Medicine, 2020). Following the American College of Sports Medicine's (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals (American College of Sports Medicine, 2020), the participants were separated into two groups: the physically active group and the physically inactive group. The physically active group consisted of 10 students (mean Body Mass Index [BMI] = 25.04 ± 3.63 kg/m^2; mean percentage body fat [BF%] = 13.33 ± 5.81), while physically inactive group consisted of 11 students (mean Body Mass Index [BMI] = 25.02 ± 5.62 kg/m^2; mean percentage body fat [BF%] = 23.81 ± 7.96).

The study's main objective was to find out whether physically active participants responded more quickly than physically inactive ones. The initial session of the survey, focusing on physical fitness assessment, was conducted over a two-hour period on a single day. The subsequent session, dedicated to measuring fire emergency reaction time, extended for three hours, and was conducted seven days later. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Technical Sciences, University of Novi Sad (protocol code 01-1626/3, 2023).

Measurements and Procedures

The pre-exercise evaluation included measurement of solely the resting blood pressure (BP). The *Procedures for Assessment of Resting Blood Pressure* recommended in the *ACSM Guidelines for Exercise Testing and Prescription* were used, as precise and proven methods for monitoring blood pressure are essential for accuracy (Gary et al., 2022). The results were successful as all the subjects had normal blood pressure according to the *Classification and management of blood pressure for adults*, and we could proceed with the testing.

Lower body power

Power, i.e. the capacity or rate at which a subject can execute work, is one of the skill-related physical fitness factors (Gary, 2022). In this study, the standing long jump, commonly known as the broad jump, was utilized to evaluate explosive leg power, a metric often employed to gauge overall muscle power. Participants were directed to position themselves with their feet slightly apart behind a line marked on the ground. They were then instructed to propel their bodies forward by swinging both arms, executing a two-foot takeoff and landing. The objective was for participants to land on both feet without falling backward while jumping as far as possible. Subsequently, following the completion of the test, the distance between the takeoff line and the closest point of contact of the subject's heels was measured (Wood, 2008). The longest distance jump was noted as the better of two tries.

Muscular endurance

Muscular endurance refers to the ability of a muscle group to sustain repetitive contractions over a period until muscular fatigue is reached (Gary et al., 2022). In this research, muscle endurance was assessed using a simple field test where participants performed the maximum number of push-ups they could execute without interruption (Canadian Society for Exercise Physiology, 2004). This method is employed to evaluate upper-body muscle endurance. Male participants in the test were directed to assume the standard "down" position (hands under the shoulders, back straight, head up, using toes as the pivot point), while female participants were instructed to start in the modified "knee push-up" position (Čvorović et al., 2021). For this study, yoga block was placed underneath the participant’s chest and served as a measure of required push up depth. The maximal number of push-ups performed without rest was noted as the final score. The test was stopped when subject could not maintain appropriate technique and strained forcibly within two repetitions.

Emergency response

In this study, the term "emergency response test" pertains to the participant's ability to react to an emergency scenario, specifically measured by the time taken to reach a designated safe location. The test was conducted in the classroom that the selected participants frequented the most. Based on how they responded to a made-up emergency, subjects' performances and the actual times they needed to reach a safe area were evaluated. The time it took the subject to leave the building and reach the safe place was a measure of the initial emergency response. It was established how long it took for the subject to get to the safe area that had been previously selected by the building's fire protection plan (Faculty of Technical Sciences, 2022). Participants were acquainted with the procedure and the safest route which could take them to the safe location outside of the building.

Participants were situated in a classroom located on the elevated ground floor. As per the fire protection protocol, participants were required to exit through the main entrance door, descend 13 stairs to reach the exterior of the building, and subsequently proceed to run or walk the remaining distance from the starting point to the designated safe location, positioned 30 meters away from the entrance. The entirety of the evacuation route spanned a distance of 55 meters. The center of the classroom's chair case served as the designated starting point for all participants, clearly demarcated with markers. The safe location, where the evacuation route concluded, was similarly marked with two prominent indicators. The subjects were advised to move as quickly as possible to the finishing point upon hearing the fire alarm, which signaled the beginning of the test. The trained staff positioned at the endpoint recorded the response time using a handheld stopwatch. Time was measured in seconds, recognizing that even a few seconds in an emergency can be pivotal (Baldwin, 1994).

Statistical analyses

The JASP software (Jeffreys's Amazing Statistics Program, GNU Affero General Public License) version 0.18.3 was utilized for data analysis. The two-tailed Student's t-test was used to assess whether there is a significant difference between the means of two groups and to test hypotheses regarding the mean of a small sample drawn from a normally distributed population. The approach investigated differences between students who were physically active and those who were physically inactive. The variables of interest in this study included muscle power (measured by the standing long jump), muscle endurance (assessed through push-ups), and fire emergency response time, evaluated using a 55-meter movement time test. According to the American College of Sports Medicine (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals (American College of Sports Medicine, 2020), the group was divided into two smaller groups: physically active participants (10 subjects) and physically inactive participants (11 subjects). The equality of variances for a variable calculated for two groups was evaluated using Levene's Test for Equality of Variances. The p-value significance threshold was set at $p \leq 0.05$. Cohen's effect size (d) was employed to quantify the discrepancies, categorizing them as follows: d < 0.2 (trivial or negligible effect), d = 0.2-0.5 (small effect), d = 0.5-0.8 (moderate effect), d = 0.8-1.3 (large effect), or d > 1.3 (very large effect), (Sullivan & Feinn, 2012).

Results

The descriptive statistics for active and inactive group is shown in Table 1.

Table 1. Descriptive statistics.

Variables	Active group (n=10)				Inactive group (n=11)			
	Mean	SD	SE	CV	Mean	SD	SE	CV
Standing broad jump (cm)	201.70	31.19	9.86	0.16	152.46	35.09	10.58	0.23
Push-ups (No.)	24.30	7.51	2.38	0.31	9.91	5.77	1.74	0.58
Movement 55m (s)	13.49	1.67	0.53	0.12	15.65	2.23	0.67	0.14

Participants who were physically active completed a 55-meter movement time test significantly ($p \leq 0.05$) faster and with a shorter emergency response time (Table 2, Figure 2). Second, physically active participants performed better on the standing broad jump test *(*Table 2, Figure 1). Finally, physically active participants performed better on the muscle endurance test (Table 2, Figure 1) than physically inactive participants. Additionally, a very large disparity was evident in the standing broad jump, while large differences were observed in push-up performance and emergency movement time. The primary hypothesis of the study was supported by the data, indicating that physically active participants exhibited faster emergency reaction times.

Table 2. Comparison between active and inactive firefighters.

Measure 1	Measure 2	t	df	p	Cohen's *d*
Standing broad jump - Active group	Standing broad jump - Inactive group	4.615	9	0.001	1.46
Push-ups - Active group	Push-ups - Inactive group	3.851	9	0.004	1.22
Movement 55m - Active group	Movement 55m - Inactive group	-2.73	9	0.023	-0.86

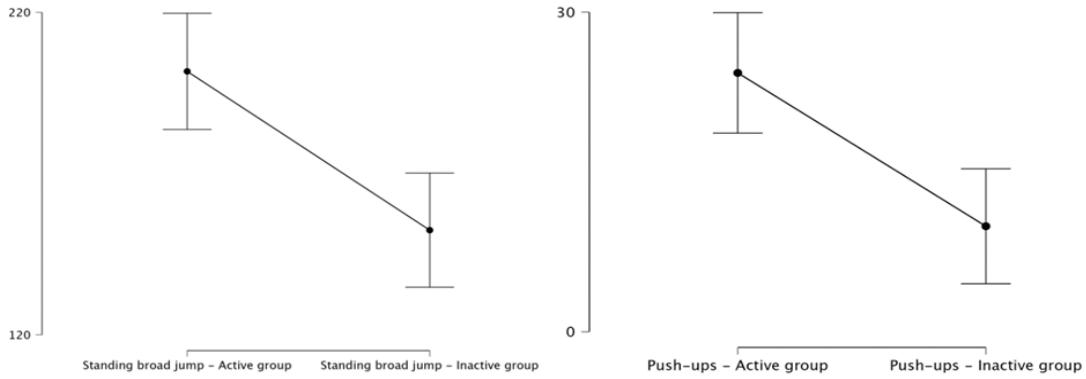

Figure 1. Descriptive plots for standing broad jump and push-ups.

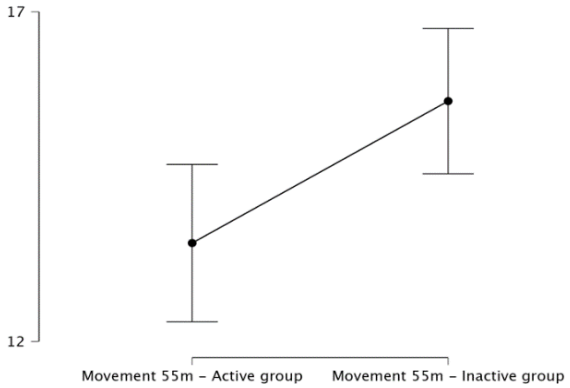

Figure 2. Descriptive plots for Movement time.

Discussion

The primary aim of this study was to investigate the potential influence of physical fitness variables, specifically muscle endurance and muscle power, on evacuation time. This investigation was based on the hypothesis that individuals with higher levels of physical fitness would complete evacuation routes more expeditiously than their less physically fit counterparts. While physical activity has yet to be formally acknowledged as a component of disaster preparedness, the findings presented herein suggest that physically active but untrained young adults may demonstrate improved performance in disaster evacuation scenarios.

Several institutions, exemplified by Boston University, advocate for an expeditious yet composed evacuation strategy: "Evacuate calmly and promptly upon activation of a fire alarm or carbon monoxide alarm" (Boston University). Extended evacuation durations may reflect a familiarity with fire evacuation protocols, accrued experience, and a deliberate, composed movement toward the designated exterior evacuation area, in accordance with the recommendations of these institutions. However, in actual evacuation scenarios, individuals typically prioritize expediently vacating the premises, potentially modifying expectations for a tranquil evacuation. Muscle power and endurance emerged as the key factors that exhibited notable distinctions between the two groups, along with a swifter emergency response observed among physically active participants. The muscle power test stands as one of the frequently utilized assessments to delineate the physical attributes of emergency personnel and serves as a pivotal performance indicator (Maupin et al., 2018). Because disaster-related situations call for high-intensity movements, power appears to be essential for emergency performance (Joseph et al., 2018). Peak power can be assessed through a range of methodologies, and forthcoming investigations could focus on techniques such as the vertical jump or the medicine ball throw test. These tests have the potential to elucidate whether muscle power directly influences emergency response capabilities.

Muscle endurance can be evaluated using various methods, and push-ups serve as a valuable performance metric. Elite tactical units have demonstrated superior muscular endurance in push-ups compared to the general population, making it a relevant and effective indicator of fitness (Maupin et al., 2018). The findings of this study provide evidence supporting the notion that endurance training enhances physical capacity and performance across a spectrum of emergency occupational responsibilities (Hendrickson et al., 2010).

One limitation of the study could be the lack of homogeneity among research participants in terms of age and fitness levels, potentially limiting the generalizability of the findings to the broader population of evacuees in typical building settings within a community. However, it is worth noting that the participants may better reflect the diverse demographics found on university campuses and similar structures. Despite the modest sample size of the study's participants, a comprehensive analysis was executed to depict a genuine scenario in which a singular ordinary university classroom could feasibly accommodate the specified number of individuals without exceeding its capacity.

The objective of this study was to determine whether a significant correlation existed between levels of physical activity and fire emergency response times. While performance ability remains critical for emergency teams, this study elucidated how certain aspects of physical fitness can impact initial fire emergency response time, thereby aiding in mitigating the effects of disasters (Mannion et al., 1999). The results of this study suggest that measures of muscle endurance and muscle power may be directly correlated with fire emergency response time.

Practical Implications

Every action outlined in each phase of disaster risk reduction should be taken seriously and routinely implemented to reduce the effects of any disaster. Health benefits of physical activity are very clear, while this study also ascertain strong connection between physical activity and emergency response (Warbuton &

Bredin, 2017). This study has demonstrated how some physical fitness factors, such as muscle power and muscle endurance, could influence emergency response times. Despite the absence of a mandate for physical activity among young adults and students, considering the demonstrated link between disaster response and physical activity, it may be advisable for both physically inactive participants in this study and their peers to consider adopting a more active lifestyle in the future. In addition to engaging in disaster preparedness training, which enhances performance during emergencies, individuals should prioritize physical activity to preserve their physical and mental well-being. This proactive approach ensures readiness to respond effectively during emergencies, potentially enabling individuals to save their own lives or the lives of others (Bajić, Veljović, & Bulajić, 2023). Finally, as corroborated by numerous studies referenced in this research, regular physical activity has the potential to preserve lives not only during disasters but also in non-crisis contexts, whereas sedentary behavior is posited to be intricately linked to morbidity, both directly and indirectly (Alvar, Sell & Deuster, 2017).

***Acknowledgment*:** The authors declare no conflict of interest. The research of the first and the third authors was partially supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-65/2024-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project "Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad" (No. 01-3394/1).

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