Research

Correlation between fitness parameters and an occupational rescue simulation among emergency care providers in North West province, South Africa: A pilot study

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Abstract

Objective

The purpose of the study was to examine the relationship between validated fitness parameters and an emergency rescue simulation (RS) circuit performed by emergency care providers (ECPs).

Methods

A cross-sectional study was selected to determine the relationship between the fitness tests and the RS. Twenty ECPs in the North West province of South Africa participated in the study. Demographic data were collected, followed by testing of anthropometric characteristics and field fitness tests measuring muscular strength, muscular endurance, aerobic capacity, anaerobic capacity and flexibility. Thereafter, participants had to complete a RS circuit. Pearson's correlation coefficient was used to assess the relationship between variables. Differences in age, gender and body mass index formed part of the descriptive statistics. A test-retest reliability method was applied to evaluate the reliability of the RS.

Results

Significant correlations were found between the RS and the 250 m shuttle run ($r=0.83$; $p<0.01$), flexed-arm hang test ($r=-0.59$; $p<0.01$), Cooper 12-minute test ($r=-0.56$; $p<0.01$), and the maximum push-up test ($r=-0.51$; $p<0.05$).

Conclusion

Findings demonstrate a possible association between aerobic capacity, anaerobic capacity, muscular strength, muscular endurance and ECP performance in an occupational task-related RS. Improved performance in these specific fitness areas may enable ECPs to be better prepared for the physical demands of their occupation. The RS may also be used as a tool to assess job (physical) preparedness of qualified ECPs during their recruitment, but this requires further validation.

Keywords:

emergency medical care; physical fitness; occupational demands; rescue simulation; physical preparedness

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Introduction

Emergency care providers (ECPs) work in a pre-hospital setting with a specific mandate to provide patient care during emergencies. Activities in their mandate include, but are not limited to, patient positioning and immobilisation, cardiopulmonary resuscitation (CPR), fluid therapy and lifting and moving of patients (1). At times, ECPs are also required to perform duties such as removal of injured patients from dangers such as vehicle wreckage through patient extrication using rescue equipment (2). Hunter et al (3) suggested that the duties of paramedics responsible for frequent injuries include manual handling and awkward tasks, combined with periods of sedentary behaviours during shifts. Therefore, due to the occupation of ECPs, it requires them to rescue casualties as rapidly and efficiently as possible (4), which places mental and physical demands on the body (Figure 1).

Studies investigating the relationship between physical fitness components of ECPs and their occupational tasks in South Africa and globally are uninitiated. Only a few studies have investigated the fitness levels and physical health measures among ECPs (5,6), despite the literature detailing the demonstration of the physical demands in the profession. For example, Russo et al (7) examined the impact of physical fitness on the quality of external chest compressions during CPR and found that rescuers of superior physical fitness were able to sustain high quality chest compressions and lower rescuer fatigue. Furthermore, Coffey et al (1) assessed the physical demands of the paramedic occupation in Canada. They found that loading and unloading of ill/injured patients, pushing and

pulling of patient loaded stretchers, as well as the carrying of medical and rescue equipment were among the most physically demanding tasks of paramedics.

There is no pre-employment physical fitness testing of ECPs, nor is there policy advocating for such in South Africa when compared to other emergency care professions such as firefighting, law enforcement and traffic officers (which conduct pre-employment fitness testing). In the rural areas of South Africa, ECPs not only work in an ambulance setting but are also formally trained to perform rescue operations in conjunction with other rescue organisations (ie. fire department). Therefore, the purpose of the study was to determine the relationship between physical fitness parameters of ECPs and an occupation specific rescue simulation (RS), designed in accordance with their intensified job-related tasks (ie. performing CPR, lifting, carrying and loading of patients and equipment, vehicle extrication).

Methods

Participants

A cross-sectional study was designed to assess the relationship between the fitness test battery and the RS parameters of ECPs. For the study, ECPs were defined as basic ambulance assistants, emergency care assistants, ambulance emergency assistants, emergency care technicians, critical care assistants, as well as emergency care practitioners, as recognised by the professional board of emergency care at the Health Professions Council of South Africa (8). Twenty male ECPs between the ages of 30 and 48 years with a minimum of 2 years of work experience as operational ECPs volunteered for the study. The

**HR = heart rate; MSD = musculoskeletal disorders; RF = risk factors; RPE = resting perceived exertion

Figure 1. Job related risk factors for ECPs

participants were free from any musculoskeletal injuries and were qualified and recruited via email contact throughout the 32 emergency medical services (EMS) stations in the North West province of South Africa. They responded by reading and completing a participant information and consent form provided. Standardised testing methods were used based on the American College of Sports Medicine criteria (9). Principles of the Helsinki agreement was followed with respect to the testing of human subjects. Ethical clearance was obtained from the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg (REC-01-159-2016). Permission was also granted by the North West Department of Health to conduct the study on their personnel.

Data collection and procedures

On signing the informed consent form, the participants met with the researcher on three occasions at the testing venue. The first visit was to conduct the fitness test; the second and third visits was for the completion of two attempts at the RS circuit. Participants required a minimum of 48 hours lapse time between attempts at the RS. During the collection of anthropometric measurements, the participants had to be in a fasted state. Participants were also requested not to participate in any exercise for 48 hours before the fitness testing and the RS simulation and were asked to have a light breakfast on the morning of testing. All tests were administered by a qualified biokineticist (specialised exercise therapist) also trained as a basic ambulance assistant. All 20 participants were tested over a period of 10 days.

Anthropometric measurements

In a fasted state, participants weight and height were measured and calculated [body weight (kg) x height (cm) squared] to determine their body mass index (BMI). The subcutaneous body fat percentage of participants was measured using a skinfold calliper (Harpender skinfold Body Calliper C-136, USA) on four areas of the body (subscapular, suprailliac, bicep, tricep) as described by Miller (10). Before the fitness testing, participants were only allowed to have a light meal or energy drink after the anthropometric measurements.

Fitness parameters

The following nine field tests were used to measure five components of fitness – aerobic capacity, anaerobic capacity, muscular strength, muscular endurance and flexibility:

- 12 minute cooper test
- maximal push-up test
- 60 seconds sit-up test
- isometric torso lift
- isometric leg lift
- modified sit-and-reach test
- hand grip test
- flexed arm hang test
- 250 m shuttle run.

Participants were taken through light warm-ups and dynamic

stretching by a qualified exercise therapist before the tests.

Rescue simulation

The RS was designed from five different physical ability tests (tasks commonly performed by ECPs in their line of duty) derived from other related studies (11-15). The RS tests were then formulated into a system of five different stations whereby the participant could perform one test after the other, moving from one station to the next in a sequential form. The tests in the RS were also organised in such a way that they imitated a typical rescue scenario. The RS required participants to have adequate recovery from the fitness test. Thereafter, 48 hours after the fitness tests, the participants were required to complete an RS consisting of five stations with no rest period in between the stations, organised in a time-trial format. Before the RS, the participants were required to wear personal protective equipment consisting of a jumpsuit, protective boots, helmet and gloves. Participants were taken through a session to familiarise themselves with the content of the simulation and were then given an opportunity to ask questions or seek clarity before beginning the RS. Once participants were familiar and confident with the RS, they could start the circuit. The fitness components tested in the RS included aerobic and anaerobic capacity as well as muscular strength and muscular endurance. The RS was conducted in a temperature-controlled environment ranging between 15°C and 20°C. The participants had to complete the RS on two different occasions (after 48 hours) in order to do a test-retest reliability of the RS.

Rescue simulation sequence

The RS circuit was designed in a manner that allowed participants to move from station-to-station in sequence (ie. in alphabetical order, from the start line to station A, B, C, D, E and then to the finish line) (Figure 2).

Station A: Ascending stair test carrying a 16.5 kg medical/rescue bag, electrocardiogram and a suction unit

The purpose of the test was to test the ability and efficiency of the ECPs to carry their medical equipment up four flights of stairs in order to reach the patient (13). The apparatus that the participant had to carry was a medical/rescue bag, medical suction unit and ECG. The participants had to ascend then descend four flights of stairs (step height of 0.17 m) with a total vertical rise of 13 m (estimated to be four floors) while carrying a medical bag, suction unit and ECG with a combined weight of 16.5 kg. The test was scored by the ability of participants to ascend and descend stairs carrying equipment within the shortest time possible. The faster person was awarded a higher score, which implied that in an emergency situation, the faster person may attend to a patient first, for various rescue tasks.

Station B: Vehicle extrication using a spreader

The purpose of the test was to determine the ability of ECPs to lift and utilise heavy vehicle hydraulic extrication tools during vehicle collisions in order to remove trapped casualties (13). A 19.6 kg 'jaws of life' hydraulic extrication spreader (Hurst ML-28)

was used for the test. The participants had to hold the vehicle extrication spreader five times at three different heights (0.9 m, 1.2 m, 1.5 m) for at least 15 seconds at each height. The test was scored according to the participants' ability to hold the spreader with the correct form in all three different positions without rest breaks.

Station C: 30 m simulated victim drag with a 120 kg manikin

The purpose of the test was to determine the ECPs' ability to drag the patient out of dangerous situations at the scene (11). A 120 kg Life Tec adult rescue training manikin and 2 m kernmantle rope was used and due to the difficulty in gripping the manikin during the drag, a kernmantle rope was tied around the manikin's armpits, making it easier to grip and drag the manikin. However, in a real-world setting, ECPs have to victim drag under the armpits using their forearms or by using a rescue blanket. The participants then had to reverse drag the manikin for a 30 m distance. The test was scored by the shortest time the participant covered the 30 m distance during the drag.

Station D: Five minutes of continuous chest compressions

The purpose of the test was to determine the ECPs' ability to perform adequate continuous chest compressions for five minutes without rest (14). A Laerdal CPR manikin was used for the test. The participants had to complete five minutes of continuous chest compressions of at least 100 bpm. The CPR manikin used had a clicking mechanism during each compression which was used to measure the effectiveness of the compressions. The test was scored according to the participants' ability to complete five-minute chest compressions without rest.

Station E: Imitation of carrying of the patient on a spine board

The purpose of the test was to determine the ability of the ECPs to lift and carry a patient with a scoop stretcher or spine board off the ground towards an ambulance (12,15). Two 24 kg kettlebells were used for the test as the scoop stretcher or spine board stretchers would require more than one person to carry. Therefore, kettlebells served as an alternative to stretchers. The participants had to squat lift a pair of 48 kg (24 kg each) kettlebells (26) and carry them for a distance of 20 m (12). The test was scored by the ability of the ECP to safely squat lift and carry kettlebells in the shortest time possible (without running) for a 20 m distance.

Data analysis

Morphological measurements (height, weight, anthropometry), fitness test and RS results were recorded on a Microsoft Excel spreadsheet. Inferential and descriptive statistical analyses were computed on the obtained data and used to describe the demographics, health and fitness parameters of ECPs. Central tendency was measured via means and standard deviations. A correlation coefficient was used to determine the relationship between two variables and to ascertain the strength of the relationship.

A test-retest was conducted to evaluate the reliability of the RS whereby participants had to complete two RS with a minimum of 48 hours rest between them. A two-tailed t-test method was used to determine the reliability of the RS. Pearson's correlation coefficient was used to assess the correlation between the anthropometric measurements, fitness test and the RS

Figure 2. Rescue simulation sequence

completion time. SPSS (version 26) (IBM, Armonk, NY) was used for the statistical analysis. Significance was set at the level of $p \leq 0.05$.

Results

Anthropometric characteristics

The anthropometric characteristics of participants are presented in Table 1. The mean age of the participants was 37 ± 4.4 years, with a BMI of 28.4 ± 5.5 kg/m², and body fat percentage of 24.2 ± 6.8 . A total of 30% of participants were classified as overweight (BMI ≥ 25) and 45% as clinically obese (BMI ≥ 30). More participants with an elevated subcutaneous body fat percentage than in the normal range (5% lean, 25% average vs. 55% high and 15% very high) was found.

Table 1. Anthropometric characteristics of participants

Participant characteristics	n	Mean	SD
Age (years)	20	37.0	4.4
Mean height (cm)	20	169.6	6.0
Mean weight (kg)	20	81.5	15.4
Mean BMI (kg/m ²)	20	28.4	5.5
Mean body fat %	20	24.2	6.8

Fitness test results

The maximum push-up test produced a mean of 21 ± 14 and one-minute sit-up at 26 ± 8 repetitions; the isometric torso lift produced a mean of 105 ± 20.9 kg and the isometric leg lift at 115.1 ± 23.5 kg. In addition, the flexed-arm hang test (FAHT) produced a mean at 29 ± 18 seconds and the modified sit-and-reach test $36 \text{ cm} \pm 6.6$ (Table 2).

Rescue simulation results

The mean RS completion time was 8.42 ± 0.4 minutes. The relationship between the RS and the fitness tests are illustrated in Table 3. The most significant relationship was found between the RS and 250 m shuttle runs, FAHT, Cooper 12-minute test and the maximum push-up test. The results, therefore, indicated that the better the participant performed in the various fitness tests, the faster they completed the RS.

Table 2. Fitness test results for participants

Test	Values	
	Mean	SD
Maximum push-up (repetitions)	21	14
One-minute sit-up (repetitions)	26	8
Isometric torso lift (kg)	105	20.9
Isometric leg lift (kg)	115.1	23.5
Flexed-arm hang test (seconds)	29	18
Grip strength (kg)	43.1	6.6
Modified sit-and-reach test (cm)	36	6.6
Cooper 12-minute test (m)	1866.5	416
250 m shuttle run test (seconds)	70	17

Table 3. Relationship between the rescue simulation (trial 2) and fitness parameters

Variables	Rescue simulation (n=20)	
	R statistic	p-value
250 m shuttles	0.83	0.000*
Flexed-arm hang test	-0.59	0.006
Cooper 12-minute test	-0.56	0.010
Maximum push-up test	-0.51	0.020
One-minute sit-up test	-0.43	0.060
Isometric leg lift	-0.39	0.080
Isometric torso lift	-0.05	0.840
Grip strength	-0.16	0.510
Modified sit-and-reach test	0.12	0.600

* $p < 0.05$

Discussion

The RS in the study was designed to determine the relationship between the physical fitness of ECPs and their ability to complete job-specific physical tasks such as performing CPR, vehicle extrication, lifting and carrying of patients among others as quickly and efficiently as possible. Their tasks are supported by Coffey et al (1) who suggested that paramedics are routinely exposed to physically demanding tasks while on duty, especially those that require loading, unloading, pushing, pulling and carrying of patients and rescue equipment. Tests that formed part of the RS were extracted from different published studies that included job tasks pertinent to ECPs and firefighters (11-14). However, it must be highlighted that the RS has not been a scientifically validated test to assess job task analysis within EMS, but was composed of selected activities commonly performed by ECPs in their line of duty.

The study found a moderate but statistically significant relationship between the RS and various fitness tests (250 m shuttle runs [$p=0.000$], FAHT [$p=0.006$], Cooper 12-minute run [$p=0.010$], and maximum push-up [$p=0.020$]) indicating that those participants who performed poorer during these fitness tests were likely to take longer to complete the RS. These findings were consistent with those of Williford et al (16) who investigated the relationship between physical fitness (pull-ups, push-ups, sit-ups, 1.5-mile run) and firefighting suppression tasks (stair climb, hoist, forcible entry, hose advance, victim rescue), whereby significant correlations were also found. The findings were also consistent with those of Michaelides et al (17) who examined the relationship between physical fitness aspects of firefighters and their job abilities through the firefighter ability test. They found that the firefighter ability test completion time was correlated with upper-body muscular endurance (push-ups and sit-ups), upper body strength and relative power. Both firefighters and ECPs occupations are physically demanding and have similarities in terms of physically handling (lifting, carrying, loading) patients as indicated by Poplin et al (18). Therefore, the results of the study had to be compared to those of studies related to firefighters as

there are limited studies on physical fitness standards of ECPs globally (19).

The study found a correlation between the RS and muscular (upper body) strength (FAHT). This indicates that ECPs with higher levels of muscular strength completed the RS faster than those with lower levels. Similar results were demonstrated by Rhea et al (11) who examined the relationship between physical fitness and job performance of firefighters, and found a significant relationship between upper-body strength levels and pulling activities (hose pull and victim drag) in firefighters. This is important because victim drag formed part of the RS. Ock et al (14) examined the influence of physical fitness on 5 minutes of continuous chest compressions and found strong correlations between higher muscular strength and prolonged effective chest compressions during CPR. This indicates that good muscular strength is necessary for effective chest compressions during prolonged CPR (>5 minutes).

Significant correlations were found between the RS and muscular endurance (maximum push-ups and FAHT). Rhea et al (11) found that upper-body muscular endurance correlated with firefighters' job task activities such as stair climbing, equipment hoist, victim drag and overall job performance. In addition, Michaelides et al (17) found that upper-body muscular endurance (push-ups) significantly contributed to the predictive power of a firefighter's test performance ability. Therefore, aerobic and anaerobic capacity remains paramount for the occupation-specific activities of ECPs.

Significant relationships were also found between aerobic (Cooper 12-minute run), anaerobic (250 m shuttle run test) capacity and the RS. Lindberg et al (13) conducted a study on field tests useful for evaluating aerobic work capacity of firefighters. Correlations were found between maximal aerobic capacity (VO₂ max) and a range of firefighting tasks (stair climbing carrying hose baskets, demolition, cutting, victim rescue, vehicle extrication, hose pulling and carrying hose baskets over terrain).

These results suggest that these components of physical fitness may be important in the performance of the RS. Hansen et al (20) investigated the impact of physical fitness on CPR quality among healthcare professionals and found that there was early rescuer physical fatigue which resulted in declined compression depth, indicative of poor cardiorespiratory endurance and muscular strength. Similar findings by Rhea et al (11) demonstrated a significant relationship between anaerobic capacity (400 m run) and the overall job performance of firefighters during a simulated firefighting job task. This further highlights the importance of aerobic and anaerobic capacity for the occupation-specific activities of ECPs.

Lastly, the study found an insignificant relationship between the RS and one-minute sit-up test, isometric torso-lift, isometric leg lift, grip strength and modified sit-and-reach test. It is

acknowledged that having a good level of overall fitness is useful, but these elements may not be useful in predicting RS performance.

Historically, there has been limited research on scientifically designed occupation-specific fitness testing such as the RS to test the physical preparedness of ECPs. One of the main challenges is that qualified ECPs in the North West province are not tested for physical fitness during recruitment for employment due to limited research in the area to advise policy. The ECPs are tested for physical fitness only when enrolling for rescue training or emergency medical care qualification at the local provincial colleges and other institutions of higher learning. The current system of physical fitness testing of ECPs makes use of the generic fitness test battery (ie. field tests such as 2.4 km run, push-ups, hang-test and sit-ups, shuttle runs), which are time-consuming and do not assess the actual job-specific tasks of ECPs, hence, the designing of the RS.

Limitations

It is assumed that a larger sample would have yielded higher correlations, and hence, the trends indicate that a further study with larger numbers is required to achieve better results. The field tests pose an inherent limitation in that they cannot provide a more accurate reflection of strength such as the one-repetition maximum test. The results of the study equated the success of adequate physical fitness with a faster RS completion time. This is a limitation because other factors (ie. safe execution of a task instead of the speed of performance of occupation-related tasks) were not taken into consideration. During the RS, a rope was tied around the manikin as an aide during victim drag in Station C as it was difficult to grip when pulling. In a real-world setting, the ECP would drag a victim with arms bent under the victim's armpits, or by using a rescue sling. The participants were not randomly sampled and the researcher had to rely on participants volunteering to complete the RS which limits the generalisability of the findings. Furthermore, the study was only composed of male participants, which is not indicative of the workforce composition. The RS was designed using job-related activities from other research papers and, therefore, no job task analysis was conducted.

Conclusion

These findings demonstrate a possible association between field fitness parameters of testing, namely aerobic capacity, anaerobic capacity, muscular strength, muscular endurance and ECP performance in an occupational task-related RS. These results are encouraging as they show trends in the RS test and field fitness testing components, which may enable ECPs to be better prepared for the physical demands of their occupation. The RS may be used as a tool to assess job (physical) preparedness of qualified ECPs during their recruitment, but this requires further validation of these results on a larger population study.

Competing interests

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

Author contributions

Conception and design of the study: YC. Data acquisition: YC, SM. Data analysis and interpretation of the data: all authors. Drafting and critical revisions of the paper: all authors. Accountability for all aspects of the work: all authors.

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