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Mission Essential Fitness: Comparison of Functional Circuit Training to Traditional Army Physical Training for Active-Duty Military

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INTRODUCTION

It is widely known that soldiers require a certain level of overall or complete fitness to meet the physical demands of war. Jumping, crawling, rolling, stopping, starting, bounding, climbing, pushing, sprinting from cover to cover, carrying heavy loads long distances and still being able to complete the mission at hand represents a short list of the required tasks placed upon a soldier.[1] Key measurable fitness components include endurance, mobility, strength and flexibility.[2] Throughout Army basic training and their Army careers, soldiers are told that they are first soldiers and that their military occupation specialty (MOS) comes second. Thus, all soldiers must be capable of completing basic infantry tasks. Today soldiers of the United States Military are deemed "Tactical Athletes" or individuals that require high levels of strength, speed, power, and agility due to potential engagement in combat.[3] Deciding on the most appropriate physical training program is imperative for soldier survival and mission success.

To date, most training research conducted by the military emphasizes combat readiness and overall performance improvements on the Army Physical Fitness Test (APFT),[1] which tests aerobic and muscular endurance. The Army Physical Readiness Training Program (APRT) is conducted five days per week with a focus on mobility, strength and endurance. The APRT program consists of a warm-up, 50 minutes of exercise, and a cool-down. The exercise portion consists of aerobic and resistance training, a combination that commonly is used by the Army and shows improved fitness and performance on the APFT.[4-5] However, some have argued that the APFT test does not adequately test combat preparedness (i.e., it does not contain mobility, strength, or anaerobic fitness components and focuses too much on endurance) and the APRT program is not sufficient for combat preparation.[6] Accordingly the Functional Movement Screen testing endurance, mobility, strength, and flexibility has been implemented for some military populations.[2,7]

Other training methods combining aerobic and resistance exercises have demonstrated similar improvements in fitness as the APRT program. For example, a 12 week study compared a circuit resistance-training program (i.e., 25 minute sessions for 3 days per week of weight machine exercises interspersed with stationary cycling in 60 second intervals) to a standard aerobic exercise program (i.e., 60 minute running sessions for 4-5 days per week) with Air Force personnel and found significant improvements on the APFT with less training volume, as well as improvements in abdominal circumference for the circuit training group only.[8] Eight weeks of weight-based training (i.e., 60-80 minute sessions for 5 days per week including weight training exercises, 3.2 kilometer runs, sprinting, agility training, and weighted hikes) were compared to the APRT program for Army personnel and resulted in similar improvements on a series of fitness tests.[9]

More recently, circuit-style programs emphasizing functional fitness exercises (i.e., training that familiarizes the body with its operational environment) performed at high intensity have begun to gain popularity among military populations.[10-11] However, in a meeting with professionals from the American College of Sports Medicine, the Department of Defense expressed reservations about programs characterized by high-intensity repetitions and short rest periods between sets due to increased risk of muscle strains, ligament tears, stress fractures, and the threat of rhabdomyolysis.[11] Stated strengths of these programs included their ability to motivate, excite, and meet unmet training needs in military personnel, as well as their ability to better address skills related to combat readiness. It was deemed important that effective implementation of such programs would need to minimize injury risk and should be monitored closely for signs of overtraining as well as effectiveness.[11]

A newer, mission-specific comprehensive strength and conditioning program called Mission Essential Fitness (MEF) was created to specifically address perceived weaknesses of the existing APRT program (e.g., insufficient for combat preparation) by focusing on movements in multiple planes using a variety of speeds in a circuit training format. MEF is designed to be integrated, progressive, periodized and focused on increasing core stability. Functional exercises are utilized to mimic movements experienced in combat situations. The purpose of this study was to compare the MEF training program to a standard APRT program. We hypothesized that soldiers randomly assigned to the MEF training would show greater overall physical preparedness through improvements on APFT, physiological and other fitness measures when compared to APRT training, while maintaining body composition and minimizing injuries.

METHODS

Participants

Following standard chain-of-command protocol, approval was obtained to conduct and evaluate the MEF training program compared with the APRT program. Active duty Army personnel were invited to participate in the study through contacts with the army chain-of-command. Rank and years of service were used to randomly assign participants to the MEF intervention group (n = 34) or the APRT group (n = 33). All participants were currently active in regular physical training. As shown in Table 1, MEF participants were 82.4% (n = 28) male, average age was 27.29±5.68 years, and average years of service were 5.52±4.9. Participants in the APRT group were 84.8% (n=28) male, 27.88±5.38 years of age and averaged 6.92±5.39 years of service. Institutional review board approval was received to publish study results.

Measures

Each of the following measures was completed prior to the initiation (baseline) and at the end of the participants' respective 8-week training programs (post-test). Testing was done during the same time of day for both groups. Participants were asked to maintain adequate hydration throughout the testing as water was provided on-site.

Army Physical Fitness Test (APFT). Pushups were tested using the Army standards; men and women began with hands shoulder width apart and elbows and body straight. Participants were required to lower themselves until their upper arms were parallel to the ground and complete as many pushups as possible in one minute, pausing only in the up position to rest.[1]

Sit-ups also were tested using the Army range of motion standards; men and women began lying on their backs with their knees bent 90-degrees.[1] While a partner secured their ankles, participants interlocked their fingers behind their head and raised up until the base of their neck was above the base of their spine. They completed as many sit-ups as possible in one minute, pausing only in the up position to rest.

One-and-a-half mile and 2 mile run times and maximal heart rate were tested simultaneously on a flat paved road running route. Participants were split up into groups of 10 and outfitted with racing numbers and heart rate monitors. Five testers monitored the run with two at the start/ finish line and two testers at the 1.5 mile mark. Run times were recorded using an Ultrak gl10-10 lane timer. Heart rates were monitored using Polar F-11 heart rate monitors. Run times and heart rates were recorded for each participant at the 1.5 and 2 mile markers.

Physiological Indicators and Body Composition. Physiological measures included resting heart rate, blood pressure, and height. Resting heart rate and blood pressure were taken using a machine after participants had rested for 10 minutes. Height was measured using a wall-mounted

FMS grid. These tests, along with body weight, were entered into the Polar Body Age System. Body weight, body composition and metabolic rate were estimated using a Tanita segmental body composition analyzer/scale (model BC418), a single-frequency device with 8 polar electrodes (Tanita, Japan). This model has shown acceptable validity in comparison to DXA for men ($r = .54$-$.78$, $p < .05$-$.001$) and women ($r = .37$-$.91$, $p < .05$-$.001$).[12] Height and weight were used to calculate body mass index (BMI).

Field Fitness Indicators. The Kasch three minute step test (i.e., a submaximal measure of cardiorespiratory fitness) using a 12-inch box and heart rate monitors was conducted where each participant stepped 24 cycles (up-up-down-down) per minute (to a metronome setting of 96) for 3 minutes.[13] Immediately after the three minutes of stepping, the participant sat down. Heart rate was taken 60 seconds after completion of stepping. The Kasch test has been established as a valid submaximal test of VO_2max in males and females ages 7-57 ($r = .95$)[14] as well as in women ages 28-35 ($r = .824$).[13]

To assess strength, one rep max bench press was tested after instructing the participants on proper form and technique for flat bench press. Participants completed 10 repetitions with a light to moderate load followed by an additional heavier warm-up set of 3-5 repetitions. Weight was added in increments until muscular failure was obtained after one successful lift. A two minute rest period was given between each lifting attempt. This test is the standard for determining isotonic strength[15] and has shown significant test-retest reliability ($r > .90$).[16]

Mobility components that were tested included flexibility, power, and agility as detailed below.

Flexibility was tested using a flex-tester sit and reach box. Participants sat shoeless with feet six inches apart, toes pointed upward, and heels flat against the flex-tester. The participants kept their hands adjacent to each other and maintained contact with the box during the reach, pushing the guide as far as possible without bending their knees. The best of three trials were recorded to the nearest 0.25 inch (or 1cm). The sit and reach test has been found to be a good predictor of hamstring flexibility with high reliability (r = .96-.98) and validity (r = .24-.53, p<.05) for females and males.[17]

To assess power, standing vertical jump was measured using a wall-mounted vertical jump tester. Participants began each test with both feet flat on the floor and reaching as high as possible, marked their reach with a magnet. The participant then lowered themselves to jump without a preparatory or stutter step. A counter movement was performed during the jump, with the arm reaching up and placing an additional marker on the wall. The score was the vertical difference between the two magnets. The best of three trials was recorded to the nearest 0.5 inch. This test has shown acceptable validity in comparison to peak and average power measured by force plates (r =.88 and r = .73, respectively)[18] as well as high reliability (Chronbach's α ≥ .962).[19]

Standing broad jump was tested to also assess power using a starting line and additional marks every three feet. Participants stood with toes just behind the starting line and jumped as far forward as possible. The participants were required to land on both feet for the jump to be scored. A marker was placed at the back edge of the athletes' rearmost heel, and the yard stick was used to determine the distance from the starting line to the mark. The best of three trials was recorded to the nearest 0.5 inch. This test has shown good reliability (ICC = 0.97) and validity for peak power (r = .334, p<.01) and mean power (r = .499, p<.01).[20]

Agility was tested using the pro-agility test, which is a highly utilized test with a standardized protocol and norms for comparing results.[21] Three parallel lines five yards apart were marked with tape. Participants straddled the centermost of the three lines using a three-point stance. On the tester's call the participant sprinted five yards to the line on the left, then changed direction and sprinted 10 yards to the line on the right, then again changed direction and sprinted five yards back to the center line. Foot contact was required at all lines. The better of two trials was recorded to the nearest 0.01 second.

Aerobic capacity was calculated using 1.5 mile run times with the following formula: relative VO_2 = 3.5 + 483 / (time to run 1.5 miles in minutes).[21]

Intervention

The MEF training program (see http://www.blissmwr.com/functionaltraining/) consisted of multiple exercises that focused on strength, power, speed, and agility and was designed to train the body in various planes of movement and at different speeds.[22] This was accomplished by using exercises that allowed the joints to be flexed, extended, and/or rotated. Movement speed was manipulated by adding resistance to the exercise such as barbells, dumbbells, resistance bands, medicine balls, sleds, tires and body weight. All exercises involved multiple joints (e.g., Olympic lifts, squats, bench press, and pull ups). Exercises were set up in a circuit fashion, including Olympic weight lifting movements, plyometrics, lower body movements (e.g., weighted walking lunges), upper body movements (e.g., band bicep curls), and core exercises (e.g., plank with feet elevated on a medicine ball). In total, fifteen different exercises were performed for 60-90 seconds each, with little to no rest in between each station, for a total of forty-five minutes. Participants attended fifteen separate MEF sessions during the eight weeks, averaging 2 sessions per week.

The APRT program (see http://www.scribd.com/doc/32717729/TC-3-22-20-Army-Physical-Readiness-Training-March-2010) followed published guidelines and focused on a combination of mobility, strength and endurance exercises.[1] APRT participants attended fifteen one-hour sessions during the eight weeks, averaging 2 sessions per week.

Statistical Analyses

All data were double-entered and standard data cleaning and verification procedures employed. Statistical analyses were conducted with PASW Statistics 18. Independent samples t-tests were used to compare groups on baseline characteristics. Analysis of covariance (ANCOVA) was used to evaluate between-group changes in study outcomes with the baseline testing value as the covariate and group as the constant. Paired samples t-tests were used to evaluate within-group changes in body composition. The value for statistical significance was set at $p < .05$.

RESULTS

Random assignment to training groups resulted in statistically equivalent groups on all baseline measures. Characteristics of each training group at baseline, including demographics, body composition, physiological indicators, APFT and other fitness indicators are shown in Table 1.

Insert Table 1 Here

Table 2 displays change scores across all measured fitness variables for both groups. On the APFT measures, the MEF intervention group significantly increased their pushups by an average of 4.2±5.4 compared to 1.3±5.9 additional pushups for the APRT group ($p = .033$). The MEF group also significantly decreased their 2-mile run times (-89.91±70.23 seconds) as compared to the APFT group (-15.33± 69.16 seconds; $p = .003$). The MEF group did show a significant decrease in heart rate of -17.0± 15.0 on the step test compared to a -9.0± 16.1 for the APRT group ($p = .004$). The MEF group improved significantly over the APRT group in bench press strength (13.2±12.1 versus 2.7± 11.5 pounds; $p= .001$) and flexibility (0.6±1.3 versus -0.5± 1.5 inches; $p= .003$). As shown in Table 3, changes in body composition measures and physiological indicators were not statistically significant for either group ($p>.05$).

Insert Tables 2 and 3 Here

Discussion

We compared a novel and comprehensive fitness training program, MEF, with standard APRT. Results indicated that MEF participants significantly improved their pushups, 2 mile run times, step test heart rate, bench press strength, and flexibility as compared to participants engaging in APRT. Thus, MEF positively impacted the comprehensive fitness domains, i.e., strength, power, both cardiorespiratory and muscle endurance, flexibility, and mobility, recently outlined as being important part of "Total Force Fitness."[2] It is notable that the MEF program produced these measurable improvements after a relatively low dose of training (i.e., 2 sessions per week), which may have helped prevent injuries and overtraining. Previous studies used 3-6 training sessions per week.[8-9] No significant differences were found between groups for changes in blood pressure, or resting heart rate. Neither group experienced significant changes in body composition nor reported any injuries.

This study provides evidence that the MEF training program results in greater fitness gains than the APRT program, differing from previous research that found similar improvements between APRT and a weight-based training program.[9] The MEF program successfully used functional exercises in multiple planes (i.e., sagittal, lateral and rotary exercises) addressing combat readiness to increase fitness,[2,6] with no reported injuries or signs of overtraining.[11] Combat situations may require soldiers to move laterally in and out of enclosed areas or vehicles with weighted packs and unstable surfaces, requiring muscles, tendons and ligament strength for controlled acceleration and deceleration. The absence of injuries during the MEF program suggests that progressive and scaled workouts are safe when incorporating weight lifting and technical lifts into a circuit-type routine that they address important fitness domains relevant to combat readiness.[2,6]

The current APFT emphasizes muscular and aerobic endurance with the use of push-ups, sit-ups, and the 2-mile run.[1] However, the U.S. military now recognizes that there are other important fitness domains that deserve attention and that are critical to mission completion and combat readiness. The APRT program currently trains soldiers in a limited number of fitness domains, while the MEF program is designed to address all physical fitness domains recognized by "Total Force Fitness."[2] The broad stimuli provided by the MEF program resulted in multiple training adaptations and fitness improvements in muscular and aerobic endurance, strength, and flexibility. In fact, the MEF may better prepare soldiers for the new APFT that also includes tests (e.g., 60m progressive shuttle runs, rower exercise, standing long jump, pushups, and a 1.5 mile run) of domains beyond those in the traditional APFT that may better prepare warriors of the demands of modern warfare.[2,6,23-24]

Our study had several important strengths including the participation of active duty Army personnel, demonstrating feasibility of real-world implementation during physical training sessions, and the fact that the MEF demonstrated measurable early phase improvements in a sample of young and healthy soldiers. In addition, we assessed a broad range of fitness domains as recommended by "Total Force Fitness."[2] Finally, the MEF program itself is a novel approach to circuit training that optimizes functional training to prepare soldiers for real-world conditions and improved combat readiness.[24-25] Our primary limitation for this study was equipment availability for broad assessment of multiple physical fitness domains. For example, it would have been ideal if the oxygen volume testing could have been done using the Bruce treadmill protocol to determine actual VO_{2max} rather than relative VO_2. Additional strength testing also could have been conducted that more closely matched the MEF training protocol to include movements such as the deadlift and shoulder press. Tracking nutrition intake could have provided more information regarding body composition. However, budgetary and practical factors limited our access to additional measures. Future studies should include these additional measures to ensure comprehensive physical fitness assessment. As well, future studies could be powered to examine gender differences as well as effects for soldiers with limited mobility.

Conclusions

In conclusion, the results of this study demonstrate that MEF improves muscular strength, endurance, cardiovascular endurance, strength, and flexibility while maintaining body composition and minimizing injuries. These outcomes support the utility of circuit-style functional fitness training for military personnel. Future research could examine whether MEF training leads to better combat specific preparedness for military personnel.

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Table 1
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Table 1. Baseline Group Characteristics.

Variable	MEF Mean (SD) n = 34	APRT mean (SD) n = 33	p-value
Demographics			
Age	27.3 (5.7)	27.9 (5.4)	.67
Percent Male	82.4 (n = 28)	84.8 (n = 28)	.78
Years of Service	5.5 (4.9)	6.9 (5.4)	.27
Army Physical Fitness Test			
Pushups (in 1 minute)	42.8 (10.9)	41.3 (10.7)	.57
Sit-ups (in 1 minute)	41.2 (5.9)	39.7 (7.8)	.37
2.0 Mile Run (time)	18:08.02 (2:08.39)[2]	17:38.40 (2:56.17)[4]	.48
Body Composition			
Height (cm)	177.1 (9.6)	175.6 (9.7)	.52
Weight (kg)	88.6 (18.3)	83.7 (17.9)	.27
BMI (kg/m^2)	28.0 (4.7)	27.0 (4.8)	.41
Body Fat Percentage	22.3 (7.9)	22.0 (6.5)	.87
Physiological Indicators			
Systolic Blood Pressure	140.9 (12.7)	137.6 (12.6)	.29
Diastolic Blood Pressure	81.4 (12.8)	80.0 (9.8)	.60
Resting Heart Rate	74.0 (15.9)	70.7 (12.7)	.36
Basal Metabolic Rate	2049.2 (421.5)	1942.3 (373.9)	.28
Relative VO_2 ($ml \cdot kg \cdot min^{-1}$)	40.6 (6.6)[3]	40.7 (4.5)[4]	.97

Field Fitness Tests			
Step Test Heart Rate	99.9 (18.7)	101.9 (22.6)	.70
1.5 Mile Run (Time)	13:33:27 (1:30:33)[3]	13:13:57 (2:07:26)[4]	.88
Vertical Jump (cm)	42.3 (11.5)	44.0 (10.1)	.52
Broad Jump (cm)	200.0 (29.1)[1]	195.8 (29.0)	.57
Agility (seconds)	5.8 (0.4)[1]	5.7 (0.4)	.90
Bench Press (kg)	71.5 (20.5)[1]	70.9 (27.2)	.93
Flexibility (cm)	26.8 (7.3)	27.6 (10.0)	.71

[1]Missing data for 1 participant

[2]Missing data for 5 participants

[3]Missing data for 6 participants

[4]Missing data for 8 participants

Table 2. Between Group Comparisons for Changes in APFT, Physiological, and Fitness Variables.

Δ Variables	**MEF mean (SD)**	**APRT mean (SD)**	**F statistic**	**p-value**
Army Physical Fitness Test (APFT)				
Δ in Pushups	4.2 (5.4)	1.3 (5.9)	4.761	**.033**
Δ in Sit-ups	0.7 (4.9)	-2.3 (4.9)	2.778	.120
Δ in 2 Mile Run time (seconds)	-83.9 (70.2)	-15.3 (69.2)	9.992	**.003**
Physiological Indicators				
Δ in Systolic Blood Pressure	-7.7 (16.1)	-3.4 (11.8)	1.196	.278
Δ in Diastolic Blood Pressure	3.4 (16.7)	0.6 (13.5)	1.446	.234
Δ in Resting Heart Rate	-6.0 (11.6)	-3.0 (11.7)	.380	.540
Δ in Basal Metabolic Rate	-22.85 (197.60)	42.39 (324.14)	1.017	.317
Δ in Relative VO_2 ($ml \cdot kg \cdot min^{-1}$)	2.39 (5.93)	1.24 (2.40)	.568	.455
Other Fitness Tests				
Δ in Step Test Heart Rate	-17.0 (15.0)	-9.0 (16.1)	8.839	**.004**
Δ in Vertical Jump (in)	1.2 (1.9)	0.7 (2.4)	.750	.390
Δ in Broad Jump (in)	3.0 (13.4)	-0.9 (3.5)	2.469	.121
Δ in Agility	-0.2 (0.4)	-0.2 (0.3)	.099	.754
Δ in Bench Press (pounds)	13.2 (12.1)	2.7 (11.5)	12.933	**.001**
Δ in Flexibility (in)	0.6 (1.3)	-0.5 (1.6)	9.729	**.003**

Δ = change

Note: Baseline values were used as covariates.

Table 3. Within Group Comparisons for Changes in Body Composition.

Δ Variables	**Δ Score Mean (SD)**	**t**	**p-value**
MEF Participants (n = 34)			
Δ Weight	1.3 (4.0)	1.92	.063
Δ Body Mass Index	0.2 (0.7)	1.26	.216
Δ Body Fat Percentage	0.3 (1.9)	0.90	.375
APRT Participants (n = 33)			
Δ Weight	0.3 (4.2)	0.45	.732
Δ Body Mass Index	0.03 (0.6)	0.27	.787
Δ Body Fat Percentage	0.1 (1.5)	0.30	.776

Δ = change

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