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HEALTH SCIENCES

Energy system contributions and determinants of performance in 400-meter military obstacle course

DALEI WANG, GUOLE JIANG, SHUANG QIN, DEYU SUN, JIEXING YAN, YUNJI CHEN, YEQIONG WANG & YIJIE TAN

Abstract: The purpose of the study is to explore the energy system contributions and determinants of performance in 400-meter military obstacle course (400m-MOC), and establish a model for predicting the performance in 400m-MOC. 50 male cadets participated in this study. Using portable gas analyzers and a blood lactate test, the energy system contributions were calculated during 400m-MOC test. Correlation analysis was conducted to ascertain the relationships between the performance of the 400m-MOC and the contributions of three different energy systems, as well as body morphology and various physical fitness components. A linear regression model was developed to predict the performance outcomes in 400m-MOC. The contributions of three different energy systems during 400m-MOC test were: phosphagen system (17.94±1.23%), glycolytic system (27.94±2.48%), and aerobic oxidative system (54.12±2.76%). Completion time for the 400m-MOC test correlates significantly with military service length, strength, BMI, speed, speed endurance, and aerobic endurance capability. The regression equation was formulated as: estimated 400m-MOC completion time=22.556 + 0.065 × 5000-meter running time-52.677 × (pull-up reps/body weight) + 0.582 × 400-meter running time. The 400m-MOC is primarily powered by the aerobic oxidative system, with aerobic endurance, upper body strength, and speed endurance being particularly crucial factors affecting its performance.

Key words: 400-meter military obstacle course, energy metabolism contribution, physical fitness demands, aerobic, anaerobic.

INTRODUCTION

Military obstacle course, due to its high demands on participants' endurance, strength, coordination, balance, and strategy, has long been considered as one of the most important means for physical training and testing of military personnel (Mullins 2012, Karakolis et al. 2017). Currently, there are over 10 types of standardized obstacle courses in Chinese military, such as 400-meter military obstacle course (400m-MOC), 400-meter sea crossing and island landing obstacle course, 500-meter obstacle course in high-altitude mountainous regions, etc. Among them, the 400m-MOC is the most widely used for Chinese military personnel. Every year, hundreds of thousands of officers and soldiers participate in the training, assessment, or competition of the 400m-MOC (Zhang 2021). Despite the significant progress made in the teaching methods and training techniques for the 400m-MOC in Chinese military, the situation of low training efficiency and weak training specificity still widely exists (Wang et al. 2018). In addition, each year, a certain proportion of cadets in military academies are unable to graduate due to unqualified performance in the 400m-MOC. Therefore, further exploring the training specificity of 400m-MOC holds significant importance for enhancing the level and efficiency of training.

Previous studies have demonstrated that exploring the energy system contributions of a sports event and understanding the key factors that determine its performance are crucial for comprehending the training specificity of a particular sports event (Reilly et al. 2009). The analysis of energy system contributions can greatly assist individuals in arranging training loads more reasonably and targeted during training (Bottollier et al. 2020). Unfortunately, there has been limited research on the energy system contributions in the 400m-MOC. The existing literature suggests that (Zhai 2018) the energy consumed during 400m-MOC is primarily provided by the anaerobic system. However, this conclusion is mainly based on experience and lacks sufficient experimental data to support it. Furthermore, identifying key physical fitness components that affect the performance of the 400m-MOC and establishing a model for predicting the performance of 400m-MOC could be invaluable. Such a model would aid soldiers in arranging their training content more reasonably, identifying areas of improvement, and ultimately enhancing their training efficiency. Previous studies have explored physical fitness components that are highly correlated with 400m-MOC performance (Zhai 2018). However, on one hand, some of the selected indicators are not conventional assessment items, and on the other hand, body morphology indicators (such as height, weight, body mass index, etc.) have not been taken into account. Therefore, further research in this area is still needed.

In this work, we calculated the energy system contributions during 400m-MOC test among cadets by using portable gas analyzers and blood lactate analyzer. Through correlation analysis and linear regression, key physical fitness components affecting the performance of the 400m-MOC were identified, and a predictive model was established. The purpose of the study is to further explore the training specificity of 400m-MOC, and thus provide experimental evidence and data support for addressing the issues of low training efficiency and weak training specificity in 400m-MOC training.

MATERIALS AND METHODS

Participants

The study recruited 50 male cadets from a military academy. All participants are able to independently complete the 400m-MOC, and none of them have suffered from training related injuries in the past six months. Each participant was made aware of the research's objectives, significance, procedures before giving their voluntary written consent to participate. The experimental process and testing methods have been reviewed and registered with the ethics committee. Cadets were randomly divided into two groups: energy system contributions study group (n=25; age: 21.4±0.8 years; height: 174.0±5.0 cm; weight: 65.1±4.7 kg; BMI: 21.6±1.9) and key physical fitness demands analysis group (n=25; age: 22.4±1.8 years; height: 173.5±4.7 cm; weight: 68.2±5.5 kg; BMI: 20.1±1.8).

Analysis of energy system contributions during 400m-MOC test

Participants of the energy system contributions study group were required to undergo two tests. The first test was to determine the maximum oxygen uptake (VO_{2max}), by using the Cosmed portable gas analyzer (K4b2, Italy). Participants performed an exercise test using the Bruce protocol on a treadmill (h/P/cosmos, Germany) until exhaustion, (Bruce et al. 1963) oxygen uptake was considered as maximal when any two of the following criteria were met: (1) a heart rate at or near age-predicted peak (220-age±10 beats/min); (2) respiratory exchange ratio > 1.1; (3) presence of a VO_2 plateau (<150 $mlkg^{-1}min^{-1}$) (Beutner et al. 2020). The formula for calculating relative VO_{2max} is: relative VO_{2max}=VO_{2max}/body weight (kg). The second test was a 400m-MOC test while carrying the portable gas analyzer, with a 48-hour interval between the two tests. The participants were not allowed to engage in other training activities within the 48-hour interval. Before the second test, participants performed a 15-minute warm-up (including jogging, static stretching, dynamic stretching, and core activation etc.) to prevent injuries during the test. After equipping the portable gas analyzer, participants wore combat camouflage uniforms and a woven belt around the waist to better secure and protect the device. While carrying the gas analyzer, participants adapted to passing through various obstacles, after completing the adaptation, participants were asked to stand in place and rest. When the participants' heart rate dropped below 120 beats per minute, the 400m-MOC test would start.

The sequence for the 400m-MOC was as follows (Figure 1): 100-meter run (#1)-bypassing the turning flag (#2)-stepping over the log posts in three steps (#3)-crossing the trench (#4)-jumping over the low wall (#5)-climbing up and down the high platform (#6)-climbing over the horizontal ladder (#7)-passing through the log bridge (#8)-climbing over the high wall (#9)-crawling under the low net (#10)-bypassing the turning flag (#11)-crossing the low net (#12)-climbing over the high wall (#13)-circling the bridge pillar (#14)-swinging over the horizontal ladder (#15)-stepping over the high platform (#16)-drilling through the hole (#17)-jumping down and climbing up the trench (#18)-stepping over the log posts in five steps (#19)-bypassing the turning flag(#20)-100-meter run(#21).

Heart rate and metabolic data were recorded during the participant's resting state, throughout the test, and within six minutes after completing the test. Blood lactate concentration was tested before the exercise, and 1 min, 3 min, 5 min, 7 min, and 10 min after the exercise using a blood lactate tester (EKF lactate scout, Germany) and test strips (Lactate scout sensors, Germany). The calculation methods for energy system contributions during the 400m-MOC test were referenced from previous study (Beneke et al. 2002, Li et al. 2015). The energy provided by aerobic oxidative system (W_{AER}) is calculated from the accumulated oxygen uptake above the rest level during exercise, W_{AER}=cumulative net oxygen consumption during the 400m-MOC test (ml)× caloric equivalent of oxygen (J/ml). Energy provided by the phosphagen system (W_{PCR}) is calculated from the fast component of oxygen debt, W_{PCR}=fast component of oxygen debt

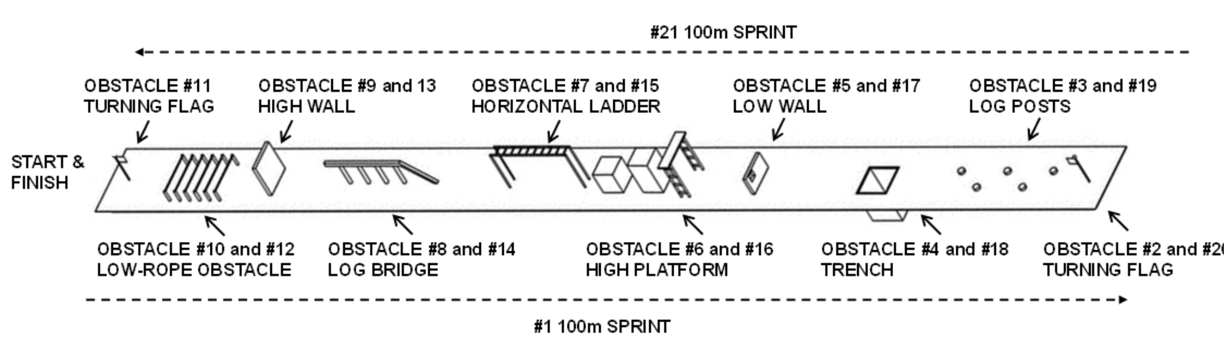

Figure 1. **Schematic Diagram of the 400-meter military obstacle course.**

after 400m-MOC test (ml)× caloric equivalent of oxygen (J/ml). Energy provided by the glycolytic system (W_{BLC}) is calculated from the net production of blood lactate above the rest level during exercise, W_{BLC} =net blood lactate (mmol/l)×oxygen lactate equivalent (ml/kg/mmol'l)×body mass (kg)×caloric equivalent of oxygen (J/ml). In these formulas, cumulative net oxygen consumption during the 400m-MOC test is the actual oxygen consumption minus the resting level of oxygen consumption. The caloric equivalent of oxygen was 21.131 J/ml when the respiratory exchange ratio >1.0. The oxygen lactate equivalent was 3.0 ml/kg/mmol'l. The total energy supply was termed as W_{TOT}, W_{TOT}=W_{PCR} + W_{BLC} + W_{AER}. The calculation of the energy system contributions of three different systems is derived from the ratio of the energy supplied by each system to the total energy supply.

Assessment of body morphology and physical fitness

25 participants of the key physical fitness demands analysis group were also required to undergo two test. The first one was the 400m-MOC test, the second one comprised nine sub-tests, and they were conducted in the following order: height measurement, body weight measurement, vertical jump, 100-meter run, 400-meter run, 2-minute pull-ups, 2-minute sit-ups, 2-minute parallel bar dips, and a 5000-meter run. There was a 48-hour interval between these two testing sessions, participants were not allowed to engage in other training activities within the 48-hour interval as well. These nine daily practice sub-tests were chosen because they offer a comprehensive evaluation of soldiers' physical qualities, including strength, speed, endurance, agility, and more. All nine sub-tests of the second session were completed in the afternoon of the testing day, where we adhered to the principle of initiating with non-fatigue tests, followed by high-intensity low-volume tests, and culminating in endurance tests. A rest period of 3-5 minutes was provided between each sub-test to minimize the effects of fatigue. The vertical jump test was conducted using an electronic measuring device (JYJ-MG, China).

Statistical analysis

Data were presented as Mean ± SD. All data were subjected to test for homogeneity of variance and test for normality by using SPSS (Statistical Package for Social Studies, version 23, SPSS Inc., Chicago). For data that were normally distributed and had homogenous variances, a paired-sample T-test was used to compare differences, such as the comparison of blood lactate concentrations before and after 400m-MOC test. For data not conforming to normal distribution or homogeneity of variance, non-parametric Wilcoxon rank-sum tests were applied for analysis. The correlation between performance of 400m-MOC and the contributions of three different energy systems, body morphology, or various physical fitness components was determined by using either Pearson or Spearman correlation analysis, depending on the distribution characteristics of the data. The degree of correlation was classified as follows according to the correlation coefficient value (r), which was defined as a direct correlation if r was a positive value and an inverse correlation if r was a negative value (Heo et al. 2010) $|r|\geq0.8$ indicating a high correlation, $0.5\leq|r|<0.8$ indicating a moderate correlation, $0.3\leq|r|<0.5$ indicating a low correlation, and $|r|<0.3$ indicating a very weak correlation (Li et al. 2018). The establishment of a predictive model for 400m-MOC performance was conducted using either multiple linear regression analysis or non-linear regression analysis, according to the distribution characteristics of the data.

P<0.05 was considered to be statistically significant in all the statistical analyses.

RESULTS

Energy system contributions during 400m--MOC test

In the energy system contributions study, 25 participants had a relative VO_{2max} test result of 57.93±4.86 ml/kg/min, with a 400m-MOC completion time of 128±9 seconds (see Table I). After the start of the 400m-MOC test, the participants' oxygen uptake (VO_2) showed a rapid increase, reaching its peak level approximately 30 seconds after the start of the test, and maintaining that level until the end of the test. During the recovery phase, VO_2 first decreases rapidly and then gradually. Six minutes after the end of the test, VO_2 has not yet fully recovered to the pre-exercise level (as shown in Figure 2).

Lactate testing results revealed that the blood lactate concentration of the participants before the 400m-MOC test was 1.89±0.57 mmol/l, and the highest concentration after the test was 15.84±2.00 mmol/l (see Figure 3), indicating a highly significant increase in blood lactate concentration (P<0.01). Based on changes in oxygen consumption and lactate testing results during the test, we calculated the contributions of three different energy systems during 400m-MOC test: the phosphagen system accounted for 17.94±1.23%, the glycolytic system for 27.94±2.48%, anaerobic system (phosphagen system + glycolytic system) for 45.88±2.76%, and the aerobic oxidative system for 54.12±2.76% (see Table I).

Table I. Statistics of participants' relative VO_{2max}, 400m-MOC completion time and energy system contributions during 400m-MOC test (n=25).

	Relative VO_{2max} (ml/kg/min)	400m-MOC completion time (s)	Energy system contributions during 400m-MOC Test (%)			
			Phosphagen system	Glycolytic system	Anaerobic system	Aerobic oxidative system
Mean ± SD	57.93±4.86	128±9	17.94±1.23%	27.94±2.48%	45.88±2.76%	54.12±2.76%

Note: Anaerobic system contribution = Phosphagen system contribution + Glycolytic system contribution.

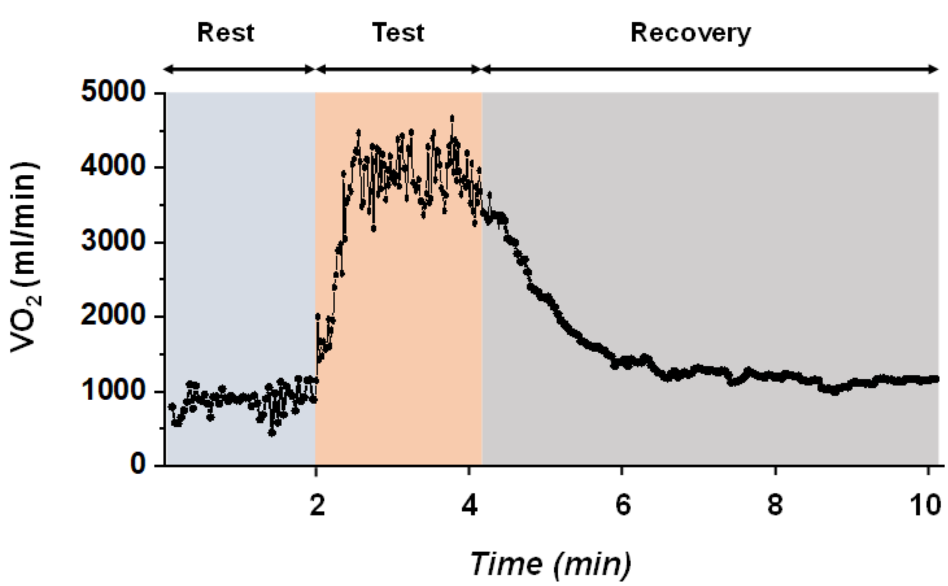

Figure 2. **Diagram of typical dynamic change of VO_2 during 400m-MOC test.**

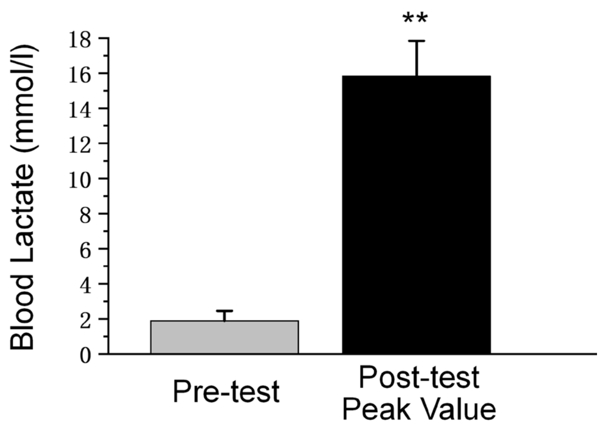

Figure 3. Comparison of blood lactate concentration before and after the 400m-MOC test (n=25). Pre-Test=blood lactate concentration before the 400m-MOC test, Post-Test Peak Value= the highest blood lactate concentration after 400m-MOC test. The data were presented as Mean ± SD, ** compared with Pre-Test, P<0.01.

Correlation between 400m-MOC completion time and relative VO2max, contributions of three different energy systems

Correlation analysis revealed (see Table II) that the 400m-MOC completion time was moderately negatively correlated with both relative VO_{2max} and the contribution of aerobic oxidative system (r = -0.764, P < 0.05; r = -0.685, P < 0.05, respectively), and highly positively correlated with the contribution of glycolytic system (r = 0.817, P < 0.05). It was also moderately positively correlated with the contribution of anaerobic system (r = 0.685, P < 0.05).

Correlation between 400m-MOC completion time and body morphology indicators, physical fitness components and other parameters

Statistical results of body morphology, physical fitness test and other parameters are as presented in Table III. Correlation analysis (see Table IV) showed that the participants' 400m-MOC completion time was weakly negatively correlated with military service length, parallel bar dip reps/body weight, and sit-up reps/body weight (r = -0.428, P < 0.05; r = -0.477, P < 0.01; r = -0.362, P < 0.05, respectively), and moderately negatively correlated with pull-up reps/body weight, and (vertical jump-height)/ body weight (r = -0.658, P < 0.01; r = -0.521, P < 0.01, respectively). It was weakly positively correlated with BMI and 100-meter running time (r = 0.435, P < 0.05; r = 0.429, P < 0.05, respectively),

Table II. Correlation between 400m-MOC completion time and relative VO_{2max}, contributions of three different energy systems (n=25).

	400m-MOC completion time (s)	Relative VO_{2max} (ml/kg/min)	Phosphagen system contribution (%)	Glycolytic system contribution (%)	Anaerobic system contribution (%)	Aerobic oxidative system contribution (%)
400m-MOC completion time (s)	1.000	-0.764*	-0.103	0.817*	0.685*	-0.685*
Relative VO_{2max} (ml/kg/min)		1.000	-0.188	-0.737*	-0.747*	0.747*
Phosphagen system contribution (%)			1.000	-0.022	0.441	-0.441
Glycolytic system contribution (%)				1.000	0.887**	-0.887**
Anaerobic system contribution (%)					1.000	-1.000**
Aerobic oxidative system contribution (%)						1.000

Note: Anaerobic system contribution = Phosphagen system contribution + Glycolytic system contribution. *Statistically significant at the 0.05 level. **Statistically significant at the 0.01 level.

moderately positively correlated with 400-meter running time (r = 0.726, P < 0.01), and highly positively correlated with 5000-meter running time (r = 0.836, P < 0.01).

Multiple regression model for prediction of 400m-MOC performance

Through multivariate stepwise regression analysis (see Table V), three parameters were ultimately selected for the regression equation, with an adjusted R^2 of 0.804. The regression equation was as follows: estimated 400m-MOC completion time = 22.556 + 0.065 × 5000-meter running time - 52.677 × (pull-up reps / body weight) + 0.582 × 400-meter running time. The regression equation was statistically significant (P < 0.01).

DISCUSSION

We explored the energy system contributions and performance determinants in the 400m-MOC and established a model for predicting performance in the 400m-MOC. Our findings revealed that the 400m-MOC is primarily powered by the aerobic oxidative system, its performance correlates significantly with military service length, strength, BMI, speed, speed endurance, and aerobic endurance capability. Among these indicators, aerobic endurance, upper body strength, and speed endurance are particularly crucial.

The direct source of energy supply during human physical activity is adenosine triphosphate (ATP). The energy released from the breakdown of ATP powers muscle

Table III. **Statistical results of participants' body morphology, physical fitness test and other parameters (n=25).**

	Military service length (years)	Height (cm)	Body weight (kg)	BMI	400m-MOC completion time (s)	100-meter run (s)	400-meter run (s)	5000-meter run (s)	2-minute pull-ups (count)	2-minute parallel bar dips (count)	2-minute sit-ups (count)	Vertical jump (cm)
Mean±SD	3.9±1.0	173.5±4.7	68.2±5.5	20.1±1.8	134±11	13.4±0.6	67.0±5.0	1250.0±87.0	11.2±3.5	15.1±4.0	65.4±13.3	275.3±23.1

Table IV. **Correlation between 400m-MOC completion time and body morphology indicators, exercise performance relative to body weight, and other parameters (n=25).**

	400m-MOC completion time (s)	Military service length (years)	Height (cm)	BW (kg)	BMI	100-meter run (s)	400-meter run (s)	5000-meter run (s)	2-minute pull-ups / BW	2-minute parallel bar dips / BW	2-minute sit-ups / BW	(vertical jump - height) / BW
400m-MOC completion time (s)	1.000	-0.428*	-0.027	0.264	0.435*	0.429*	0.726**	0.836**	-0.658**	-0.477**	-0.362*	-0.521**
Military service length (years)		1.000	0.395*	-0.146	-0.304	-0.298	-0.308	-0.439*	0.102	0.041	-0.056	0.184
Height (cm)			1.000	0.524**	-0.010	-0.171	-0.114	-0.025	-0.368*	-0.233	-0.399*	-0.007
BW (kg)				1.000	0.743**	0.308	0.219	0.341	-0.455*	-0.220	-0.409*	-0.654**
BMI					1.000	0.565**	0.331	0.463*	-0.447*	-0.345*	-0.260	-0.815**
100-meter run (s)						1.000	0.666**	0.428*	-0.206	0.019	-0.186	-0.430*
400-meter run (s)							1.000	0.711**	-0.315	-0.103	-0.334	-0.422*
5000-meter run (s)								1.000	-0.461*	-0.265	-0.232	-0.467*
2-minute pull-ups / BW									1.000	0.752**	0.649**	0.554**
2-minute parallel bar dips / BW										1.000	0.573**	0.441*
2-minute sit-ups / BW											1.000	0.468*
(vertical jump - height) / BW												1.000

Note: BW=Body weight; BMI= Body mass index; * statistically significant at the 0.05 level, ** statistically significant at the 0.01 level.

contraction to overcome resistance and perform work, thus converting biological energy into mechanical energy (Linari et al. 2015). Due to the limited storage of ATP in the human body, ATP is consumed and synthesized simultaneously. Its synthesis relies on three different energy systems: the phosphagen system, the glycolytic system, and the aerobic oxidative system. Among them, the phosphagen system and the glycolytic system are collectively referred to as anaerobic system as it does not require oxygen participation (Yang et al. 2022). During physical activity, the three major energy systems are always working simultaneously. However, due to differences in exercise intensity and duration among various sports, the proportion of energy contribution from these three systems varies (Calvo et al. 2021). Therefore, exploring the energy system contributions is crucial for deeply understanding the training specificity of a sports event (Doria et al. 2020, Ulupınar et al. 2021).

We found that during the 400m-MOC test, the energy contribution by the aerobic oxidative system was 54.12±2.76%, while the energy contribution by the anaerobic system was 45.88±2.76% (with the glycolytic system contributing 27.94±2.48% and the phosphagen system contributing 17.94±1.23%). Through further correlation analysis, it was found that there was a moderate negative correlation between the 400m-MOC completion time and the energy contribution from the aerobic oxidative system, while there was a moderate positive correlation between the 400m-MOC completion time and the anaerobic energy contribution. In other words, the higher the proportion of energy contribution from the aerobic oxidative system, the better the performance in the 400m-MOC test; conversely, the higher the proportion of anaerobic energy contribution, the worse the performance. Additionally, the correlation analysis between the 400m-MOC completion time and relative VO_{2max} also demonstrated a moderate negative correlation. Given that relative VO_{2max} is a critical physiological factor affecting the energy supply capacity of the aerobic oxidative system, a higher relative VO_{2max} value suggests a stronger capability of this system (Lee & Zhang 2021). Therefore, both the aerobic oxidative system's energy contribution and relative VO_{2max} are negatively correlated with the 400m-MOC completion time. These results indicate that the 400m-MOC primarily relies on the aerobic oxidative system for its energy supply (54.12±2.76%), although energy contribution from anaerobic system also occupies a relatively high proportion (45.88±2.76%).

Previous report has suggested that the 400m-MOC is primarily powered by anaerobic energy system (Zhai 2018). This conclusion was primarily drawn based on the similarity in distance

Table V. Multiple regression model for prediction of 400m-MOC performance (n=25).

Variable	Non-standardized Regression Coefficients (B)	Standardized Regression Coefficients (Beta)	T-value	P	R^2	Adjusted R^2	F	Sig.
Constant	22.556	-	1.174	0.254	0.830	0.804	32.535	0.000
5000-meter running time	0.065	0.478	3.405	0.003				
Pull-up reps / BW	-52.677	-0.350	-3.367	0.003				
400-meter running time	0.582	0.276	2.103	0.048				

Note: BW=Body weight; P=Probability value; R^2= R-squared; F=F-statistic.

between the 400m-MOC and the 400-meter run. Since the 400-meter run is primarily powered by anaerobic energy system (accounting for 59%) (Duffield et al. 2005) it was assumed that the 400m-MOC should also be primarily powered by anaerobic energy system. This study, for the first time, has precisely calculated the energy system contributions during 400m-MOC through experiments, confirming that the 400m-MOC is primarily powered by the aerobic oxidative system, with a significant contribution from anaerobic system as well. The difference in energy supply mechanisms between the 400-meter run and the 400m-MOC is primarily due to the differences in duration and intensity of the events. Since participants need to overcome various obstacles as they run, this makes the 400m-MOC take longer to complete. Compared to pure running, the speed is relatively slower, and the intensity is correspondingly lower. The analysis of the energy system contributions during 400m-MOC test is of great significance for guiding future training, suggesting that training processes should be specifically designed with targeted methods and intensities to improve soldiers' relative VO_{2max} and anaerobic threshold, thereby enhancing the energy supply capacity of their aerobic oxidative system. This will lay a solid foundation for energy supply to improve soldiers' performance in the 400m-MOC.

In addition to analyzing the energy system contributions of the 400m-MOC, identifying the key physical fitness components affecting the performance is equally crucial for a profound understanding of the training specificity of 400m-MOC (Farina et al. 2021, Orantes-Gonzalez et al. 2022). This study found that 400m-MOC completion time was negatively correlated with military service length, parallel bar dip reps/ body weight, pull-up reps / body weight, sit-up reps / body weight, and (vertical jump - height) / body weight, while positively correlated with BMI index, 100-meter running time, 400-meter running time, and 5000-meter running time. Here, a greater length of military service indicates more years of training and experience; parallel bar dip reps/ body weight and pull-up reps / body weight represent the upper body's push and pull strength against one's own body weight, respectively; sit-up reps / body weight reflect the core strength against one's own body weight; (vertical jump - height) / body weight represents the lower body's explosive power against one's own body weight; and the times for the 100-meter run, 400-meter run, and 5000-meter run respectively represent speed, speed endurance, and aerobic endurance capability (Le Hyaric et al. 2024). These results suggest that more years of training and experience, better strength against one's own body weight, a lower BMI index, and better speed, speed endurance, and aerobic endurance are key factors for better performance in the 400m-MOC. The reason why this study chooses the index of relative strength quality against body weight is as follows: Firstly, it is to eliminate the influence of different weights among different individuals; secondly, in the process of obstacle crossing, a large number of actions such as climbing, crawling, and hanging require overcoming one's own body weight to complete, so it is more reasonable to choose the index of relative strength quality against body weight. The findings of this study show certain similarities with the report from the United States Military Academy (Bishop et al. 1999) which found a significant correlation between performance in the indoor military obstacle course and lighter body weight, greater upper and lower body explosive power against one's own body weight, and stronger latissimus dorsi strength against one's own body weight. Although the indoor military obstacle course differs in content from the 400m-MOC, they both have high demands on soldiers' strength qualities relative to their own body weight. Previous study also found significant correlations between the performance in 400m-MOC and 100-meter run, 200-meter run, 400-meter run, 800-meter run, pull-ups, standing long jump, 10-meter low posture crawl, bench press, and weighted squat (Zhai 2018). These findings share some similarities with those of the current study, however, the 10-meter low posture crawl, bench press, and weighted squat included in the previous study are not commonly assessed items for Chinese officers and soldiers. Additionally, factors such as endurance, as well as body morphology indicators like height, weight, and body mass index, were not taken into account. This study further identifies more key physical fitness components related to 400m-MOC performance, providing valuable reference for the selection of subsequent training methods and the development of training programs. It also reconfirms that the 400m-MOC is a comprehensive event that requires a wide range of physical capabilities and is influenced by a combination of various physical factors.

Based on the analysis of key physical demands, this study also established a predictive model for the performance of 400m-MOC: estimated 400m-MOC completion time = 22.556 + 0.065 × 5000-meter running time - 52.677 × (pull-up reps / body weight) + 0.582 × 400-meter running time. This regression equation includes three physical fitness indicators: 5000-meter running time, pull-up reps/ body weight, and 400-meter running time. In terms of goodness-of-fit, an adjusted R^2 closer to 1 indicates a better fit (Diamond 2016) the adjusted R^2 of this study is 0.804, suggesting a good fit. Regarding model significance, it is determined by the P-value of the F-test. Generally, a P-value less than 0.05 is considered to indicate significance of the model, for this study, it is 0.000, indicating that the regression model has significant statistical meaning. The absolute values of the standardized regression coefficients can be used to compare the importance of different indicators (Nimon & Oswald 2013) in this regression equation, the importance ranking of the three parameters is 5000-meter running time (|0.478|)> pull-up reps/ body weight (|-0.350|) > 400-meter running time (|0.276|), showing that the 5000-meter running time has the greatest impact on the 400m-MOC performance, once again confirming the importance of aerobic oxidative system. The establishment of this predictive model suggests that aerobic endurance, upper body strength, and speed endurance are particularly crucial factors affecting its performance. This will provide significant guidance for officers and soldiers to promptly identify their own deficiencies and thereby improve the specificity and efficiency of their training.

CONCLUSIONS

This study experimentally confirms for the first time that the 400m-MOC is primarily powered by the aerobic oxidative system. Enhancing soldiers' relative VO_{2max} and anaerobic threshold, as well as developing their aerobic oxidative system's energy supply capacity, serves as the metabolic foundation for improving performance in the 400m-MOC. Key factors that influence performance in this event include longer years of training and experience, better strength relative to body weight, a lower BMI index, better speed capability, speed endurance capability, and aerobic endurance capability. Among these indicators, aerobic endurance, upper body strength, and speed endurance are particularly crucial.

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DALEI WANG[1]
https://orcid.org/0000-0001-5329-8208

GUOLE JIANG[1,2]
https://orcid.org/0009-0003-1923-363X

SHUANG QIN[3,4]
https://orcid.org/0009-0003-1722-0392

DEYU SUN[1]
https://orcid.org/0009-0008-5936-4796

JIEXING YAN[1]
https://orcid.org/0009-0009-1619-056X

YUNJI CHEN[1]
https://orcid.org/0009-0004-8591-8474

YEQIONG WANG[1]
https://orcid.org/0009-0001-4624-5295

YIJIE TAN[5]
https://orcid.org/0009-0004-1058-1109

[1]National University of Defense Technology, Basic Education College, 1 Fuyuan Road, Kaifu District, Changsha Hunan 410071, China

[2]Beijing Sport University, Sports Coaching College, 48 Xinxi Road, Haidian District, Beijing 100084, China

[3]Beijing Sport University, School of Sport Medicine and Rehabilitation, 48 Xinxi Road, Haidian District, Beijing 100084, China

[4]Hunan University of Chinese Medicine, College of Acupuncture and Tuina and Rehabilitation, 300 Xueshi Road, Hanpu Science and Education Park, Yuelu District, Changsha Hunan 410208, China

[5]Changsha University, School of Physical Education, 98 Hongshan Road, Kaifu District, Changsha Hunan 410022, China

Correspondence to: **Guole Jiang**
E-mail: jguole0524@bsu.edu.cn

Author contributions

Dalei Wang and Guole Jiang designed this research. Dalei Wang, Guole Jiang and Shuang Qin, collected and analyzed the data and drafted the original manuscript. Deyu Sun, Jiexing Yan, Yunji Chen and Yeqiong Wang conducted the experiment and collected the data. Yijie Tan edited the manuscript. All authors read and approved the final manuscript.