

Relationship between anthropometrics and physiological determinants on military-specific skills

HORST STOCKER¹, PETER LEO², STEFAN LANDL³
^{1,2,3}Department of Physical Training, Theresian Military Academy, AUSTRIA

Published online: September 30, 2019
(Accepted for publication: August 30, 2019)
DOI:10.7752/jpes.2019.03242

Abstract:

The assessment and longitudinal monitoring of officer cadet's anthropometrics and physiological characteristics are indirectly related to their military specific skills. In previous research evaluations of testing procedures and performance determinants have been investigated intensively. Therefore, the aim of this study was to evaluate the relationship of anthropometrics and performance characteristics on military specific skills. In this study 53 male officer cadets (N=53; mean \pm SD age 24.6 \pm 4.6 years; body mass 77.2 \pm 9.3 kg; height 1.80 \pm 0.6 cm; BMI 24.1 \pm 2.2; $\dot{V}O_{2max}$ 53.74 \pm 3.0 mL·kg⁻¹ min⁻¹) were assigned to this study. Testing procedure involved a 2400m running test, one repetition maximum (1RM), military specific test (MST) and military march. Correlation and multi regression analyses were conducted to compare the relationship between strength and endurance parameters on the military specific skills. Derived $\dot{V}O_{2max}$ of the 2400m running test significantly correlated with BMI (r = -0.285, p = 0.033). BMI significantly influenced 1RM of leg press LP (r = 0.389, p = 0.004), seated bench pull SBP (r = 0.710, p = 0.001) and seated bench pull SR (r = 0.570, p = 0.001). In addition, height significantly correlated with 1 RM of LP (r = 0.349, p = 0.010). Linear correlation according to Pearson compared the influence of physical performance parameters including 2400m running test, 1 RM of LP, SBP and SR on the MST and the 3200m march. 1RM of LP, SBP and SR did not correlate significantly with MST and the military march (p > 0.005). However, $\dot{V}O_{2max}$ derived from the 2400m running test showed a significant relationship with the total time in the MST (r = -0.340, p = 0.010) and military march (r = -0.428, p = 0.001). The results indicate that the endurance determinants predominantly influence the military specific skills more than the 1RM. In addition, the importance of a high level of muscular endurance for MST and the 3200m march are recommended.

Key Words: physical fitness, military basic tasks, BMI, oxygen uptake, muscular endurance,

Introduction

Many changes in the society have had major effects on the role of the military of today. New health standards, changes of motoric and physiological capabilities of children and young adults [22] have impact on the selection process of required personnel [9]. In the course of history, different criteria have been used to determine who would be selected to enter military as professional soldier. As a consequence, there is less tolerance for poor performance in strength, coordination and endurance [16] for a further military career [20]. Weak physical fitness in case of overweight and inactivity has influence on sickness absence [1] and overuse injuries [13] during training [23]. To identify the appropriate potential for a cadre function common fitness tests were used but relationship to job performance was not always clear. In previous researches [21] several tasks were defined which are common for all soldiers as basic skills to perform [10]. According to NATO research manual movement of equipment along a surface, repeated lifting equipment on/ off ground or vehicle, carry various equipment items over distances, move fast- with or without change of direction for short distances, crawl in high and low techniques and march with load were considered as military basic tasks in this research study [17]. The aim of the study was to investigate the correlations between common fitness tests and simulated basic military tasks.

Material & methods

53 male officer cadets were recruited for this study. Each of them attends a three-year academic military leadership degree program at the Theresian Military Academy in Wiener Neustadt, Austria. In this educational program daily physical fitness and activities are of great importance in order to ensure adequate fitness for military tasks/operations as well as for a healthy and balanced lifestyle. The evaluation and assessment of a standardized physical testing battery is approached since multiple years.

This testing procedure involves:

- 2400m running test

- One repetition maximum test
- Loaded military march
- Military Specific Test

2400m Running Test

The selected distance was applied to the Cooper Test concept which is an often-used method to quantify aerobic fitness in military research. The test was performed on a 400m running track, with a 15min individual warm up program. The officer cadets were registered with a bib number in order to ensure accurate lap count and timing. The subjects were sent off in a 5 second countdown and each of them was asked to perform maximum exertion at each stage of the test. In order to exclude a learning effect, participants performed two recognitional trials prior to the intervention. One repetition maximum test

One repetition maximum

One repetition maximum (1RM) was assessed on a machine based multi rowing machine (see figure below). Leg press (LP), seated bench press (SBP) and seated bench pull (SR) were the selected exercises.

Loaded March and Military Specific Test

Military specific skills involved a 3.200m march in full military equipment (KAZ 03/3 with weapon AUG77 see figure below) carrying 25kg load. The goal was to finish the 3.200m on selective terrain in the fastest possible time for each individual.



Figure 1: Concept 2 Dyno see Concept 2 Training Guide



Figure 2: Soldier with full military equipment

The second part is the military specific test (MST), which includes four sections (see figure below). Total time as well as split times were recorded. Section A: Moving in selective terrain includes change in direction, speed and position over a total distance of 140m including 10m of crawling.

Section B: Load pulling of 50kg over a total distance of 40m
 Section C: Load carrying of 2x18kg over a total distance of 100m.(exercise farmer's walk)
 Section D: Load lifting / releasing of 5x24kg on a 125cm high box (exercise dead lift)

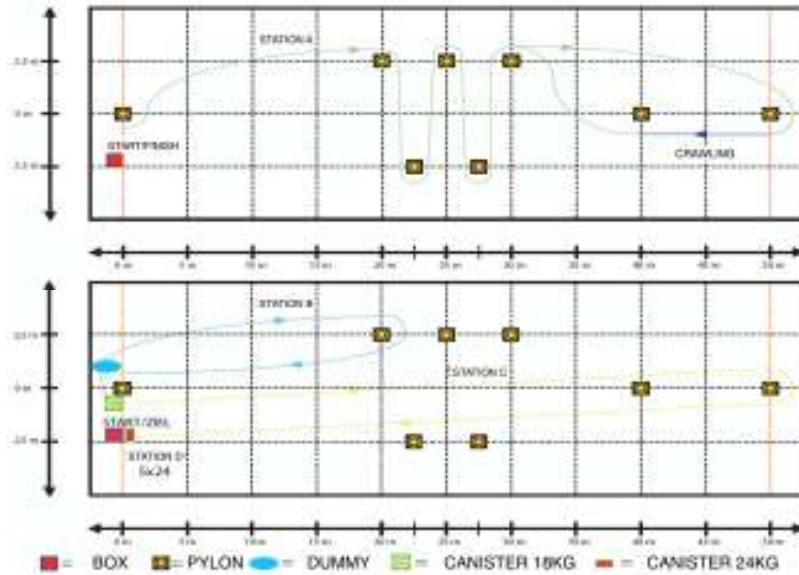


Figure 3: Military Specific Test

Data analysis

Split times of military basic tasks, 2400m running test and loaded march were recorded with a manual timing system (Hanhart Modul 3, Hanhart 1882 GmbH, Güttenbach, Germany). One repetition maximum (1RM) for leg press (LB), seated bench press (SBP) and seated bench pull (SR) were performed on a machine based multi rowing machine (Concept 2 Dyno, Concept 2 Ltd, UK). In a further step second by second data and 1RM values were prepared in Microsoft Excel (Windows 10, Microsoft Windows, Washington, US) for statistical calculations. Relative $\dot{V}O_{2max}$ values were derived from the 2400m distance running time using following equation according to the Cooper test [4].

$$\dot{V}O_{2max} (ml \cdot min^{-1} \cdot kg^{-1}) = 3.5 + \frac{483}{2400m \ time \ [min]}$$

A further formula derived $\dot{V}O_{2max}$ from 2400m running time was applied to compare the original Cooper based results with the new approach.

$$\dot{V}O_{2max} (ml \cdot min^{-1} \cdot kg^{-1}) = \frac{388849}{2400m \ time \ [sec]} - 11.288$$

However, the new approach indicated a higher standard deviation and coefficient of variation compared to the traditional method [13], so the cooper formula was selected for $\dot{V}O_{2max}$ estimation.

Statistics All descriptive data are presented as mean ± standard deviation (SD). Normal distribution of the data was tested using Shapiro Wilk (p>0.05). Correlation and multi regression analyses were conducted to compare the relationship between strength and endurance parameters on the soldier's occupational tasks. All statistical analyses were generated using the SPSS statistics 20 software package (IBM Corporation, Armonk, New York).

Results

3.1. Subjects

The officer cadets (N = 53, Age: 24.6 ± 4.6 years) average of maximum oxygen consumption ($\dot{V}O_{2max}$) of 53.74 ml · min⁻¹ · kg⁻¹ during the 2400m distance running test to maximal exertion. The subject's anthropometric and physiological characteristics are listed in the table below.

Table 1: Descriptive statistics of the physiological and anthropometric profile (mean ± SD; 95 % CI confidence interval).

Variables	Mean ± SD N = 53	95 % CI N = 53
Age [Years]	24.6 ± 4.6	23.3 – 25.9
Height [m]	1.80 ± 0.6	1.78 – 1.81
Body mass [kg]	77.2 ± 9.3	74.6 – 79.8
BMI [$\frac{kg}{m^2}$]	24.1 ± 2.2	23.4 – 24.7
relative $\dot{V}O_{2max}$ [ml · min ⁻¹ · kg ⁻¹]	53.74 ± 3.0	52.8 – 54.5

BMI = body mass index, $\dot{V}O_2$ = maximum oxygen consumption

Physical Performance Tests

For cardiorespiratory fitness a standardized 2400m running test was performed on a track to assess endurance performance. Regarding strength testing push-ups, leg press, bench press and bench pull were performed on a concept. In table 2 physical performance parameters are presented.

Table 2: Descriptive statistics of the physical performance tests (mean ± SD; 95 % confidence interval).

Variables	Mean ± SD N = 53	95 % CI N = 53
2400m Test [mm:ss]	09:37 ± 34 [s]	09:26 – 09:46
Military Specific Test [mm:ss]	02:15 ± 35 [s]	02:04 – 02:25
Military March [mm:ss]	19:40 ± 02:02	19:04 – 20:16
Push-Up [reps]	40 ± 9	37 – 43
Leg press [kg]	264 ± 41	251 – 277
Seated Bench Press [kg]	98 ± 16	93 – 104
Seated Bench Pull [kg]	103 ± 17	97 – 109

Military Specific Test

Military basic skills were assessed with a military specific test as described above. Participants had to complete all four sections in one run (see table below).

Table 3: Descriptive statistics of the occupational tasks (mean ± SD; 95 % confidence interval).

Variables	Mean ± SD N = 53	95 % CI N = 53
Total [mm:ss]	02:15 ± 35 [s]	02:04 – 02:25
Station A [s]	55.7 ± 4.7	54.38 – 57.07
Station B [s]	24.4 ± 3.7	23.3 – 25.4
Station C [s]	45.3 ± 7.0	43.3 – 47.3
Station D [s]	15.1 ± 10.1	12.3 – 18.0

Influence of anthropometrics on physical performance

Pearson’s linear correlation was used to investigate the effects of anthropometric parameters height, body mass and body mass index (BMI) on the 2400m running test (see table 4). No significant relationship was found between height ($r = -0.199$, $p = 0.142$), body mass ($r = -0.008$, $p = 0.548$) and BMI ($r = 0.057$, $p = 0.677$) on 2400 m running time. Derived $\dot{V}O_{2max}$ of the 2400m running test however significantly correlated with BMI ($r = -0.285$, $p = 0.033$). Regarding strength parameters LP, SBP, and SR no significant relationship was found for body mass ($p > 0.05$). BMI significantly influenced LP ($r = 0.389$, $p = 0.004$), SBP ($r = 0.710$, $p = 0.001$) and SR ($r = 0.570$, $p = 0.001$). In addition, height significantly correlated with the LP ($r = 0.349$, $p = 0.010$). A multi linear regression analysis compared the influence of anthropometrics on strength parameters and showed a significant influence on the LP ($F_{(3,49)} = 6.173$, $p = 0.001$) with a R^2 of 25.3% explained variance. Height ($p = 0.004$) and BMI ($p = 0.001$) demonstrated a significant influence on the LP.

Table 4: Pearson correlation coefficient on anthropometrics and physiological determinants

	BM [kg]		Height [cm]		BMI		$\dot{V}O_{2max}$ [ml/min/kg]	
	r	p	r	p	r	p	r	p
Leg Press [kg]	-0.70	0.621	0.34	0.010*	0.38	0.004	0.12	0.360
Seated Bench Press [kg]	-0.43	0.762	0.19	0.157	0.71	0.001*	-0.05	0.969
Seated Bench Pull [kg]	-0.22	0.887	0.13	0.376	0.57	0.001*	-0.00	0.969
2400m running [mm:ss]	-0.00	0.952	0.19	0.142	0.57	0.677	-0.22	0.104
Military march [mm:ss]	-0.21	0.114	0.45	0.743	0.53	0.699	-0.42	0.001*
Military Specific Test [mm:ss]	-0.25	0.61	-0.14	0.287	0.10	0.941	-0.34	0.010*

BM = body mass, BMI = body mass index, $\dot{V}O_{2max}$ = relative maximum oxygen uptake, *significant relationship

Influence of physical performance on military specific skills

Linear correlation according to Pearson compared the influence of physical performance parameters including 2400m running test, LP, SBP and SR on the soldier cadet’s military specific skills including the MST and military march (see table 4). Strength parameters did not correlate significantly with the MST and military march ($p > 0.005$). However as shown in Table 4 below, $\dot{V}O_{2max}$ derived from the 2400m running test showed a significant relationship with total time in the MST ($r = -0.340$, $p = 0.010$) as well as all split times ($p < 0.05$). Furthermore $\dot{V}O_{2max}$ was found to have a significant effect on the military march ($r = -0.428$, $p = 0.001$) see Figure 4.

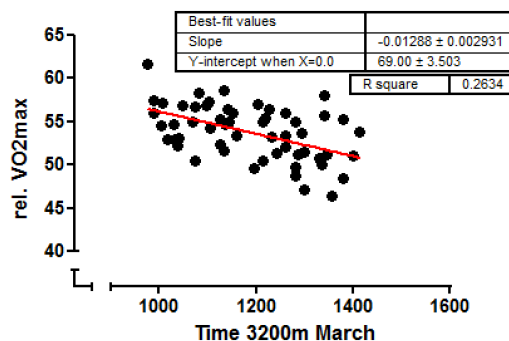


Figure 4: Relationship of $\dot{V}O_{2max}$ and military walk

Discussion

As the results of this study indicate aerobic performance is a strong determinant of military specific skills. In contrary 1RM of LP, SBP and SR did not show a statistically significant relationship with the MST and military walk. The subjects in this study were classified as moderately trained according to the aerobic determinants [15] with small variations in weight and BMI. These findings are in contrast to other studies in military research, where large effects have been reported in the relationship of anthropometric and physical determinants [18]. In addition, the influence of anthropometrics on physical performance is often associated to lean body mass [19] predominantly in studies with large heterogeneity. The collective homogeneity in this study is probably due to pre selection criteria for officer cadets while other research is mainly based on cross sectional data from soldiers in military basic training to special forces [6]. Muscular strength has shown to be related to military specific skills in the literature **Error! Reference source not found.** Especially muscular endurance ability has been named frequently as a greater predictor for military fitness than 1RM [3]. These findings are in line to our observations, as 1RM of upper and lower extremities did not show a significant relationship to either general physical performance nor military specific skills. Cardiorespiratory fitness in general and military population is known to be an important aspect for both, health and performance. Due to that reason many military fitness test batteries consist of minimum one cardiorespiratory fitness assessment. The most commonly used methods in the literature are capacity tests in form of fixed distance or duration among 1.5-3km or 8-12min in order to reach $\dot{V}O_{2max}$ [8]. As an alternative, shuttle runs can be performed depending on the available material and group size. The approach in this study for assessing cardiorespiratory fitness was based on current military research recommendations. In this study a close interaction of 2400m running performance to military specific skills as well as to the military march can be confirmed. These findings support that aerobic performance might have a larger influence on military performance than 1RM, which is also confirmed by other research findings [11].

One limitation of this study is that $\dot{V}O_{2max}$ values of the 2400m running test have not been measured directly with a breath by breath spiro-ergometry system. This could lead to under- or overestimation of real $\dot{V}O_{2max}$ for an individual [2]. Nevertheless, applying the Cooper formula in large cohorts [5] like the military has been a frequently used method, which was one of the reasons why $\dot{V}O_{2max}$ in this study was derived from 2400m running time [12].

Conclusions

The results indicate that the endurance determinants predominantly influence the military specific skills more than the 1RM. In addition, these findings underpin the importance of a high level of muscular endurance for MST and the military march [13]. Anthropometric characteristics have demonstrated to influence both strength [18] and endurance components [5]. We recommend further research in this direction to get a better understanding for requirements for military specific skills.

References:

- [1] Anderson, M. K., Grier, T., Hauschild, V., & Jones, B. H. (2015). Injury Rates, Limited Duty Days, Medically Not Ready Rates, and Injury Risk Factors in an Army Chemical Brigade (No. USAPHC-TR-S. 0032423.3-15). Army Public Health Center (Provisional) Aberdeen Proving Ground MD.
- [2] Batista, M. B., Romanzini, C. L. P., Castro-Piñero, J., & Ronque, E. R. V. (2017). Validity of field tests to estimate cardiorespiratory fitness in children and adolescents: a systematic review. *Revista Paulista de Pediatria*, 35(2), 222-233
- [3] Colmenero, M. H., Vicente, G. F., & Ruiz, J. R. (2014). Assessment of physical fitness in military and security forces: a systematic review. *European Journal of Human Movement*, (32), 3-28.
- [4] Cooper, K. H. (1968). A means of assessing maximal oxygen intake: correlation between field and treadmill testing. *Jama*, 203(3), 201-204.

-
- [5] Drinkard, B., McDuffie, J., McCann, S., Uwaifo, G. I., Nicholson, J., & Yanovski, J. A. (2001). Relationships between walk/run performance and cardiorespiratory fitness in adolescents who are overweight. *Physical Therapy*, 81(12), 1889-1896.
- [6] Farina, E. K., Taylor, J. C., Means, G. E., Williams, K. W., Murphy, N. E., Margolis, L. M., ... & McClung, J. P. (2017). Effects of combat deployment on anthropometrics and physiological status of US Army special operations forces soldiers. *Military medicine*, 182(3-4), e1659-e1668.
- [7] Friedl, K. E., Knapik, J. J., Häkkinen, K., Baumgartner, N., Groeller, H., Taylor, N. A., ... & Nindl, B. C. (2015). Perspectives on aerobic and strength influences on military physical readiness: report of an international military physiology roundtable. *The Journal of Strength & Conditioning Research*, 29, S10-S23.
- [8] Grant, S., Corbett, K., Amjad, A. M., Wilson, J., & Aitchison, T. (1995). A comparison of methods of predicting maximum oxygen uptake. *British journal of sports medicine*, 29(3), 147-152.
- [9] Hansen, B. H., Anderssen, S. A., Andersen, L. B., Hildebrand, M., Kolle, E., Steene-Johannessen, J., ... & Sardinha, L. B. (2018). Cross-sectional associations of reallocating time between sedentary and active behaviours on cardiometabolic risk factors in young people: An International Children's Accelerometry Database (ICAD) analysis. *Sports medicine*, 48(10), 2401-2412.
- [10] Hauschild, V. D., DeGroot, D. W., Hall, S. M., Grier, T. L., Deaver, K. D., Hauret, K. G., & Jones, B. H. (2017). Fitness tests and occupational tasks of military interest: a systematic review of correlations. *Occup Environ Med*, 74(2), 144-153.
- [11] Knapik, J., Daniels, W., Murphy, M., Fitzgerald, P., Drews, F., & Vogel, J. (1990). Physiological factors in infantry operations. *European journal of applied physiology and occupational physiology*, 60(3), 233-238.
- [12] Kuipers, H., Verstappen, F. T. J., Keizer, H. A., Geurten, P., & Van Kranenburg, G. (1985). Variability of aerobic performance in the laboratory and its physiologic correlates. *International journal of sports medicine*, 6(04), 197-201.
- [13] Kyröläinen, H., Häkkinen, K., Kautiainen, H., Santtila, M., Pihlainen, K., & Häkkinen, A. (2008). Physical fitness, BMI and sickness absence in male military personnel. *Occupational medicine*, 58(4), 251-256.
- [14] Leamon, S. M., & Nevola, V. R. (2003). A review of health-related physical fitness and its application within the UK Armed Forces. QinetiQ. KI/CHS/PUB030167. QinetiQ Group plc, Farnborough.
- [15] McArdle, W. D., Katch, F. I., & Katch, V. L. (1991). *Exercise physiology: energy, nutrition, and human performance*.
- [16] Nindl, B. C., Beals, K., Witchalls, J., & Friedl, K. E. (2017). Military human performance optimization and injury prevention: strategies for the 21st century warfighter. *Journal of science and medicine in sport*, 20, S1-S2.
- [17] *Optimizing Operational Physical Fitness. Final Report of Task Group 019, NATO. Research and Technology Organisation, 2009.*
- [18] Pierce, J. R., DeGroot, D. W., Grier, T. L., Hauret, K. G., Nindl, B. C., East, W. B., & Jones, B. H. (2017). Body mass index predicts selected physical fitness attributes but is not associated with performance on military relevant tasks in US Army Soldiers. *Journal of science and medicine in sport*, 20, S79-S84.
- [19] Reilly, T., Spivock, M., Prayal-Brown, A., Stockbrugger, B., & Blacklock, R. (2016). The influence of anthropometrics on physical employment standard performance. *Occupational Medicine*, 66(7), 576-579.
- [20] Robinson, M., Siddall, A., Bilzon, J., Thompson, D., Greeves, J., Izard, R., & Stokes, K. (2016). Low fitness, low body mass and prior injury predict injury risk during military recruit training: a prospective cohort study in the British Army. *BMJ open sport & exercise medicine*, 2(1), e000100.
- [21] Rohde, U., Rüter, T., & Leyk, D. (2017). Basic Military Fitness Tool (BMFT): A reliable field uniform-test for performance prediction of strength-related common military tasks. *Journal of Science and Medicine in Sport*, 20, S170.
- [22] Ruiz, J. R., Cavero-Redondo, I., Ortega, F. B., Welk, G. J., Andersen, L. B., & Martinez-Vizcaino, V. (2016). Cardiorespiratory fitness cut points to avoid cardiovascular disease risk in children and adolescents; what level of fitness should raise a red flag? A systematic review and meta-analysis. *Br J Sports Med*, 50(23), 1451-1458.
- [23] Taanila, H., Suni, J. H., Kannus, P., Pihlajamäki, H., Ruohola, J. P., Viskari, J., & Parkkari, J. (2015). Risk factors of acute and overuse musculoskeletal injuries among young conscripts: a population-based cohort study. *BMC musculoskeletal disorders*, 16(1), 104.
- [24] Vaara, J. P., Kyröläinen, H., Niemi, J., Ohrankämmen, O., Häkkinen, A., Kocay, S., & Häkkinen, K. (2012). Associations of maximal strength and muscular endurance test scores with cardiorespiratory fitness and body composition. *The Journal of Strength & Conditioning Research*, 26(8), 2078-2086.