Aandstad, A., Sandberg, F., Hageberg, R., Kolle, E. (2020). Change in anthropometrics and physical fitness in norwegian cadets during 3 years of military academy education. *Military medicine, 185*(7-8), E1112-E1119. 10.1093/milmed/usz470

Pages: 17
Words: 3998
Tables: 4
Supplemental materials (Figures): 2
References: 30
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Change in Anthropometrics and Physical Fitness in Norwegian Cadets during 3 Years of Military Academy Education

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Running head (short title): Physical Fitness in Cadets

Funding/COI: None

Acknowledgments: We would to thank all the cadets for participating in the study, and the sports officers for assisting during testing. Thanks to the Norwegian Defence University College, the Norwegian Military Academy, the Royal Norwegian Naval Academy and the Royal Norwegian Air Force Academy for general support of the study. Finally, thanks to Elena V. Aandstad for language revision.

Disclaimer: The views expressed are solely those of the authors and do not reflect the official policy or position of the Norwegian Defence University College, the Ministry of Defence or the Norwegian Government.

Keywords: Aerobic power, muscle strength, body composition, soldiers, longitudinal

ABSTRACT

Introduction: High physical fitness is associated with increased occupational performance, better health and reduced risk of injuries in military personnel. Thus, the military emphasizes physical training to maintain or develop physical fitness in their soldiers. It is important to monitor the effect of the physical training regime, but such information is lacking for Norwegian military cadets. Hence, the primary aim of the present study was to investigate changes in anthropometrics and physical fitness among male and female Norwegian Army, Navy and Air Force cadets during 3 years of military academy education.

Materials and methods: 260 male and 29 female Norwegian cadets from the Army, Navy and Air Force academies volunteered to participate. Anthropometrics, muscular power, muscular endurance and maximal oxygen uptake were measured at entry (T0) and end of each year (T1, T2 and T3). Linear mixed models were used to examine the development in anthropometrics and physical fitness. We applied to the Regional Committee for Medical and Health Research Ethics to review the study prior to start-up, but the study was considered exempted from notification. The study was reviewed and approved by the Norwegian Social Science Data Services.

Results: Male and female cadets significantly increased their body weight, fat free mass, body mass index and percent body fat by 1–5% from T0 to T3. Skeletal muscle mass was unchanged. Muscular power (medicine ball throw and vertical jump) and muscular endurance (pull-ups and push-ups) increased by 3–20% in male cadets, while female cadets only increased results significantly for the medicine ball throw (10%). Relative maximal oxygen uptake decreased by 4% in both sexes, while absolute maximal oxygen uptake only decreased significantly (by 2%) in male cadets. Most of the observed changes were classified as trivial or small, according to calculated effect sizes. The observed changes were generally of similar magnitude for male and female cadets, and similar among the three academies.

Conclusions: Anthropometrics and physical fitness were relatively stable in Norwegian male and female Army, Navy and Air Force cadets during 3 years of military academy education. Observed

changes were typically classified as trivial or small. The initial gap in physical fitness between male and female cadets did not narrow during the education years. Norwegian male and female cadets displayed relatively good physical fitness profiles, compared to sex-matched cadets and soldiers from previously studied military populations.

INTRODUCTION

Physical fitness is a valued attribute in military personnel, as higher fitness coincides with greater military performance, better health and fewer injuries and disabilities.[1-4] Muscular strength (including power), muscular endurance, cardiorespiratory endurance (aerobic power) and body composition are important components of physical fitness.[5] The military emphasizes development of all of these components, since fitness is considered a "force multiplier" on the battlefield. Thus, it is important to study military personnel's fitness levels and their development during training and education, to gain knowledge on how to develop these elements effectively.

Cross-sectional levels of physical fitness and its change during military training are described in several studies of both professional and conscript soldiers worldwide.[6-9] Previous publications also include military cadets, but these studies are typically hampered by low sample sizes,[10,11] short follow-up periods,[12,13] or male-only populations.[14-16] Today, an increasing number of females serve in the armed forces. Thus, we need data on both sexes, as female soldiers may differ from males regarding fitness level, effect of exercise training, and injury risk.[13,17,18] Furthermore, the majority of previous studies have included cadets from only one military branch or academy, resulting in few comparisons among Army, Navy and Air Force. The branches may emphasize physical capacity differently during selection and education, and it is therefore necessary to include representative samples of both male and female cadets from all branches.

An academy education for an officer will typically last from one to several years. Physical fitness may change significantly over such a long time span, and longitudinal study designs are therefore needed. We have identified a few previous studies reporting longitudinal (9 months to 4 years) changes in fitness levels in military cadets.[10,11,14,16,17,19] One is our own pilot study, where we examined changes in anthropometrics and aerobic power among male Norwegian Air Force cadets during 3 years of academy education.[14] The data revealed no significant changes in any of the fitness measurements between entry and end of the education period. Shortcomings in our previous study were the inclusion of only male cadets from one academy and branch, and that we did not measure muscular strength, muscular power, or muscular endurance.

Cadets educated at one of the Norwegian military academies will fill different types of jobs in the Norwegian Armed Forces, such as platoon commanders, staff officers, ship officers or logistics officers. Some will proceed with more leadership education, while a few may ultimately become fighter pilots or special operation force soldiers. Hence, the necessity of a high fitness level will vary among the cadets. During the academy years, all cadets participate in military training and field exercises that are physically strenuous.[20] Relatively good fitness is therefore required during the academy years and possibly also in their future military assignments. Although physical training is emphasized during the education period, the effect of this training is not well known. Thus, a longitudinal study of changes in cadets' physical fitness should give valuable feedback to the academies on the outcome of the implemented exercise training.

The main aim of this study was to examine changes in anthropometrics, aerobic power, muscular power and muscular endurance among Norwegian male and female Army, Navy and Air Force cadets during 3 years of military academy education.

MATERIALS AND METHODS

Study design

This 3-year longitudinal observational multi-center study had four periods of data collection. The first test period (baseline, T0) took place within the first week after enrollment at the academy. The subsequent three test periods were administered within the two final months of the first (T1), second (T2) and third (T3) study year, respectively.

Subjects

We invited all male (n = 260) and female cadets (n = 29) from the classes of 2010 and 2011 at the Norwegian Military (Army) Academy (Oslo), the Royal Norwegian Naval Academy (Bergen) and the Royal Norwegian Air Force Academy (Trondheim) to participate in the study. All 289 cadets volunteered and gave their informed written consent. We applied to the Regional Committee for Medical and Health Research Ethics to review the study prior to start-up, and the study was considered exempted from notification. The study was reviewed and approved by the Norwegian Social Science Data Services. Mean (SD) age at baseline was 23.1 (2.7) and 22.5 (2.3) years for male and female cadets, respectively ($p = 0.335$). There were also no significant differences in age among the three academies ($p = 0.129$).

Almost half (n = 136) of the cadets who initially volunteered to participate either withdrew from the study at a later stage or were transferred to another military location in Norway or abroad. Other cadets were temporarily sick, injured or absent during one or several measurements or test periods. As long as a cadet participated in at least one data collection period, his or her data were included in the analysis. Figure 1S (see supplemental materials) provides a flowchart illustrating the number of cadets with accepted data for the different test variables during the course of the study, including permanent dropouts. Of the 289 cadets who initially volunteered for the study, participation rates were 95%, 83%, 54% and 40% at T0, T1, T2 and T3, respectively.

Data collection and measurements

The data collection took place locally at the academies. The same two test leaders (A.Aa. and R.H.) administered the testing during the study, using the same protocols and equipment at all four data collection periods. Sport teachers from the academies occasionally assisted during testing.

Bodyweight (BW) and height were measured using a combined digital scale and stadiometer (model 708, Seca Corp., Hamburg, Germany) to the nearest 0.1 kg and 5 mm, respectively. Height was measured only at baseline. The scale was calibrated with 40–80 kg of weight plates (Eleiko Sport AB, Halmstad, Sweden) before each period. Body mass index (BMI) was calculated by dividing BW (kg) by height (m) squared.

Body composition was measured with a Quantum II (RJL Systems Inc., Clinton Township, MI) single frequency bioelectrical impedance analysis (BIA). Details of this procedure have been explained elsewhere.[14] Testing was conducted in the morning before breakfast (6–7:30 a.m.) with the cadets in an overnight fasting condition. The subjects were allowed to drink water *ad libitum* prior to testing. The following equations were used to calculate fat free mass (FFM), skeletal muscle mass (SMM) and percent body fat (BF):

FFM (males) = $0.485 \cdot H^2/R + 0.338 \cdot BW + 5.32$.[21]

FFM (females) = $0.476 \cdot H^2/R + 0.295 \cdot BW + 5.49$.[21]

SMM = $0.401 \cdot H^2/R + 3.825 \cdot \text{sex} - 0.071 \cdot \text{age} + 5.102$.[22]

BF (%) = $[(BW - FFM)/BW] \cdot 100$.

H = height (cm); R = resistance (ohm); BW = body weight (kg); age (years); sex, female = 0 and male = 1

We have previously reported reliability and validity of the FFM equations applied to military personnel, including male and female cadets.[23]

Maximal oxygen uptake ($\dot{V}O_{2max}$) was measured directly in a mobile test laboratory placed at the military academies. All subjects were familiar with the test, since a familiarization trial was administered 1 or 2 days prior to the “true” baseline $\dot{V}O_{2max}$ test. The familiarization trial was terminated 1–2 minutes before maximal effort was achieved. The $\dot{V}O_{2max}$ test started with the subject completing a warm-up procedure consisting of 15 minutes low-to-moderate intensity running, 3x30 seconds high intensity running, followed by a 2–3 minutes of stretching. The subject then put on the nose clip and mouthpiece, the latter connected to a two-way valve (model 2700, Hans Rudolf Inc., Shawnee, KS). The test was performed on a treadmill (model PPS 55 Sport, Woodway GmbH, Weil am Rhein, Germany) using a stepwise protocol with constant incline of 5.2%. Initial speed was set individually (8–13 $km \cdot h^{-1}$) so that fatigue would be expected to occur within 4–7 minutes of running. Initial speed was based on self-reported 3,000-m run time and performance in the treadmill familiarization trial. The initial running speed was kept similar for all four data collection periods. Time to exhaustion (TTE) was registered at the time the cadet could no longer continue running. Peak heart rate (HR_{peak}) was registered (model S 610, Polar Electro OY, Kempele, Finland) during the test. A blood sample was taken from a fingertip 3 minutes post test and analyzed (model 1500 Sport; YSI Inc., Yellow Springs, OH) for peak blood lactate concentration $[La^{-}]b_{peak}$. Oxygen uptake was measured continuously with an automated metabolic gas analysis system (model Oxycon Pro, Erich Jaeger GmbH, Hoechberg, Germany), using the mixing chamber mode set at 30 second sampling intervals. The average of the two highest consecutive measurements was registered as $\dot{V}O_{2max}$. The system was gas calibrated with room air and certified calibration gases, and volume calibrated manually with a 3-L syringe (Hans Rudolf Inc.), before every second test (once every hour). The main criterion for accepting the $\dot{V}O_{2max}$ test was an observed leveling off for $\dot{V}O_2$ at the end of the test (less than 2 $mL \cdot kg^{-1} \cdot min^{-1}$ increase between the two last measurements). If the main criterion was not met, the test was still accepted if both peak respiratory exchange ratio (RER_{peak}) and $[La^{-}]b_{peak}$ were ≥ 1.1 and 8.0 $mmol \cdot L^{-1}$, respectively. Due to technical errors in the metabolic analyzer, $\dot{V}O_{2max}$ data from 101 tests at T1 were not accepted and consequently excluded from the analysis.

Muscular power was assessed by vertical jump and medicine ball throw. The starting position for the vertical jump was upright with the dominant side of the body next to a wall. The dominant arm was raised straight up as high as possible to mark the standing height with the middle finger covered in black shoe polish. The ankles and knees were flexed and arms were swung to enhance the propelling upward movement of the body. The difference between the reached height mark and the jump height mark was measured in centimeters with a tape measure. The starting position for the medicine ball throw was upright with the feet placed shoulder-width apart behind a tape mark on the floor. The arms were flexed while the hands held a 6-kg medicine ball (model all in sport, IFAS Sport A/S, Dal, Norway) against the center of the chest. The ankles, knees and hips were flexed and arms were forcefully extended to enhance the propelling forward movement of the ball. The feet were not allowed to lose contact with the floor or touch the tape mark on the floor during the throw. The spot where the ball hit the floor was recorded to the nearest 0.5 meter using tape marks on the floor as guidance. One to three familiarization trials were given prior to vertical jump and medicine ball throw testing. Three trials were then performed, with the best result in each event recorded.

Muscular endurance was assessed by tests of push-ups and pull-ups. Push-ups were performed from a starting position on the floor, with palms shoulder-width apart and with a straight body. The body was then raised until the elbows were fully extended, followed by lowering the body until the chest touched the test leader's flat hand held on the floor. Different versions of the pull-up test were used for male and female cadets. The starting position for male cadets was hanging vertically from a bar (beam) using an overhand grasp and with straight arms and legs. The body was raised until the chin was over the bar. The starting position for female cadets was hanging horizontally from a bar (beam) using an overhand grasp and with straight arms and legs. The heels were placed on a bench to achieve a horizontal starting position. The body was raised until the chest touched the bar. The maximum numbers of push-ups and pull-ups were recorded.

Statistical analysis

All outcome variables, including their residuals, were checked for normality by visual inspections of data distribution plots. Differences between two independent groups at baseline were analyzed with an independent samples *t*-test, while differences among three groups were analyzed with a one-way ANOVA with Tukey as *post hoc* test.

Linear mixed models were used to examine changes among the four data collection periods. The anthropometrical and physical fitness variables acted as dependent variables, while time was the independent variable (fixed factor). We first stratified our analyses by sex, then by sex and academy. The repeated covariance type was set to compound symmetry, and the method for model fitting was the restricted maximum likelihood. The least significant difference (LSD) approach was used when comparing main effects.

Presented mean values, including standard deviations (SD) and 95% confidence intervals (CI) are based on estimated marginal means, if not otherwise stated. This applies to both baseline characteristics and change over time. Effect sizes were calculated by subtracting the estimated marginal mean at T3 from T0, and dividing the result by the SD from T0. Interpretation of effect size thresholds were as follows: ≤ 0.19 (trivial), 0.20–0.49 (small), 0.50–0.79 (medium), and ≥ 0.80 (large).[24] Significance level was set at $p < 0.05$. Statistical analyses were performed in SPSS v. 25 (IBM Co., Armonk, NY). Graphs were produced with GraphPad Prism version 8.0.1 (GraphPad Software, San Diego, CA).

RESULTS

From entry to end of 3 years of academy studies, BW, FFM, BMI and percent BF increased significantly in male cadets by 1–5%, and in females by 3–5% (Table 1 and 2, respectively). Skeletal muscle mass did not change in either sex. For muscular power and muscular endurance, male cadets increased their performance in all four tests by 3–20%, while female cadets only increased performance significantly in the medicine ball throw (10%). Relative and absolute $\dot{V}O_{2max}$, together with treadmill time to exhaustion, decreased in male cadets by 2–5%, while only relative $\dot{V}O_{2max}$ decreased significantly in female cadets (4%). In male cadets, the magnitude of the change in vertical jump and relative $\dot{V}O_{2max}$ reached effect sizes of 0.50 and 0.54 (medium effects), respectively. In female cadets, medicine ball throw and relative $\dot{V}O_{2max}$ reached effect sizes of 0.80 (large effect) and 0.50 (medium effect), respectively. All other changes were classified as trivial or small (effect sizes < 0.50). The confidence intervals for Δ T3–T0 overlapped between male and female cadets for all variables, indicating no significant difference in 3-year change in anthropometrics and physical fitness between sexes. Changes in muscular power, muscular endurance and $\dot{V}O_{2max}$ throughout all four test periods are presented graphically for male and female cadets in Figure 2S (supplemental materials).

Anthropometrical and physical fitness characteristics are presented stratified by academy in Table 3 (males) and Table 4 (females). In male cadets, significant differences (5–7%) in baseline SMM, FFM, BMI, medicine ball throw and vertical jump were evident among the three academies. Male Army cadets scored significantly higher than Air Force or Naval cadets in four of these five variables. In female cadets, the only significant difference at baseline was a higher BF percentage in Air Force cadets compared to Navy cadets. Several anthropometrical and physical fitness variables changed significantly from T0 to T3 in male and female cadets from the three academies, respectively. However, the Δ T3–T0 confidence intervals overlapped among the academies, indicating no significant differences in changes among the academies. Exceptions to this were a larger increase in BW in male Air Force cadets vs. male Army cadets, and a larger increase in FFM for female Air Force cadets vs. female Navy cadets.

Only 43% of the cadets who conducted tests at baseline were still part of the study at T3 (Figure 1S). At baseline, male cadets who later dropped out from the study had 1.0 (0.2, 1.8) kg lower SMM, 1.8 (0.2, 3.5) kg lower FFM and 0.15 (0.02, 0.28) $L \cdot min^{-1}$ lower absolute $\dot{V}O_{2max}$ compared to male cadets who remained in the study at T3. No significant differences were found for the other outcome variables. In female cadets, no significant differences at baseline were found for any outcome variables between those who dropped out and those who remained in the study at T3.

DISCUSSION

Overall findings of the present study were that BW, BMI, FFM, BF, muscular power and muscular endurance increased in Norwegian cadets during 3 years of military academy education, while relative aerobic power was reduced. However, most of the changes were classified as trivial or small. The only fitness variable that demonstrated an effect size corresponding to a large change was the medicine ball throw in female cadets (10% improvement, effect size 0.80). The observed changes were generally of similar magnitude for male and female cadets, and similar among the three academies.

The present study generally confirms the findings in our previous pilot study on male Air Force cadets.[14] Together, the two studies reveal that physical fitness does not change greatly during the education period at Norwegian military academies. This is partly in line with previous international studies. In the 1970s, Daniels et al[10] studied 11 male and 7 female US Army cadets over 2 years of academy education, and found that body composition, aerobic power and maximal strength were unchanged or improved by ≤ 10% over the period. They also concluded that female cadets did not narrow the initial sex-gap in fitness, which is a similar finding as in the present study. Oliver et al[11] investigated changes in fitness in 7 male and 6 female U.S. ROTC cadets during 9 months of military education. The cadets reduced their relative $\dot{V}O_{2max}$ by 6–9%, but the changes were not significant – probably due to low sample sizes. At the same time, 2-mile run time was unaltered (males) or improved (females), while muscular strength and muscular endurance generally increased. Harwood et al[17] demonstrated that 106 British male and female cadets improved their aerobic power, muscle strength, muscular endurance and anthropometric status by typically 3–10% over a 44 week course. The improvements were generally larger in females than in males. In a study of 120 Serbian cadets (sex not reported), Maric et al[19] showed that performance in most fitness field tests were unchanged during 4 years of military academy studies. This is in contrast to a recently published study by Borges et al,[16] who found increased fat free mass and clear improvements in 3,000-meter run performance and muscular endurance in 29 Brazilian male cadets over 34 weeks of military training. Thus, with some exceptions, most previous studies have also demonstrated no or rather small mean changes in anthropometrics and physical fitness during military academy education.

If physical fitness is unchanged after one or more years of an academy education, this does not necessarily mean that the exercise-training regime has failed. If initial fitness level is high, or if the cadets fulfill designated minimum requirements at entry, a goal could simply be to maintain fitness throughout the academy years. In terms of aerobic power, Norwegian cadets compare favorably against cadets from the other countries referred to above. A review of 19 international studies published after year 2000 found that mean relative $\dot{V}O_{2max}$ ranged from 39 to 57 $mL \cdot kg^{-1} \cdot min^{-1}$ in various groups of male soldiers.[25] Thus, it is rare to find soldiers demonstrating substantially higher mean aerobic power than our studied male cadets. Regarding occupational requirements, NATO has previously recommended that soldiers should have a $\dot{V}O_{2max}$ of at least 3–3.5 $L \cdot min^{-1}$ to avoid acute fatigue during common physically demanding military work.[26] At entry, 98% of our studied male cadets fulfilled NATO's 3.5 $L \cdot min^{-1}$ requirement, while the corresponding percentage for female cadets was only 19%. From an occupational perspective, this indicates that maintaining male cadets' aerobic power could be a sufficient goal for the Norwegian academies, while it would be beneficial to increase aerobic power in female cadets. A similar discussion for muscular strength, muscular endurance and body composition is more challenging, since clear occupational requirements lack for these fitness components. Compared to international reference data, our impression is that Norwegian cadets' performance in push-ups and pull-ups, as well as their body fat values, were relatively similar to cadets from other countries.[10-12,16,17,19,27,28]

One of our initial hypotheses was that baseline anthropometrics and fitness would be more favorable in Army cadets, compared to Navy and Air Force cadets. Although we found some differences in favor of the male Army cadets, the differences were generally small or non-significant. One reason could be that cadets from all three branches carried out the same type of selection tests, and had to pass the same sex-adjusted minimum requirements. This included 3,000-m run in ≤ 13:00 minutes (males) and 14:00 minutes (females), push-ups ≥ 20 reps. (males) and 12 reps. (females), pull-ups ≥ 4 vertical reps. (males) and 5 horizontal reps. (females), and sit-ups ≥ 20 reps (both sexes).

Longitudinal changes in anthropometrics and physical fitness were also comparable among Army, Navy and Air Force cadets, indicating similar effect of training among the academies. Yet, we have limited information related to type, intensity or amount of exercise carried out at the three academies. Generally, the cadets participated in two obligatory sessions per week with physical education. This included theory and instruction lectures, and practical sessions like running, swimming, cross-country skiing, circuit training, hand-to-hand combat, etc. Many cadets also engaged in individual training or intra-mural sports during spare time. It was not organized specific training with the intention of increasing performance in the tests carried out in the present study. The absence of specific training in relatively fit individuals is a possible reason for the lack of improvements in the fitness tests.

Study strengths and limitations

Major strengths of the present study include the 3-year longitudinal design, a large sample size with inclusion of nearly all cadets from two school years in all military academies in Norway (Army, Navy and Air Force), and the inclusion of both sexes. The comprehensive study design allowed for an in-depth understanding of physical fitness in Norwegian cadets, including longitudinal developments, differences between male and female cadets, and differences among academies (branches). Another strength was that four major fitness components were evaluated, i.e. aerobic power, muscular power, muscular endurance and body composition. Aerobic power was measured directly, which is considered the gold standard measurement of integrated cardiopulmonary-muscle oxidative function.[29] This direct procedure is rarely used in large-scale longitudinal military studies. Moreover, the same test leaders and the same test laboratory and equipment were used throughout the study, which increases reliability and internal validity.

A limitation to the present work is the substantial drop-out rate during the course of the study. While participation was high at T0 and T1, only about half of the cadets remained in the study at T3.

Although linear mixed models analyses are capable of making use of incomplete datasets, the uncertainty of our estimated marginal means increases due to the missing data. Another possible limitation is the lack of thorough habituation prior to performing baseline tests of medicine ball throw and vertical jump, which were new test modalities for the cadets. A previous test – retest reliability study demonstrated a bias of +4% for the medicine ball throw at retest in unaccustomed military recruits.[30] Thus, some of the performance increase in medicine ball throw (and maybe also vertical jump) may be attributed to technical improvements from T0 to T3. A similar bias should not apply to push-ups and pull-ups, which were well-known exercises for all cadets; as well as the $\dot{V}O_{2max}$ test where a thorough familiarization trial was administered prior to the baseline test.

Conclusions

Despite a small increase in mean muscular power and muscular endurance, as well as a small reduction in relative aerobic power, we conclude that anthropometrics and physical fitness were relatively stable in Norwegian cadets during 3 years of military academy education. Developments were similar for male and female cadets, and for cadets from the Army, Navy and Air Force academies. The initial gap in physical fitness between male and female cadets did not narrow during the 3 years. Almost all male cadets fulfilled previously recommended minimum requirements for aerobic power. In female cadets, the corresponding figure was just one out of five. Yet, both Norwegian male and female cadets display relatively good physical fitness profiles, compared to male and female cadets and soldiers from other national and international military populations.

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Figure legends below

Figure 1S. Flowchart of male (♂) and female (♀) cadets with accepted test data, and cadets permanently lost to follow-up during the four test periods (T0, entry; T1, end of first year; T2, end of second year; T3, end of third year). In addition, some cadets had missing data during the course of the study due to sickness, injuries and absence. $\dot{V}O_{2max}$, maximal oxygen uptake; end., endurance.

Figure 2S. Changes in muscular power, muscular endurance and aerobic power in male (♂) and female (♀) cadets during 3 years of military academy studies. The X-axis represents data collection periods (0, study start; 1, end of first year; 2, end of second year; 3, end of third year). The symbols represent mean values including 95% confidence intervals.

Table 1. Anthropometrical and physical fitness characteristics in male cadets, including change (Δ) between entry (T0) and end of 3 years of academy studies (T3). The T0 and Δ T3–T0 data represent estimated marginal means (except for height) with standard deviations (SD) and 95% confidence intervals (CI), respectively. Effect sizes and *p*-values represent change between T0 and T3.

Variable	n	T0 (SD)	Δ T3–T0 (95% CI)	Effect size	*p*-value
Anthropometrics					
Height (cm)	246	180.9 (6.1)[†]	N/A	N/A	N/A
Body weight (kg)	252	79.5 (9.0)	1.7 (1.2, 2.1)	0.19	< 0.001
Skeletal muscle mass (kg)	252	36.2 (3.3)	0.0 (-0.3, 0.3)	0.00	0.948
Fat free mass (kg)	252	67.1 (6.5)	0.8 (0.4, 1.1)	0.12	< 0.001
Body fat (%)	252	15.3 (4.0)	0.8 (0.3, 1.3)	0.20	0.001
Body mass index ($kg \cdot m^{-2}$)	252	24.3 (2.3)	0.5 (0.4, 0.7)	0.22	< 0.001
Muscular power/endurance					
Vertical jump (cm)	248	53.1 (6.0)	3.0 (2.3, 3.8)	0.50	< 0.001
Medicine ball throw (m)	248	6.1 (0.6)	0.2 (0.1, 0.3)	0.33	< 0.001
Pull-ups vertical (reps.)	247	8.9 (4.2)	1.8 (1.4, 2.3)	0.43	< 0.001
Push-ups (reps.)	248	35.8 (9.6)	1.3 (0.1, 2.5)	0.14	0.035
Cardiorespiratory endurance					
$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	239	4.47 (0.52)	-0.10 (-0.15, -0.06)	0.19	< 0.001
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	239	56.6 (4.6)	-2.5 (-3.1, -1.9)	0.54	< 0.001
Time to exhaustion (sec.)	239	322 (38)	-15 (-22, -8)	0.39	< 0.001

[†] Observed arithmetic mean
N/A, not available

Table 2. Anthropometrical and physical fitness characteristics in female cadets, including change (Δ) between entry (T0) and end of 3 years of academy studies (T3). The T0 and Δ T3–T0 data represent estimated marginal means (except for height) with standard deviations (SD) and 95% confidence intervals (CI), respectively. Effect sizes and *p*-values represent change between T0 and T3.

Variable	n	T0 (SD)	Δ T3–T0 (95% CI)	Effect size	*p*-value
Anthropometrics					
Height (cm)	28	166.8 (5.5)†	N/A	N/A	N/A
Body weight (kg)	29	62.7 (8.8)	2.9 (1.7, 4.2)	0.33	< 0.001
Skeletal muscle mass (kg)	29	23.8 (2.5)	0.3 (-0.3, 0.8)	0.12	0.301
Fat free mass (kg)	29	48.0 (5.3)	1.3 (0.5, 2.1)	0.25	0.001
Body fat (%)	29	23.1 (3.3)	1.2 (0.1, 2.3)	0.36	0.036
Body mass index ($kg·m^{-2}$)	29	22.5 (2.4)	1.0 (0.6, 1.5)	0.42	< 0.001
Muscular power/endurance					
Vertical jump (cm)	29	41.4 (4.9)	1.9 (-0.3, 4.2)	0.39	0.089
Medicine ball throw (m)	29	4.1 (0.5)	0.4 (0.2, 0.6)	0.80	< 0.001
Pull-ups horizontal (reps.)	28	15.3 (6.0)	0.8 (-1.6, 3.3)	0.13	0.480
Push-ups (reps.)	28	17.7 (7.1)	2.7 (-0.5, 5.9)	0.38	0.094
Cardiorespiratory endurance					
$\dot{V}O_{2max}$ ($L·min^{-1}$)	28	3.02 (0.44)	0.02 (-0.07, 0.12)	0.05	0.639
$\dot{V}O_{2max}$ ($mL·kg^{-1}·min^{-1}$)	28	48.0 (3.6)	-1.8 (-3.2, -0.4)	0.50	0.013
Time to exhaustion (sec.)	28	303 (39)	-8 (-27, 11)	0.21	0.404

† Observed arithmetic mean
N/A, not available

Table 3. Anthropometrical and physical fitness characteristics in male Army, Navy and Air force cadets, including change (Δ) between entry (T0) and end of 3 years of academy studies (T3). All data represent estimated marginal means with standard deviations (SD) or 95 % confidence intervals (CI).

Variable	Army cadets (n = 108–113)		Navy cadets (n = 78–84)		Air force cadets (n = 53–55)	
	T0 (SD)	Δ T3–T0 (95% CI)	T0 (SD)	Δ T3–T0 (95% CI)	T0 (SD)	Δ T3–T0 (95% CI)
Anthropometrics						
Body weight (kg)	80.8 (9.6)	1.2 (0.5, 1.8)*	78.8 (8.2)	1.7 (0.8, 2.6)*	77.6 (8.8)	3.4 (2.2, 4.7)*
Skeletal muscle mass (kg)	36.9 (3.4)[2]	-0.1 (-0.5, 0.2)	35.9 (3.2)	-0.1 (-0.6, 0.3)	35.2 (3.1)	0.5 (-0.3, 1.2)
Fat free mass (kg)	68.5 (7.0)[2]	0.5 (0.0, 1.0)	66.6 (6.1)	0.5 (-0.2, 1.2)	65.2 (5.9)	2.0 (0.9, 3.1)*
Body fat (%)	15.0 (3.7)	0.7 (0.1, 1.4)*	15.4 (3.8)	0.7 (-0.1, 1.6)	15.6 (4.7)	1.2 (0.1, 2.3)*
Body mass index ($kg \cdot m^{-2}$)	24.6 (2.3)[2]	0.4 (0.2, 0.6)*	24.3 (2.3)	0.5 (0.2, 0.8)*	23.5 (2.2)	1.0 (0.6, 1.4)*
Muscular power/endurance						
Vertical jump (cm)	53.5 (5.9)	3.1 (2.1, 4.1)*	51.5 (6.1)	3.3 (1.9. 4.8)*	54.8 (6.1)[1]	2.0 (-0.1, 4.1)
Medicine ball throw (m)	6.2 (0.6)[1]	0.2 (0.1, 0.3)*	5.8 (0.5)	0.3 (0.1, 0.5)*	6.1 (0.7)[1]	0.2 (0.0, 0.5)*
Pull-ups vertical (reps.)	8.7 (3.8)	1.9 (1.4, 2.5)*	8.9 (4.6)	1.9 (1.1, 2.9)*	9.3 (4.5)	1.2 (0.0, 2.4)*
Push-ups (reps.)	36.7 (9.0)	1.0 (-0.5, 2.4)	35.8 (10.3)	1.7 (-0.7, 4.0)	34.2 (10.1)	0.3 (-3.3, 3.9)
Cardiorespiratory endurance						
$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	4.59 (0.50)	-0.13 (-0.19, -0.07)*	4.39 (0.49)	-0.11 (-0.20, -0.01)*	4.34 (0.57)	-0.05 (-0.18, 0.07)
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	57.1 (4.4)	-2.5 (-3.3, -1.7)*	56.1 (4.8)	-2.6 (-3.9, -1.3)*	56.2 (4.8)	-2.8 (-4.3, -1.3)*
Time to exhaustion (sec.)	327 (37)	-15 (-24, -7)*	323 (38)	-18 (-32, -4)*	312 (40)	-14 (-30, 3)

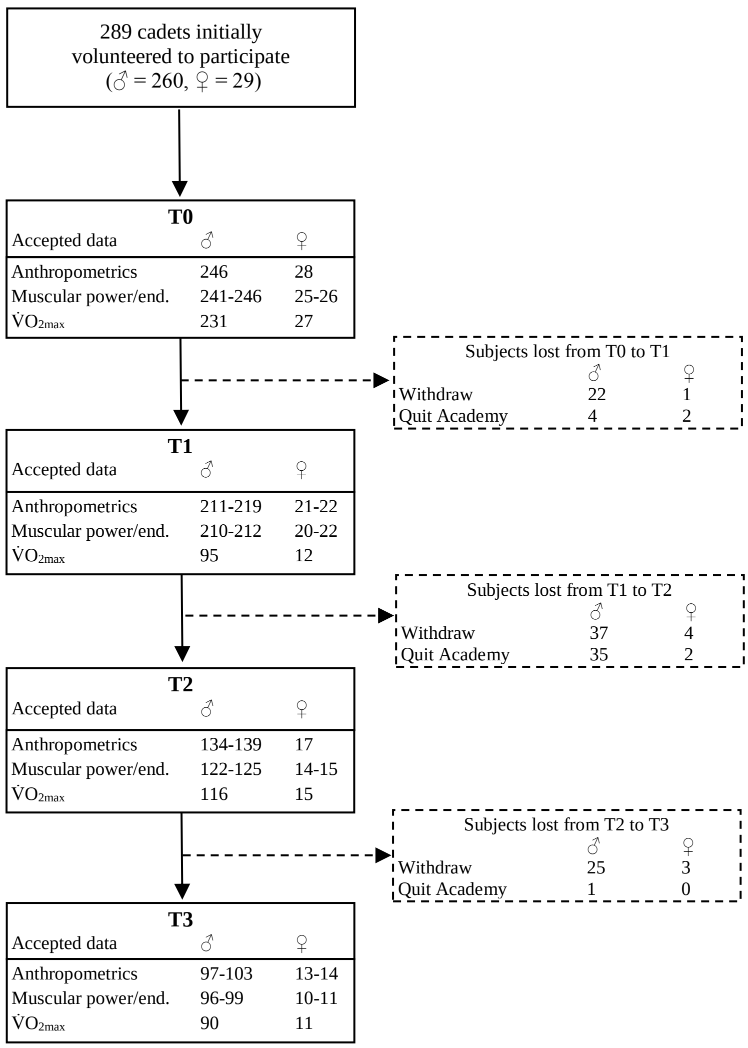
[1]Significantly higher at T0 compared to Navy cadets
[2]Significantly higher at T0 compared to Air Force cadets
*$p < 0.05$ for Δ T3–T0

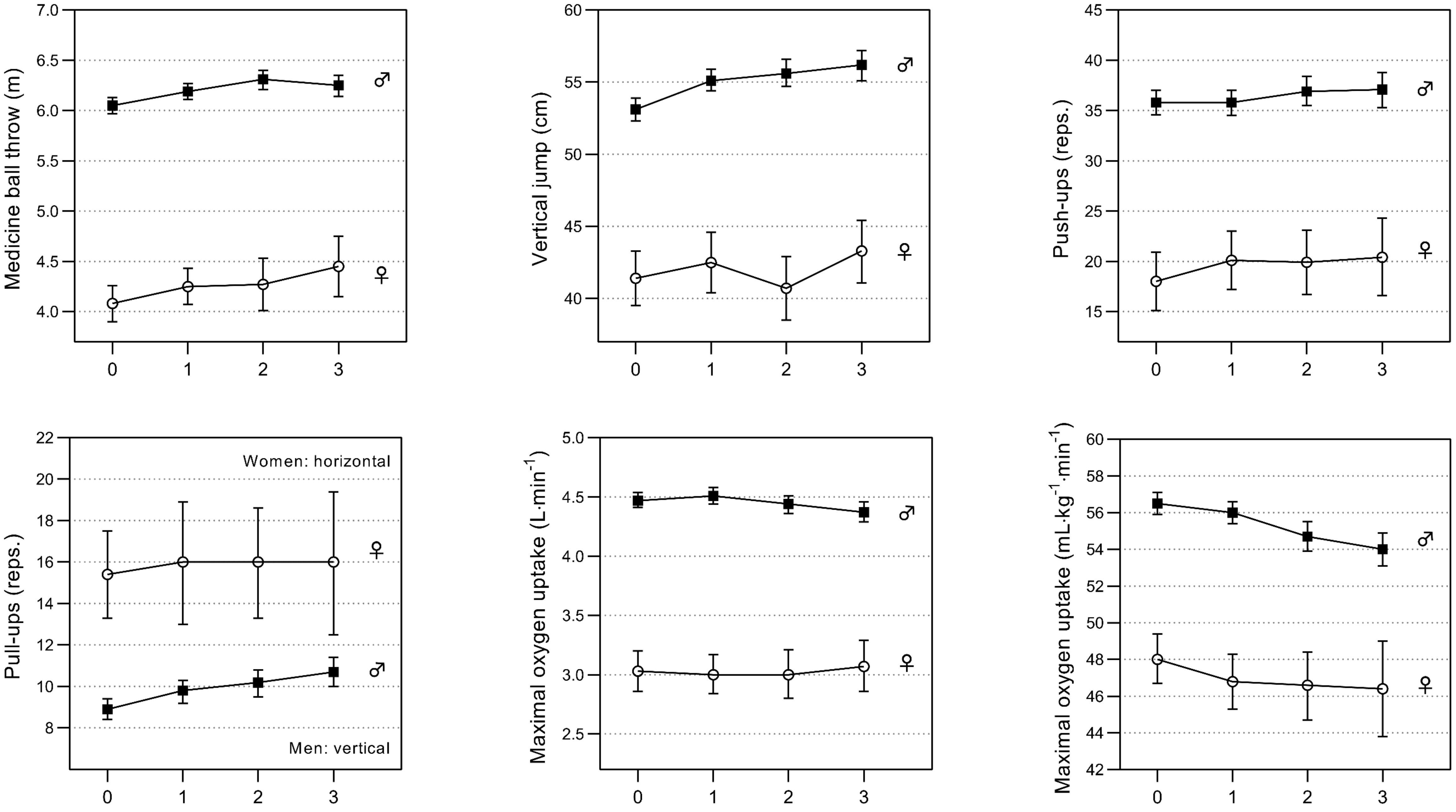
Table 4. Anthropometrical and physical fitness characteristics in female Army, Navy and Air force cadets, including change (Δ) between entry (T0) and end of 3 years of academy studies (T3). All data represent estimated marginal means with standard deviations (SD) or 95 % confidence intervals (CI).

Variable	Army cadets (n = 5)		Navy cadets (n = 13–14)		Air force cadets (n = 9–10)	
	T0 (SD)	Δ T3–T0 (95% CI)	T0 (SD)	Δ T3–T0 (95% CI)	T0 (SD)	Δ T3–T0 (95% CI)
Anthropometrics						
Body weight (kg)	62.3 (6.5)	0.0 (-3.0, 3.0)	62.7 (10.6)	2.4 (0.8, 4.1)*	62.8 (7.7)	4.7 (2.8, 6.5)*
Skeletal muscle mass (kg)	23.9 (1.9)	0.7 (-1.5, 2.8)	24.4 (2.7)	-0.3 (-1.1, 0.5)	22.8 (2.5)	1.0 (0.2, 1.7)*
Fat free mass (kg)	48.1 (4.1)	1.1 (-2.0, 4.2)	48.7 (6.1)	0.4 (-0.5, 1.3)	47.0 (4.9)	2.7 (1.8, 3.7)*
Body fat (%)	22.7 (1.9)	0.0 (-3.9, 4.0)	21.9 (3.5)	2.1 (0.7, 3.4)*	25.0 (3.3)[1]	1.1 (-1.1, 3.3)
Body mass index ($kg \cdot m^{-2}$)	23.2 (1.7)	0.0 (-1.0, 1.1)	22.0 (2.9)	0.8 (0.2, 1.4)*	23.0 (1.8)	1.7 (1.1, 2.3)*
Muscular power/endurance						
Vertical jump (cm)	42.6 (3.8)	4.8 (-5.0, 14.6)	42.2 (5.0)	1.3 (-2.0, 4.7)	39.6 (5.2)	2.7 (-1.1, 6.5)
Medicine ball throw (m)	4.1 (0.3)	0.1 (-0.6, 0.8)	4.1 (0.5)	0.5 (0.2, 0.7)*	4.1 (0.6)	0.3 (-0.1, 0.7)
Pull-ups horizontal (reps.)	N/A	N/A	15.9 (5.4)	2.5 (-0.5, 5.5)	13.9 (6.2)	-1.2 (-4.7, 2.3)
Push-ups (reps.)	21.4 (6.7)	10.3 (-7.1, 27.7)	15.2 (6.1)	2.4 (-1.1, 6.0)	19.6 (7.4)	2.7 (-3.1, 8.6)
Cardiorespiratory endurance						
$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	3.19 (0.45)	0.03 (-0.19, 0.25)	2.99 (0.50)	0.00 (-0.18, 0.18)	2.97 (0.38)	0.03 (-0.10, 0.16)
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	51.1 (2.5)	0.1 (-2.7, 2.9)	47.3 (3.1)	-1.7 (-4.2, 0.8)	47.4 (4.0)	-2.7 (-4.5, -0.8)*
Time to exhaustion (sec.)	N/A	N/A	303 (40)	-9 (-43, 24)	298 (39)	-10 (-36, 16)

[1]Significantly higher at T0 compared to Navy cadets
N/A, not available due to uncertain validity of model fit
*$p < 0.05$ for Δ T3–T0

Supplemental Materials




Medicine ball throw (m)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
1
2
3
♂
♀
Vertical jump (cm)
60
55
50
45
40
Push-ups (reps.)
45
40
35
30
25
20
15
Pull-ups (reps.)
22
20
18
16
14
12
10
8
Women: horizontal
Men: vertical
Maximal oxygen uptake (L·min-1)
5.0
4.5
4.0
3.5
3.0
2.5
Maximal oxygen uptake (mL·kg-1·min-1)
60
58
56
54
52
50
48
46
44
42